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Analysis of environmental health risk due to exposure to Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2) in children at PT. Tonasa Cement

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Abstract

Air pollution tends to increase, especially in cement industrial areas. Air that is polluted in certain amounts and over a long period of time can have an impact on human health, disrupting plant and animal life. Sources of exposure to Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) gas in cement factories can be found in production units, such as the reclaimer, raw mill, combustion (pre-heater, rotary kiln, and cooler), finish mill, and packhouse. This type of research is descriptive quantitative research. Sampling was carried out at 8 locations around the cement industrial area using Purposive Sampling technique. The number of samples was 80 people children 8 environmental sample points, namely ambient air quality parameters SO_2 and NO_2. Data analysis was carried out by calculating intake and risk quotient values. If the risk quotient is > 1, then it is deemed necessary to carry out risk management. The result is Environmental health risks of exposure to SO_2 and NO_2 in the PT Semen Tonasa industrial area for children are as follows: The RQ SO_2 value in the PT Semen Tonasa industrial area is in the range 0.0407– 0.4154 with the average RQ SO_2 value being 0.1498. The RQ NO_2 value in the PT Semen Tonasa industrial area is in the range 0.0471 – 0.552 with the average RQ NO_2 value being 0.2265. These results may increase our understanding of the risks of cement production to human health, and the distance that pollution may travel from cement plants, further reinforcing the need for cement pollution control and mitigation.

Keywords: EHRA, SO_2, NO_2, Risk Management, Cement Industry.

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1. Introduction

Air, which contains a certain amount of oxygen, is an essential component for life, both humans and other living creatures. Air is a mixture of gases, consisting of about 78% Nitrogen; 20% Oxygen; 0.93% Argon; 0.03% Carbon Dioxide (CO_2) and the rest consists of Neon (Ne), Helium (He), Methane (CH_4) and Hydrogen (H_2) [1]. According to the World Health Organization (2020), 7.3 million people died due to air pollution and the highest cases occurred in the Middle East and Southeast Asia with an average level of pollution per year exceeds the threshold value [1]. In Indonesia, the death rate due to air pollution is more than 60,000 cases per year. Air pollution can reduce the average life expectancy of Indonesians by around 1.2 years. The biggest contributor to air pollution in Indonesia is caused by the use of coal, consumption of gasoline and diesel [2]. Air that is polluted in certain amounts and over a long period of time can have an impact on human health, disrupting plant and animal life [3]. The main source of particles is the fuel combustion process and industrial processes [4]. Air pollutants include CO, NO_2, SO_2, hydrocarbons and particulates [5]. Industrial activities have the potential to pollute the environment, for example air pollution originating from smoke and dust which can reduce the quality of the environment which in turn reduces the quality of life of the people who live around the industrial area [6].

One of the industries that has quite high growth in Indonesia is the cement industry, where the production process uses high temperature heating. The main fuel used is coal and the main raw material is lime. The dominant emissions resulting from the cement manufacturing process are particles in the form of dust and gases such as SO_2 and NO_2 [7]. NO_2 gas is a quite dangerous pollutant with the characteristic reddish-brown color, sharp smell, and can cause eye irritation and pain in the lungs. NO_2 is formed from the oxidation of Nitrogen Oxide (NO) gas, which is emitted from the combustion of fuel at high temperatures. [8]. Meanwhile, sulfur dioxide (SO_2) is an air pollutant gas consisting of sulfur and oxygen. SO_2 is formed when fuels containing sulfur such as coal, oil, or diesel are burned [9]. Sources of exposure to Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) gas in cement factories can be found in production units, such as the reclaimer, raw mill, combustion (pre-heater, rotary kiln and cooler), finish mill and packhouse [10]. This is supported by research conducted by Ardianarsya et al., (2019) at PT [11]. Semen Indonesia found that the dominant parameters produced from each emission source were particulates, SO_2 and NO_2, which were mostly produced in the raw mill process because the unit used coal as fuel for the production process. Environmental health risk analysis of Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) exposure is considered important because long-term and short-term exposure to SO_2 and NO_2 can cause respiratory problems. One of the diseases that arises from NO_2 exposure is Chronic Obstructive Pulmonary Disease (COPD). Meanwhile, SO_2 gas, if inhaled through breathing and accumulated in the body, can cause lung function disorders, irritation and asthma in the human respiratory system [12]. Based on the results of research from Ronald et al in 2020 around the Manado Shopping Center area, it shows that lifetime exposure to SO_2 gas in street vendors in the area is found to pose a risk to health. Exposure to NO_2 gas in street vendors both in real time and in life time poses a risk to health. It is recommended [3]. Another research by Ayu and Suparjan (2022) regarding environmental health risk analysis of SO_2 and NO_2 on roads in the Bone Bolango area. The results of the risk analysis show that the risk level of SO_2, NO_2, CO and TSP agents is at risk for the child population for the next 30 years [1]. The negative impacts resulting from polluting materials can be estimated to have a large health risk. To find out how big the health risk is, research was carried out regarding environmental health risk analysis and spatial patterns of exposure to Sulfur Dioxide (SO_2) and Nitrogen Dioxide (NO_2) originating from the PT Industry. Tonasa Cement.

