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Environmental health risk analysis of particulate matter (PM2.5) and particulate matter (PM10) exposure at children in the cement industry area

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Abstract

Air pollution tends to increase, especially in cement industrial areas. Generally, an industry carries out combustion activities to process raw materials. Therefore, it produces pollutants such as Particulate matter (PM2.5 and PM10). This study aims to determine the public health risks due to exposure to PM2.5 and PM10 at children in the cement industry area. 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 PM2.5 and PM10. 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 of this study shows the ambient air concentration around the cement industrial area with PM2.5 and PM10 parameters. The highest PM2.5 concentration was in region 3, namely 20.8 $\mu g/m^3$ and the lowest concentration was in region 2, namely 8.3 $\mu g/m^3$. The projected lifetime intake of ADD for children is 0.0021 – 5.4227. In the 5th year, the projected mean non-carcinogenic ADD still meets the requirements, because it does not exceed the RFC PM2.5 value, namely 0.0012. In the 25th year, the projected mean PM10 value for children is 4.9158 and in the 30th year it decreases significantly to 3.2210. Exposure to PM2.5 with a 30 years average projection of 4.6679 mg/kg/day and PM10 of 3.2210 mg/kg/day, if inhaled by children living around cement industrial areas with an average body weight of 27 kg is not safe and risk for an exposure frequency of 350 days/year for the next 30 years. Air pollution around the cement industry is increasing due to burning activities in processing raw materials. As well as the dust accumulation in the form of fly ash and bottom ash particles, which are considered in the B3 waste category. Optimization of multi-cyclone, conditioning tower, raw mill, and electrostatic precipitator (EP) equipment in parallel as a means of capturing dust from flue gas.

Keywords: Pollutants, Particulate, Industry Cement, EHRA.

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1. Introduction

The cement industry is one of the industries used in the physical construction of infrastructure facilities and infrastructure [1]. The type of processing and raw materials the industry uses can determine the air pollution produced [2]. Generally, an industry carries out combustion activities to process raw materials. This processing process produces pollutants such as gas and particulates [2-4]. Air pollutants originating from industrial activities are divided into five groups of contaminants, namely Nitrogen oxide (NO_2), Sulfur oxide (SO_2), Carbon monoxide (CO), Hydrocarbons (HC), and particulates [5]. Particulates come in different sizes and chemical decompositions [1]. In air quality science, PMs are classified based on size, with the most common distinction being aerodynamic diameter [6]. Particulate Matter (PM) is dust particles that float in the air for long periods [5]. Particulate Matter 2.5 (PM2.5) is a type of air pollutant with a diameter < 2.5μm [6]. Meanwhile, Particulate Matter 10 (PM10) is a type of particle in solid or liquid form that floats in the air with a value, medium, and has an aerodynamic diameter of ≤ 10μm [7].

Particulate Matter comes from various sources, including biomass burning, coal burning, vehicle emissions, and industrial emissions [8]. It is estimated that exposure to PM2.5 causes 5 million premature deaths per year globally. Anoth-er 0.5 million annual premature deaths are also attributed to climate change-related PM2.5 pollution [9]. The 2020 World Air Quality Report Region & City PM2.5 report shows that Indonesia is ranked 1st in the country with the highest concentration of PM2.5 (μg/m³) in Southeast Asia with an average PM2.5 (μg/m³) of 40.8 (μg/m³) [10]. About 50% of the total dust emissions in the atmosphere are PM10. These emissions contribute significantly to atmospheric warming and scatter and absorb solar radiation [11]. Sources of exposure to PM2.5 and PM10 in cement factories come from production units such as raw mills, kilns, coat mills, cement mills, and packing houses [12]. Environmental health risk analysis of exposure to PM2.5 and PM10 is essential because many people live close to cement industrial areas. PM2.5 and PM10 can penetrate and be stored in the lungs. Therefore, people are at significant risk of exposure to PM2.5 and PM10 respiratory and cardiovascular disorders, as well as lung cancer [4]. Novirsa and Achmadi (2012) researched PM2.5 risk analysis in the PT Semen Padang area [4]. The results of the lifetime risk calculation show that there are three risk areas with an RQ value > 1, namely Ring 2 (500 – 1,000 m), Ring 4 (1,500 – 2,000m), and Ring 5 (2,000 – 2,500m). The safest area that people can live in in the cement industrial area is above 2.5 km from the industrial center, with the safest concentration of 0.028 mg/m^3 [4]. Research conducted by Nur et al., (2021) regarding the risk of public health problems due to expo-sure to PM10 in Padang City. The research results show that the PM10 concentration is 0.152 μg/m^3, exceeding the quality standard by Government Regulation 41 of 2009. The intake value of PM10 expo-sure by inhalation at point four has an RQ value >1, indicating that exposure is unsafe for the community along the Gunung Sarik road. So, it needs to be controlled [13]. The area around the cement industry is a residential area which has the potential for air pollution and health problems due to cement industry activities. Based on the description above, researchers are interested in examining environmental health risk analysis and spatial patterns of exposure to PM2.5 and PM10 in the Cement industrial area.

