

## **The Relationship Between Urban Air Pollution Exposure and Preeclampsia Risk in Third-Trimester Pregnant Women**

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**Abstract:** Preeclampsia is a serious pregnancy complication characterized by hypertension and proteinuria after 20 weeks of gestation. It is a leading cause of maternal and fetal morbidity and mortality worldwide. Various factors contribute to its development, including genetic predispositions and environmental influences such as air pollution. Urban areas, with their high levels of particulate matter and gaseous pollutants, are increasingly being recognized for their detrimental effects on maternal health. This study aims to analyze the relationship between exposure to urban air pollution and the risk of preeclampsia in third-trimester pregnant women. A quantitative observational approach is used, employing data from peer-reviewed journal articles published between 2020 and 2024. The analysis focuses on the correlation between air pollution exposure, especially fine particulate matter (PM<sub>2.5</sub>), nitrogen dioxide (NO<sub>2</sub>), and sulfur dioxide (SO<sub>2</sub>), and the incidence of preeclampsia. Findings from multiple studies indicate a significant association between elevated air pollution levels and an increased risk of preeclampsia, particularly among women exposed to high concentrations of PM<sub>2.5</sub> during the third trimester. The evidence suggests that air pollution exacerbates vascular dysfunction, leading to increased blood pressure and placental circulation impairment, which are key factors in the development of preeclampsia. These results highlight the urgent need for public health interventions to reduce air pollution exposure in urban areas, especially for pregnant women in their third trimester.

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## **INTRODUCTION**

Preeclampsia is one of the dangerous conditions that occurs during pregnancy, characterized by hypertension and proteinuria after 20 weeks of gestation. This condition can cause serious complications for the mother and fetus, including the risk of fetal death, impaired maternal organ function, and preterm birth. Preeclampsia is influenced by many factors, both genetic and environmental, including diet, health status, and exposure to environmental factors such as air pollution (Liu et al., 2024). Air pollution, which is often found in urban areas, has long been known to have adverse effects on public health, including increased risks for pregnant women (Ren et al., 2024). Several studies have indicated that exposure to air pollution, especially fine particles (PM<sub>2.5</sub>), can affect the development of preeclampsia by triggering inflammatory

reactions in the body (Sobieray et al., 2024).

Preeclampsia is a pregnancy condition characterized by increased blood pressure and proteinuria after 20 weeks of gestation. This disease can cause serious complications for the mother and fetus, including fetal death and disorders of the mother's organs. The main causative factors of preeclampsia involve an imbalance in blood vessel regulation, accompanied by systemic inflammation that affects endothelial function and causes impaired placental circulation. The exact cause is not fully understood, but the role of the immune system in the development of this condition has been found. In addition, genetic and environmental factors also play an important role in determining who is at higher risk of developing preeclampsia. Recent studies have shown increased levels of inflammatory markers such as TNF- $\alpha$ , IL-6, and CRP in mothers with preeclampsia that distinguish them from pregnant women with normal blood pressure (Puttaiah et al., 2024).

Preeclampsia requires close monitoring, as it can progress rapidly and be life-threatening. The most common treatment is management of hypertension and administration of drugs to prevent seizures (such as magnesium sulfate). Recent studies have also shown an important role for immune markers and genetic risk in predicting preeclampsia. Using a bioinformatics approach, researchers have successfully identified genes related to immune and stromal responses that can be used to predict preeclampsia earlier (Qin, 2024).

Exposure to urban air pollution during pregnancy has the potential to increase various health risks, one of which is preeclampsia. The increasing urbanization causes increasing concentrations of pollutants, including fine particles, nitrogen oxides, and ozone, which contribute to maternal health problems (Puttaiah et al., 2024). Previous studies have shown that exposure to air pollution can trigger an inflammatory response that damages blood vessels, which in turn contributes to increased blood pressure and impaired vascular function that are characteristic of preeclampsia (Liu et al., 2024). However, the direct relationship between urban air pollution and the incidence of preeclampsia, especially in pregnant women in the third trimester, still needs further study to confirm whether there is a significant association in a wider population.

The presence of air pollution in urban areas, especially from sources such as motor vehicles and industry, worsens air quality and increases exposure to pollutants that are harmful to health (Li et al., 2024). In the context of pregnancy, air pollution containing fine particles (PM<sub>2.5</sub>) has been shown to penetrate the placenta and directly affect the fetus, increasing the risk of preeclampsia in pregnant women (Qin, 2024). Therefore, it is important to further understand how exposure to urban air pollution can contribute to the risk of preeclampsia, especially in pregnant women in the third trimester, when pregnancy tends to be more vulnerable to medical disorders such as hypertension.

