



## Assessing the health risks associated with particulate matter pollution in vulnerable communities

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### Abstract

The growing impact of air pollution on both human health and the environment is a critical global issue. Air pollution is a leading risk factor, significantly contributing to disease and premature death. This review focuses on particulate matter (PM), a key pollutant, and its links to respiratory & cardiovascular health problems. While ambient air pollution negatively affects overall health, its consequences are not evenly distributed, with certain populations being more vulnerable. There is increasing recognition that, in addition to general public health measures, specific attention should be directed toward protecting these high-risk groups. This paper uses risk analysis and available evidence to explore the vulnerability of different populations to air pollution. Numerous epidemiological studies worldwide have consistently documented the harmful effects of air pollution, with an estimated seven million deaths globally each year attributable to it. Among the various pollutants, PM is particularly harmful and has the potential to cause diverse health issues. Notably, Indian cities are frequently ranked among the most polluted in the world by the World Health Organization, particularly concerning PM levels.

**Keywords:** Air pollution, particulate matter, vulnerable groups, health risks

### Introduction

The atmosphere is one of the building blocks of the biosphere for the life-supporting environment on this planet. The availability of clean air is vital for the well-being of human health and the proper functioning of the environment. The atmosphere serves as a medium through which emitted air pollutants are dispersed and transported (Vallero, 2014) [1]. These pollutants further undergo a chemical transformation and contribute to atmospheric pollution. The growing concerns about air pollution and its associated impacts on health and the environment have taken a central position in the priority research areas. Air pollution has far-reaching effects on local, regional, and global levels based on the residence time of pollutants in the atmosphere and their physicochemical dynamics.

The particulate matter (PM) concentration is found to have aggravated impacts on human health and the environment (Janssen *et al.* 2013; Harrison *et al.* 2017) [2, 3]. Thus, assessment of PM trend has become crucial worldwide especially in the urban areas. Many government bodies have made PM monitoring as a mandatory one and framed their own standards to reduce the impacts. Several continuous ambient monitoring stations are installed to monitor PM concentration throughout the year in populated and polluted areas. In general, these monitoring stations assess PM in two aerodynamic sizes, i.e. PM<sub>10</sub> and PM<sub>2.5</sub>. Globally, the annual mean PM<sub>10</sub> and PM<sub>2.5</sub> concentrations are found to be 30.85 (minimum–maximum: 1–540) µg m<sup>-3</sup> and 18.07 (1–217) µg m<sup>-3</sup>, respectively (WHO 2018) [4].

PM having an aerodynamic diameter <10 µm enters the human body through nasal or oral pathway (Storey-bishoff *et al.* 2008) [5]. Depending on size, the inhaled PM will be deposited in various parts of the respiratory tract, i.e. head, tracheobronchial, and alveolar regions (Deng *et al.* 2019; Manojkumar *et al.* 2019) [6, 7]. The deposited PM, even at lower concentrations, has the ability to cause health effects (Boldo *et al.* 2006; Marzouni *et al.* 2016) [8, 9]. This results in

short-term and long-term effects such as hospital admissions (Luong *et al.* 2017), chronic obstructive pulmonary disease (COPD) (Vodanos *et al.* 2014) [10], acute lower respiratory infection (ALRI) (Mehta *et al.* 2013) [11], pneumonia (Jiang *et al.* 2018) [12], stroke (Kettunen *et al.* 2007) [13], reduced heart rate variability (Nyhan *et al.* 2013) [14], cardiovascular diseases (CVD) (Wu *et al.* 2016) [15], DNA damage (Tan *et al.* 2017), low birth weight (Han *et al.* 2018) [16] increased likelihood of suicide (Min and Kim H-J, 2018) [17] and ultimately mortality (Li *et al.* 2017) [18].

A recent study from the World Health Organization (WHO) shows that PM concentration is linked to 7 million global deaths per annum with a high contribution from Southeast Asia and Western Pacific regions. These deaths are attributed to ischaemic heart disease (IHD) (36%), stroke (33%), COPD (17%), ALRI (8%), and lung cancer (LC) (6%) (WHO 2014) [19]. India is one of the Southeast Asian countries with a high urbanization rate of 31%, and by 2050, it is expected to add 416 million urban population (UN 2018) [20]. At present, many cities in India are experiencing rapid urban agglomeration. This made Indian cities to have top places in the WHO's list of most polluted cities by PM.

