The impacts of air pollution on women and children health.

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Executive summary

Evidence is mounting that exposure to air pollutants such as particulate matter (PM), ozone (O_3), nitrogen oxides (NOx) and sulfur dioxide (SO_2) of anthropogenic origin can lead to increased prevalence of respiratory problems, cerebrovascular disease, ischaemic heart disease, lung cancer, chronic obstructive pulmonary and in some cases death. Today, there is increasing scientific evidence which indicates that women and children are particularly susceptible to air pollution. Adverse pregnancy outcomes such as low birth weight, preterm birth, mortality and congenital anomaly have all been linked to exposure to high levels of air pollution. In most low and middle income countries, women and children are disproportionately exposed to poor indoor air quality (coming from use of biomass for cooking and indoor heating) as they spend more time around the family stove during cooking and other domestic activities. Also, increases in the concentrations of ambient $PM_{2.5}$ have been linked to increased risk of cardiovascular attack and fatality, notably among postmenopausal women. On average, about 18% of preterm births globally can be linked to high $PM_{2.5}$ exposure during pregnancy. Furthermore, exposure to higher PM concentrations can lead to congenital anomaly, particularly cardiovascular defects. Socioeconomic status may modify the effect of air pollution on health. The poor are more likely to be affected not only because of high exposure to air pollution but also due to their susceptibility to other illnesses and inadequate access to basic health services. To solve this problem, there is a pressing need to switch to clean energy source for cooking stoves (especially in developing countries), transport and industry. This switch to cleaner energy is expected to greatly reduce the emissions of air pollutants and improve health outcomes.

1. Introduction

The emission of air pollutants such as particulate matter (PM), ozone (O_3), nitrogen oxides (NOx) and sulfur dioxide (SO_2), mainly from anthropogenic activities, remain one of the greatest threat to human health. Exposure to higher concentrations of air pollutants can lead to serious illness and in some cases death. For example, exposure to high doses of common air pollutants has been linked to respiratory problems, cerebrovascular disease, ischaemic heart disease, lung cancer and chronic obstructive pulmonary disease (Burnett et al., 2014; Ghude et al., 2016). The impacts of air pollution vary from one person to another, and depend on air pollutant concentration levels, length of exposure to different pollution sources, socioeconomic circumstances and the predisposition to harmful effects resulting from other medical conditions.

There is increasing scientific evidence that air pollution can have serious effects on women and children's health. Adverse pregnancy outcomes such as low birth weight (Huang et al., 2015), preterm birth (Zhao et al., 2015; Malley et al., 2017) and congenital anomaly (Ritz et al., 2002) have been linked to exposure to air pollution. For instance, women and children are particularly susceptible to emissions originating from the combustion of coal, wood and dung in inefficient cooking stoves. This occurs primarily indoors, wherein women and young children are persistently subjected to higher doses of air pollutants as they spend proportionately more time around the family cooking stove than other family members (Laumbach et al., 2011). Also, Chen et al. (2005) suggested that exposure to high concentrations of particulate matter may pose greater health risks to women compared to men. In their study, they found positive association between increases in $PM_{2.5}$ concentrations and prevalence of fatal coronary heart disease in females but not for males.

Further to this, ambient air pollution has led to increased mortality in children, increased risk of perinatal mortality, especially in highly polluted areas, increased acute respiratory problems, exacerbation of asthma, lower lung function, increased sickness rates and school absences (Bates, 1995). Furthermore, air pollutants like NOx and PM can cause serious respiratory problems for children who are very active and spend a lot of time outdoors, where they can be exposed to high doses of air pollutants. The exposure to higher concentrations of air pollutants may be particularly harmful to children's vulnerable lungs that are still developing (Gilliland et al., 1999).

Socioeconomic deprivation (measured in term of education, income/wealth and occupation) may modify the effect of the link between air pollution and health (Martins et al., 2004). In general, people with higher education, better occupation and income are less susceptible to air pollution and associated health effects compared to disadvantaged segments of the population, with lower education and income. According to the World Bank, the occurrence of serious respiratory health problems is twice as high in households with low income compared to households with high income (World Bank, 2006). The poor are more likely to be affected not only because of high exposure to air pollution but also due to their susceptibility to other illnesses and inadequate access to basic health services.

It is clear that the emissions of pollutants need to be tackled in order to reduce the associated disease burden and the disproportionate impacts on people with lower socioeconomic status, especially women and children, in rapid developing economies such as India and China where air pollutant concentration levels have consistently exceeded the National Ambient Air Quality Standards or the World Health Organization limits (WHO, 2005).

The purpose of this report is to summarise the evidence that air pollution poses elevated health risks to women, children and people with low socioeconomic status. The report looks at the impact of air pollution on women and children, as well as the modification of these health impacts by socioeconomic status, based on previous research in different parts of the world. The report is structured as follows: Section 2 describes the adverse effect of air pollution on women and children's health. In Section 3 we discuss the link between socioeconomic status and the associated health impacts of air pollution. Concluding remarks are discussed in Sections 4.

