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Relationship between prenatal exposure to environmental pollutants and postpartum depression

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Abstract

Background: In both animal and human studies, exposure to environmental pollutants has been associated to depressed symptoms. The health of mothers and children is significantly impacted by postpartum depression (PPD), which affects up to 1 in 5 mothers worldwide.

Objective: Evaluated the relationship between prenatal exposure to environmental contaminants and postpartum depression.

Methodology: We investigated the relationship between prenatal and postpartum depression exposure to particulate matter ($PM_{2.5}$) with symptoms of psychological dysfunction at 1 and 6 months postpartum in Lahore city, Raiwand Tehsil (2918 women with accessible data). A hybrid satellite based spatiotemporally resolved model was used to obtain daily $PM_{2.5}$ estimates, which were then averaged during pregnancy and the first postpartum year. The relationship between PM2.5 exposure and probable PPD (EPDS score 13) was evaluated and the symptoms of anhedonia, depression, and anxiety (derived from EPDS subscales) were evaluated by using the spss software version 21.

Results: A 5-g/m^3 increase in average $PM_{2.5}$ exposure during pregnancy was linked to an elevated risk of PPD at 6 months (95% CI. The 6-month EPDS subscale symptom scores for anhedonia ($p = 0.03$) and depression ($p = 0.04$) were likewise elevated in association with average $PM_{2.5}$ exposure during pregnancy. An increased risk of depressive symptoms was linked to increases in $PM_{2.5}$ and NO_2 during the second trimester. A lower risk was linked to the IQR increase in O_3 throughout the first trimester. At six months after giving birth, PPD and the signs of anhedonia and depression were strongly correlated.

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Conclusions: According to our research, pregnant women are at a higher risk of developing depression or anxiety when there are higher levels of NO_2, and O_3 in environment.

Introduction

One of the most prevalent disorders in women after giving birth is postpartum depression (PPD), also known as postnatal depression (PND). Up to 2017, according to earlier research, the global incidence of PPD ranged from around 9.5% in high income nations to about 20.8% in middle income countries to about 25.8% in low income countries [1]. Depressed mood, anxiety, and anhedonia are the three fundamental elements of the heterogeneous disease known as PPD. These three dimensions may present at different times during the postpartum period. PPD may have a negative impact on mother child bonding and the effectiveness of social, physical, and vocational performance. Lack of health insurance or insufficient coverage, lack of awareness of the signs of mental health problems, cultural stigma associated with mental illness, and the scarcity of culturally competent and multilingual mental health professionals are all obstacles to receiving mental health services. [2]. A factor that contributes to 20% of maternal deaths shortly after giving birth is the feeling of helplessness that comes with acute illness, which can endanger life and inspire suicide. Additionally, problems including a lack of bonding to the newborn (34%), a fear of harming the kid, and even, in severe situations, suicide attempts have been documented [3,4,5]. According to current estimates, 10 to 20% of American postpartum women suffer from anxiety or depression disorders, which have an effect on both the women's health and the consequences for their offspring. Therefore, a public health objective is to identify modifiable risk factors for unfavourable postpartum psychosocial functioning [6]. Some populations bear a disproportionate amount of the cost. For instance, epidemiological statistics show that prevalence rates of anxiety, depressed mood, and anhedonia are higher in urban ethnic communities, especially among Black and Hispanic mothers, as well as among women with lower socioeconomic level [2,7,8]. Other results imply that cultural and environmental factors influence the subjective perception of affective states differently. Together, these lines of study highlight the necessity of differentiating individual symptom profiles in order to more fully assess risk, especially among postpartum women who may have different exposure to outdoor air pollution [9].

PPD is especially concerning in low and middle income countries due to its high prevalence and the lack of resources for its diagnosis and treatment. Determining PPD risk factors that can be changed is crucial for public health. Studies on animals and people have provided evidence that ambient air pollution is linked to poor cognitive functioning. Ambient air pollution exposure has been linked to anxiety and depressive like symptoms in adult rats [10,11,12,13]. The majority of study in human studies has been on ageing and non-pregnant people. Adults in South Korea [14] and the United States [15,16] have shown signs of depression and anxiety after being exposed to more particulate matter. In two trials, short-term $PM_{2.5}$ exposure was also connected to a higher incidence of depressive hospitalization [17,18,19,20].