A recent study shows that an annual average of 1 million deaths is related to PM in India. This is approximately one-seventh of global deaths and 69% of deaths in South and Southeast Asian region (Shi *et al.* 2018) [21].

The current Indian scenario of air pollution constitutes a 'serious health emergency'. According to the Global burden of disease study, India had more than 1.09 million premature deaths in 2015, attributable to ambient air pollution (AAP), with nearly 24% increase in last 10 years [22].

### Sources of particulate pollution

Sources of PM in India include both stationary and mobile sources. Stationary sources are industrial units, power plants and brick kilns. North India has largest number of these

brick kilns. Coal mines and thermal electric plants are in central, Northern and Eastern India. North India is also landlocked, and devoid of mitigating effect of sea breezes. This makes the north and north-eastern belt the most polluted part of the country, with higher particulate matter concentrations as compared with South India; Indo Gangetic region has the highest recorded particulate matter concentrations. Other sources of urban PM include diesel driven electricity generators, road dust, and waste burning. Periodic causes like firecracker and crop residue burning are also important Major sources.

### Health effects of particulate pollution on vulnerable groups

Ambient air pollution can have adverse effects on the health of exposed populations, but individuals or groups are not equally vulnerable, and pollution reduction benefits are likely to be unevenly distributed within a population. While the use of total-population risks is a valid approach for public health protection, it is increasingly recognized that more attention on vulnerable groups is necessary.

Sub-populations considered by the WHO as vulnerable to air pollution include – in addition to young children, elderly, and persons with certain underlying diseases foetuses, those exposed to other toxicants that add to or interact with air pollutants, and the socio-economically deprived (WHO, 2004) [23] Furthermore, Bell *et al.* (2002) [24] identify as potentially vulnerable those exposed occupationally, ethnic and economic groups with high prevalence of chronic disease, as well as genders with differing exposure and/or responses to air pollution.

### Children

Studies of different air pollutants, exposure levels and locations suggest disproportionate health impacts for children (Kim, 2004; Schwartz, 2004; WHO, 2005) [25, 27] Health effects can be persistent and chronic, while exposure at certain ages may affect lung development or have additional consequences such as school absenteeism (Gauderman *et al.*, 2004; Gilliland *et al.*, 2001; WHO, 2005) [25, 28, 29] Physiologic immaturity and developmental changes largely account for children's differential susceptibility to air pollutants (Moya *et al.*, 2004; WHO, 2005) [25, 30] Young children inhale more air per unit time and accounting for body weight, while the smaller surface area of their lung means that relatively more inspired air reaches the lung. Children's airways are narrower compared to adults, and pulmonary function is immature until just before adulthood.

### Elderly

Exposure to ambient air pollutants can lead to earlier death and higher risks of death and disease for elderly populations mainly associated with cardiorespiratory health (Aga *et al.*, 2003; Anderson *et al.*, 2003; Filleul *et al.*; Gouveia and Fletcher, 2000; Sandstrom *et al.*, 2003) [31, 35]. Old age is associated with several factors that can contribute to compromised physiological capacity to cope with air pollution such as biological effects of past exposures and weakened immune responses (Sandstrom *et al.*, 2003) [35]. In addition, susceptibility for the elderly is largely attributed to a higher prevalence of underlying conditions, particularly cardiovascular and respiratory diseases.

### Materials and Methods

Using risk analysis concepts, population characteristics and factors associated with vulnerability to health effects of ambient air pollution exposure were identified and described by bringing together relevant information from different sources and disciplines. Literature searches were performed, using the PubMed database to identify studies reporting air pollution health risks for specific sub-populations. Peer-reviewed articles, and reports from the World Health Organization or research institutions performing active research in the area of health effects of air pollution were included in the study if they presented epidemiologic, exposure, risk, or health impact assessments for specific sub-populations. Publications that have conceptually addressed issues related to vulnerable populations or vulnerability were also taken into account.

### Results and discussions

Population characteristics include a range of factors that interact and contribute to vulnerability. Age, often considered important primarily for its physiological implications, also influences exposure through behaviours and activities that can be more easily modified for prevention. Children are widely recognized as a high-risk group, but their level of vulnerability can vary depending on their stage of development. Pregnant women, though not always explicitly identified as vulnerable, face increasing evidence of reproductive risks. Socioeconomic factors, which have been relatively understudied, can impact the ability to cope with challenges and also interact with susceptibility and exposure to air pollution. Vidarbha faces a critical environmental threat in the coming decades as numerous coal-fired thermal power plants are being established in the region. These plants are projected to make Vidarbha one of India's most polluted areas within 10-20 years, due to their massive emissions of harmful pollutants including fly ash, mercury, radioactive materials, SO<sub>2</sub>, and CO<sub>2</sub>, with the latter significantly contributing to climate change.

