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IMPACT OF PM2.5 EXPOSURE ON MATERNAL AND NEONATAL HEALTH IN GLOBAL CLIMATE CHANGE

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Abstract

Introduction: Climate change and air pollution, particularly PM2.5, are critical global concerns. PM2.5 refers to fine particulate matter with a diameter of less than 2.5µm, capable of penetrating the lungs and entering the bloodstream, leading to severe health issues, especially for pregnant women and neonates. This study aims to analyze the impact of PM2.5 exposure on maternal and neonatal health in the era of global climate change and to develop mitigation strategies that midwives can implement. Method: A literature review was conducted following PRISMA guidelines. The databases searched included PubMed, SagePub, and ScienceDirect, yielding 303 articles based on keywords such as risk factors, impact, negative effects, air pollution, pregnancy, maternal and neonatal outcomes, and PM2.5. After screening, 15 relevant studies were selected for review. Discussion: PM2.5 exposure has been linked to adverse pregnancy and birth outcomes worldwide, including fetal growth restriction, low birth weight (LBW), small for gestational age (SGA), preterm birth, and increased neonatal morbidity and mortality. While some studies have examined the relationship between PM2.5 and seasonal variations in pregnancy outcomes, the biological mechanisms remain unclear. Midwives can help mitigate these effects through education on air circulation, lighting, green spaces, and reducing household burning, alongside interdisciplinary collaboration. Conclusion: PM2.5 exposure during pregnancy, exacerbated by climate change, has been confirmed to contribute to poor birth outcomes. Mitigation efforts are essential to protect maternal and neonatal health.

Keywords: *air pollution, maternal and neonatal outcomes, negative effects, PM 2.5, pregnancy.*

INTRODUCTION

Climate change and increasing air pollution are currently one of the pressing environmental issues globally. According to WHO, until 2019, outdoor air pollution resulted in 4.2 million premature deaths caused by fine particles that cause various diseases such as respiratory and cardiovascular (WHO 2024). Air pollution is composed of various elements such as fine particles (PM 2.5), coarse particles (PM10), nitrogen dioxide (NO2), carbon monoxide (CO), sulfur dioxide (SO2) and ozone (O3) (Liu et al. 2019). The increase in industrial activity, transportation and use of fossil fuels affects the quality of inhaled air (Aryanta and Maharani 2023).

PM 2.5 or Particulate Matter 2.5 is a type of aerosol particle in the form of fine particulates that have a diameter of less than or equal to 2.5 microns (Arba 2019). Although many other pollutants have significant impacts on pregnancy and poor neonatal outcomes, PM 2.5 is currently a major public concern because it is used as the main air quality indicator for the world air quality report (IQAIR 2023). With a very small size, PM 2.5 cannot be filtered by the body and has a greater ability than other pollutants to penetrate deep into the lungs, settle in the alveoli and enter the bloodstream, causing tissue damage and infection (Erickson et al. 2016). Key components of PM 2.5 include sulfate, black carbon, nitrate, and ammonium. PM 2.5 comes from various sources, including vehicle, industrial and household fuel combustion, coal and wood combustion, dust and sand storms and forest fire smoke (Erickson et al. 2016; Aryanta and Maharani 2023; IQAIR 2023). PM 2.5 concentrations tend to be high in dense urban and urban areas with high industrialization and transportation use.

Climate change contributes to worsening air quality. PM 2.5 pollutants can persist for long periods in the atmosphere to perform various activities.PM 2.5 can affect cloud formation and precipitation patterns, where the lower the precipitation, the higher the PM 2.5 concentration (Yang et al. 2016). As a result, climate change does not occur as it should. Other activities, such as PM 2.5 containing black carbon, can absorb and spread solar radiation. As a result, there is an increase in hot temperatures that can affect weather patterns and climate change (Fujino and Miyamoto 2022). Climate change will also affect the dispersion and distribution patterns of PM 2.5 so that areas that were previously less exposed can now become more vulnerable to increased air pollution, including the spread of PM 2.5 pollutants.