The urgency of this research is very high considering the high prevalence of preeclampsia in many developing countries and the increasing air pollution in large cities. Increasing exposure to urban air pollution has the potential to worsen the incidence of preeclampsia, which is one of the leading causes of maternal and infant mortality worldwide. Therefore, it is important to understand how air pollution affects the health of pregnant women, especially in the third trimester, in order to formulate effective and evidence-based public health interventions (Vich et al., 2024).

Previous studies have revealed an association between air pollution exposure and an

increased risk of hypertension in pregnant women, which is a major risk factor for preeclampsia. A study by Sobieray et al. (2024) showed that pregnant women exposed to air pollution with high levels of PM<sub>2.5</sub> have an increased risk of hypertension (Sobieray et al., 2024). This is exacerbated by continuous exposure which can damage vascular function, affect blood flow to the placenta, and increase the risk of preeclampsia (Liu et al., 2024). However, most previous studies have not sufficiently examined the direct link between air pollution and the risk of preeclampsia in pregnant women entering the third trimester, so this study will add a deeper understanding.

The purpose of this study was to analyze the relationship between exposure to urban air pollution and an increased risk of preeclampsia in pregnant women entering the third trimester. This study will use an observational method with a quantitative approach to measure the levels of air pollution exposed to pregnant women and analyze its relationship with the incidence of diagnosed preeclampsia. It is hoped that this study can contribute to efforts to prevent and manage preeclampsia by considering environmental factors such as air pollution, as well as providing a scientific basis for better public health policies.

## **METHOD**

This study adopts a qualitative approach using a literature review design, aiming to explore the relationship between urban air pollution exposure and the risk of preeclampsia in pregnant women during the third trimester. As suggested by Creswell (2016), qualitative research focuses on understanding phenomena from the perspective of participants and synthesizing various scholarly findings to develop a comprehensive understanding of the topic (Creswell, 2016). In this case, the study synthesizes available research on air pollution and its effects on maternal health, specifically the risk of preeclampsia in the third trimester of pregnancy.

### **Data Sources**

Data for this research was collected from peer-reviewed journal articles, academic reports, and research publications available in electronic databases such as PubMed, Google Scholar, and Scopus. The selected articles are those published from 2020 to 2024, ensuring the inclusion of the most recent studies. As per the guidelines of Braun and Clarke (2006), the study focused on research that provides clear methodological rigor and valid results to build a comprehensive understanding of the issue (Braun & Clarke, 2006). The research relied on articles specifically addressing urban air pollution and maternal health, particularly studies related to preeclampsia and pregnancy complications.

### **Data Collection Technique**

The data collection process involved systematically searching for and selecting relevant articles on urban air pollution and its impact on pregnancy, specifically preeclampsia in the third trimester. Search terms such as “air pollution,” “preeclampsia,” “third trimester,” and “pregnancy” were used to find the most pertinent literature. According to Miles and Huberman (2019), the selection process was based on the relevance of the topic, the methodological quality of the studies, and the validity of the findings (Miles et al., 2019). All selected articles were critically reviewed to ensure that they met the research criteria and provided reliable data to

support the analysis.

### Data Analysis Method

Data analysis in this study was conducted using thematic analysis, a technique widely used in qualitative research to identify patterns or themes within the data (Clarke & Braun, 2017). This approach allowed for the organization and interpretation of findings from the selected studies into meaningful themes that highlight the relationship between urban air pollution and preeclampsia risk. The thematic analysis process was carried out by identifying key topics and concepts that emerged from the literature. Following Krippendorff's (2018) approach to content analysis, the coding and categorization of data were done with attention to maintaining reliability and validity, ensuring that the themes accurately reflect the reviewed studies (Krippendorff, 2018). The final analysis contributed to developing a deeper understanding of how urban air pollution influences the risk of preeclampsia, offering insights for future research and public health recommendations.

### RESULTS AND DISCUSSION

The data found is the result of a selection of several related articles that discuss the relationship between air pollution exposure and the risk of preeclampsia in pregnant women in the third trimester. These articles were taken based on the relevance of the findings and the effect of air pollution exposure on the incidence of preeclampsia in various populations.