### Conclusion

Evidence related to components of vulnerability is often dispersed across various fields of study and has not been comprehensively evaluated in an integrated way. A deeper understanding of population vulnerability could enhance the scientific foundation for assessing risks and inform the development of policies or health protection strategies aimed at mitigating the effects of air pollution. Air quality monitoring in Vidarbha showed SO<sub>2</sub> and NO<sub>2</sub> levels within prescribed limits across major cities. However, Chandrapur recorded elevated levels of PM<sub>10</sub>, PM<sub>2.5</sub>, and higher AQI compared to other locations, necessitating urgent mitigation measures particularly at mines, quarries, and construction sites.

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## References

- Fundamentals of Air Pollution - Daniel A. Vallero - Google Books [Internet]. [cited 2024 Aug 20]. Available from: [https://books.google.co.in/books/about/Fundamentals\\_of\\_Air\\_Pollution.html?id=iFcXAWAAQBAJ&redir\\_esc=y](https://books.google.co.in/books/about/Fundamentals_of_Air_Pollution.html?id=iFcXAWAAQBAJ&redir_esc=y)
- Harrison RM, Bousiotis D, Mohorjy AM, Alkhalaf AK, Shamy M, Alghamdi M, *et al.* Health risk associated with airborne particulate matter and its components in Jeddah, Saudi Arabia. *Sci Total Environ*,2017:590–591:531–9.
- Janssen NAH, Fischer P, Marra M, Ameling C, Cassee FR. Short-term effects of PM<sub>2.5</sub>, PM<sub>10</sub> and PM<sub>2.5–10</sub> on daily mortality in the Netherlands. *Sci Total Environ*,2013:463–464:20–6.
- Air quality database 2018 [Internet]. [cited 2024]. Available from: <https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database/2018>
- Storey-Bishoff J, Noga M, Finlay WH. Deposition of micrometer-sized aerosol particles in infant nasal airway replicas. *J Aerosol Sci*,2008:39(12):1055–65.
- Deng Q, Deng L, Miao Y, Guo X, Li Y. Particle deposition in the human lung: Health implications of particulate matter from different sources. *Environ Res*,2019:169:237–45.
- Manojkumar N, Srimuruganandam B, Shiva Nagendra SM. Application of multiple-path particle dosimetry model for quantifying age specified deposition of particulate matter in human airway. *Ecotoxicol Environ Saf*,2019:168:241–8.
- Boldo E, Medina S, LeTertre A, Hurley F, Mücke HG, Ballester F, *et al.* Aphis: Health impact assessment of long-term exposure to PM (2.5) in 23 European cities. *Eur J Epidemiol*,2006:21(6):449–58.
- Marzouni MB, Alizadeh T, Banafsheh MR, Khorshiddoust AM, Ghozikali MG, Akbaripoor S, *et al.* A comparison of health impacts assessment for PM<sub>10</sub> during two successive years in the ambient air of Kermanshah, Iran. *Atmospheric Pollut Res*,2016:7(5):768–74.
- Vodonas A, Friger M, Katra I, Avnon L, Krasnov H, Koutrakis P, *et al.* The impact of desert dust exposures on hospitalizations due to exacerbation of chronic obstructive pulmonary disease. *Air Qual Atmosphere Health*,2014:7(4):433–9.
- Mehta S, Shin H, Burnett R, North T, Cohen AJ. Ambient particulate air pollution and acute lower respiratory infections: a systematic review and implications for estimating the global burden of disease. *Air Qual Atmosphere Health*,2013:6(1):69–83.
- Jiang W, Lu C, Miao Y, Xiang Y, Chen L, Deng Q. Outdoor particulate air pollution and indoor renovation associated with childhood pneumonia in China. *Atmos Environ*,2018:174:76–81.
- Kettunen J, Lanki T, Tiittanen P, Aalto PP, Koskentalo T, Kulmala M, *et al.* Associations of Fine and Ultrafine Particulate Air Pollution with Stroke Mortality in an Area of Low Air Pollution Levels. *Stroke*,2007:38(3):918–22.
- Nyhan M, McNabola A, Misstear B. Comparison of particulate matter dose and acute heart rate variability response in cyclists, pedestrians, bus and train passengers. *Sci Total Environ*,2014:468–469:821–31.
- Wu CF, Shen FH, Li YR, Tsao TM, Tsai MJ, Chen CC, *et al.* Association of short-term exposure to fine particulate matter and nitrogen dioxide with acute cardiovascular effects. *Sci Total Environ*,2016:569–570:300–5.
- Han Y, Ji Y, Kang S, Dong T, Zhou Z, Zhang Y, *et al.* Effects of particulate matter exposure during pregnancy on birth weight: A retrospective cohort study in Suzhou, China. *Sci Total Environ*,2018:615:369–74.
- Min JY, Kim HJ, Min KB. Long-term exposure to air pollution and the risk of suicide death: A population-based cohort study. *Sci Total Environ*,2018:628–629:573–9.
- Li G, Xue M, Zeng Q, Cai Y, Pan X, Meng Q. Association between fine ambient particulate matter and daily total mortality: An analysis from 160 communities of China. *Sci Total Environ*,2017:599–600:108–13.
- Fundamentals of Air Pollution [Internet],2014 [cited 2024]. Available from: <https://shop.elsevier.com/books/fundamentals-of-air-pollution/vallero/978-0-12-401733-7>
- World Population Prospects - Population Division - United Nations [Internet]. [cited 2024]. Available from: <https://population.un.org/wpp/>
- Shi Y, Matsunaga T, Yamaguchi Y, Li Z, Gu X, Chen X. Long-term trends and spatial patterns of satellite-retrieved PM<sub>2.5</sub> concentrations in South and Southeast Asia from 1999 to 2014. *Sci Total Environ*,2018:615:177–86.
- Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, *et al.* Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet Lond Engl*,2017:389(10082):1907–18.
- Europe WHORO for. Health aspects of air pollution: results from the WHO project “Systematic review of health aspects of air pollution in Europe.” 2004 [cited 2024]. Available from: <https://iris.who.int/handle/10665/107571>
- Bell ML, Davis D, Cifuentes L, Cohen A, Gouveia N, Grant L, *et al.* International expert workshop on the analysis of the economic and public health impacts of air pollution: Workshop summary. *Environ Health Perspect*,2002:110:1163–8.
- Europe WHORO for, Health EC for E and. Effects of air pollution on children’s health and development: a review of the evidence,2005 [cited 2024]. Available from: <https://iris.who.int/handle/10665/107652>
- Kim JJ, American Academy of Pediatrics Committee on Environmental Health. Ambient air pollution: health hazards to children. *Pediatrics*,2004:114(6):1699–707.
- Schwartz J. Air pollution and children’s health. *Pediatrics*,2004:113(4 Suppl):1037–43.
- Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, *et al.* The effect of air pollution on lung development from 10 to 18 years of age. *N Engl J Med*,2004:351(11):1057–67.
- Gilliland FD, Berhane K, Rappaport EB, Thomas DC, Avol E, Gauderman WJ, *et al.* The effects of ambient