2. Materials and methods

2.1. Type of Research

This type of research is descriptive quantitative research Sampling was carried out at 8 locations around the cement industrial area using Purposive Sampling technique. The number of samples was 80 children and 8 environmental sample points, namely ambient air quality parameters SO_2 and NO_2. Data analysis in this study, the environmental health risk analysis (EHRA) was implemented in the following stages:

2.1.1. Hazard identification

At this stage, the type of particulates produced during combustion activities in processing cement raw materials that pollute the air are determined.

2.1.2. Dose-response analysis

A dose-response analysis was carried out based on the standardization issued by the US-EPA Agency for the Reference Concentration (RfC) value of PM2.5, which is 0.0012 milligrams per kilogram per day (mg/kg/d) and PM10, 0.005 milligrams per kilogram per day (mg/kg/d).

2.1.3. Exposure analysis

$$ADD = \frac{C \ x \ InhR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT} \text{ (Equation 1)}$$

Where:

- ADD=Average daily dose (mg/kg/day).
- C=Concentration of contaminant in air (mg/m^3).
- InhR=Inhalation Rate (m^3/hour).
- ET=Exposure time (hour/day).
- EF=Frequency of exposure (day/year).
- ED=Duration (year).
- BW=Body Weight (kg).
- AT=Averaging time (day).

2.1.4. Risk characterization

Risk characterization for non-carcinogenic effects was done by dividing intake by the dose or concentration of risk agents. Health risk characteristics are expressed as Risk Quotient (RQ) to evaluate potential non-carcinogenic health hazards due to contaminant exposure with non-carcinogenic health guidelines.

$$RQ = \frac{ADD}{RfC} \text{ (Equation 2)}$$

Where:

- RQ = Risk Characterization.
- RfC = Reference Concentration.

2.1.5. Risk Management

After carrying out an environmental health risk analysis and obtaining a Risk Quotient (RQ) value ≥ 1, follow-up actions must be carried out. In risk management, a risk management strategy is carried out, which includes determining safe limits [13].

2.2. Sample Collection

Eight locations included in Ring 1 Mangilu Village, Biring Ere Village, Sapanang Village, Samalewa Village, Bulu Cindea Village, Bowong Cindea Village, Bontoa Village, Taraweang Village, Pangkajene Islands Regency (Pangkep), South Sulawesi Province were used for the study's ambient air and human sample sampling. The sampling location was at point 1, namely in Biring Ere Village, Bungoro District, precisely in front of the Taqwa Mosque, Biring Ere Village with coordinates S: 4º 47' 08.4" E: 119º 36' 29.4". The sampling location was at point 2, namely in Mangilu Village, Bungoro District, precisely in front of the Kampung Sela Mosque with coordinates S: 4º 46'40.0" E: 119º 37' 42.7".

The sampling location is at point 3, namely in Sapanang Village, Bungoro District, precisely in front of the Sapanang Village Head's Office with coordinates S: 4º 48' 13.8" E: 119º 34'38.0". The sampling location is at point 4, namely in Bontoa Village, Minasa Tene District on Jalan Poros Tonasa

– Bungoro with coordinates S: 4º 48' 07.7" E: 119º 35' 43.7". The sampling location is at point 5, namely in Bulu Cindea Village, Bungoro District, precisely in front of Bujung Tangaya Elementary School with coordinates S: 4º 48" 44.4" E: 119º 30" 00.3" The sampling location is at point 6, namely in Bowong Cindea Village, Bungoro District, in front of the Biringkassi Port Organizing Unit Office with coordinates S: 4º 48' 24.5" E: 119º 31' 26.2". The sampling location is at point 7, namely in Taraweang Village, Labbakkang District with coordinates S: 4º 46' 54.0" E: 119º 135' 59.3". The sampling location is at point 8, namely in Samalewa Village, Bungoro District, precisely at the Bungoro intersection with coordinates S: 4º 48'54.5" E: 119º 32'43.1".