Indonesia is a country that is vulnerable to the impacts of climate change, including worsening air quality, especially in big cities such as Jakarta and Surabaya. Based on the air quality technology centre called IQAIR, in 2023, Indonesia was ranked 14th in the world with an average PM 2.5 concentration of 37 $\mu g/m^3$ (IQAIR 2023). This figure is 5-7 times higher than the PM 2.5 standard set by WHO, which is 0-5 $\mu g/m^3$. The highest average PM 2.5 concentration in 2023 was in the city of Bogor, which had a PM 2.5 concentration of 49.9 $\mu g/m^3$ (IQAIR 2023).

Then, the data obtained from the fertility rate in the world, until 2022 in Indonesia, there are an average of 2-3 births/woman (Roser, Roders Gurairo, and Dattani 2022). In fact, the number of women in Indonesia reaches 137.9 million women. Based on the high PM 2.5 in the air and the high average birth rate in Indonesia, PM 2.5 is a major problem that needs to be studied because pollutants can enter the mother's body and can be distributed to the fetus so that, it can affect maternal and neonatal outcomes.

Several studies have shown that the impact of PM 2.5 will worsen the quality of air inhaled by pregnant women, thus potentially affecting the health of pregnant women and their birth outcomes. PM 2.5 inhaled by the mother can cause respiratory problems because, during pregnancy, there is an increased need for oxygen to be distributed to the fetus (Calle-Martínez et al., 2023). PM 2.5 particles can also enter the bloodstream, causing inflammation and oxidative stress. The presence of inflammation and oxidative stress can damage the placenta and its function and result in poor birth outcomes (Ritz et al. 2022). Exposure to PM 2.5 can result in impaired fetal development, such as decreased gestational age, birth weight, body length, head circumference and Apgar score (Liu et al. 2019). Other consequences include LBW (Low Birth Weight), SGA (Small Gestation Age), premature birth and even death (Hu et al. 2023; Guo et al. 2020; Malley et al. 2017). These impacts occur due to the mechanism of PM 2.5 effects related to endocrine disorders, oxidative stress, inflammatory responses, DNA damage and hemodynamic responses (Ritz et al. 2022).

Although there are several studies linking PM 2.5 to health risks during pregnancy, there is still a research gap in understanding the specific mechanisms by which PM 2.5 interacts with the bodies of pregnant women and their fetuses. In addition, research studies in tropical areas such as Indonesia are still few. Other studies are mostly conducted in developed countries with measurable levels of air pollution, while research in developing countries, such as Indonesia, is still very limited.

The Indonesian government has issued various policies to address air pollution, such as controlling motor vehicle emissions, regulations related to land burning and limiting the use of industrial gas. However, the implementation and enforcement of these policies are often not optimal and cause pros and cons. Indonesia is a developing country where economic growth is highly dependent on the industrial sector and natural resources. Production restrictions in certain industries and fuel use controls can affect the financial income of the industry. In fact, these policies can be seen as important steps to protect public health, including pregnant women. Reducing air pollution can reduce the risk of pregnancy complications, improve quality of life, and reduce long-term health burdens.

This study aims to analyze the impact of PM 2.5 exposure on maternal and neonatal conditions in the era of global climate change. This study will describe the results of a literature search related to the negative impacts of PM 2.5 exposure on pregnant women and newborns and how midwives can mitigate these problems.

