REVIEW ARTICLE

A Review on the Relationship between Maternal Exposure to Ambient Air Particulate Matter (PM10) and Infants' Birth Weight in Asia

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ABSTRACT

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Introduction In 2015, almost half of low birth weight babies in the world were born in Southern Asia. It is contributed by multiple factors including maternal exposure to the elements in the environment during the antenatal period. Particulate matter (PM10) pollution in Southeast Asian region have been extensively studied with known attributions and sources. It is also known that PM10 is able to restrict foetal growth at molecular level. This review intends to investigate if the unborn in Asia are affected by air pollutants indirectly through their mothers.

Methods Publications from Scopus and Science Direct digital databases in Asian region from 2015 onwards were reviewed. Details collected were the year of publication and study location, the study design, investigated air pollutants, exposure estimation methods used, the timing of exposure in relation to pregnancy, pregnancy outcome measured and the relative risk or odds of effect.

Results A total of eight full text articles were included. Most of the studies were of cohort and quasi experimental designs, involving local air monitoring measurements to assign exposure.

Conclusions There were more studies considered multiple air pollutants as contributing risk rather than a single pollutant. The exposure was measured according to stages of pregnancy and the trimester stratification is the most often method used. Modalities used in representing birth outcomes were not confined to birth weight alone but also included the length of gestation. Exposure to PM_{10} have been found to be associated with reduction in birth weight and increased risk for preterm birth in Asia.

Keywords Air particulate matter - PM10 - antenatal - birth weight - infant.

INTRODUCTION

The living standards and access to health services have improved tremendously during the last few decades in Southeast Asia. Unfortunately, low birth weight (LBW) is still a major problem in this region with the ratio of one LBW in every four births.[1]

In 2015, 20 million (14.6%) of all the babies born globally were detected to have LBW and 48% of them occur in Southern Asia.[2] Even in Malaysia, incidence rate for LBW infants in Malaysia remains stagnant at around 10% of all live births.[3]

Birth weight of an infant, which is measured within the first hour of life, is a useful indicator of the health status of the mother and the foetus during pregnancy. LBW is defined as weight of less than 2,500 grams[4] and is attributed by a collection of multiple factors including maternal health status, the state and quality of healthcare system delivery; and also the surrounding environment.[5]

Since 1997, Southeast Asian region has been plagued by the occurrence of recurrent severe haze which correlates with elevated ambient levels of PM10 and PM2.5.[6] Despite the severity of these events attributed to the biomass burning from Sumatra, another key factor which was alarming was that the local sources of air pollution, emanating from motor vehicles and local open burning continuously contributes to ambient PM2.5 in Klang Valley.[7] As assessment on a ten-year period between 2003 and 2014,[8] found that fire aerosols are the main culprit for the haze in cities of Bangkok, Kuala Lumpur, Singapore and Kuching. Lee et al (2017) also reported that an alarming number of populations have been exposed to relatively persistent hazy conditions.[8] There is a plausible evidence that exposure to PM10 during pregnancy is attributed to foetal growth restriction via molecular modification on placenta.[9]

This paper attempts to review recent publications associating exposure to ambient air pollution, specifically on particulate matter (PM10) and birth outcomes in the Southeast Asian region. The main purpose of this exercise is to determine the extent of the problem in this region and secondly to establish the knowledge gap in this aspect. As nations in Southeast Asia progress and develops, environmental risk factors are becoming important. Identifying the risks and the burden of disease are crucial in order to develop interventions that are feasible at the regional and population level.

METHODS

A systematic literature search was conducted to determine the association between exposure to ambient air particulate matter during pregnancy and birth outcomes. Publications are searched through Scopus and Science Direct digital databases using the following keywords. The keywords used for study population were "maternal" OR "antenatal" OR "prenatal" OR "pregnancy". For intervention, keywords used were "particulate matter" OR "PM" OR "fine dust" OR "air pollutant". For outcome, keywords used are “birth weight” and “infant”. Boolean operator “OR” was applied in combining search keywords for each study population, intervention and outcomes, whereby “AND” was applied in title and abstract search combining study population, intervention and outcome. Limits were set for only articles in English which are accessible in full text and published from the year 2015 onwards. The population studied in these search was exclusive to the Asian region.

The abstracts identified were then screened for relevance. Review papers and animal studies were excluded from this review. The article selection process is shown in Figure 1.