3. Result

3.1. Respondent Characteristics

The individuals who reside in the research locations Biring Ere Village, Bulu Cindea Village, Bowong Cindea Village, Bontoa Village, Taraweang Village, Pangkajene Islands Regency (Pangkep), South Sulawesi Province are the respondents. Based on Table 1 demonstrates that there are more female responders than male ones. The largest age group of respondents was in the 6–12year age bracket, with 80 individuals, or 50%, while female respondents made up 101 persons, or 63.1% of the total. Of the 100 responses, or 62.5%, the majority had only completed elementary school. There were 80 respondents (or 50%) who did not have a job; 40 respondents (or 25%) had a body weight of ≥61 kg, and 20 respondents (or 12.5%) had the lowest body weight of 41 to 50 kg.

3.2. Ambient air concentration around the PT industrial area. Semen Tonasa, Pangkajene Islands Regency, SO_2 and NO_2 parameters

Respondents in this study were children aged 6–12 years with an average body weight of 27 kg. Body weight reflects nutrients in the human body; people with an ideal body weight are sufficiently nourished. Figure 2 shows the ambient air concentration around the PT industrial area. Semen Tonasa, Pangkajene Islands Regency, SO_2 and NO_2 parameters. The highest SO_2 concentration was in Bontoa village, namely 51.3 µg/m_3 and the lowest was in Bulu Cindea village, namely 16.1 µg/m^3. Meanwhile, the highest NO_2 concentration was in Samalewa village, namely 46.2 µg/m_3 and the lowest was in Biring Ere village, namely 16.9 µg/m^3. Of the 8 location points, none exceeded environmental quality standards for each parameter.

3.3. Risk Assessment

Table 2 shows that the age of the respondents ranges from 6 years-45 years with a middle value (median) of 19 years. Respondents' body weight ranged from 11 kg – 92 kg. Respondents' inhalation rate for children was 0.5 and adults 0.83 m^3/hour. Respondents' exposure frequency ranged from 317-365 days/year.

3.4. Non-Carcinogenic Intake Exposure to SO_2 and NO_2

The intake value is the value of exposure by analyzing the characteristics of respondents to determine each risk agent as measured from the ambient air in Pangkajene Islands Regency. The results of calculating the intake that enters the body in real time projections (Dt), the minimum, maximum and mean values are presented in the Table 3. Table 3's data on 160 respondents' real-time intake values of non-carcinogenic SO_2 reveals that the mean value for adults is 0.0112, higher than the value for children (0.0039). In the meantime, children's average lifetime intake of non-carcinogenic SO_2 during years 5 through 30 is estimated to be between 0.0021 and 0.0127, greater than that of adults, who are expected to be between 0.0015 and 0.0091. Since the overall average lifetime and real-time non-carcinogen consumption is less than the RfC SO_2 value of 0.026, it still satisfies the standards. Table 4's real-time intake value of non-carcinogenic NO_2 for 160 respondents indicates that adults' mean values are greater than children's, at 0.0129 and 0.0045, respectively. In the meanwhile, adults' mean lifetime consumption of non-carcinogenic NO_2 for years 5 through 30 is estimated to be between 0.0018 and 0.0106, which is less than children's mean intake of 0.0024 to 0.0147. Since the total average lifetime and real-time non-carcinogen consumption is less than the RfC NO_2 value of 0.02, it still satisfies the standards.

3.5. Risk Level Characteristics

Inhaled gases such as SO_2 and NO_2 can enter the human body. PM (particulate matter) has an impact on health hazards. Risk Questient (RQ) notation is used to indicate the risk level for non-carcinogenic impacts. If RQ > 1, risk must be managed; if RQ < 1, risk does not need to be managed, but it must be maintained in all circumstances to keep the RQ value from exceeding. Table 5 presents the real-time non-carcinogenic risk level value, or Risk Quotient (RQ) SO2, for 160 respondents (adults and children). The mean value for adults is 0.4298, higher than the average for communities surrounding industrial areas for children, which is 0.1498. Because the RQ number is less than 1, PT. Semen Tonasa is not in danger. As for the anticipated lifetime RQ for years 5 through 30, it is around 0.0812 – 0.4873 for children and approximately 0.0586 – 0.3514 for adults. This indicates that, in the 5–30year forecast, the typical neighborhood surrounding PT. Semen Tonasa's industrial area is not at danger because the average RQ value is less than 1. Table 6 shows that for 160 respondents (adults and children), the real-time non-carcinogenic risk level value, or Risk Quotient (RQ) NO2, is 0.6473 for adults and 0.2265 for children. This difference indicates that, on average, neither adults nor children are at risk because the RQ value is greater than 1. In contrast to adults, who have an RQ lifetime forecast of 0.0884 to 0.5303 for years 5 through 30, children have a greater projection, ranging from 0.1221 to 0.7326. For adults and children aged 5 to 30, the estimated mean RQ is still not at danger.

