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Systematic Review

Impact of ambient and indoor air pollution on birth weight: a systematic review

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ABSTRACT

The global burden of disease caused by particulate matter exposure has increased significantly. Increasing epidemiological evidence indicates that ambient particulate matter pollution is associated with unfavorable health outcomes, including adverse birth outcomes. In addition to several determinants studies have correlated birth weight with prenatal exposure to particulate matter. This review aims to examine the relationship of pollutants with low birth weight. A systematic literature search was performed using PubMed and Google Scholar electronic databases. A total of 96 studies were reviewed and 18 studies fulfilled the inclusion criteria. In India exposure to ambient PM2.5 is strongly associated with low birth-weight. In Thailand, the entire pregnancy exposure was associated with reduced birth weight both for PM10 and biomass burning. The multiple GAM model have shown a direct and significant relationship between exposure to PM10 and SO_2 on low birth weight. A 10 $\mu g/m^3$ increase in gap-filled satellite-based whole-pregnancy PM2.5 exposures was associated with a change in birth weight. The critical window period for exposure varied between the geographical locations. All of this research is subjected to several limitations regarding the assessment of outcome-exposure. We demonstrated that, maternal exposure to particulate matter during the pregnancy could increase the risk of low birth weight, and the critical window period differed for geographical locations. These findings expand our knowledge of the harmful effects of PM2.5 and biomass burning on new-born weight. Therefore, pregnant women should be informed about the negative consequences of air pollution and avoid exposure to polluted air during pregnancy.

Keywords: Ambient and indoor air pollution, Pregnancy, Low-birth-weight

INTRODUCTION

In many countries, air pollution continues to persist or worsen, posing significant environmental and public health threats.[1] An estimated 7 million premature deaths occur annually as a result of ambient and household air pollution.[2] Air pollutants include ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbons, particulate matters (PM), benzene and soot.[3] Particulate matter refers to solid particles that are typically larger than colloids and have the ability to remain suspended in the air or temporarily combine with another gas.[4] The presence of these particles may exert a substantial impact on human health.[5] Pregnant women and their fetuses are sensitive to air pollution due to physiological changes that occur during pregnancy.[6] Exposure to particulate matter particles smaller than 2.5 microns has been linked to an increased likelihood of chronic disorders during pregnancy, such as low birth weight, premature labor, and negative health effects on the child. (cognitive impairment and asthma).[7-11] Among the complications due to SO_2 and NO_2 exposure are increased risk of low birth weight infant during 3rd to 5th months of gestation, reduction in the age of pregnancy and complications arising from it such as preterm labor, fetal cardiovascular and pulmonary abnormalities, and increased risk of small for gestational age (SGA) newborn.[12-17]

One of the side effects of pollutants is an increased risk of low birth weight.[17] There are several markers for determining the health status of a community, one of the most important of which is birth weight, which is directly related to infant mortality rates.[18] Low birth weight refers to the weight below 2500 grams in newborns.[19] Numerous studies have provided strong evidence linking exposure to ambient air pollution with negative birth outcomes, such as low birth weight. Due to different geography, meteorological condition, and the impact of race and ethnicity, there is a significant variation in the relation between ambient air pollution and fetal growth. Therefore the purpose of this review was to summarize the existing epidemiological evidence of the association between ambient and indoor air pollution with low birth-weight.

Objectives

To examine the association between Low birth weight and prenatal exposure to ambient and indoor air pollution. To identify critical time window for exposure in Low birth weight development.

METHODS

Literature search strategy

A systematic review of the existing literature on ambient air pollution and low birth weight was carried out in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA). A systematic, comprehensive bibliographic search using Medline (National library of Medicine) database for the years 2019 to March 2023, using the Pubmed interface. Medical Subject Headings (MeSH) for 2013 were used as search terms from the USNLM Institutes of Health. These were Air Pollution, “Particulate Matter”, “Carbon Monoxide”, “Nitrogen Dioxide”, “Pregnancy Outcome”, “Pregnancy Complications”, “Birth Weight”, low birth weight or * Infant, low birth weight. The same search terms was then repeated for searching in google scholar.

Selection criteria

Studies meeting the following eligibility criteria were selected from the identified papers: 1) papers published in peer-reviewed journal, 2) papers published in English language and 3) human epidemiological studies with any study design.