RESEARCH METHOD

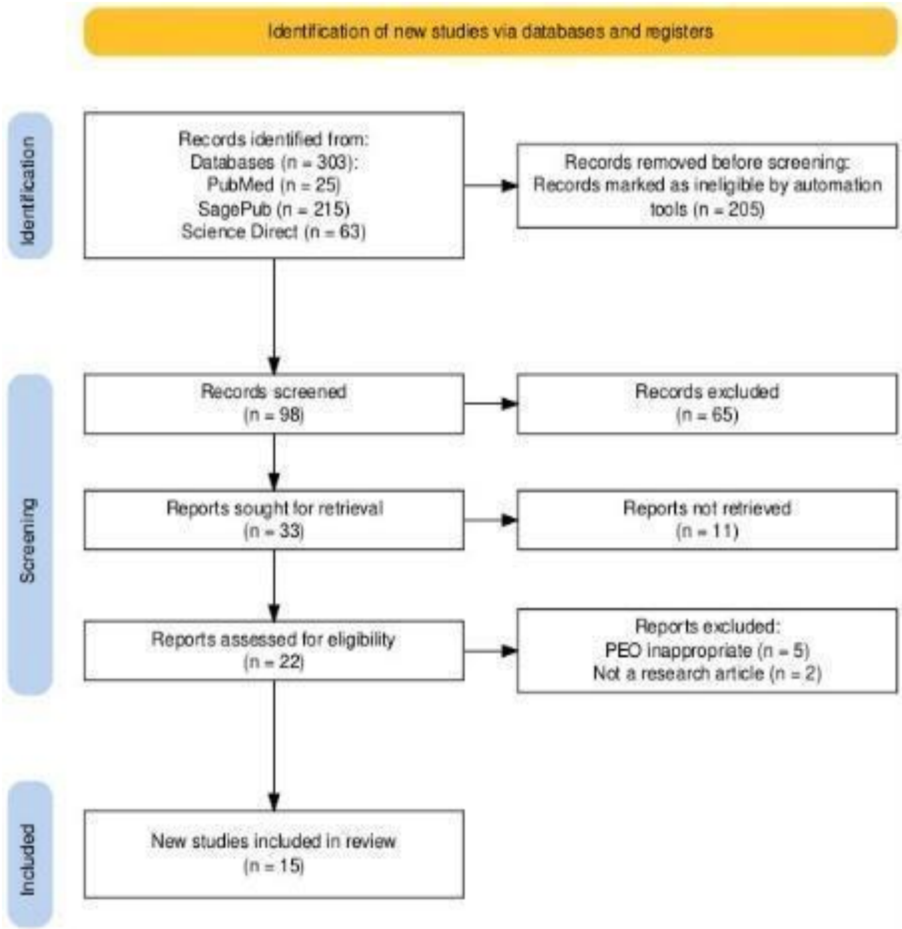

Figure 1. Prisma Chart
Source : (Haddaway et al. 2022)

The literature search method to be analyzed, using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Articles were collected from 3 databases, namely PubMed, SagePub, and ScienceDirect. Articles were obtained using the keywords risk factor, impact, negative effect, air pollution, pregnancy, maternal and neonatal outcomes, and PM 2.5, which were combined using Boolean operations. Twenty-two articles were obtained that met the inclusion criteria, including articles published in the last 10 years, containing keywords, written in English, and available in free full-text form.

Next, an abstract review of the article was conducted to determine the suitability and relevance to the title, PEO (Population, Exposure, and Outcome) and method of the article. The PEO used includes pregnant women and newborns, exposure to air pollution, especially PM 2.5 and the impact on pregnancy and neonatal. Articles that are not research and have research methods in the form of reviews are not included. Based on this, 15 articles will be included in this literature review article.

RESULT AND DISCUSSION

Many previous studies have reported that exposure to pollution. Air plays a role in adverse effects on pregnancy and birth (Mitku et al. 2023). In many countries, it has been reported that exposure to air pollution and environmental temperature has a negative impact on births such as LBW (low birth weight), small gestational age (SGA), and premature births (Arroyo et al. 2016; Hu et al. 2023). One of the air pollutants that is frequently measured and associated with poor pregnancy outcomes is particles with an aerodynamic diameter of less than 2.5 μm (PM 2.5).