2 Adverse effects of air pollutants on children and women's health

2.1 Relative risk for heart disease in women

Today, it is increasingly established that exposure to high doses of fine particulates increases the risk of coronary heart disease. In an earlier study, Chen et al. (2005) assessed the effect of long-term exposure to particulate matter and risk of coronary heart disease in three metropolitan regions in California, USA, by monitoring a cohort of over 3000 people for 22 years. Interestingly, this study shows greater coronary heart disease risk due to exposure to high concentrations of PM for females, but not for males. In a related study, Miller et al. (2007)

investigated the association of long-term exposure to $PM_{2.5}$ with cardiovascular events in postmenopausal women without previous cardiovascular disease in 36 USA metropolitan areas. They found that every 10 μg/m^3 long-term increase in the concentrations of $PM_{2.5}$ was associated with a 24% increase in the risk of cardiovascular attack. They concluded that long-term exposure to higher $PM_{2.5}$ concentrations was linked to increased prevalence of cardiovascular disease and death among postmenopausal women.

2.2 Association of air pollution and adverse pregnancy outcome

Exposure to high levels of air pollutants can lead to adverse pregnancy outcomes. For instance, research has shown that exposure to high air pollution within given periods of pregnancy may decrease birth weight (Pedersen et al., 2013; Huang et al., 20015). In their study, Huang et al. (2015) assessed the adverse birth outcomes of maternal exposure to PM_{10} and NO_2 during pregnancy in Beijing. The study revealed that maternal exposure to $NO_{2,}$ especially during the third trimester, is an important determinant of birth weight. They found that each 10 μg/m^3 increase in NO_2 concentration was associated with 13.78 g reduction in birth weight. Similarly, Pedersen et al. (2013) evaluated the effect of maternal exposure to low doses of ambient air pollution on birthweight across 12 European countries. They found that every 5 μg/m^3 increase in concentration of $PM_{2.5}$ during pregnancy was linked with an increased risk of low birthweight at term (adjusted odds ratio [OR] 1·18, 95% CI 1·06–1·33). Interestingly, they also found increased risk of low birthweight at term at concentration levels lower than the European Union annual average $PM_{2.5}$ limit of 25 μg/m^3.

Furthermore, research has shown that exposure to particulate matter during pregnancy can also increase the rate of preterm birth. For example, Zhao et al. (2015) investigated the association between high level exposure to PM_{10} during pregnancy and risk of preterm birth in Lanzhou, China. This study revealed that increased risk of preterm birth was associated with exposure to high PM_{10} concentrations, especially during the last two months of pregnancy. In a related study, Pereira et al. (2014) assessed the link between preterm birth and exposure to elevated ambient $PM_{2.5}$ in Connecticut USA between 2000 and 2006. Results from this study reveal that, for a given woman, exposure to elevated $PM_{2.5}$ concentrations is more likely to result in preterm birth compared to pregnancy from the same woman at lower exposure. Specifically, their results indicate that exposure to elevated levels of $PM_{2.5}$, especially during the first trimester, can increase risk of preterm birth by about 7% in all women and up to 18% among

Hispanic women. On average, about 18% of preterm births globally (estimated 2.7 million preterm births) are associated with anthropogenic $PM_{2.5}$ (Malley et al., 2017).

2.3 Increased risk of birth defects

In general, exposure to elevated levels of air pollutants has been associated with congenital anomaly. Jin et al. (2015) illustrated that there are significant positive associations between congenital malformations (especially the great arteries and cardiac septa) and concentrations of air pollutants (PM_{10}, NO_2 and SO_2) in Lanzhou, China. The results of this study show that a 40.5% increase in the number of days on which PM_{10} concentrations exceed the 150 $\mu g/m^3$, result in the doubling of the odds of having a baby with congenital malformations. In a related study, Ritz et al (2002) found a significant association between prenatal exposure to CO and cardiac ventricular septa defects in California, USA. Also, they observed that high level surface ozone concentrations was linked to increased risk of aortic artery and valve defects, as well as pulmonary artery and valve defects.

2.4 Air pollution and perineonatal mortality

Research on infant and perinatal mortality has shown that exposure to higher concentrations of air pollutants may result in premature death. de Medeiros et al. (2008) examined the association between air pollutants emission from traffic and perinatal mortality in São Paulo, Brazil. Results from this study indicate that the risk of early neonatal death increases with increasing exposure to traffic-related air pollutants. Specifically, they found that mothers more exposed to air pollutants from traffic experienced 50% increased risk compared to those less exposed. In another study, Yorifuji et al. (2016) found a significant association between PM concentrations (lower than stipulated in the Japanese guideline) and postneonatal mortality in Japan. They derived an odds ratio of 1.06 (95% confidence interval: 1.01-1.12) for infant mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5.}$

2.5 Adverse respiratory health outcomes

Exposure to high levels of air pollutants has been shown to have numerous adverse respiratory health effects, especially in asthmatic children (Aekplakorn et al., 2003). The study of Aekplakorn et al. (2003) concluded that the decrease in pulmonary function among asthmatic children was associated with increases in particulate air pollutants. Other studies, such as Preutthipan et al. (2004), have also illustrated that higher concentrations of PM_{10} caused respiratory health symptoms not just in asthmatic children in Bangkok, Thailand, but also in nonasthmatic children. In another study, Ghude et al. (2016) applied integrated exposure response to investigate the association of high exposure of children < 5 years old to $PM_{2.5}$ and acute lower respiratory illness in India. They estimated a total of 7300 (95%CI: 4900–9000) premature mortalities due to acute lower respiratory illness in 2011.