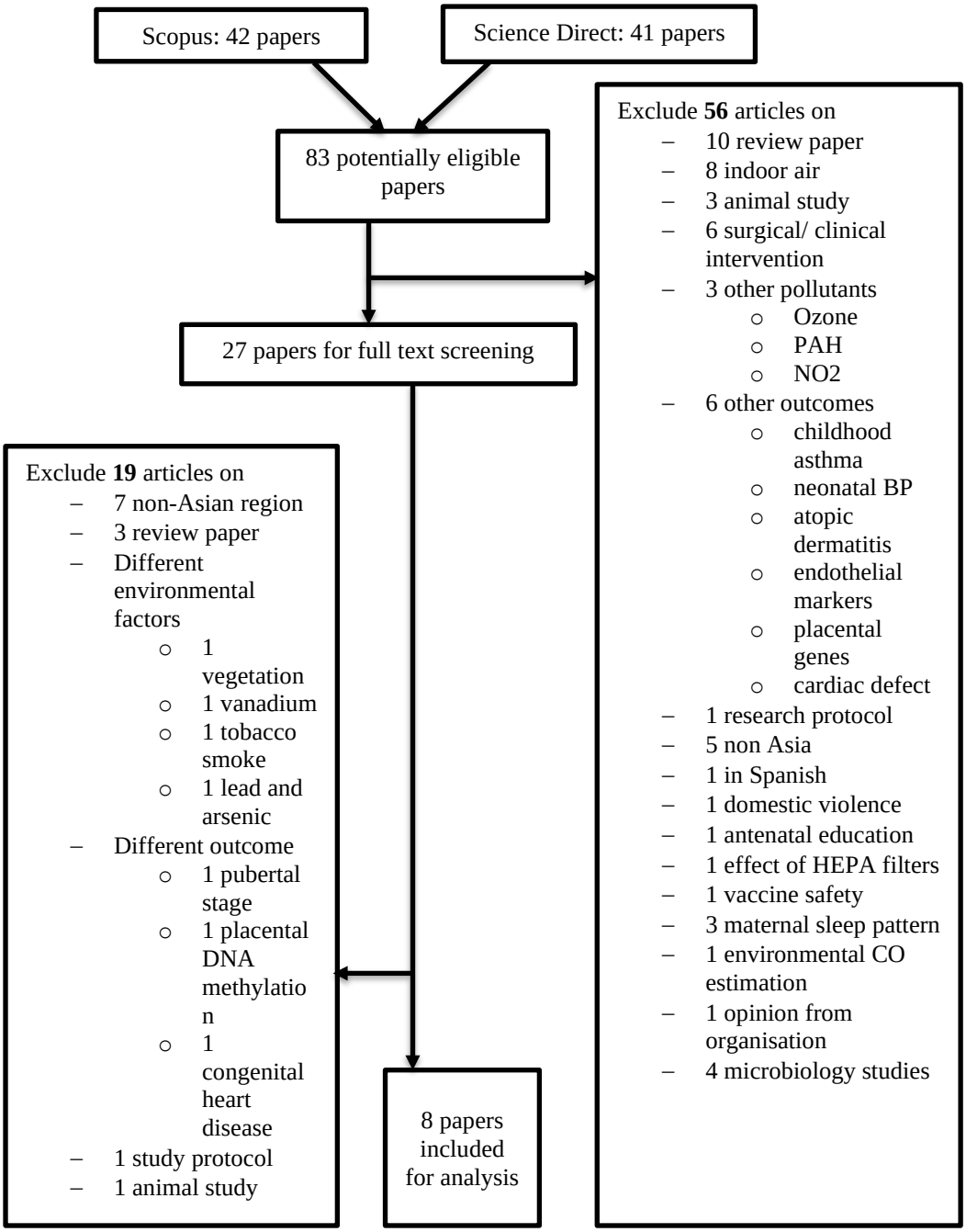

Figure 1 Article selection processThe variables were manually extracted from these articles which include year of publication and country, type of study design, type of air pollutants studied, exposure estimation methods, the timing of exposure in relation to pregnancy, the level of PM10 exposure, pregnancy outcome measured and the relative risk or odds of effect.

