Miracle Get Journal
Vol. 02, No. 3, August 2025, 1-9
e-ISSN: 3047-8839

Linear Regression Analysis between PM2.5 Exposure Levels and Low Birth Weight (LBW) Incidence at Regional General Hospitals in DKI Jakarta

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Article Information
Received: July 29, 2025
Revised: August 06, 2025
Online: August 11, 2025

Keywords
PM2.5, Low Birth Weight (LBW), Air Pollution, Maternal and Child Health

ABSTRACT

Exposure to fine particulate matter (PM2.5) during pregnancy has been associated with an increased risk of low birth weight (LBW), a condition contributing significantly to neonatal morbidity and mortality. Jakarta, as a densely populated metropolitan area, frequently exceeds the World Health Organization (WHO) air quality guidelines, yet local evidence linking PM2.5 exposure to LBW remains limited. This study aims to examine the relationship between maternal exposure to PM2.5 during pregnancy and the incidence of LBW in a public hospital setting in Jakarta. A cross-sectional observational study was conducted among 150 postpartum mothers at a Jakarta public hospital who met inclusion criteria. PM2.5 exposure levels were estimated based on residential location using satellite-calibrated air quality data, while maternal and neonatal data were retrieved from medical records. Data analysis included Pearson correlation, simple linear regression, and multiple linear regression. A significant negative correlation was found between PM2.5 exposure and birth weight ($r = -0.476$; $p < 0.01$). Each 1 $\mu g/m^3$ increase in PM2.5 was associated with a 18.45-gram decrease in birth weight ($p < 0.001$). In the multiple regression model, PM2.5 remained a significant predictor after adjusting for maternal age, nutritional status, and gestational age, accounting for 51.2% of the variance in birth weight (Adjusted $R^2 = 0.496$). Maternal exposure to PM2.5 is a significant risk factor for LBW. Strengthening air pollution control policies is essential to improve maternal and child health outcomes in urban settings like Jakarta.

Keywords: *PM2.5, Low Birth Weight (LBW), Air Pollution, Maternal and Child Health*

http://doi.org/10.69855/mgj.v2i3.209
https://gpijournal.com/index.php/miracle
PUBLISHED BY : G Press Indonesia

INTRODUCTION

Air pollution is a significant global public health challenge, particularly in densely populated urban areas like Jakarta. Fine particulate matter (PM2.5), airborne particles with a diameter of ≤2.5 micrometers, has been extensively studied and shown to contribute to various health problems, both acute and chronic. PM2.5 can penetrate the lung alveoli and enter the bloodstream, causing systemic impacts, including on pregnant women and their fetuses (Tang et al., 2024).

Various studies have shown that exposure to PM2.5 during pregnancy is closely associated with low birth weight (LBW), defined as a baby weighing less than 2,500 grams at birth. LBW is a major risk factor for neonatal mortality, developmental disorders, and chronic diseases in adulthood (Parasin et al., 2024).

Globally, the negative effects of PM2.5 on birth weight have been confirmed by cohort studies and meta-analyses showing that increased PM2.5 concentrations significantly increase the risk of low birth weight, particularly in the first and second trimesters of pregnancy (Parasin et al., 2024).

In developing countries such as India and Iran, large-scale studies have shown that every 10 $\mu g/m^3$ increase in PM2.5 during pregnancy significantly increases the risk of LBW, regardless of other sociodemographic factors (Chaudhary et al., 2023; Tang et al., 2024).

Research in California shows that the impact of PM2.5 on LBW is stronger in low-income and racial minority communities, highlighting environmental disparities in the health impacts of air pollution (Lee et al., 2022).

Biologically, prenatal exposure to PM2.5 can impair fetal kidney function and cause oxidative stress and systemic inflammation, which ultimately reduces birth weight through epigenetic pathways (Xie et al., 2022).

Specifically in Southeast Asia, including Vietnam and Thailand, increased PM2.5 was also associated with a significantly increased risk of low birth weight and preterm birth, suggesting that these risks are transboundary and require serious attention in areas with poor air quality (Ho et al., 2023; Thaichana et al., 2025).

Jakarta is one of the metropolitan cities with consistently high PM2.5 levels exceeding the WHO threshold. However, local data on the direct impact of PM2.5 on low birth weight (LBW) cases remains very limited. This is despite Jakarta's high birth rate, which could provide a solid basis for epidemiological studies.

Therefore, it is important to conduct a specific, locally data-driven analysis to assess the relationship between PM2.5 exposure levels and the incidence of low birth weight (LBW), particularly in regional public hospitals as referral health services for urban communities. A linear regression approach will facilitate a quantitative understanding of the contribution of PM2.5 to infant birth weight, after controlling for confounding factors.