2. Material and Methods

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 PM2.5 and PM10.

2.1. 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

$$ADD = \frac{C \ x \ InhR \ x \ ET \ x \ EF \ x \ ED}{BW \ x \ AT}$$

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.

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

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 [14].

3. Result and Discussion

Respondents in this study were children aged 6–12 years with an average body weight of 27kg. Body weight reflects nutrients in the human body; people with an ideal body weight are sufficiently nourished. Low body height or weight can be influenced by nutritional intake into the body and physical activity. In a study, it was found that the toxic substance in the body is inversely proportional to body weight because the greater the body weight, the wider the toxic substance distribution in the body. An individual with a great body weight has more fat contained in the body. Figure 1 shows the ambient air concentration around the cement industrial area with PM2.5 and PM10 parameters. The highest PM2.5 concentration was in region 3, namely 20.8µg/m^3 and the lowest concentration was in region 2, namely 8.3µg/m^3. There are 2 regions that exceed the PM2.5 concentration quality standard (15µg/m^3), namely region 4 at 20.8µg/m^3 and region 8 at 16.1µg/m^3.

Meanwhile, the highest PM10 concentration was in region 8, namely 39.2µg/m^3 and the lowest PM10 concentration was in region 5, namely 21.4μg/m^3. The PM10 concentration at the research location is below the quality standard (50μg/m^3). The measurement results do not exceed the US EPA quality standard limits. The low concentration of PM2.5 ambient in region 2 is possible because the environment around the area still has a lot of green land cover. PM2.5 will settle on plant leaves to reduce the amount to residential areas [15]. Wind speed affects the distribution of pollutants. The concentration of contaminants will decrease if the wind blows hard and spreads the pollutants horizontally or perpendicularly. PM2.5 is so small that the wind easily carries it. Substantial wind speeds will have contaminants flying everywhere, polluting the air elsewhere. On the other hand, if the wind speed is weak, pollutant substances will accumulate and can pollute the air in people's residences close to the location of the pollution [15]. Using coal as fuel in the cement industry results in significant pollutant emissions into the air [16]. Surrounding cement industrial areas may also experience financial losses due to reduced plant productivity and environmental damage due to changes in community habitat structure. The accumulation or accumulation of dust can harm vegetation such as plants, grasslands, trees, moss, and lenses due to reduced photosynthesis [17].

3.1. Hazard identification

Hazard identification is the first step in EHRA. Hazard identification is used to identify specific risk agents that can cause health problems if the body is exposed for a short or long time [14,18] (Table 1).

3.2. 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 milligram per kilogram per day (mg/kg/d).

3.3. Exposure analysis

Exposure analysis aims to identify and calculate the number of exposed populations and the period of exposure to the agent [19]. Apart from that, exposure analysis also aims to identify risk agent exposure pathways so that the amount of intake received by individuals in at-risk populations can be calculated [18]. Includes methods for estimating the potential, frequency, deviation, and course of exposure to pollutants in humans [19]. The projected lifetime intake of ADD PM2.5 for children is 0.0009 – 4.6679 and PM10 is 0.0021–5.4227. In the 5th year, the projected mean non-carcinogenic ADD still meets the requirements, because it does not exceed the RFC PM2.5 value, namely 0.0012. In the 25th year, the projected mean PM10 value for children is 4.9158 and in the 30th year it decreases significantly to 3.2210. The exposure to air pollutants is measured by calculating the amount of intake that enters the body [1] (Table 2). Determination of exposure analysis (exposure assessment) is carried out by entering the values of anthropometric characteristics and human activities into a formula [4]. Particulate Matter can reach the lower respiratory tract and settle in the lung or alveolar area [20]. Consequently, PM-bound pollutants will interact with extracellular lung fluid, as many can dissolve (bioaccessible fraction) and then be absorbed into the bloodstream (bioavailable fraction). These interactions can be induced by different mechanisms such as paracellular transport (diffusion through tight junctions between alveolar cells) and transcellular transcytosis (transcytosis through alveolar membrane ligands and other non-specific interactions) [21].