RESULTS

In the beginning, the search found 83 abstracts from potentially eligible papers regarding ambient air pollution and birth outcomes, 42 from Scopus and 41 from Science Direct database respectively. 56 of the articles were excluded for irrelevance which includes incorrect region, incorrect pollutant or pollution from indoor sources. There were 10 review papers on particulate matter and six on its health effects. However, these papers looked into relationship between PM exposure with hypersensitivity reactions such as childhood asthma and atopic dermatitis; endothelial changes to placenta, lining of blood vessels and blood pressure. Only 27 papers were fit for full text screening.

At the end of the full text article screening process, there were 8 papers that were found relevant and suitable for further analysis. Information of interests includes the region of which the population were studied, the method used in

determining individual pollutant exposure, the timing of the exposure in relation to pregnancy, the exposure level measured and the birth outcomes observed. The list of articles and the information retrieved is summarised in Table 1.

Table 1 Summary of publications associating maternal exposure to ambient air PM_{10} and birth outcomes in Asia

No	Publication title, (author, year), study population & design	Air pollutants	Exposure estimation Method	Timing	Maternal PM_{10} exposure level, Mean (SD) µg/m^3	Outcome	Assosiation with PM_{10} exposure RR/ OR (95% CI)
1.	Ambient air pollutant PM_{10} and risk of preterm birth in Lanzhou, China (Zhao et al. 2015) China, Cohort	PM_{10}, NO_2, SO_2	a)NM method b)IDW approach (based on both home and work addresses)	i. entire pregnancy ii. last four iii. last six, or iv. last eight weeks before delivery; and v. each trimester	a) NM method i.140.5 (21.7) ii.137.8 (53.9) iii.137.2 (49.5) iv.137.1 (45.8) v.1st = 139.7 (40.8), 2nd = 141.5 (39.7), 3rd = 138.0 (39.7) b) IDW method i.142.1 (17.6) ii.139.5 (51.7) iii.139.7 (48.5) iv.140.1 (46.0) v.1st = 140.1 (42.3), 2nd = 144.7 (39.7), 3rd = 141.5 (40.8)	PTB (before 37 weeks)	Exposure level (≥150µg/m^3) of PM_{10} during a. entire pregnancy was associated with an ▪ increased risk of PTB (1.48; 1.22-1.81) and ▪ higher for medically indicated PTB (1.80, 1.24-2.62) b. the last six weeks of pregnancy was associated with increased risk of very PTB (2.03; 1.11–3.72).
2.	Ambient air pollution and adverse birth outcomes: a natural experiment study (Huang 2015) China, Quasi experimental	CO, SO_2, and PM_{10}	Multiple pollutant model from 28 air monitoring sites	3 trimesters	The monthly average concentration in ambient during study period was 134.72 (35.16) µg/m^3	PTB and LBW	No relationship was found. PM_{10} (per 10 ug/m^3) a. 1st trimester ▪ PTB 0.98 (0.94, 1.02), p= 0.258 ▪ LBW −1.18 (−3.21, 0.85) p=0.254 b. 2nd trimester ▪ PTB 0.96 (0.91, 1.00), p= 0.074 ▪ LBW 0.43 (−1.74, 2.60) p=0.699 c. 3rd trimester ▪ PTB 0.98 (0.94, 1.02), p=0.299 ▪ LBW −2.55 (−5.29, 0.20) p=0.069

No	Publication title, (author, year), study population & design	Air pollutants	Exposure estimation Method	Timing	Maternal PM_{10} exposure level, Mean (SD) $\mu g/m^3$	Outcome	Assosiation with PM_{10} exposure RR/ OR (95% CI)
3.	Differences in Birth Weight Associated with the 2008 Beijing Olympics Air Pollution Reduction: Results from a Natural Experiment (Rich et al. 2015) China, Quasi experimental	$PM_{2.5}$, SO_2, NO_2, and CO	NM station average concentrations	monthly during entire pregnancy	Ambient $PM_{2.5}$ ranges 43.7 - 69.8, with mean at 61.3 (11.1)	BW	Interquartile range (IQR) increases in $PM_{2.5}$ (19.8 $\mu g/m^3$) in the 8th month of pregnancy were associated with significant decreases in birth weight – 18 g; (–32 g, –3 g)
4.	Particulate matter and early childhood body weight (Kim 2016) South Korea, Cohort	PM_{10}	IDW modelling method	During entire pregnancy	52.8 (6.2), actual range 38.7 - 75.2	BW and child's weight at six, 12, 24, 36, and 60 months	No association of PM_{10} with birth weight −0.004 (−0.07, 0.06) p=0.90
5.	Relationship of ambient air pollutants and hazardous household factors with birth weight among Bedouin-Arabs (Yitshak-Sade et al. 2016) Israel, Retrospective cohort	PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3	IDW	i. the entire pregnancy, ii. the third trimester and iii. the last month of pregnancy	(Median) $PM_{2.5}$ 5.3 (3.45) mg/m^3; PM_{10} 47.2 (38) mg/m^3	Birth weight	No association of birth weight with PM_{10} claimed but analysis result not shown
6.	Estimation of disease burdens on preterm births and LBWs attributable to maternal fine particulate matter exposure in	$PM_{2.5}$	Population-weighted annual-average concentrations of $PM_{2.5}$	Annual rates	56.19, with range 40.82 - 76.09 $\mu g/m^3$	PTB and LBW	According to Ambient Air Quality Standards of China - relative to the Class I standard (15 $\mu g/m^3$), the weighted ORs of a. PTBs were 1.54 (1.18–1.91) and b. LBWs 1.32 (1.04–1.72)