Study results that did not meet these criteria were excluded, and studies that met the criteria were shortlisted for inclusion. The list was further narrowed down based on their exposure assessment methods. It was specifically decided to include only studies that characterised exposure with quantitative methods during pregnancy. Additionally, we decided to include studies that used personal monitors to assess all-day exposure, since most people, especially pregnant women, spend most of their time indoors (at home, at work, or at social gatherings). Exclusion criteria were letter, guidelines, case report, and animal or in vitro studies.

Literature screening and data extraction

Two independent reviewers evaluated the relevance of the studies for inclusion. There were four levels of study screening used in the study selection process. Disagreement was resolved by discussion. During the first level of screening, studies were excluded based on a review of their titles. In the second level of screening, all studies that passed the initial stage were further assessed by reviewing their abstracts for relevance. For the third level of screening, the complete text of relevant papers was obtained and any additional citations requiring further evaluation from the abstract-level 2 stage were considered. A hand search was conducted for level 4 screening, specifically targeting recent reviews and previously retrieved original articles. Any additional referenced manuscripts were also included in the systematic review. A pre-designed standard data collection form was then used to systematically extract data from each selected study. Information regarding the study designs, methodologies, pollutants, source and timing of exposure, study location, results, desired outcomes, and any potential confounding factors that were taken into account during the statistical analyses were obtained.

RESULTS

Bibliographic search

Our combined search to MEDLINE and Google Scholar retrieved 96 records. The initial screening of manuscript titles and abstracts excluded 24 records that did not meet the eligibility criteria. Common reasons for articles’ exclusion included studies non-English language and studies that did not develop a quantitative approach for assessing exposure. We excluded another 17 articles after examination of the full text. In addition. Additionally, two articles were found by searching the reference lists of retrieved reviews and articles. In total 18 articles were considered appropriate for inclusion in the review

Characteristics of included studies

Study characteristics included in the analysis are given in Table 1. Among the relevant studies four were conducted in United States and China, three in India, One in Norway, southern Sweden, Finland, Thailand, Korea, Iran and Africa. Sixteen studies PM2.5 (n=16), ten studies of PM10, (n=10), eight studies of NO2 (n=8), six of SO_2 and O_3

(n=6), four of CO (n=4), and two of NO (n=2) major pollutants were studied with in relation to low birth weight. Two studies (n=2) combined both ambient and indoor air pollution to study the causes low birth weight. Time of trimester exposure was found in six studies (n=6). The records on Birth outcomes were obtained from health surveys (n=5), birth registration (n=3) and from hospital records (n=10). The pollutant measures were taken from model derivation (n=2), satellite derived (n=5), personal or residence exposure (n=4), and from air quality monitoring stations (n= 7).

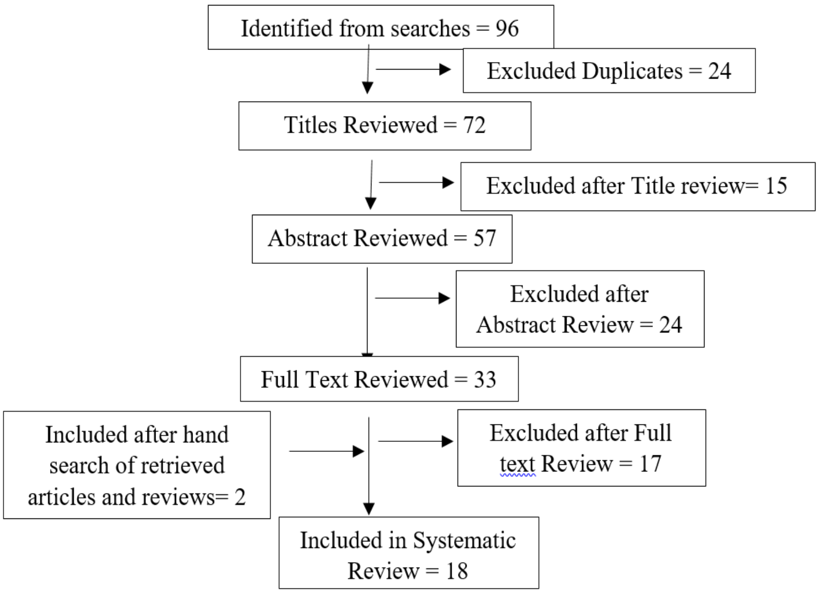

Figure 1: PRISMA flow-chart.