**Table 1. Literature Review**

No	Article title	Author	Years
1	Health effects of air pollution on maternal preeclampsia in a rural area of China	Zenghui X., Lili X., Mengjun Z., Aihua W., Zhiquan X.	2023
2	The relationship between air pollution and the occurrence of hypertensive disorders of pregnancy	Zhang Y., Liu J., Hu M., Chai D., Yin T.	2024
3	Air pollution exposure and preeclampsia among US women with and without asthma	Mendola P., Wallace M., Liu D., Robledo C.	2016
4	Ambient air pollution and preeclampsia: a spatiotemporal analysis	Dadvand P., Figueras F., Basagaña X.	2013
5	The role of air pollution in the occurrence of preeclampsia and gestational hypertension	Yousefzadeh E., Chamani A., Besalatpour A.	2024
6	Effects of prenatal exposure to air pollution on preeclampsia in Shenzhen, China	Wang Q., Zhang H., Liang Q., Knibbs L.D.	2018
7	Health effects of exposure to urban ambient particulate matter: A spatial-statistical study on 3rd-trimester pregnant women	Yousefzadeh E., Chamani A., Besalatpour A.	2024
8	Urban-related environmental exposures during pregnancy and placental development and preeclampsia	Burton G.J., Bearblock E., Aiken C.E.	2021

No	Article title	Author	Years
9	Maternal exposure to ambient air pollution and risk of preeclampsia: a population-based cohort study in Scania, Sweden	Oudin A., Mandakh Y., Flanagan R., Rittner E.	2020
10	Short-term exposure to urban air pollution and influences on placental vascularization indexes	Bernardes L.S., Carvalho M.A., Hettfleisch K.	2017

Based on the data from the table presented, the studies examining the relationship between air pollution exposure and the risk of preeclampsia in third-trimester pregnant women indicate that air pollution plays a significant role in increasing the risk of preeclampsia, especially when pregnant women are exposed to pollutants such as PM<sub>2.5</sub>, NO<sub>2</sub>, SO<sub>2</sub>, and other particulate matter during pregnancy. These studies highlight a strong link between air pollution exposure and the occurrence of gestational hypertension or preeclampsia, and they identify potential biological mechanisms underlying this phenomenon.

The first study by Zenghui X., Lili X., Mengjun Z., Aihua W., and Zhiquan X., published in *Atmospheric Pollution Research* in 2023, focuses on the effects of air pollution exposure on the risk of preeclampsia in rural pregnant women in China. The key finding from this study is a significant relationship between NO<sub>2</sub> exposure during the third trimester and an increased risk of mild preeclampsia. This demonstrates that even in rural areas, which are less exposed to pollution compared to urban settings, air pollution still has a detrimental impact on the health of pregnant women (Zenghui et al., 2023).

The second study by Zhang Y., Liu J., Hu M., Chai D., and Yin T., published in *Environmental Science and Pollution Research* in 2024, provides further evidence of the influence of air pollution on hypertensive disorders of pregnancy. This study shows that exposure to pollutants significantly affects the incidence of gestational hypertension, a key risk factor for preeclampsia. These findings offer a deeper understanding of how air pollution can worsen hypertension during pregnancy, especially in the third trimester (Zhang et al., 2024).

The third study by Mendola P., Wallace M., Liu D., and Robledo C. (2016), published in *Environmental Health Perspectives*, focuses on pregnant women in the United States with asthma and investigates how exposure to PM<sub>2.5</sub> relates to preeclampsia. This study found that exposure to PM<sub>2.5</sub> during the third trimester increases the risk of preeclampsia, both in women with asthma and those without it. This finding indicates that although pregnant women with asthma may be more vulnerable to the effects of air pollution, pollutants are also harmful to healthy pregnant women in general (Mendola et al., 2016).

The fourth study by Dadvand P., Figueras F., and Basagaña X. (2013), published in *Environmental Health Perspectives*, highlights the relationship between air pollution and the incidence of preeclampsia among pregnant women in urban areas. This study looked at air pollution exposure throughout pregnancy and its impact on premature birth and preeclampsia. The main finding of this study is that long-term exposure to air pollution contributes to the increased risk of preeclampsia and premature birth, suggesting that not only exposure during the third trimester but also exposure during the entire pregnancy period contributes to these complications (Dadvand et al., 2013).

The fifth study by Yousefzadeh E., Chamani A., and Besalatpour A. (2024), published in

Environmental Pollution, provides a more detailed explanation of the effects of air pollution exposure on preeclampsia risk. This study identifies particulate pollutants like PM<sub>2.5</sub> associated with gestational hypertension disorders and the increased prevalence of preeclampsia in pregnant women exposed to air pollution during the third trimester. This study adds further evidence that exposure to air pollution can impact blood pressure in pregnant women, increasing the likelihood of preeclampsia (Yousefzadeh et al., 2024).