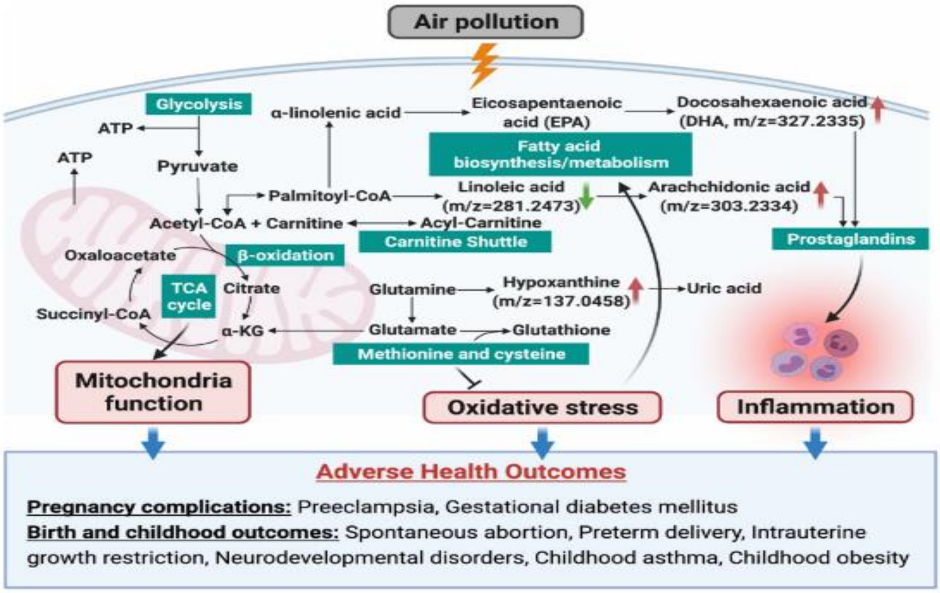

Figure 2. Mechanisms by which air pollution influences adverse pregnancy outcomes
Source : (Ritz et al. 2022)

Based on Figure 2, air pollution causes poor pregnancy and birth outcomes by inducing inflammation due to increased arachidonic acid and docosahexaenoic acid, causing prostaglandin production. In addition, air pollution contains inorganic and organic compound particles that cause mitochondrial dysfunction and activate inflammatory cells that produce reactive oxygen species/ROS.

1. Impact of PM 2.5 Exposure on Fetal Growth Deficit Incidence

Several studies have shown an association between particulate matter (PM) and increased risk of mortality and morbidity. Maternal PM exposure during pregnancy has been associated with impaired fetal development and adverse birth outcomes.[20]. Based on research conducted by (Jedrychowski et al. 2017), exposure to PM 2.5 during pregnancy causes an average birth length deficit of 0.5 cm ($\beta = -0.11$, $p = 0.017$) and an average newborn head circumference deficit of 0.03 cm ($\beta = -0.11$, $p = 0.014$). The study analyzed that the amount of PM 2.5 in the air is greatly influenced by the season, especially the season with heat waves. The ratio can be five times higher than the season without heating (r = 0.617, r 2 = 38.1%). Previous studies have stated that exposure to heat waves increases the secretion of oxytocin and antidiuretic hormone or dehydration causes decreased uterine blood flow and induces fetal hypoxia.

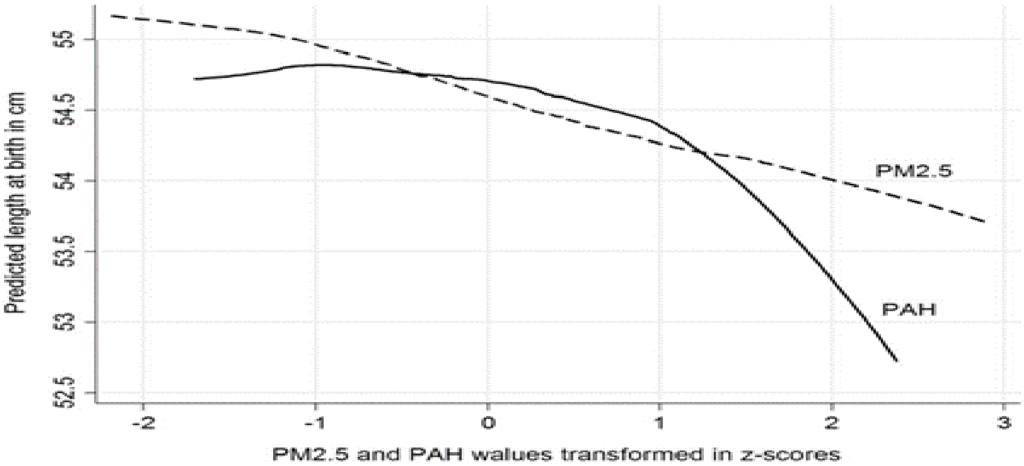

Figure 3. Relationship between PM 2.5 Exposure During Pregnancy and Prediction of Infant Birth Length (cm)
Source : (Jedrychowski et al. 2017)