Table 1: Summary of studies' characteristics and exposure- outcome assessment methodology of studies included in the review.

Study characteristics	Exposure assessment	Pollutants studied	Time of trimester exposure	Outcome	Main results
HAPIN trial, observational analysis in India[20]	24-h personal exposure assessments	PM2.5, carbon monoxide, black carbon	Not specific trimester exposure	Low birth weight (in grams)	Prenatal exposure to PM2.5 and black carbon was associated with a reduction in birth weight
Cumulative effect of PM2.5 components is larger than the effect of PM2.5 mass on child health in India[21]	Health dataset was obtained from demographic health survey (DHS) version seven, which provides national-level health data for India as the NFHS-4 and PM2.5 exposure from integrating satellite-derived PM2.5 with outputs from the weather research forecasting (WRF) and community multi-scale air quality modelling system (WRF-CMAQ) model	PM2.5, NO^{3-}, NH^{4+}	Not specific trimester exposure	Anaemia, acute respiratory infection, and low birth weight	For every 10 μgm^{-3} increase in PM2.5 exposure, anaemia, acute respiratory infection, and low birth weight prevalence increase by 10%. NO^{3-}, elemental carbon, and NH^{4+} were more associated with the three health outcomes than other PM2.5 species

Continued.

Study characteristics	Exposure assessment	Pollutants studied	Time of trimester exposure	Outcome	Main results
Adverse health impacts of outdoor air pollution, including from wildland fires, in the United States[22]	"Health of the Air" reports	PM2.5 O_3.	Not specific trimester exposure	Preterm low-weight births cardiovascular and respiratory morbidity	10,660 preterm and/or low-weight births
The effect of ambient air pollution on birth outcomes in Norway[23]	Medical Birth Registry (MFR), and Norwegian Institute for Air Research (NILU)	CO, NO, NO_2, O_3, SO_2, PM10, PM2.5 and PM1	Third trimester	Birth weight and birth length,	Prenatal exposure to ambient nitric oxide in the last trimester causes significant birth weight and birth length loss
Administrative cohort study from southern Sweden[24]	Hospital records and flat, two-dimensional Gaussian plume air dispersion model	PM2.5	Not specific trimester exposure	Low birth weight (in grams)	Ambient exposure to air pollution during pregnancy reduces babies' birth weight and indicates that locally produced PM2.5 from both traffic-related sources and small-scale residential heating (mainly wood-burning) contribute to this association.
The association between ambient PM2.5 and low birth weight in California, United States[25]	Annual mean concentration of PM2.5 California Air Resources Board's (CARB) air monitoring network and LBW infants from the CalEnviroScreen 4.0	PM2.5	Not specific trimester exposure	Low birth weight (in grams)	A 1 $\mu g\ m^{-3}$ increase in PM2.5 was associated with a 0.03%, increase in the percentage of LBW infants in a census tract.
Association between ambient air pollution and birth weight by maternal individual- and neighborhood-level stressors in California, United states[26]	Ambient air quality monitoring data from US environmental protection agency air quality system and birth weight from electronic medical records	PM2.5, PM10, NO_2	Early to mid-pregnancy	Low birth weight (in grams)	PM2.5 from 4 to 24 gestational weeks = −34.0 g, PM10 from 9 to 14 gestational weeks= −39.4 g and NO_2 from 9 to 14 gestational weeks= −40.4 g change in birth weight.
Maternal exposures to particulate matter and preterm birth and low birth weight in Africa[27]	Use of satellite-derived PM2.5 estimates and the demographic health and surveys data	PM2.5	Not specific trimester exposure	preterm birth, low birth weight	$PM_{2.5}$ exposure was significantly associated with preterm birth (8%) and low birth weight (28%)
Association of prenatal exposure to ambient air pollution with adverse birth outcomes and effect modification by socioeconomic factors in United States[28]	Exposure to particulate matter was estimated at each participant's residential address point location and birth outcomes from birth record	PM2.5	Third trimester	Preterm birth, small gestational age and birth weight	Prenatal PM2.5 (2 $\mu g/m^3$) was associated with 114 g lower birthweight

Continued.