The relationship between environmental pollution during pregnancy and postpartum psychological functioning has not been extensively studied in the past. A diverse sample of Black, Hispanic, and white mothers in Boston participated in a study in Mexico City that found that mid-pregnancy exposure to $PM_{2.5}$ was linked to an increase in postpartum anhedonia symptoms during the first year after delivery. After stratifying by race/ethnicity, the study also found that the subpopulation of Black mothers had the strongest associations between

Amna Iqbal Butt
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$PM_{2.5}$ and symptoms of depression and anhedonia [2,21].

Pakistan is the fifth most populated nation in the world, it is an old territory with a sizable population of 212.2 million people. In terms of pollution levels, Pakistan has historically had very poor results, with many of its megacities generating enormous volumes of smoke, haze, and lethal fog that permeates the air and causes a variety of problems for its citizens. Pakistan was rated as having "unhealthy" air quality in 2019 with a $PM_{2.5}$ value of 65.81 g/m^3. Particulate matter ($PM_{2.5}$) is defined as having a diameter of 2.5 micrometer or smaller, or about 3% the width of a typical human hair [22,23,24,25,26,27].

The precise pathophysiology of PPD development with exposure to environmental contaminants is yet unknown. It has been linked by researchers to genetic differences, neurological inflammation, and hormone imbalance. Due to the interdependence of these states, it is challenging to pinpoint the specific PPD mechanism. In investigations on both animals and people, environmental pollution has been shown to raise the risk of neurological and mental illnesses. Studies have shown that long-term exposure to particulate matter with a diameter of less than 2.5 micrometres ($PM_{2.5}$) and short-term exposure to particulate matter with a diameter of less than 10 micrometres (PM_{10}) increases the risk of depression. Another study conducted in Mexico found a correlation between rising mental health difficulties and mean PM 2.5 exposure. According to a research in a U.S. pregnancy cohort, Black women who were exposed to $PM_{2.5}$ in the second trimester had higher overall scores on the Edinburgh Postnatal Depression Scale (EPDS) 21 [28,29,30].

As a result, we assumed that exposure to environmental pollutants may cause PPD, but no pertinent studies have been conducted in Pakistan. To the best of my knowledge, very few researches have looked at the connections between PPD and air pollution globally. In this study, we investigated the association of $PM_{2.5}$ concentrations with prenatal and postpartum women which were linked to higher depression six months after delivery. We determined the relationship between exposure to $PM_{2.5}$ during pregnancy and psychological functioning, measured using the EPDS.

Methdology:

Our study was a prospective longitudinal cohort study that ran for two years, from July 2020 to September 2022, in the gynaecology and obstetrics departments of hospitals in Raiwind Tehsil, Lahore. Using the software OpenEpi version 3, a sample size of 2918 was generated with a confidence interval of 95%. A woman had to be at ≥18 years old, at ≥20 weeks pregnant, intend to stay in the City for the next two years, have access to a phone, not have a history of heart or kidney disease, not drink frequently, and not be taking any steroid or anti-epilepsy medications in order to be eligible to participate in the study.

Data Collection

PPD was evaluated using the Edinburgh Postpartum Depression Score Questionnaire. Pregnant women who met the inclusion criteria were chosen from hospitals in Raiwind, Lahore, after receiving ethics committee approval. We collected the data from the Pakistan Meteorological Department in Lahore and maternal psychological functioning from postpartum women in Lahore's multi-hospitals. Data were also gathered through questionnaires on likely indoor environmental pollution sources, modes of transportation, and prior exposure to cigarette smoke. After receiving participant's informed consent, the interviewer asked questions in the local language and documented the participants' responses on the appropriate questionnaire. Due to inevitable drop outs, data was collected until the target sample size was reached. A 10 item self-reported tool with strong sensitivity and specificity, the EPDS has 10 items. The total score ranges from

Amna Iqbal Butt
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0 to 30, with higher scores indicating higher levels of depression symptoms. Each item is scored on a 4-point scale a minimum rating of 13.