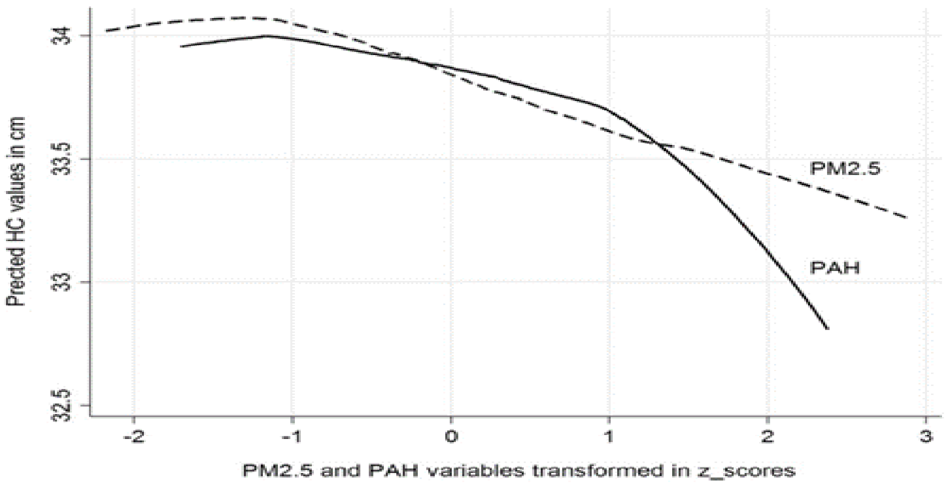

Figure 4. Relationship between PM 2.5 Exposure During Pregnancy and Prediction of Infant Head Circumference (cm)
Source : (Jedrychowski et al. 2017)

The biological mechanisms by which PM 2.5 impacts adverse pregnancy outcomes are not fully understood. PM 2.5 is a proxy for environmental toxicants, including PAHs, sulfates, metals, and black carbon. PM 2.5 is almost always present in combustion processes that produce other toxicants that adversely affect fetal growth and serve as a surrogate for specific etiologic agents responsible for birth deficits.

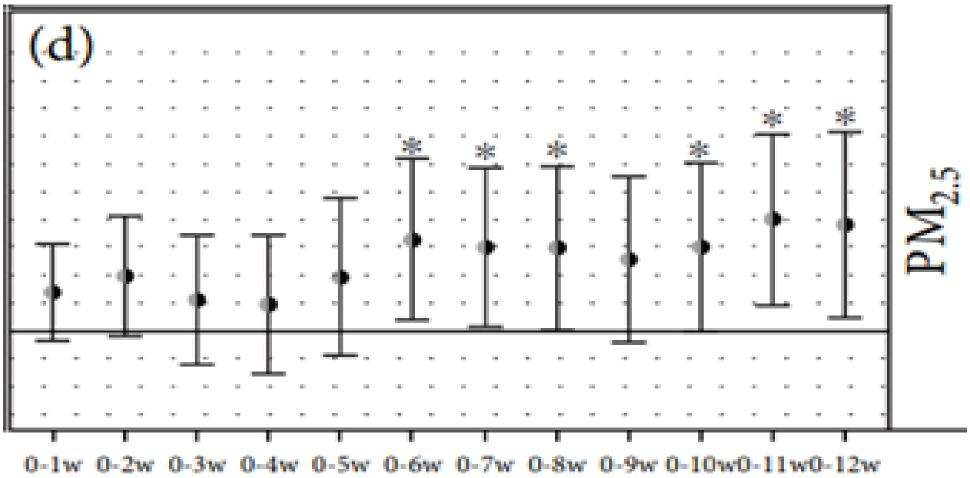

Figure 5.Effect of PM 2.5 Exposure on CRL Measured at 11 Weeks of Gestation
Source : (Iodice et al. 2018)

Other studies have different findings, namely that fetuses whose mothers were exposed to PM 2.5 had a longer crown-to-hip length (CRL). High (pFDR ≤ 0.05) measured in the 11th week of pregnancy (Iodice et al. 2018). The most likely explanation for this occurrence is that at early gestational ages, PM exposure may act as a selection mechanism, causing the stronger fetuses to survive.