Study characteristics	Exposure assessment	Pollutants studied	Time of trimester exposure	Outcome	Main results
The association of in-utero exposure to ambient fine particulate air pollution with low birth weight in India - cross-sectional study[29]	Matched data on birth weight from the National Family and Health Survey (NFHS) conducted in India in 2015-16 with high-resolution spatial data on annual ambient PM2.5 concentration	PM2.5	Not specific trimester exposure	Low birth weight (in grams)	Exposure to ambient PM2.5 is strongly associated with LBW in India
Associations of adverse pregnancy outcomes with high ambient air pollution exposures: project ELEFANT in China[30]	Leveraged 10,960 pregnant women from the project ELEFANT and daily average particulate matter concentrations were collected based on Chinese Air Quality Reanalysis datasets.	PM2.5, PM10, NO_2, SO_2, CO, O_3	Second trimester	Preterm birth and low birth weight	A 10% increase in proportion of days with daily average PM2.5 exceeding 25 μg/m^3 over the entire pregnancy was most apparently associated with risk of LBW (HR, 17.42)
Gestational exposures to outdoor air pollutants in relation to low birth weight, a retrospective cohort study in China[31]	Daily concentrations of outdoor air pollutants were collected in each residence-located district. Parents reported health information	PM_{10}, NO_2, SO_2	Early months	Low Birth weight	Exposures to outdoor NO_2 consistently associated with LBW
Exposure to ambient particulate matter and biomass burning during pregnancy in Thailand[32]	Birth outcome data from the Ministry of Public Health-Thailand and hourly air quality data from the Thai Pollution Control Department	PM2.5, PM10, NO_2 O_3	First and second trimester	Low birth weight	The entire pregnancy exposure was associated with reduced BW both for PM10 (−6.81 g per 10 µg/m3) increase in PM10 and biomass burning (−6.34 g per 1 SD increase in fires/km^2
Effects of air pollution on the risk of low birth weight in a cold climate, stratified analyses of Espoo cohort study, Finland[33]	GIS-based exposure assessment	PM2.5, PM10, SO_2, NO_2, CO, O_3.	Not specific trimester exposure	Low birth weight (in grams)	Prenatal exposure to air pollutants in a cold climate increases the risk of LBW at relatively low levels of air pollution
The association between air pollution and low birth weight and preterm labor in Ahvaz, Iran, a time series study[34]	Low birth weight from hospital records and air pollutant data from the environmental protection agency and the Khuzestan Province	PM2.5, PM10, SO_2, NO, NO_2, CO, O_3.	Not specific trimester exposure	Preterm birth and low birth weight	The results of multiple GAM model have shown that there is a direct and significant relationship between exposure to PM_{10} and SO_2 and low birth weight
Combined effects of ambient air pollution and home environmental factors	A questionnaire was conducted to survey each child's birth outcome and each mother's exposure to	PM10 SO_2 NO_2 parental smoking	Conception month and first trimester	Term low birth weight	TLBW was significantly associated with exposure to ambient PM10 during pregnancy, with OR=1.47, significantly

Continued.

Study characteristics	Exposure assessment	Pollutants studied	Time of trimester exposure	Outcome	Main results
on low birth weight - cohort study in China[35]	home environmental factors for home environmental factors and personal exposure recorder for ambient exposure				related with parental smoking at home OR=2.17
Association between ambient particulate matter concentration and fetal growth restriction stratified by maternal employment, in Korea[36]	Obtained from national birth certificate data in Seoul, Korea, from statistics Korea	$PM_{2.5}$, PM_{10}	Not specific trimester exposure	Low birth weight, small for gestational age	Proportions of LBW were 1.5% in employed and 1.6% in non-employed
Associations between birth outcomes and maternal PM2.5 exposure in Shanghai, China[37]	Birth registration records and satellite-derived estimates or central-site measurements	PM2.5	Not specific trimester exposure	Birth weight, preterm birth, term LBW.	A 10 $\mu g/m^3$ increase in gap-filled satellite-based whole-pregnancy PM2.5 exposure was associated with a −12.85 g change in birth weight and increased risk of term LBW (OR 1.22)