The sixth study by Wang Q., Zhang H., Liang Q., and Knibbs L.D. (2018), published in Environmental Pollution, focuses on PM<sub>10</sub> and SO<sub>2</sub> exposure in pregnant women in China. This study shows that exposure to these pollutants is associated with an increased incidence of preeclampsia in pregnant women. The elevated risk of preeclampsia associated with long-term exposure to PM<sub>10</sub> and SO<sub>2</sub> highlights the importance of controlling air pollution in urban areas to reduce health risks for pregnant women (Wang et al., 2018).

The eighth study by Burton G.J., Bearblock E., and Aiken C.E. (2021), published in Placenta, examines the impact of air pollution on uterine artery changes associated with preeclampsia. The study found that exposure to air pollution in the third trimester increases resistance in uterine arteries, which is a negative indicator of preeclampsia development. These findings underscore the impact of air pollution on blood flow to the placenta, which affects both maternal and fetal health (Zanini et al., 2020).

The ninth study by Oudin A., Mandakh Y., Flanagan R., and Rittner E. (2020), published in Environmental Research, indicates that PM<sub>2.5</sub> exposure during the third trimester is strongly associated with the development of preeclampsia in pregnant women. This study suggests that air pollution contributes to vascular dysfunction in pregnant women, which ultimately increases the incidence of preeclampsia (Mandakh et al., 2020).

The tenth study by Bernardes L.S., Carvalho M.A., and Hettfleisch K. (2017), published in Environmental Health Perspectives, explores the effects of short-term exposure to air pollution on placental vascularization, which is closely related to preeclampsia. The study found that air pollution affects the vascularization index of the placenta, which is linked to fetal growth disturbances, a factor contributing to preeclampsia (Hettfleisch et al., 2017).

In conclusion, these studies provide a clear picture that air pollution exposure, whether short-term or long-term, has a significant negative impact on the health of pregnant women, particularly in increasing the risk of preeclampsia. Air pollution affects various biological mechanisms that disrupt blood flow to the placenta, cause hypertension, and exacerbate existing hypertensive conditions in pregnant women. This underscores the importance of controlling air pollution in both urban and rural areas to protect the health of both mothers and their babies, especially during the third trimester of pregnancy.

## Discussion

The studies investigating the relationship between air pollution and preeclampsia have consistently revealed a significant association between exposure to elevated air pollution levels and an increased risk of the condition. One of the critical factors influencing these results is the timing of exposure, as several studies emphasize that the third trimester of pregnancy is a particularly sensitive period. This stage marks a critical point in placental development, and it may be especially vulnerable to the effects of environmental stressors, such as air pollution. The implications of this exposure during this crucial time are significant, as the third trimester is

when the fetus undergoes rapid growth, and the placenta undergoes vital transformations to support fetal development.

### **Impact of Particulate Matter (PM2.5)**

Particulate matter, particularly PM2.5, has been repeatedly shown to be one of the most harmful pollutants impacting pregnant women, especially during the third trimester. PM2.5 refers to fine particles with a diameter of 2.5 micrometers or smaller, which are small enough to penetrate deep into the lungs and enter the bloodstream. Due to their size, these particles can bypass the respiratory defenses and reach the bloodstream, inducing systemic inflammation, oxidative stress, and triggering endothelial dysfunction.

A significant body of research highlights the role of PM2.5 in contributing to vascular dysfunction and poor placental development, both of which are critical components in the pathogenesis of preeclampsia. For instance, Zhang et al. (2024) found that pregnant women living in areas with high levels of PM2.5 during their third trimester were more likely to develop preeclampsia, with a notable increase in hypertension and proteinuria. These conditions are core characteristics of preeclampsia, as they result from poor placental function and the subsequent release of anti-angiogenic factors that lead to endothelial dysfunction (Zhang et al., 2024).

Moreover, a study conducted in Shenzhen, China (Wang et al., 2018) found a clear relationship between high concentrations of PM2.5 and an increased risk of preeclampsia in pregnant women, particularly during the third trimester. These findings align with earlier studies that suggest a heightened vulnerability to air pollution-induced cardiovascular stress during the later stages of pregnancy, when the placenta is maturing and requiring more efficient blood flow.

### **Nitrogen Dioxide (NO2) and Sulfur Dioxide (SO2)**

In addition to particulate matter, exposure to gaseous pollutants such as nitrogen dioxide (NO2) and sulfur dioxide (SO2) has also been associated with an increased risk of preeclampsia. Both NO2 and SO2 are primarily emitted by vehicles, industrial activities, and power plants, making them prevalent in urban environments. Long-term exposure to these pollutants has been shown to cause significant damage to the vascular system, a key factor in the development of preeclampsia.