3.4. Risk characterization

Risk characteristics are the determination of risk levels, such as determining the risk status or not of a risk agent at a particular concentration, which ultimately causes health problems [22]. Health risk characteristics are expressed as Risk Quotient (RQ) to evaluate potential non-carcinogenic health hazards due to contaminant exposure with available non-carcinogenic health guidelines (MRL, RfD, RfC). The RQ value is obtained by dividing non-carcinogenic intake by RfD or RfC. Exposure to PM2.5 with a 30 years average projection of 4.6679 mg/kg/day and PM10 of 3.2210 mg/kg/day, if inhaled by children living around cement industrial areas with an average body weight of 27 kg is not safe and risk for an exposure frequency of 350 days/year for the next 30 years. The RQ value in this study for inhalation was RQ ≥ I (Figure 2).

Table 1: Hazard identification.

Question	Description
What specific risk agents are dangerous?	Particulate Matter (PM2.5) and Particulate Matter (PM10)
What is the media environment of existing risk agents	Air
How big is the concentration of risk agents in environmental media	The average results of PM2.5 measurements in environmental media (air) are 0.00461 mg/m^3 and PM10 0.018505 mg/m^3
What potential health symptoms or critical effects	The community around the industrial cement has a significant risk of respiratory problems, lung cancer, and cardiovascular disorders due to exposure to PM2.5 and PM10.

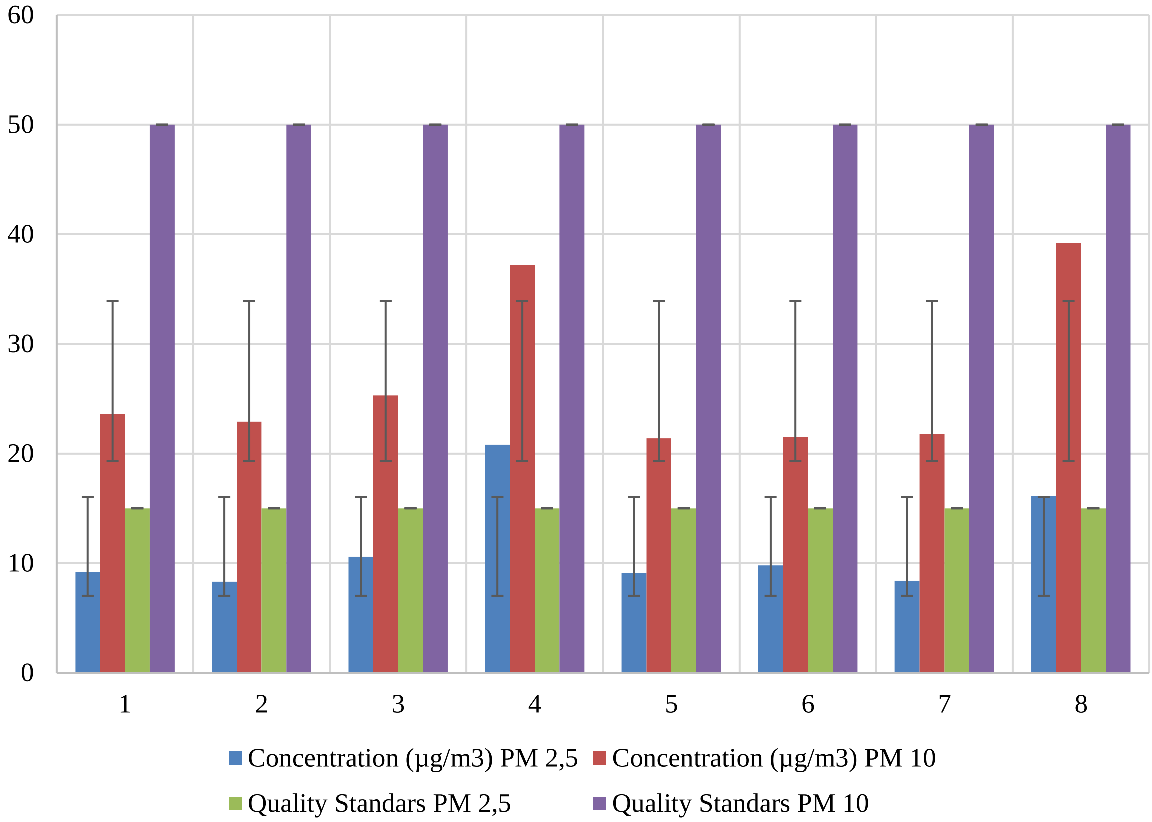

Figure 1: Graph of Ambient Air Measurement Results in the Cement Industry.