No	Publication title, (author, year), study population & design	Air pollutants	Exposure estimation Method	Timing	Maternal PM_{10} exposure level, Mean (SD) $\mu g/m^3$	Outcome	Assosiation with PM_{10} exposure RR/ OR (95% CI)
	Shanghai, China (Liu et al. 2017) China, Ecological						
7.	Maternal exposure to air pollutants during the first trimester and foetal growth in Japanese term infants (Michikawa et al. 2017) Japan, Retrospective Cross Sectional	O_3, suspended PM, NO_2, and SO_2	NM station to the respective delivery hospitals	i. Entire pregnancy ii. First trimester (0-13 weeks) iii. Second trimester (14-27 weeks) iv. Third trimester (28-36 weeks)	Suspended PM i. Entire pregnancy 27.4 (7.1) ii. 1st trimester 27.5 (7.9) iii. Second trimester 27.3 (7.8) iv. Third trimester 27.2 (8.2)	SGA and adverse BW	No association with PM a. Exposure during entire pregnancy ▪ SGA 0.98 (0.89 - 1.07) ▪ Adverse BW 0.93 (0.83 - 1.05) b. Exposure during the first trimester ▪ SGA 1.00 (0.93 - 1.07) ▪ Adverse BW 0.98 (0.89 - 1.07)
8.	Effects of particulate matter exposure during pregnancy on birth weight: A retrospective cohort study in Suzhou, China (Han et al. 2018) China, Retrospective cohort	$PM_{2.5}$ and PM_{10}	IDW method	i. first trimester (0-12 weeks) ii. second trimester (13-27 weeks) iii. third trimester (28 weeks to birth)	$PM_{2.5}$ i. 1st trimester 66.35 (29.10) ii. 2nd trimester 59.60 (14.86) iii. 3rd trimester 60.05 (17.88) iv. Entire 62.35 (6.62) PM_{10} i. 1st trimester 88.62 (19.21) ii. 2nd trimester 86.67 (16.31) iii. 3rd trimester 85.36 (19.07) iv. Entire 88.27 (7.31)	BW and gestational age	Gestational exposure at 10 $\mu g/m^3$ increments in the 2nd trimester led to decreases in birth weight of ▪ $PM_{2.5}$: 4.94 g (− 9.828, − 0.046) and ▪ PM_{10} : 5.65 g (− 10.110, − 1.188)

It was found that China is the leader of research in this particular area, followed by an article each from Japan, South Korea and Israel (Figure 2). Four of the studies were conducted as cohort study. There was one cross-sectional/ prevalence study and one ecological study. The two quasi experimental studies were conducted during the 2008 Beijing Olympics in China which utilise the vigilant air quality monitoring and enforcement during that important event (Figure 3).

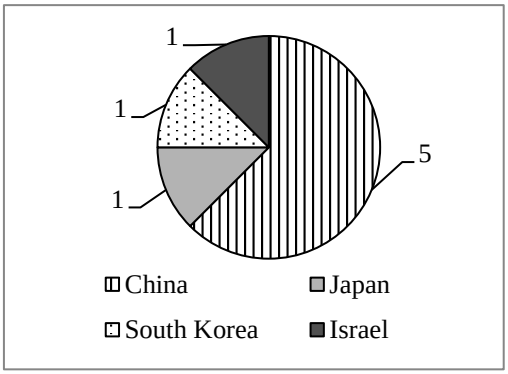

Figure 2 Publications according to study location in Asia.