3.6. Risk Management

Table 7 indicates that risk management has to be carried out during SO_2 cleaning (Dt) for newborns (Min) as young as 21 and older as 32, with maximum and minimum values of 198 and 270.

During the NO_2 withdrawal period, the minimum (Min) was between 18 and 27, while the maximum (Max) was between 149 and 223. The SO_2 tolerance (tE) for children Min 17 and 26, and Max 159 and 144. Adults' exposure times (tE) to NO_2 range from min 14 to max 22 to max 119 to 112. Children's minimum frequency of exposure (fE) to SO_2 is 248; adults' maximum value is 2414; and adults' maximum value is 3290. Children's minimum frequency of exposure (fE) to NO_2 is 211, while children's maximum value is 1800 and adults' maximum value is 2716.

4. Discussion

4.1. SO_2 in Ambient Air

Numerous sectors, including electricity generating, oil and gas production, mineral processing, diesel engine vehicles, and the burning of fossil fuels containing sulfur, are major producers of SO_2 gas. The oxidation of sulfur in raw materials and the burning of fuels containing sulfur produce sulfur dioxide. In the preheating kiln, the raw material's sulfur is reduced to SO_2 and SO_3 at a temperature between 370 and 420 degrees Celsius [19]. According to measurements of ambient air quality around PT. Semen Tonasa's industrial area in Pangkajene Islands Regency, Bontoa village had the highest SO_2 concentration (51.3 µg/m^3), while Bulu Cindea village had the lowest SO_2 concentration (16.1 µg/m^3). No place surpasses the quality standard limitations. related study on the neighborhoods surrounding the cement factory. Residential areas near the cement factory had SO_2 values ranging from 0.005 to 0.029 mg/Nm^3, according to research by Ardhinni (2022) [19]. The direction and speed of surface winds influence the flow and distribution of released air pollutants. High wind speeds in pollutant source areas will more quickly carry pollutants away from the source. On the other hand, low wind speeds will cause air pollutants to concentrate and last longer around the pollution source [20].

4.2. NO_2 in Ambient Air

In cement kilns, burning fuel at high temperatures releases NOx. In cement kilns, three forms of NOx are produced: heat, fuel, and NO_X feed. More than 90% of the flue gas in the kiln is NOx, with the remaining portion often being NO_2 [21]. High temperatures in the atmosphere cause nitrogen to oxidize, creating thermal NOx. The literature reports threshold temperatures between around 1200°C and 1600°C (2200°F and 2900°F) for thermal NO_x production. Large volumes of thermal NO are produced in the burning zone of the kiln due to the flame temperature being much higher than this. The oxidation of nitrogen compounds in the raw materials supplied into the kiln (feed NO_x) also contributes to NOx emissions. Another possibility is that the fuel's nitrogen compounds are oxidizing (fuel NO_x) [22]. The NO_2 concentration was found to be highest in Samalewa Village, at 46.2 µg/m^3, and lowest in Biring Ere Village, at 16.9 µg/m^3, based on measurements of the ambient air quality around the industrial area of PT. Semen Tonasa, Pangkajene Islands Regency. At the research site, the NO_2 concentration is less than the 200 µg/m3 quality threshold [23]. Weather patterns can have an impact on the amount of NO_2 pollution in the surrounding air. The impact of weather conditions must be considered since the diffusion process in a passive sampler occurs naturally based on variations in concentration gradients. Higher wind speeds are the reason for the low NO_2 concentration at the research site because they move pollutants away from the source of emissions. This study is consistent with that conducted by Anggrika in the vicinity of the junction, where the NO_2 concentration was 100.07 µg/m^3 in Studio A and 81.77 µg/m^3 at the Police Post at a high wind speed of 6 m/s. Then, in the third week, the NO2 concentration rose to 81.87 µg/m^3 at the Police Post and 109.14 µg/m^3 at Studio A, while the wind speed reduced to 5.75 m/s. Due to the predominant wind direction toward the Studio A location and the lack of significant wind speed changes, Studio A has greater NO_2 levels [24].