Levels of $PM_{2.5}$ during pregnancy

Estimated daily $PM_{2.5}$ exposure for each cohort member throughout pregnancy. Established the gestational age at birth, gestational age was calculated using the last menstrual period (LMP) and a normal physical examination [31]. The gestational age identified by the physical exam was utilized in place of the gestational age established by the LMP if the difference between the two was greater than 3 weeks. Then, a hybrid spatio-temporal model that integrates Aerosol Optical Depth (AOD) observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite with a spatial resolution was used to predict daily $PM_{2.5}$ exposure [32]. Estimated the daily residential $PM_{2.5}$ levels for each participant, remote sensing data were calibrated using meteorological data, land use regression (LUR) factors, and municipal ground level monitors of $PM_{2.5}$. The model was ran utilizing day specific calibrations of AOD data calibrated against ground $PM_{2.5}$ measurements and LUR and meteorological variables (roadway density, temperature, relative humidity, planetary boundary layer, and daily precipitation), as well as LUR and meteorological data. Took into consideration temporal fluctuations in the $PM_{2.5}$ and AOD association, mixed effect models including geographical and temporal predictors and day-specific random effects were used. A seasonal smooth function of latitude and longitude and a time-varying average integrating local monitoring were used to fit the model for days lacking AOD data. Cross-validated R_2 of 0.724 indicates that the model performed well when monitor-level leave one out cross validation was used to evaluate model performance. During pregnancy and the three clinically defined trimesters (first trimester: 1–13 weeks, second trimester: 14–27 weeks, third trimester: 28 weeks–delivery), we computed the average $PM_{2.5}$ levels.

Analysis of data

By using SPSS version 21, the obtained data was entered, purified, and analyzed. For categorical factors like gender, age, education level, etc., percentages and mean were determined. After correcting for socio-demographic covariates, the link between prenatal exposure to environmental pollutants and the development of postpartum depression was also examined using the chi-square test, which considered a p-value of 0.05 as significant. An independent t-test was used to compare the PPD means for the two cohorts. The PPD scores were measured at prenatal visits as well as at the end of the first and sixth postpartum months , and repeated measure ANOVA was used to compare the results for the two cohorts.

Results:

Characteristics of sample The study population's summary data are shown in Table 1. The majority of participants (47%) just completed high school from the 2918 pregnant women. The average age was 32.9. The majority of participants (55%) had high incomes, while the majority of women (53.3%) said they had never smoked. The mean environmental pollutant concentrations for each trimester during the study period are shown in Table 2. Average exposure levels for NO_2, $PM_{2.5}$, and O_3 during pregnancy were 34.8 ppb, 26.4 g/m3, and 41.2 ppb, respectively.

Amna Iqbal Butt
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Table 1 presents descriptive data for the study population (n=2918)

Characteristics	n(%)
Age (years)	32.9%
Age groups	
≥18 years	1718(58.8%)
25-35 years	1200(41.1%)
Education	
Illiterate	318(10.8%)
Primary/Middle	500(17%)
Matriculation/Inter	1400(47.97%)
Graduation & above:	700(23.9%)
Gestational age (weeks)	39.3 %
Family Income	
less than 20,000	250(8.5%)
20,000 – 50,000	1618(55%)
50,000 to 80,000	632 (22.5 %)
more than 80,000	418(14%)
Smoking history	
Maternal perinatal smoking	200(6.8%)
Maternal passive smoking:	1050(36.9%)

Table 2 shows the typical levels of environmental pollutants during pregnancy.

Pollutant and trimester	Mean	IQR
O_3		
1^{st}	42.6	25.5
2^{nd}	41.1	24
3^{rd}	40.0	25
Pregnancy	41.2	10
NO_2		
1^{st}	35.0	12
2^{nd}	35.5	12
3^{rd}	34	11
Pregnancy	34.8	9
$PM_{2.5}$ (μg/m^3)		
1^{st}	25.9	10.8
2^{nd}	26.9	11.5
3^{rd}	26.6	11.2
Pregnancy	26.4	6.5

IQR stands for interquartile range; $PM_{2.5}$, NO_2, and ozone are examples of particulate matter respectively.

Amna Iqbal Butt
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Table 3 shows the symptoms of depression.

Symptoms of depression	Level	N(%)
Probable depression, pregnancy	EPDS equal to 13	27%
Probable PPD, 1 month	EPDS equal to 13	18%
Probable PPD, 6 months	EPDS equal to 13	18%
Anhedonia subscale	Score	0%
EPDS during pregnancy, total	Score	8 (4, 13)
EPDS at 1 month, total	Score	5 (2, 9)
EPDS at 6 months, total	Score	6 (2, 10)

At the 1 and 6 months postpartum visits, 18% of individuals were identified as most likely having PPD (EPDS scores 13). Anxiety had the highest scores on the EPDS subscale at six months, followed by anhedonia and depression. Pregnancy related $PM_{2.5}$ and PPD at six months.