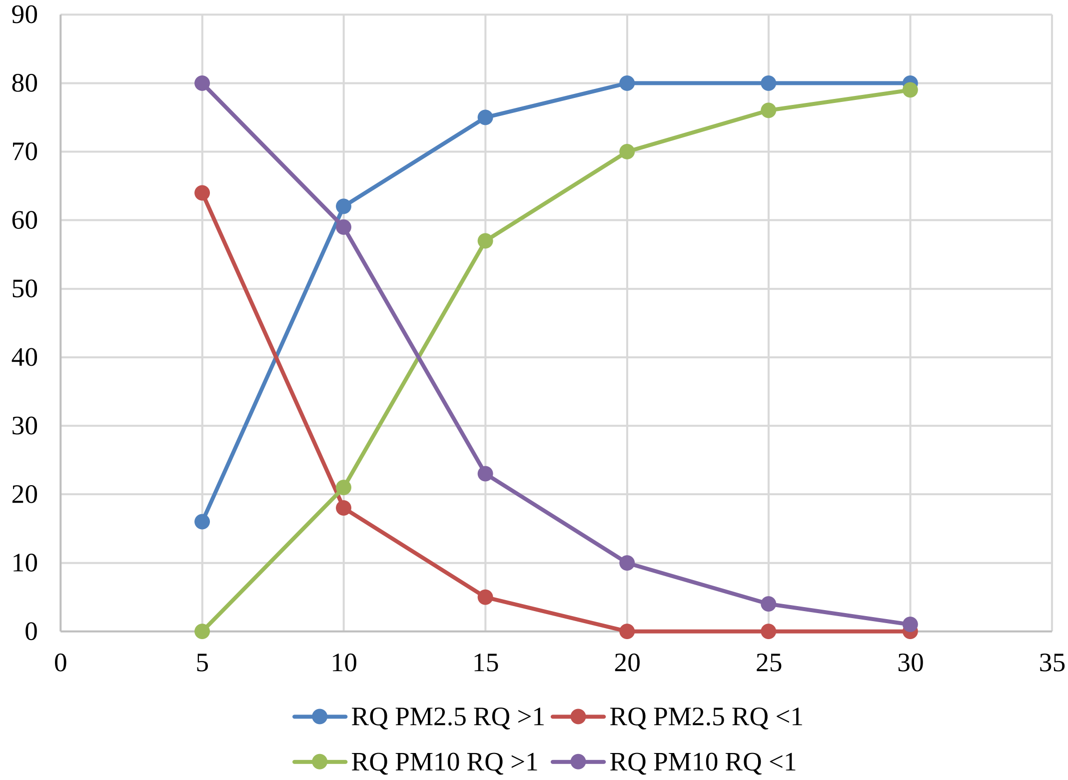

Figure 2: Risk Quotient (RQ) of PM 2.5 and PM10 during 30 years of exposure time.

Table 2: Min, max and average non-carcinogenic ADD values for duration of PM2.5 and PM10 exposure around the cement industrial area.

Children	ADD PM2.5 (mg/kg/day)			ADD PM10 (mg/kg/day)			Information	
	Min	**Max**	**Average**	**Min**	**Max**	**Average**	**PM2.5**	**PM10**
5	0.0004	0.0023	0.0009	0.0008	0.0047	0.0021	MS	MS
10	0.0013	9.8910	2.7194	1.6200	9.3900	4.2078	TMS	TMS
15	1.0510	7.0390	2.7435	1.0000	9.8400	5.3592	TMS	TMS
20	1.4010	9.3850	3.6443	1.0100	9.8300	5.4227	TMS	TMS
25	1.0250	9.6480	4.2082	1.0500	9.9000	4.9158	TMS	TMS
30	1.1190	9.9270	4.6679	1.0100	9.8700	3.2210	TMS	TMS

In line with research conducted by PM10, the intake value of PM10 exposure by inhalation at point four has an RQ value > 1, indicating that exposure is unsafe for the community along the Gunung Sarik road, so it needs to be controlled [13]. Environmental health risk analysis where several variables such as concentration of PM2.5 and PM10, inhalation rate, duration of exposure, frequency of exposure, number of years of exposure, body weight, and average period will influence the characteristics of people living in cement industrial areas. A Risk Quotient value, RQ < 1, indicates a minor health risk and needs to be maintained, while an RQ value ≥ 1 has a significant risk and needs to be controlled.

4. Conclusions

Air pollution around the cement industry is increasing due to burning activities in processing raw materials. This processing process produces pollutants such as gas and particulates Sources of exposure to PM2.5 and PM10 in cement factories come from production units such as raw mills, kilns, coat mills, cement mills, and packing houses. Some of the impacts resulting from exposure to PM2.5 and PM10 include respiratory problems, lung cancer, and cardiovascular disease. The greater the exposure to a risk agent, the greater the health risk, so air quality management needs to be carried out to control the risk of the effects of this exposure. Ambient air quality management: Crusher material, dryer material, raw mill, blending material, kiln, cement mill, and packer. As well as the dust accumulation in the form of fly ash and bottom ash particles, which are considered in the B3 waste category. Optimization of multi-cyclone, conditioning tower, raw mill, and electrostatic precipitator (EP) equipment in parallel as a means of capturing dust from flue gas.

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