4.3. Risk to Health

Long-term dust exposure at home or at work can result in respiratory symptoms, even though dose-response studies of SO_2 and NO_2 classify them as non-carcinogenic risk agents [27]. One type of air pollution that is deemed hazardous to the general public is pollutant gasses, which can have negative effects on health including reduced lung function, cardiovascular problems, and early mortality. Children, the elderly, those with heart and respiratory conditions, and pregnant women are especially susceptible to health issues [25]. As exposure time increases, so do the health hazards [25]. Even in affluent nations where exposure restrictions are not exceeded by the content of polluting gases, there has been a documented rise in the prevalence of sickness among youngsters residing near cement manufacturers [28]. Individuals who are exposed to SO_2 and NO_2 are more likely to get cardiac problems and lung illness. Furthermore, respiratory symptoms, such as respiratory tract irritation and breathing difficulties, are more common in youngsters and the elderly [26]. Human respiratory systems may be affected by SO_2 in the form of gas or acid, which is produced when SO_2 dissolves with water found in the atmosphere and precipitation. Inhaled pollutants cause oxidative stress and systemic inflammation by localizing inside the lung tissue. This in turn sets off other effector pathways, such as the creation of biological intermediates such changed phospholipids, the activation of the HPA axis, platelet activation, and autonomic dysfunction. This route causes inflammation, atherothrombosis, endothelial and vascular damage, epigenomic alterations, and eventually culminates in the development of cardiovascular disease [29].

4.4. Risk Management

The purpose of risk management is to shield people from danger. The goal of the risk management method is to set safe boundaries for things like the risk agent's concentration, amount eaten, exposure time, frequency, and duration. Furthermore, to attain safe limits, institutional, socioeconomic, and technical methods are employed [25]. The sustainability of the cement supply chain depends critically on minimizing negative environmental effects [30]. In order for relevant institutions and the government to plan and implement appropriate measures to mitigate high pollutant occurrences in the upcoming years, it is necessary to have an understanding of the statistical distribution of air quality data in order to forecast high pollutant concentrations. The intensity of the emission source and the weather have an impact on ambient air pollution levels [31].

4.5. Spatial Pattern

GIS technology combines the distinct mapping visualization and analysis capabilities with standard database functions, such as statistical analysis and querying. The spatial technique is a way to gather observational data that takes location or spatial factors into account. Geospatial impacts are displayed as weighting or as position coordinates (longitude, latitude).

Table 1: Distribution of Respondent Characteristics in Pangkajene Islands Regency (Pangkep) in 2023.

Variable	Frequency (n)	Percentage (%)
Gender		
Male	59	36,9
Female	101	63,1
Age		
6 – 12 Years	80	50.0
26 – 32 Years	33	20.6
33 – 39 Years	9	5.6
40 – 45 Years	38	23.8
Education		
No school	5	3.1
Elementary school	100	62.5
Junior high school	13	8.1
Senior high school	40	25.0
Bachelor	2	1.3
Work		
Housewife	47	29.4
Self-employed	27	16.9
Farmer/fisherman	3	1.9
Laborer	3	1.9
Student	80	50.0
Weight		
10 – 20 Kg	18	11.3
21 – 30 Kg	37	23.1
31-40 Kg	21	13.1
41-50 Kg	20	12.5
51-60 Kg	24	15.0
≥61 Kg	40	25.0

Source: Primary Data, 2023.