According to Table 4, a 5-g/m^3 increase in $PM_{2.5}$ exposure during pregnancy was not linked with "chronic" PPD (PPD at 1 and 6 months, but it was 2.53 times more likely to cause late onset of PPD. The strongest correlation between $PM_{2.5}$ exposure during pregnancy and PPD at 6 months was found among women who did not have depression during pregnancy or at one month after delivery.

The relative hazards for $PM_{2.5}$ are shown in Table 4. For PPD (EPDS≥13) onset subtypes at 6 months following childbirth, there were changes of 5 g/m^3.

Subtype of 6-month PPD	Number of cases	RR (95% CI)	P
Late postnatal onset (no PPD at 1st month+ PPD at 6th month)	55	2.5 3 (1.40, 4.73)	0.002
(PPD at 1st and 6th months	55	1.09 (0.63, 1.76)	0.83

Discussion:

This prospective cohort study found a strong correlation between environmental pollution levels and postpartum depression and anxiety symptoms in mothers. Increased risks of depressive symptoms during the third trimester were linked to an IQR increase in exposure to $PM_{2.5}$, NO_2, and O_3 during the second and third trimesters, respectively. Additionally, we discovered a link between an IQR increase in $PM_{2.5}$ and NO_2 exposure during the second trimester and an increased risk of anxiety symptoms. A higher cutoff score for anxiety was substantially linked with first-trimester O_3 exposure. The results held up well in a variety of sensitivity tests. Our data imply that mid-to-late pregnancy exposure to particulate matter, NO_2, and O_3 may be linked to mental problems during pregnancy. The correlations between pollutants evaluated in this study and depressed symptoms did not show any

Amna Iqbal Butt
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evidence of effect modification. However, we saw stronger correlations between several contaminants and anxiety symptoms in low-income or former smoker women. According to our knowledge, this is the first study to look into how exposure to environmental pollution during a certain stage of pregnancy affects prenatal and postpartum depression in expectant mothers. Only three epidemiologic studies have looked at the relationship between air pollution and risks to pregnant women's mental health to yet [33,34,35]. According to our findings for prenatal and postpartum depression, a recent study in the United States examined the link between maternal depression and air pollution exposure during the three months prior to conception, the first trimester, and the entire pregnancy. It discovered that an IQR increase in PM_{10}, $PM_{2.5}$, and NO_2 exposure throughout the entire pregnancy was linked to an 11%-21% increased risk of maternal depression, as determined by the International Classification of Diseases (ICD) code [34]. However, this study was unable to offer information regarding the period of diagnosis and only diagnosed maternal depression based on delivery admission medical data. Additionally, they were unable to describe depression symptoms and may have overlooked a significant number of patients who were unaware they were experiencing depressive symptoms [36]. Ahlers and Weiss (2021) examined the relationship between third-trimester depressive symptoms as measured by the 9-item Patient Health Questionnaire and prenatal exposure to $PM_{2.5}$ using data from 50 pregnant women. Exposure to $PM_{2.5}$ and NO_2 was linked to higher scores on the Global-Severity-Indices, indicating higher levels of emotional stress, according to a Chinese study that looked at the relationship between air pollution and mother stress during pregnancy. They did not discover any meaningful connections specifically with depressive symptoms [33]. Our findings are in line with a study from the United States that found an association between mid-pregnancy $PM_{2.5}$ exposure and postpartum depression based on the Edinburgh Postnatal Depression Scale (EPDS) [7]. We discovered that mid to late pregnancy is vulnerable for the negative impact of environmental pollution on maternal depressive symptoms. Similar to this, a recent study in Mexico found that a higher pregnancy $PM_{2.5}$ level was linked to a higher EPDS score for postpartum depression in mothers [2]. To the best of our knowledge, no research has looked into the relationship between environmental toxins, notably O_3, and prenatal and postpartum depressive symptoms throughout pregnancy. But three researches (Lin et al., 2017, Niedzwiecki et al., 2020, and Lamichhane et al., 2021) partially explored the link of our interest [2,35,36]. There were no statistically significant connections discovered by Lin et al. (2017) when they investigated the lag effect of NO_2 on the anxiety subscale of the Symptom Checklist-90-Revised Scale during pregnancy [35]. In a similar vein, Niedzwiecki et al. (2020) found no evidence of a link between pregnancy-related $PM_{2.5}$ exposure and anxiety scores on the EPDS at 6 months postpartum [2]. According to research by Lamichhane et al. (2021), pregnant women may be more likely to experience sadness or anxiety due to elevated levels of particulate matter, NO_2, and O_3 [36]. Previous research that was conducted by (Kioumourtzoglou et al., 2017; Lim et al., 2012; Pun et al., 2017; Zhang et al., 2019; Zhao et al., 2020); showed substantial positive relationships of short- or long-term pollutant concentrations with depression and anxiety in non-pregnant populations [37,38,16,39,40]. Increases in short-term NO2, and O_3 were shown to be strongly linked with depressed symptoms according to the Geriatric Depression scale in a panel research of 560 senior people in Korea (Lim et al., 2012). An relationship between greater $PM_{2.5}$ and O_3 exposure over the course of the previous year and an elevated risk of depression diagnosis and antidepressant use was discovered in a cohort study of middle-aged and older women in the United States (n = 41844) [37]. Increased O_3 levels were linked to higher odds of depression and anxiety diagnoses, according to a study in the general population conducted in Germany using ICD codes [40]. Studies conducted in non-pregnant individuals complement our results of significant correlations between exposure to particulate matter, NO_2, and O_3 during pregnancy with prenatal and postpartum depression or anxious symptoms. Inconsistencies in studies may have resulted from variations in study