Moreover, some studies have established a connection between domestic use of coal and solid biomass fuels on the one hand and respiratory diseases on the other, among rural women and children, notably in developing countries. For example, Po et al. (2011) performed a meta-data analysis to investigate the systematic connection between use of biomass fuels and respiratory outcomes among rural women and children. They found significant associations between domestic use of biomass fuels and acute respiratory infections in children, as well as with bronchitis and chronic obstructive pulmonary disease in women. Furthermore, Baumgartner et al. (2011) measured the exposure of women and children to indoor concentrations of $PM_{2.5}$ in different kitchens in rural Yunnan, China. Their results show that women especially were exposed to high concentrations of $PM_{2.5}$, especially during the winter months, during which they spend more time indoors.

3 The association of socioeconomic circumstances and health effects of air quality

Disadvantaged groups are more often exposed to air pollution and may also be more susceptible to the resultant health effects. Martins et al. (2004) assessed how the association of exposure to particulate matter (PM_{10}) and respiratory mortality among elderly people is influenced by socioeconomic status in São Paulo City, Brazil. In summary, the authors found the effect of PM_{10} on health was negatively correlated to people with college education and high family income but positively correlated to people living in slums. They concluded that socioeconomic deprivation is a significant risk factor that should be considered when determining the adverse health effects of air pollution.

Furthermore, in developing countries women and children are disproportionally affected by exposure to poor indoor air quality stemming from use of biomass for cooking and indoor heating. In some cultures, notably in developing countries, women are mainly responsible for cooking for the family. Some begin at a young age by helping their mothers prepare food, spending between three to seven hours per day near the stove for many years (Po et al., 2011).

In an earlier study, Armstrong and Campbell, (1991) found that Gambian children were exposed to the same high levels of biomass smoke as their mother, since the infants are sometimes carried on their mother's back for warmth and care while the mother is cooking .

Moreover, the disproportionate impacts of air pollution on the health of the most disadvantaged cohort of the population make air pollution a threat to shared and inclusive prosperity (World Bank, 2016). According to the World Bank report, the poor are more likely to live and work in polluted environments where they are less able to avoid exposure or self-protect. For instance, Maantay, (2007) found that people living within a certain buffer in south Bronx, New York, were not only more likely to be hospitalized for air pollution associated asthma than those living outside the buffers, but also more likely to be from minority groups and poor. Also, in China, large point sources of air pollution are increasingly moving from city centres to the outskirts and rural areas (Zhao et al., 2014). Further to this, Zhao et al. (2014) indicated that more poor migrants in the outskirts of cities or rural dwellers are increasingly being exposed to serious industrial pollution. Faced with higher levels of exposure to air pollutants, coupled with inadequate access to better health care, the poor are more likely to suffer heavily from associated health effect of air pollution.

4 Conclusion

It is clear from the scientific literature that air pollution and its associated effects on health is a cause for concern, especially in highly polluted regions. In this short review, we present the current state of knowledge of the effects of air pollution on the health on women, children and people with low socioeconomic status. The following conclusions can be drawn:

Results from the literature show that there is a clear connection between air pollution and adverse effect on women's and children's health. Different studies clearly indicate that exposure to air pollutants (particulate matter, ozone, nitrogen oxides and sulfur dioxide) is a contributory factor for respiratory problems, cerebrovascular disease, ischaemic heart disease, lung cancer, chronic obstructive pulmonary and in some cases death.

On the one hand, there is a connection between high levels of SO_2, stemming mainly from anthropogenic activities, and lower birth weight, and on the other hand, consistent association of PM exposure and congenital anomaly, particularly cardiovascular defects. A substantial proportion of cases of low birthweight at term and congenital anomaly could be prevented by improving air quality.

Children are more likely to be subjected to high health risk associated with exposure to air pollutants because they are physically active and spend more time outdoor during periods when the concentration of air pollutants are likely to be high. Also, women and children are more susceptible to poor indoor quality especially in developing countries, especially during cold periods when a lot of coal and biomass fuels are used for indoor heating and cooking.

Socioeconomic status modifies the effect of air pollution on health. Poor people are more likely to be affected, not only because of have higher than average exposure to air pollution, but also due to their susceptibility to other illnesses and inadequate access to basic health services.

So far, a lot of studies have be conducted in the developed world under relative lower exposure compared to the exposure recorded in highly polluted countries, such as India and China. Nevertheless, an increasing number of studies are now being carried out in more highly polluted countries, including China, and the findings from these studies indicate that the impacts of air pollution on women and children health’s can be severe. There is an urgent need to increase research effort on understanding the association of air pollution and related health impacts in highly polluted countries, and to find effective policies and measures which will lead to substantial decreases in emissions of, and exposures to, harmful air pollutants.

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