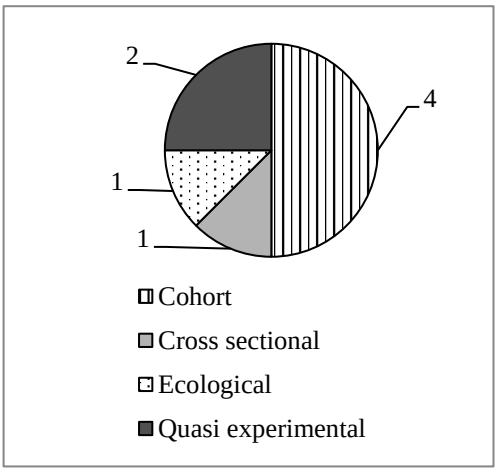

Figure 3 Publications according to study design.

Estimation of exposure levels were often calculated using measurements done at ground ambient air monitoring station which was then extrapolated to the subjects' residential or work addresses using the inverse distance weightage (IDW) approach. Four out of eight papers used this method of estimation. Second most popular method was to use direct readings from the nearest monitoring station (NM method) to the hospitals where the women delivered their new born or their residential address. Estimation by modelling was least used to estimate maternal exposures during pregnancy. An ecological study by Liu et al 2017, used the annual average concentrations in a specifically selected region, by a combination of satellite data and ground measurements using chemical transport model.[10]

Only two papers studied particulate matter exposure as the single risk to birth outcome whereby other papers also included exposure to other air pollutants which included ambient ozone (O3), sulphur dioxide (SO2), nitrogen dioxide (NO2) or carbon monoxide (CO) (Figure 4).

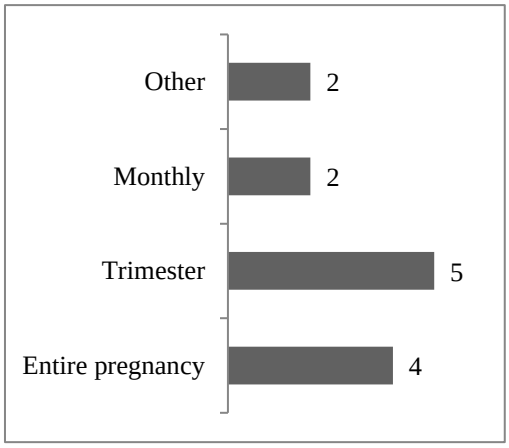

Figure 4 Timing of exposure assessment in relation to stage of pregnancy

Pollutant exposure was assessed either for the entire pregnancy or stratified to monthly exposure or according to trimesters. Five publications stratified the pollutant exposure according to trimester of pregnancy followed by exposure averaged for the entire pregnancy. Exposure was also stratified into monthly in two studies and another done weekly, or more specifically exposure in the last four, six and eight weeks before delivery (Figure 5).