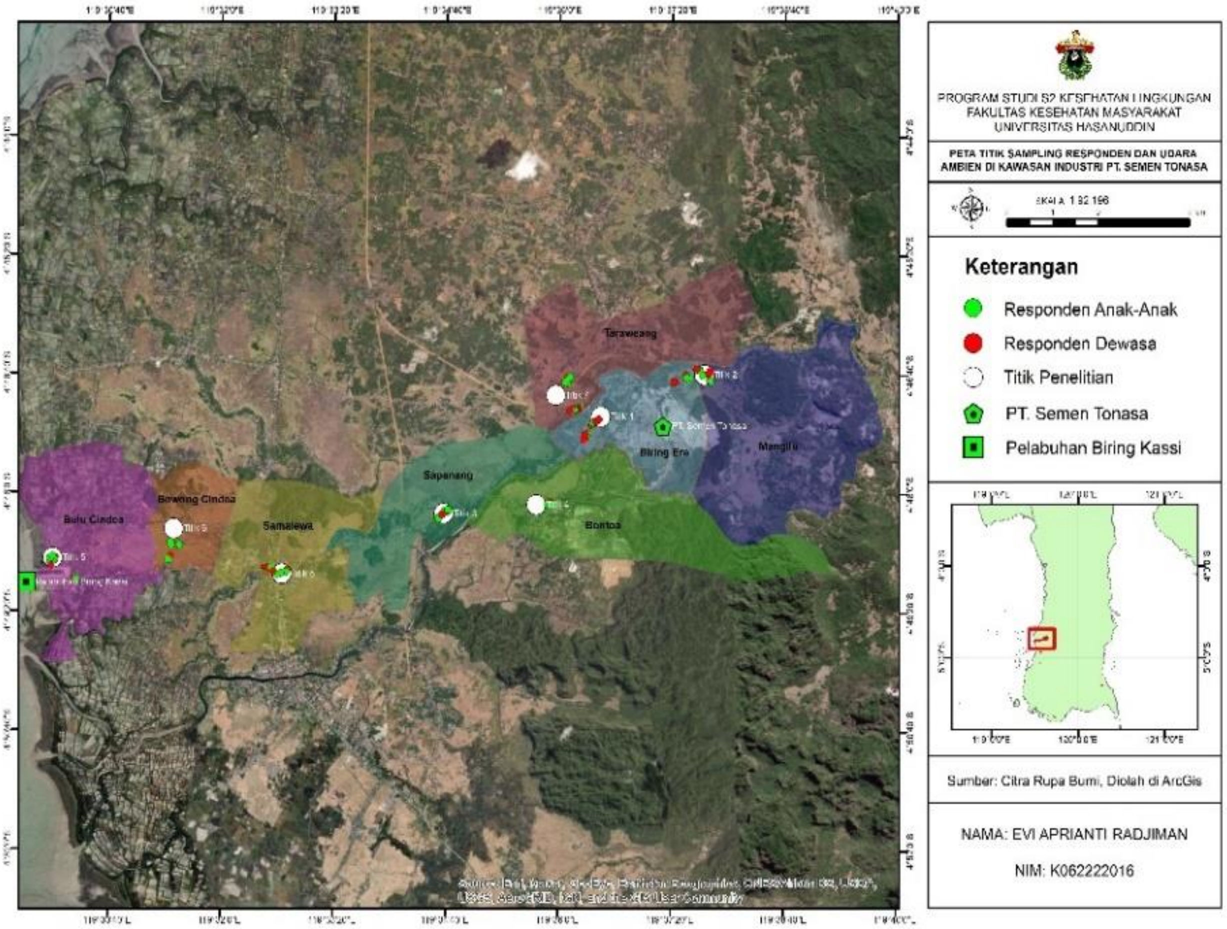

Figure 1: Sampling Location.