2. Exposure to PM2.5 on the incidence of baby birth weight and SGA

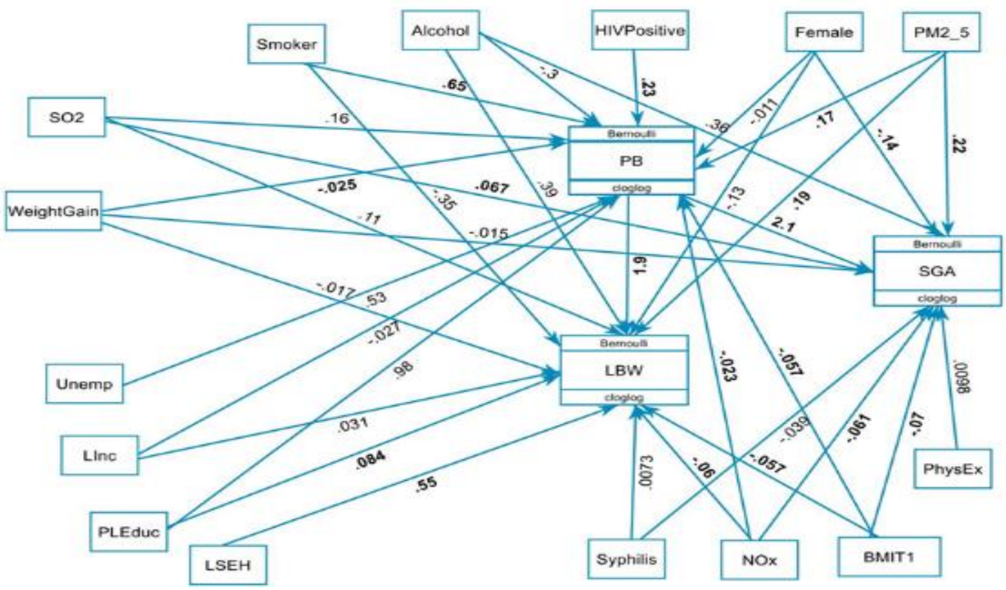

Figure 6.GSEM chart predicting adverse birth outcomes in Maternal and Child Health Epidemiology

Source : (Mitku et al. 2023)

Based on research conducted by (Mitku et al. 2023) shown in the GSEM chart, PM 2.5 exposure provides an indirect effect of PM 2.5 on BBLR or Low Birth Weight (LBW) through premature birth (PB), but this indirect effect is quite low (AOR = 0.03, 95% CI: 0.02, 0.04). Meanwhile, the direct effect is quite high (AOR = 1.3, 95% CI: 1.02, 1.42), which produces a significant positive total effect (total effect = 1.94, 95% CI: 1.49, 2.34)17. PM 2.5 exposure during the entire pregnancy reduces birth weight by 5.93 g (95% CI: -8.36, -3.49) (Guo et al. 2020). Another study also concluded that exposure to PM 2.5 increases the risk of LBW (Hu et al. 2023; Jedrychowski et al. 2017). Directly, PM 2.5 increased the incidence of SGA by 3% to 4% OR = 1.03 (95% CI: 1.01, 1.04) (Guo et al. 2020). The direct effect mechanism of PM 2.5 on SGA has not been explained, but an increase in PM 2.5 exposure of 10-µg/m3 in all pregnancies is associated with the occurrence of SGA.