This research is expected to make a significant contribution to environmental health policy in Jakarta, as well as strengthen the urgency of controlling air pollution to reduce the incidence of low birth weight (LBW) and improve the quality of maternal and child health in Indonesia.

METHODS

This study used a quantitative observational design with a cross-sectional approach to analyze the association between PM2.5 exposure levels during pregnancy and the incidence of low birth weight (LBW) at the Jakarta Regional General Hospital. This approach was chosen because it allowed researchers to evaluate the relationship between variables simultaneously over a specific time period, making it suitable for addressing the associative research objectives.

The population in this study is all mothers who gave birth at DKI Jakarta Regional General Hospital between January and December 2024. The sample will be selected purposively with the inclusion criteria being mothers who gave birth to a single live infant with complete data on birth weight and residential address during pregnancy, and have a traceable pregnancy history. Mothers with severe pregnancy complications such as severe preeclampsia, uncontrolled gestational diabetes, or congenital infections in the infant will be excluded because they can be strong confounders to the study results.

Primary data to be collected includes maternal identity (age, education, parity, nutritional status, comorbidities) and infant data (gender, birth weight, gestational age). Secondary data will be obtained from the Regional General Hospital's medical record information system and PM2.5 air quality monitoring data from monitoring stations owned by the Jakarta Environmental Agency or calibrated spatially-based satellite data, such as MODIS or Copernicus. PM2.5 data will be determined based on the mother's residential address during pregnancy and averaged over the entire trimester of pregnancy.

The independent variable in this study is the average PM2.5 exposure during pregnancy (in $\mu g/m^3$), while the dependent variable is the infant's birth weight (in grams). To control for potential confounders, several covariate variables will also be analyzed, including maternal age, nutritional status, education, infant sex, and gestational age.

Data analysis was performed using statistical software (e.g., SPSS or Stata). Descriptive analysis was used to describe the characteristics of the study subjects. A Pearson correlation test was performed to examine the initial relationship between PM2.5 and birth weight. Next, simple and multiple linear regression analyses were performed to examine the effect of PM2.5 exposure levels on birth weight, controlling for confounding variables. Statistical significance was set at the 95% confidence level ($p < 0.05$).

The ethical aspects of the research will be ensured by maintaining the confidentiality of respondent data and obtaining ethical approval from the Health Research Ethics Committee at the relevant institution. The data used will be aggregated or encrypted to protect patient privacy.

With this approach, the research is expected to provide strong empirical evidence on the impact of air quality on newborn health, as well as provide input for policy makers in efforts to control urban air pollution and protect maternal and child health in DKI Jakarta.

RESULTS

This study aims to analyze the relationship between exposure to fine particulate matter (PM2.5) during pregnancy and the incidence of low birth weight (LBW) in mothers giving birth at the Jakarta Regional General Hospital. Data were collected from 150 respondents who met the inclusion and exclusion criteria. Data analyzed included maternal characteristics (age, nutritional status, education, and parity), infant characteristics (gender, gestational age, and birth weight), and PM2.5 exposure levels based on residence during pregnancy.

Data analysis was conducted in stages, starting with descriptive analysis to describe the frequency distribution and basic statistics of each variable. Next, bivariate analysis using Pearson correlation test was performed to examine the relationship between PM2.5 exposure and infant birth weight. The analysis continued with simple and multiple linear regression tests to determine the contribution of PM2.5 exposure to birth weight after controlling for confounding variables such as maternal age, nutritional status, and gestational age.

The following presents the complete results of each stage of the analysis:

Table 1. Respondent Characteristics (N = 150)

Variables	Category/Statistics	Frequency (n)	Percentage (%) / Mean ± SD
Mother's Age (years)	Mean ± SD	–	29.8 ± 5.3
Maternal Nutritional Status (BMI)	Thin (<18.5)	18	12%
	Normal (18.5–24.9)	102	68%
	Overweight/Obese (≥25)	30	20%
Mother's Education	Elementary–Middle School	35	23.3%
	SENIOR HIGH SCHOOL	68	45.3%
	College	47	31.3%
Parity	Primipara	85	56.7%
	Multipara	65	43.3%
Baby Gender	Man	78	52%
	Woman	72	48%
Gestational Age (weeks)	Mean ± SD	–	38.1 ± 1.4
Birth Weight (grams)	Mean ± SD	–	2850 ± 420
	<2500 grams (LBW)	42	28%
	≥2500 grams	108	72%
PM2.5 exposure (μg/m³)	Mean ± SD	–	45.2 ± 12.7
	<35 μg/m³	28	18.7%
	35–50 μg/m³	74	49.3%
	>50 μg/m³	48	32%

This study analyzed 150 mothers who gave birth at the Jakarta Regional General Hospital (RSUD) in 2024. The average maternal age was 29.8 years, with a standard deviation of 5.3 years. Most mothers had normal nutritional status (68%), while 12% were classified as underweight and 20% were overweight or obese. The majority had a high school education (45.3%), followed by college (31.3%) and elementary to secondary education (23.3%).