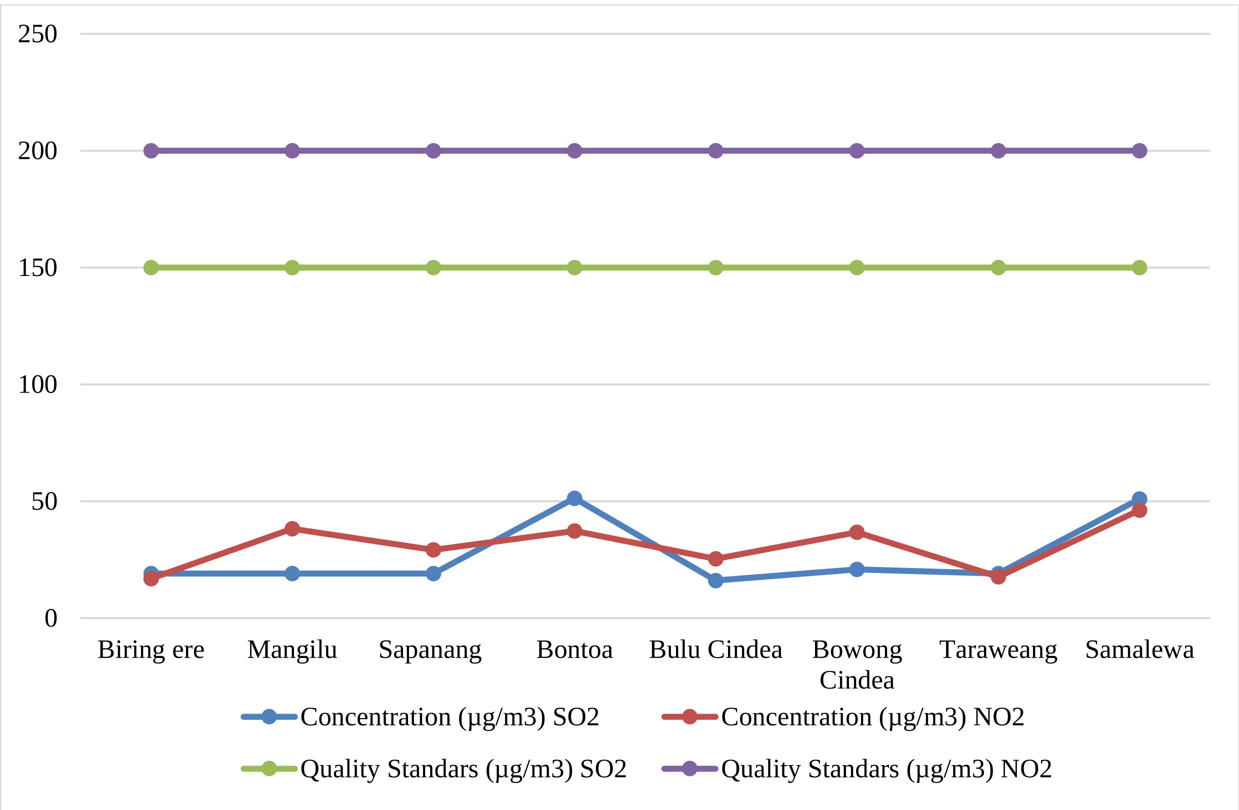

Figure 2: Graph of Ambient Air Measurement Results in the Cement Industry.

Table 2: Characteristics of respondents based on body weight and community activity patterns in Pangkep Regency 2023.

Indicator	Min	Max	Median	Information
Age	6	45	19	Years
Weight	11	92	41	Kg
Inhalation rate (R)	0.5	0.83	0.6650	m^3/Hours
Frequency of Exposure (fE)	317	365	365	Day/years

Source: Primary Data, 2023.

Table 3: Min, Max and Mean Non-Carcinogenic Intake Values of Respondents for Duration of SO_2 Exposure around the PT industrial area. Semen Tonasa, Pangkajene Islands District.

Intake (mg/kg/day)	Min		Max		Average		Information	
	Child	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**
Realtime	0,0011	0,0031	0,0108	0,0326	0,0039	0,0112	MS	MS
Lifetime								
5	0,0007	0,0005	0,0061	0,0041	0,0021	0,0015	MS	MS
10	0,0013	0,0010	0,0122	0,0081	0,0042	0,0030	MS	MS
15	0,0020	0,0014	0,0183	0,0122	0,0063	0,0046	MS	MS
20	0,0026	0,0019	0,0245	0,0163	0,0084	0,0061	MS	MS
25	0,0033	0,0204	0,0306	0,0024	0,0106	0,0076	MS	MS
30	0,0039	0,0029	0,0367	0,0244	0,0127	0,0091	MS	MS

Information: MS (qualify), TMS (No qualify).
*Note: RFC SO_2 (0.026).
Source: Primary Data, 2023.

Table 4: Min, Max and Mean Non-Carcinogenic Intake Values of Respondents for Duration of NO_2 Exposure around the PT industrial area. Semen Tonasa, Pangkajene Islands District.

Intake (mg/kg/day)	Min		Max		Average		Information	
	Child	**Adult**	**Child**	**Adult**		**Child**	**Adult**	**Child**
Realtime	0,0009	0,0029	0,0110	0,0288	0,0045	0,0129	MS	MS
Lifetime								
5 Years	0,0007	0,0004	0,0055	0,0037	0,0024	0,0018	MS	MS
10 Years	0,0013	0,0009	0,0111	0,0074	0,0049	0,0035	MS	MS
15 Years	0,0020	0,0013	0,0166	0,0111	0,0073	0,0053	MS	MS
20 Years	0,0027	0,0018	0,0222	0,0148	0,0098	0,0071	MS	MS
25 Years	0,0034	0,0022	0,0277	0,0184	0,0122	0,0088	MS	MS
30 Years	0,0040	0,0027	0,0332	0,0221	0,0147	0,0106	MS	MS

Information: MS (qualify), TMS (No qualify).
*Note: RfC NO_2 (0.02).
Source: Primary Data, 2023.