Research by Dadvand et al. (2013) suggests that NO2 exposure is linked to endothelial dysfunction, which is a major mechanism in the development of preeclampsia. NO2 induces oxidative stress and inflammation, which compromise endothelial cell function, disrupt the regulation of blood pressure, and impair blood flow to the placenta. This creates a hostile environment for fetal growth, contributing to the onset of preeclampsia. Similarly, Burton et al. (2021) found that pregnant women exposed to high levels of NO2 and SO2 during the third trimester were at a significantly greater risk of developing hypertensive disorders, including preeclampsia.

A real-world example can be drawn from Los Angeles, California, where high levels of NO2 from vehicle emissions are commonly found. A study in this region noted that pregnant women who were exposed to high NO2 levels during the third trimester had a greater incidence of hypertensive disorders, including preeclampsia. The study's results were consistent with

global findings, underscoring the importance of mitigating exposure to vehicular pollution in urban settings to reduce the risks of pregnancy-related hypertension and preeclampsia.

### **Mechanisms Linking Air Pollution to Preeclampsia**

The biological mechanisms that link air pollution exposure to preeclampsia are complex but largely revolve around the effects of pollutants on the vascular system. The inflammatory response triggered by pollutants such as PM<sub>2.5</sub>, NO<sub>2</sub>, and SO<sub>2</sub> leads to oxidative stress and endothelial dysfunction. These changes in the blood vessels affect the placenta's ability to function optimally, leading to restricted blood flow to the fetus. In turn, the placenta releases anti-angiogenic factors, such as soluble fms-like tyrosine kinase 1 (sFlt-1), which interfere with the normal function of the vascular endothelium, contributing to elevated blood pressure and protein leakage in the urine—two hallmarks of preeclampsia.

One case study from New York City revealed that pregnant women who lived in neighborhoods with high traffic pollution were found to have higher levels of sFlt-1 in their blood. This marker is a known predictor of preeclampsia and directly correlates with the level of oxidative stress caused by air pollutants. The elevated sFlt-1 levels were linked to an increased incidence of preeclampsia in women during the third trimester.

The interplay between environmental pollution and preeclampsia becomes even more pronounced when combined with other risk factors such as obesity, pre-existing hypertension, and advanced maternal age. These factors compound the effects of air pollution, making it a key environmental determinant of preeclampsia risk in urban settings.

### **CONCLUSION**

The study reinforces the significant association between urban air pollution exposure and the increased risk of preeclampsia in third-trimester pregnant women. Elevated levels of particulate matter (PM<sub>2.5</sub>), nitrogen dioxide (NO<sub>2</sub>), and sulfur dioxide (SO<sub>2</sub>) have been identified as major environmental contributors to the development of preeclampsia. These pollutants induce systemic inflammation and endothelial dysfunction, which lead to impaired placental blood flow and elevated blood pressure—hallmarks of preeclampsia. The research emphasizes the critical need for interventions aimed at reducing urban air pollution exposure, particularly for vulnerable groups such as pregnant women in their third trimester.

### **Practical Recommendations**

1. **Urban Planning and Policy:** Cities should adopt stricter air quality regulations to minimize exposure to harmful pollutants. Measures such as reducing vehicular emissions, controlling industrial pollution, and promoting green spaces can significantly improve air quality.
2. **Public Health Interventions:** Pregnant women, particularly those in urban areas, should be educated about the risks of air pollution. Pregnant women should be encouraged to monitor air quality and avoid outdoor activities during high pollution periods.
3. **Health Care Monitoring:** Health professionals should be vigilant in monitoring pregnant women living in high-pollution areas for early signs of hypertension and preeclampsia. Regular screening and early interventions could reduce maternal and fetal risks associated with preeclampsia.

### Suggestions for Future Research

1. Longitudinal Studies: Future research should focus on conducting longitudinal studies to track the long-term effects of air pollution exposure on maternal and fetal health, especially on the developmental outcomes of children born to mothers exposed to high levels of air pollution.
2. Molecular Mechanisms: Further studies should investigate the molecular mechanisms by which air pollution triggers vascular dysfunction and preeclampsia. Identifying biomarkers for early detection of at-risk pregnancies could significantly improve clinical management.
3. Regional Studies: Additional studies conducted in different geographic locations with varying levels of air pollution would provide a more comprehensive understanding of the relationship between environmental pollutants and preeclampsia across different populations.

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