Relationship between exposures and low birth weight

For every 10 μg^{-3} increase in PM2.5 exposure low birth weight prevalence increase by 10%. A 1 μg^{-3} increase in PM2.5 was associated with a 0.03%, increase in the percentage of low birth weight infants in a census tract. PM2.5 from 4 to 24 gestational weeks caused -34.0 g, and PM10 from 9 to 14 gestational weeks caused -39.4 g reduced birth weight. PM2.5 exposure was significantly associated with low birth weight (28%), and in India exposure to ambient PM2.5 is strongly associated with low birth-weight. In a study in Thailand, the entire pregnancy exposure was associated with reduced birth weight both for PM10 (−6.81 g per 10 $\mu g/m^3$) increase in PM10 and biomass burning caused −6.34 g birth weight per 1 SD increase in fires/km^2. The Multiple GAM model have demonstrated a direct and significant relationship between exposure to PM10 and SO_2 and low birth weight. A 10 $\mu g/m^3$ increase in gap-filled satellite-based whole-pregnancy PM2.5 exposures was associated with a −12.85 g change in birth weight (OR=1.22). In China, TLBW was significantly associated with exposure to ambient PM10 during pregnancy, (with OR=1.47) and significantly related with parental smoking at home (OR=2.17).

Prenatal exposure to ambient nitric oxide, PM2.5 with black carbon was associated with a reduction in birth weight. In Finland, a study done during cold climate resulted that prenatal exposure to air pollutants in a cold climate increases the risk of Low Birth Weight at relatively low levels of air pollution. In southern Sweden, Ambient exposure to air pollution during pregnancy reduces babies' birth weight and indicates that locally produced PM2.5 from both traffic-related sources and small-scale residential heating (mainly wood-burning) contribute to this association.

DISCUSSION

A review of the existing evidence on quantified outdoor and indoor exposures and low birth weight has been presented in this review. The limited number of studies that attempt to quantify both indoor and all-day exposure to specific pollutants during pregnancy is highlighted in our study. The main pollutants of interest among the robust studies identified for consideration were exposure to PM10, PM2.5, SO_2, O_3, NO_2, CO, and NO. These studies show an increased risk of exposure to PM2.5 and PM10 with low birth weight, but these findings should be interpreted with caution as a number of methodological limitations exist across these studies.[20,21,24-28,30,32,35,37] A very limited amount of research has been conducted on the effects of indoor exposure on birth weight during pregnancy. In a Meta-analysis of six studies done to see this association revealed a 74% additional risk of giving a low birth weight child in sub-Saharan Africa.[38] The critical window period for exposure varied between the geographical locations.

It is important to note that all of this research is subject to several limitations regarding the assessment of outcome-exposure. Some of the included studies performed all day personal exposure but did not manage to distinguish the clear effect of solely indoors exposure and to capture all pregnancy trimester exposure and outcome assessment was through hospital records. In most of these studies, exposure has been associated with low birth weight, and when considering the magnitude of the problem and the severity of the associated risks, it is now more important than ever to characterize and quantify indoor air pollutants accurately. The magnitude of individual exposure to air pollution in different types of indoor microenvironments requires further research. There should be consideration of different sources of indoor pollution, different lifestyle scenarios, as well as the mobility of pregnant women during future studies.

When determining the impact of indoor exposure on pregnancy outcome, it is important to consider the impact of exposure to external sources of pollutants and specific types of external pollutants (e.g. exposure during commuting).[39] It is well known that commuting is one of the most common ways to be exposed to air pollution, as most commutes occur during peak hours when pollution levels are at their highest and people are in close proximity to traffic.[40,41] In addition, to get a better understanding of the specific consequences of maternal exposure to air pollution and to identify critical window of exposure, it's important to look at fetal development at different stages of pregnancy rather than just at birth using direct methods of assessment like ultrasound measurement.

CONCLUSION

We performed a systematic review of the association between prenatal exposure to particulate matter and low birth weight. We demonstrated that, maternal exposure to particulate matter during the pregnancy could increase the risk of Low birth weight, and the critical window period differed for geographical locations. Studies conducted in advanced countries resulted stronger associations. These findings expands our knowledge of the harmful effects of PM2.5 and biomass burning on new-born weight, emphasizing the importance of implementing interventions aimed at addressing particulate matter-related issues in expectant mothers. Further original study designs are needed to study the impact of different exposure assessment modalities.

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