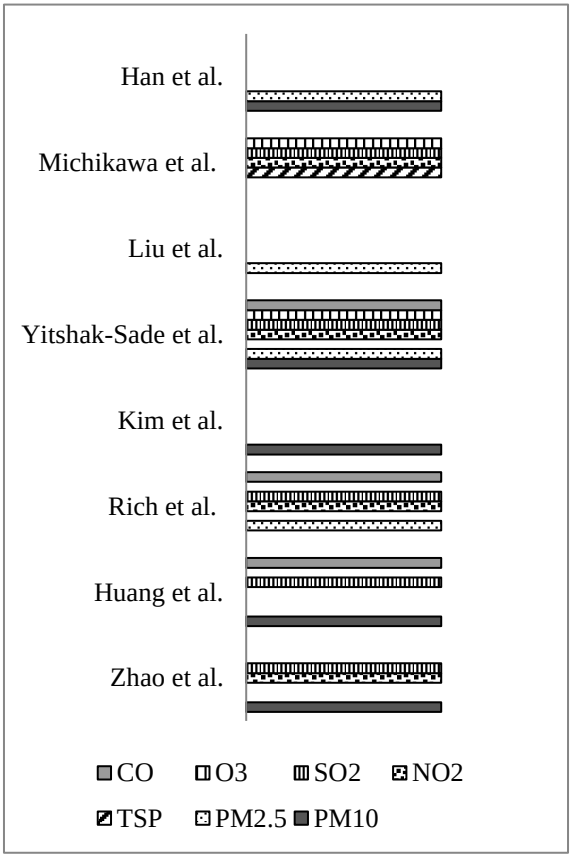

Figure 5 Single or multiple air pollutants exposure assessment

The mean exposure level to PM10 during entire pregnancy was highest observed in Lanzhou China[11] at 140 µg/m3, which was measured in year 2010 to 2012. The second highest exposure level was also seen in China at almost 90 µg/m3.[12] Exposure seen in South Korean mothers was at 50 µg/m3[13] and the lowest in Japan at 27 µg/m3.[14] The ecological study design do not estimate individual

exposure as expected.[10] Three other papers only mentioned ambient air pollutant concentrations rather the actual level of PM10 exposure estimated during pregnancy.[15-17]

Birth outcomes that were selected as determinant variables in these publications were birth weight (BW), completed gestation (defined as completed 37 or 36 weeks) and child's weight gain up to 60 months after delivery. Four out of the eight publications showed effect of either increased risk of preterm birth (PTB),[11] decreased birth weight;[15,16] or higher odds for both PTB and LBW.[10]

DISCUSSION

A big portion of Southeast Asian population were exposed to particulate matter pollution and the duration of exposure is prolonged each year[8] indicating an escalating problem in the region. The source of PM pollution in this region mainly were from fire aerosols and non-fire related human activities resulting in untimely deaths predominantly in major affected cities such as Jakarta, Bangkok and Hanoi.[18]

Initially, this review was done to identify publications from Southeast Asian region in order to gauge the burden of air pollution on new-born's health. However, no publications were retrieved from this region indicating a gap of knowledge in the area. Majority of publications, indicating the vast knowledge in this matter originated from China. Nevertheless, there were review papers and studies conducted to measure association of PM exposure with other outcomes which were not in the focus of this review.

The most frequent study designs regarding birth outcomes were of retrospective cohort with very large sample size showing a massive amount of data collection involved. The quasi experiment done by Rich et al. (2015) and Huang (2015) took advantage of the more vigilant air quality control during the Olympic Games in 2008 in Beijing, China, to facilitate the research. [15,16] Most researches assigned the environmental exposure using measurement readings from air quality monitoring stations. These data were then extrapolated using inverse distance weightage (IDW) where the pollutant concentration decreases when the subject's locality went further from the station. This method can be simplified by using directly the nearest monitoring (NM) station's readings.[14] The exposure assessment method can also be made more specific by using time weighted average, taking into consideration of exposure at both home and work.[11] Mathematical modelling of environmental data had also been used which involved extensive Environmental Science Studies input.

Most papers use multiple pollutant exposures in their researches which allow controlling for each pollutant exposure. Assessing exposure according to pregnancy trimesters was the most popular stratifying approach used. It is noted that PM10 pollution in Asia were more severe in China [11,12] as seen in estimated maternal exposures and reflected by mean ambient concentrarion averages, as compared to in South Korea, Israel or Japan. This may be the reason that significant relationship between exposure to ambient PM10 during pregnancy and birth outcomes were seen in papers hailed from China.

Maternal exposure to ambient air particulate matter evidently attributed to increased PTB and lower birth weight, in half of the papers reviewed. The risk on PTB was substantial with 1.5 times higher odds among those with higher PM exposure. However, the magnitude of effect on birth weight were small. The finding is comparable to Dadvand et al. (2013) which reviewed assessment done in nine countries.[19] It reported that higher incidence of LBW among term infants was associated with increment in PM10 and PM2.5 exposure during pregnancy. The particulate matter also had detrimental effects on children.[20]

This review was specifically done among publications from the Asian region which were relevant and genetically compatible to the Southeast Asian community. This review however does not include pollutant exposures from indoor or household sources.

CONCLUSION

Worsening PM pollution in Southeast Asian region are affecting massive number of people and studies done are showing its detrimental health effect including premature deaths. Exposures to ambient air particulate matter, either PM10 or PM2.5 have been shown to increase risk for PTB and reduced birth weight in regions severely polluted by it. There were no published studies from Southeast Asian region during this review associating it with birth outcomes and thus highlights the need for research in this region.

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