- air pollution on school absenteeism due to respiratory illnesses. *Epidemiol Camb Mass*,2001:12(1):43–54.
30. Moya J, Bearer CF, Etzel RA. Children's behavior and physiology and how it affects exposure to environmental contaminants. *Pediatrics*,2004:113(4 Suppl):996–1006.
  31. Aga E, Samoli E, Touloumi G, Anderson HR, Cadum E, Forsberg B, *et al.* Short-term effects of ambient particles on mortality in the elderly: results from 28 cities in the APHEA2 project. *Eur Respir J Suppl*,2003:40:28s–33s.
  32. Anderson HR, Atkinson RW, Bremner SA, Marston L. Particulate air pollution and hospital admissions for cardiorespiratory diseases: are the elderly at greater risk? *Eur Respir J Suppl*,2003:40:39s–46s.
  33. Filleul L, Rondeau V, Cantagrel A, Dartigues JF, Tessier JF. Do subject characteristics modify the effects of particulate air pollution on daily mortality among the elderly? *J Occup Environ Med*,2004:46(11):1115–22.
  34. Gouveia N, Fletcher T. Time series analysis of air pollution and mortality: effects by cause, age and socioeconomic status. *J Epidemiol Community Health*,2000:54(10):750–5.
  35. Sandström T, Frew AJ, Svartengren M, Viegi G. The need for a focus on air pollution research in the elderly. *Eur Respir J Suppl*,2003:40:92s–5s.