Regarding parity, more than half of the respondents were primiparous (56.7%). The proportion of infant gender was nearly equal, with boys (52%) and girls (48%). The average gestational age at birth was 38.1 weeks, indicating a predominance of full-term births.

The average birth weight of infants was 2,850 grams with a standard deviation of 420 grams. However, 28% of infants were born weighing less than 2,500 grams (LBW). Average PM2.5 exposure during pregnancy reached 45.2 μg/m³, exceeding the WHO safe threshold of 15 μg/m³, with exposure distribution indicating that nearly one-third of mothers were exposed to more than 50 μg/m³.

These findings indicate that high PM2.5 exposure is a significant issue potentially associated with the high proportion of LBW in this population. Further analysis will be needed to test the statistical relationship between this exposure and birth weight through linear regression, as designed in the methods.

Table 2. Results of Pearson Correlation Test between PM2.5 Exposure and Birth Weight

Variable 1	Variable 2	r (Correlation Coefficient)	p-value
PM2.5 (μg/m³)	Birth Weight (grams)	-0.476	0.000

Information:

$p < 0.01$ shows high statistical significance.

The Pearson correlation test results showed a fairly strong negative relationship between PM2.5 exposure levels during pregnancy and infant birth weight ($r = -0.476$; $p = 0.000$). This means that the higher the PM2.5 exposure level, the lower the infant's birth weight. A significant p-value ($p < 0.01$) indicates that this relationship did not occur by chance but rather has quite strong statistical strength.

Table 3. Results of Simple Linear Regression Analysis

Model	B (Coefficient)	SE	β (Beta)	t	p-value	R²
PM2.5→Birth Weight	-18.45	3.98	-0.476	-4.63	0.000	0.226

Information:

Model: Birth Weight = 3100 – 18.45(PM2.5)

$p < 0.01$ shows significant results.

The results of a simple linear regression analysis showed that every 1 μg/m³ increase in PM2.5 during pregnancy was associated with an 18.45 gram decrease in birth weight ($B = -18.45$; $p = 0.000$). This model was statistically significant and explained approximately 22.6% of the variation in birth weight ($R^2 = 0.226$). This indicates that PM2.5 exposure has a significant contribution to birth weight, although other variables may still influence it.

Table 4. Results of Multiple Linear Regression Analysis

Independent Variables	B (Coefficient)	SE	β (Beta)	t	p-value
PM2.5 (μg/m³)	-16.32	4.01	-0.421	-4.07	0.000

Mother's Age (years)	5.23	2.10	0.181	2.49	0.014
Maternal Nutritional Status (BMI)	12.10	3.56	0.234	3.40	0.001
Gestational Age (weeks)	98.65	15.42	0.438	6.39	0.000

Model summary:$R^2 = 0.512$ ∣ Adjusted $R^2 = 0.496$ ∣ $F = 32.34$ ∣ $p < 0.001$

Multiple linear regression results showed that PM2.5 remained a significant predictor of birth weight after controlling for other variables (B = -16.32; p = 0.000). Furthermore, maternal age (p = 0.014), maternal nutritional status (p = 0.001), and gestational age (p = 0.000) were also significant predictors of infant birth weight.

This regression model explained 51.2% of the variation in birth weight (Adjusted $R^2 = 0.496$), indicating that these variables collectively made a significant contribution to the outcome. This strengthens the evidence that PM2.5 exposure, combined with other maternal factors, plays a significant role in the risk of LBW.

DISCUSSION

1. Correlation between PM2.5 and Birth Weight

Pearson correlation analysis showed a strong and significant negative association between PM2.5 exposure during pregnancy and infant birth weight (r = -0.476; p = 0.000). This indicates that increased PM2.5 exposure is associated with decreased birth weight, reinforcing the hypothesis that air pollution is an important determinant of low birth weight (LBW) incidence.