3. PM2.5 Exposure to Premature Birth and Low Fetal Development

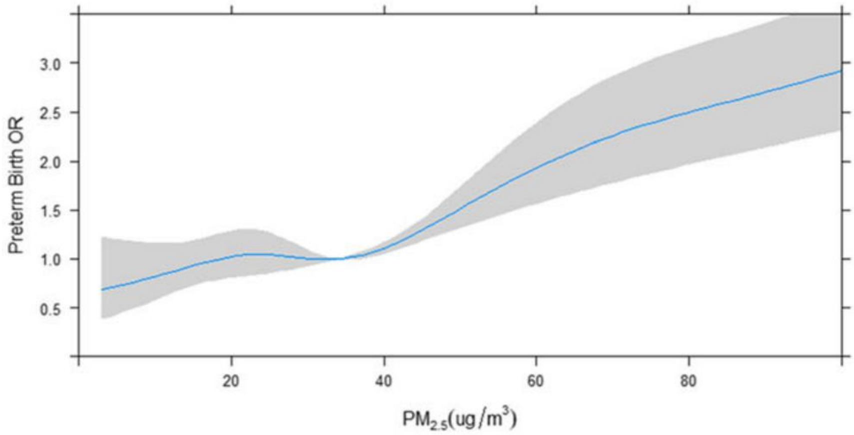

Figure 7.The Relationship Between PM 2.5 Concentration and Premature Birth

Source : (Liu et al. 2019)

Research conducted by Malley et.,al (2017) took global data, namely 183 countries, to analyze the impact of PM 2.5 exposure on preterm birth. Southeast Asia is one of the countries that contribute 10% to 86% of PM 2.5-related preterm births in the global total. Figure 7 shows that PM 2.5 levels of more than 40 µg/m3 increase the risk of higher preterm birth. The mechanism of the effect of PM 2.5 exposure on the incidence of preterm birth is suspected to be due to oxidative stress reactions, lung and placental inflammation, coagulopathy, endothelial dysfunction, hemodynamic responses and intrauterine inflammation (IUI), which have been shown to increase the risk of preterm birth. Supported by research by *(Arroyo et al., 2016)* confirmed that PM 2.5 exposure had an impact on preterm birth in the second trimester and was worse if it occurred in the first trimester of pregnancy (RR= 1.026 (1.018-1.034)).

Table 3 Seasonal distribution of air pollution

Seasons	Month	$PM_{2.5}$ ($\mu g/m^3$)
Spring	3	39.07
	4	35.49
	5	24.13
Summer	6	20.63
	7	23.15
	8	23.55
Autumn	9	29.63
	10	47.82
	11	40.27
Winter	12	41.15
	1	66.24
	2	46.38

Figure 8. Distribution of PM 2.5 against seasons
Source : (Liu et al. 2019)

Based on Figure 8, winter shows high levels of PM 2.5 in the air, reaching 66.24 µg/m3 compared to other seasons. An increase in PM 2.5 exposure of every 10 µg/m3 during the first trimester increases the risk of premature birth by 4.3% (OR 1.043, 95% CI 1.01–1.09 ($p<0.05$)). The increase in PM 2.5 exposure is influenced by the temperature of the season. Based on Figure 8, the distribution of PM 2.5 is very high in winter, indicating that during this period, pregnant women are very vulnerable to the dangers of premature birth due to exposure to PM 2.5 (Liu et al. 2019).

4. Impact of PM 2.5 Exposure on Immune Cell Balance

Research conducted by (Aguilera et al. 2022) in 186 pregnant women with an average gestational age of 20 weeks confirmed that exposure to pollutant compounds, one of which is PM, has a negative impact on pro-inflammatory and anti-inflammatory responses during pregnancy. Higher PM 2.5 exposure was positively associated with IL4 gene methylation and inversely associated with Th2 cell percentage in the first week to six months. In a mouse model, it was found that PM exposure disrupted the inflammatory response in the respiratory tract, causing Th1/Th2 imbalance. This air pollutant affects the signalling pathway and expression of T cells associated with decreased IFNγ and IL10 expression, thus disrupting the Th1/Th2 balance (Aguilera et al. 2022).