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populations and study areas, exposure levels, exposure assessment techniques, measured pollutants, study design, use of depression and anxiety scales, sample size, and covariates.

Nevertheless, some studies found no significant association between pollution and depression [16]. In our investigation, we found that particulate matter and NO_2, which are associated with higher risks of depression and anxiety, show comparable patterns of risk when averaged over the second trimester. A substantial positive correlation between depression symptoms and average O_3 exposure throughout the first trimester was observed. However, the results for O_3 averaged during the first trimester differ from those for the third trimester. We found that O_3 exposure during pregnancy is linked to a moderate reduction in the risk of depression (11%), which is consistent with the result that O_3 exposure during pregnancy is linked to a reduced likelihood of any depression [34]. According to Cho et al. (2014), ozone is a secondary pollutant that is created as a result of photochemical processes involving primary pollutants [41]. Jia et al., (2017) concluded that O_3 levels are frequently inversely associated to particulate matter which was supported by the fact that ozone was adversely correlated with all other pollutants examined in this investigation [42]. The molecular mechanisms relating environmental pollution to mental problems may be explained by many pathways. The routes include disruption of the endocrine system or metabolic processes, oxidative stress or inflammation, and alteration of neurotransmitters [43]. Environmental contaminants that can enter the brain and cause oxidative stress and neuroinflammation include particulate matter, nitrogen oxides, and O_3 [36]. Mice models showed that exposure to $PM_{2.5}$ and low-light conditions at night may cause neuroinflammation, change the structure of the hippocampus formation, and result in a depressive-like reaction [44]. Reactive oxygen species and oxidative stress are produced as a result of chronic inflammation in the brain, which can damage the blood-brain barrier, change the immune system, and impair normal brain function[45].

Limitations:

The limitations of the current investigation should be taken into account. First, the LUR model was used to estimate exposure to environmental pollution based on maternal residential address. This model did not take into account exposure when women were away from their homes (for example, at work or while travelling), which may have led to some exposure misclassification. Maternal mobility during pregnancy is typically restricted to residential regions, according to research [46]. In light of this, we think that this flaw had little impact on our exposure estimates and was unlikely to have affected our conclusions. Second, just one assessment was made during pregnancy to determine the relationship between prenatal and postpartum depression using self-reports. Furthermore, the start of mental problems in pregnant women may have been significantly influenced by stressful life experiences such major parental illness, accidents, or marital discontent.

Conclusions:

In the current study, average $PM_{2.5}$ and NO_2 concentrations allocated to each pregnant woman's home address were positively correlated with her depression and anxiety symptoms. According to the exposure period, there was a substantial positive connection between O_3 and depression in the first trimester but a negative one in the third. Our results add to the growing body of research indicating that environmental pollution causes cognitive dysfunction in expectant mothers, and that further air pollution reduction could be a useful strategy for lowering the prevalence of mental disorders. Future studies on the effects of air pollution on maternal anxiety and depression may contribute to our understanding of how psychological traits affect the occurrence of depressive and anxious symptoms during pregnancy.

Amna Iqbal Butt
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Amna Iqbal Butt
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