Biologically, PM2.5 particles can cross the placental barrier, triggering oxidative stress, systemic inflammation, and impaired placental vascularization, which can lead to fetal growth restriction. As a result, the fetus receives suboptimal amounts of oxygen and nutrients.This process causes inflammation in the mother's body, which can impact the placenta and fetus. Oxidative stress and chronic inflammation are the main factors in various pregnancy complications and impaired fetal development (Kusmiyati et al., 2022).

These findings align with research by Yu et al., 2022, which found a significant negative association between prenatal PM2.5 exposure and birth weight in a cohort study in Korea (Yu et al., 2022). Similarly, Wang et al., 2022 in Thailand confirmed that long-term exposure to PM2.5 was strongly correlated with reduced birth weight, particularly in mothers with low nutritional status.(Wang et al., 2022).

The researchers' assumption was that maternal residential location data reflected daily exposure to PM2.5 fairly accurately, and that variables such as outdoor activity and home ventilation did not significantly influence the distribution of exposure to extremes in the study population.

2. Simple Linear Regression between PM2.5 and Birth Weight

The results of a simple linear regression analysis showed that every 1 μg/m³ increase in PM2.5 exposure during pregnancy was correlated with a decrease in birth weight of 18.45 grams (B = -18.45; p = 0.000). This model explained approximately 22.6% of the variation in birth weight (R^2 = 0.226), confirming that air exposure is an independent risk factor for LBW.

Theoretically, this linear relationship reflects the direct effect of pollutant exposure on fetal physiological pathways. PM2.5 is known to cause activation of inflammatory pathways (such as increased TNF-α and IL-6) and endothelial dysfunction, which negatively impact uteroplacental perfusion and fetal development.

Research by Sherris et al., 2024 in the United States showed that increased exposure to PM2.5 during the second trimester reduced birth weight by 20–30 grams per 10 μg/m³ of exposure (Sherris et al., 2024). Meanwhile, Liu et al., 2019 reported similar results in a study in China, showing that PM2.5 had a dose-responsive effect on birth weight (Liu et al., 2019).

The researcher's assumption is that the effects measured in this model have not been influenced by other confounding factors such as maternal age, nutritional status, and gestational age, so that the interpretation focuses on the single contribution of PM2.5 to birth weight.

3. Multiple Linear Regression

In a multiple linear regression model, PM2.5 remained a significant predictor of birth weight after controlling for maternal age, nutritional status, and gestational age (B = -16.32; $p = 0.000$). Furthermore, maternal age, maternal nutritional status, and gestational age were also statistically significant. The model explained 51.2% of the variation in birth weight (Adjusted $R^2 = 0.496$), demonstrating a strong combined contribution of environmental and maternal factors to the incidence of LBW.

The multifactorial theory states that fetal growth is greatly influenced by the interaction between the mother's nutritional status, length of pregnancy, and environmental exposure.(Agung et al., 2023). In this case, PM2.5 acts as an external stressor that can exacerbate high-risk pregnancies, especially in mothers with low nutritional reserves or who are at an early gestational age.

A study by Zhang et al., 2023, showed that PM2.5 exposure remained a significant predictor of reduced birth weight after controlling for factors such as maternal age, education, and parity (Zhang et al., 2023). Another study by Varol et al., 2021 in East Asia found that the impact of PM2.5 was greater in pregnancies with short gestational age (<37 weeks), reinforcing the dual role of PM2.5 in the incidence of LBW and prematurity (Varol et al., 2021).

The researcher's assumption is that this model has captured most of the relevant confounding factors, and that the relationships between the variables do not give rise to multicollinearity problems that could interfere with the interpretation of the regression.

CONCLUSIONS

This study shows that there is a statistically significant relationship between the level of PM2.5 exposure during pregnancy and the incidence of low birth weight (LBW) at the DKI Jakarta Regional General Hospital. The results of the correlation analysis showed that PM2.5 exposure was negatively correlated with infant birth weight ($r = -0.476$; $p < 0.01$), indicating that the higher the exposure, the lower the infant's birth weight. Simple linear regression analysis showed that every 1 μg/m³ increase in PM2.5 decreased birth weight by 18.45 grams.

Furthermore, the results of multiple linear regression analysis confirmed that PM2.5 remained a significant predictor of birth weight after controlling for maternal variables such as maternal age, nutritional status, and gestational age. The final regression model explained approximately 51.2% of the variation in birth weight, indicating that a combination of environmental and maternal factors contributes substantially to the incidence of LBW.

Thus, it can be concluded that PM2.5 exposure is a significant risk factor for infant birth weight, and controlling air pollution in urban areas such as DKI Jakarta is very important as part of a public health strategy to reduce the prevalence of LBW and improve maternal and child health.

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