5. Complications in Pregnancy, Childbirth, and the Postpartum Period

Research conducted by (Calle-Martínez et al. 2023) linked emergency hospitalization data due to obstetric complications with exposure to air pollutants. Much scientific evidence shows that environmental factors such as pollution and Extreme meteorological phenomena affect pregnancy outcomes. During pregnancy, the body's thermoregulatory capacity decreases due to body mass growth, increased metabolic needs and decreased sweating, making pregnant women vulnerable to the impacts of climate change. In addition, air pollution reacts chemically and physically, the large inspiratory capacity of pregnant women increases their oxygen needs so that inhaled air pollutants increase and enter the bloodstream. The research data analyzed included hyperemesis gravidarum, hypertension, premature labour, KPD, and complications in pregnancy, childbirth, and the postpartum period. However, only in the data on complications in pregnancy, childbirth, and the postpartum period did PM 2.5 exposure have an effect (RR = 1.010, CI 1.001-1.020) with a very small risk of 1.02%.

The results showed that PM 2.5 was one of three pollutants that contributed to 8.4% of hospital admissions due to pregnancy complications. In addition, changes in cold temperatures, even a decrease of 1°C, will increase the risk of pregnant women being hospitalized due to premature rupture of membranes (PROM) by 24%. The risk of hospitalization due to emesis gravidarum is three times greater.

6. Midwife Strategy Management in Preventing the Impact of PM 2.5 Exposure on Pregnant Women's Health and Birth Outcomes

a. Optimization of Education and Counseling

Midwives can optimize preventive measures against exposure to PM 2.5 pollutants and heat waves by maintaining good and cool air circulation in the home, especially for couples and pregnant women who live in urban or industrial areas. Efforts to maintain good air circulation in the home can be made by having an air filter, adequate home lighting, and planting green plants.

Green plants with dense leaves and non-slippery leaf surfaces (e.g., hairy) with overlapping positions can reduce PM 2.5 exposure. This is related to the theory put forward by Schneider, who said that areas with sufficient surfaces and non-slippery surfaces help accelerate and increase particle deposition. These plants should be placed at a height of 0-1.5 m above the surface. Types of plants that fit these criteria are shrubs and vines that can be planted on fences (Aguilera et al. 2022).

Midwives can also provide education on reducing household burning, especially the use of solid fuels. Because it can produce chemical particles, one of which is PM 2.5, which can increase the risk of premature birth, small gestational age, LBW and other complications (Malley et al. 2017).

b. Collaboration between sectors of society

Collaboration between midwives and the community can be done. Already It is explained that green plants such as shrubs and vines planted on fences can reduce the risk of exposure to PM 2.5. Examples of plants that can be planted are duranta repens and Stephanotis floribunda. Collaboration with the community to create a movement to plant these plants can be done to reduce exposure to PM 2.5 on a wider scale. In addition, a good waste management movement can also be carried out. This is related to the risk of household burning, which can produce PM 2.5 particles.

Midwives can also collaborate with doctors or other health workers in the development of new therapies that target specific gene sites in cases of PM 2.5 impact on the body's immune cell imbalance (Aguilera et al. 2022). In addition, midwives can also collaborate with doctors in providing regular USG monitoring measures to review changes in fetal growth as an early predictive step in pregnant women who live in areas with high exposure to air pollutants (Iodice et al. 2018).

CONCLUSION

Exposure to PM 2.5 pollutants during pregnancy, accompanied by seasonal temperature changes, has been confirmed by several studies to cause adverse birth outcomes. The relationship between the amount of PM 2.5 in the air and seasonal temperatures has been reported differently in several studies, possibly due to differences in regions of the country that also have different climatological conditions. The impact of PM 2.5 exposure on pregnancy outcomes such as LBW, small gestational age, fetal growth deficit, and overall immune system disorders has not been explained by its biological mechanism with certainty, so further more in-depth research is needed.

SUGGESTION

The lack of journal articles related to the impact of air pollutants, specifically in Indonesia, one of which is PM 2.5, is expected to be an opportunity for researchers to conduct further analysis in this field. Considering the poor air quality conditions in Indonesia, especially in urban areas, can be a problem that must be handled, one of which is by health workers, namely midwives, because the impacts caused by air pollutants are very dangerous for the health of mothers and babies.

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