Table 5: Min, Max and Mean Risk Quotient (RQ) SO_2 values around the PT industrial area. Semen Tonasa Pangkajene Islands Regency 2023.

RQ (mg/kg/day)	Min		Max		Average		Information	
	Child	Adult	Child	Adult	Child	Adult	Child	Adult
Realtime	0,0407	0,1183	0,4154	1,2532	0,1498	0,4298	MS	MS
Lifetime								
5 Years	0,0252	0,0185	0,2351	0,1567	0,0812	0,0586	MS	MS
10 Years	0,0504	0,0370	0,4702	0,3133	0,1624	0,1171	MS	MS
15 Years	0,0756	0,0555	0,7053	0,4700	0,2436	0,1757	MS	MS
20 Years	0,1008	0,0740	0,9405	0,6266	0,3248	0,2342	MS	MS
25 Years	0,1260	0,0925	1,1756	0,7833	0,4061	0,2928	MS	MS
30 Years	0,1512	0,1110	1,4107	0,9400	0,4873	0,3514	MS	MS

Information: MS (qualify), TMS (No qualify).
*Note: if risk RQ > 1, no risk if RQ < 1.
Source: Primary Data, 2023.

Table 6: Min, Max and Mean Risk Quotient (RQ) NO_2 values around the PT industrial area. Semen Tonasa Pangkajene Islands Regency 2023.

RQ (mg/kg/day)	Min		Max		Average		Information	
	Child	Adult	Child	Adult		Child	Adult	Child
Realtime	0,0471	0,1433	0,5520	1,4380	0,2265	0,6473	MS	MS
Lifetime								
5 Years	0,0336	0,0224	0,2769	0,1845	0,1221	0,0884	MS	MS
10 Years	0,0672	0,0448	0,5538	0,3690	0,2442	0,1768	MS	MS
15 Years	0,1008	0,0672	0,8307	0,5535	0,3663	0,2651	MS	MS
20 Years	0,1345	0,0896	1,1075	0,7380	0,4884	0,3535	MS	MS
25 Years	0,1681	0,1120	1,3844	0,9225	0,6105	0,4419	MS	MS
30 Years	0,2017	0,1344	1,6613	1,1069	0,7326	0,5303	MS	MS

Information: MS (qualify), TMS (No qualify).
*Note: if risk RQ > 1, no risk if RQ < 1.
Source: Primary Data, 2023.

Table 7: Min, Max and Mean Risk Management Values Around the PT Industrial Area. Semen Tonasa Pangkajene Islands Regency 2023.

Variable	Min		Max		Mean	
	Child	Adult	Child	Adult	Child	Adult
Risk Management Dt SO_2	21	32	198	270	81	112
Risk Management Dt NO_2	18	27	149	223	50	69
Risk Manajement tE SO_2	17	26	159	144	65	84
Risk Manajement tE NO_2	14	22	119	112	40	52
Risk Manajement fE $S0_2$	248	381	2414	3290	964	1340
Risk Manajement fE NO_2	211	325	1800	2716	600	828

*Note: RFC SO_2 (0.026) NO_2 (0.02).
Source: Primary Data 2023.

The findings of the real-time RQ calculations conducted with respondents who reside in the vicinity of PT. Semen Tonasa's industrial area indicate that there is no risk to children aged 6-12 at any of the research locations. While there is no risk in other villages, there are adult respondents in Bontoa and Samalewa subdistricts between the ages of 26 and 45 who are at risk. This is because the ambient air quality measurements of SO_2 and NO_2 do not exceed quality standards.

5. Limitations

- This research is limited by the researcher's incompetence so that the research locations chosen are only those in the Ring 1 category of the PT industrial area. Tonasa Cement.
- The number of respondents at each location in this study is limited, based on the researcher's ability and the respondent's willingness.
- Inhalation rate values are still based on existing research or secondary data, not direct measurements for each individual in society.

6. Conclusions

Environmental health risks of exposure to SO_2 and NO_2 in the PT Semen Tonasa industrial area for children are as follows: The RQ SO_2 value in the PT Semen Tonasa industrial area is in the range 0.0407– 0.4154 with the average RQ SO_2 value being 0.1498. The RQ NO_2 value in the PT Semen Tonasa industrial area is in the range 0.0471 – 0.552 with the average RQ NO_2 value being 0.2265.

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Use of AI tools declaration
The author used Grammarly to improve the language in this research.

Conflict of interest
The authors declare that they have no conflict of interest.

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