PERSPECTIVE

Impact of Air Pollution on Child Health in India and the Way Forward

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Recent research in epidemiological modelling reveals that air pollution affects child health in various ways resulting in low birthweight, stillbirth, preterm birth, developmental delay, growth failure, poor respiratory and cardiovascular health, and a higher risk of anemia. India has embarked on the national clean air program, but a much stronger coordinated multi-sectoral approach is required to minimize the child health burden caused by air pollution. Air pollution should be treated as a public health crisis that can only be managed with policy backed by science, gradual transition to clean energy use, emission reduction supported by clean air technologies, long-term commitment from the Government, and cooperation of the citizens.

Keywords: *Clear air, National clean air program, PM2.5, Under-5 mortality*.

India has made remarkable progress in reducing the under-five child mortality rate (U5MR) from 83.1 in 2000 to 42.4 per 1000 livebirths in 2017. Yet, the country had the largest proportion of the global under-five deaths in 2017 [1], with 68.2% being attributed to malnutrition, followed by 10.8% to unsafe water and sanitation, and approximately 8.8% to exposure to air pollution [1].

CHILD HEALTH BURDEN ATTRIBUTABLE TO AIR POLLUTION

The Global Burden of Disease (GBD) India study led by the Indian Council of Medical Research (ICMR) and the Public Health Foundation of India (PHFI) has estimated the U5MR of male and female children at the state level from 1990 to 2019 [2]. In the earlier GBD exercises, the child mortality burden attributable to air pollution was only estimated in terms of acute respiratory infection, while low birthweight was added later as another manifestation. **Fig. 1** shows the under-five deaths per 100,000 population attributable to air pollution in 2019. The top three states with the highest burden were Uttar Pradesh, Rajasthan, and Madhya Pradesh. The states with the least burden were Kerala, Goa, and Tamil Nadu. If the trends from 2000 to 2017 were to continue, India would be on track to meet the United Nations Sustainable Develop-ment Goal 3.2 target of reducing the U5MR below 25 deaths per 1000 live births by 2030 [3] but will fall short of meeting the National Health Mission target of reducing the U5MR below 23 deaths per 1000 live births by 2025 [1].

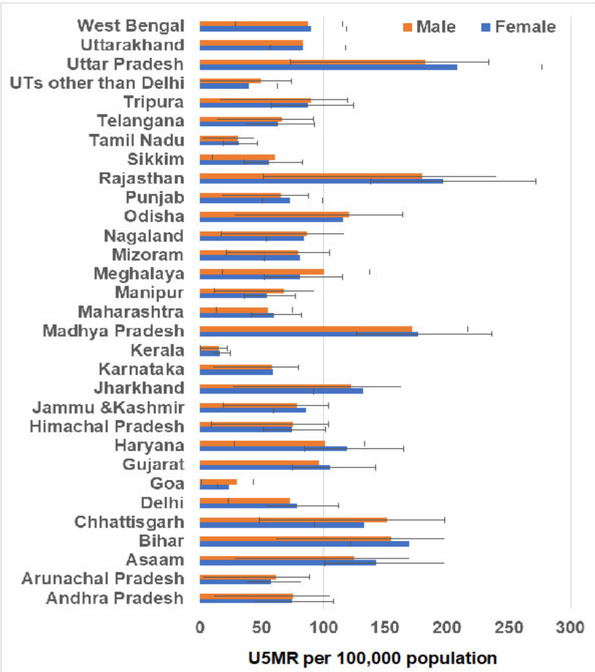
HARMFUL EFFECTS OF AIR POLLUTION ON CHILD HEALTH

The effect of air pollution on the health of a child begins from the intrauterine stage and continues through the early years (**Fig. 2**). Exposure during pregnancy has been found to result in low birthweight, preterm delivery, and stillbirth [1,4,5]. A 10 $\mu g/m^3$ increase in fine particulate matter (PM size <2.5 µm) exposure during pregnancy was reported to be associated with a 2% increase in the prevalence of low birthweight (OR 1.02; 95%CI:1.005, 1.041) after adjusting for other confounders [4]. Another study found ambient PM2.5 exposure in the third trimester to have a significant association with neonatal mortality (OR: 1.016; 95% CI 1.003-1.030, for every 10 $\mu g/m^3$ increase in ambient PM2.5 exposure) [6]. In comparison to those having in-utero exposure to ambient PM2.5 of less than 26.7 $\mu g/m^3$, the fetuses having higher in utero PM2.5 exposures showed a non-linear increase in the risk of low birthweight from PM2.5 levels of 39.3-44.7 $\mu g/m^3$ to greater than 77.3 $\mu g/m^3$ [7]. Besides these, several studies have shown robust associations of air pollution with various other child health outcomes like stunting, wasting, underweight [8,1], childhood anemia [9], allergic rhinitis, asthma [10,11], pneumonia [12], abnormalities in lung development [13], acute respiratory infection [14-16], atherosclerosis [17] behavioral and developmental delay [18,19] as well as the impact on academic performance [20].

LACUNAE IN RESEARCH AND NEW DIRECTIONS

Though studies have convincingly demonstrated air pollution as a major risk to child health, not just in the National capital region (NCR) Delhi but in the entire country, still several critical knowledge gaps exist.

The lack of an adequate ground-based monitoring network in India poses a challenge for optimal assessment



Error bars show 95% UI. Amongst the union territories (UTs), statistics were given separately for Delhi, and the data were combined for all other UTs. The data are compiled from the GBD India database.

Fig. 1 Annual mortality burden of children under the age of five years in India in 2019 attributable to air pollution per 100,000 population.

of ambient PM2.5 exposure to children before and after birth. To address this issue, studies have followed two approaches. In a cross-sectional design, the studies either assumed limited ground-based measurements as representative of the exposure in the entire city [21] or used satellite-derived PM2.5 as a proxy for personal exposure [6]. Each of these approaches has its strengths and weaknesses. The statistical approach relies heavily on the dependency of PM2.5 on a few dominant predictor variables and the availability of data of all critical variables at the desired spatio-temporal scale [22,23]. The physical approach relies on the representativeness of the vertical distributions of PM and the accuracy of the available information about its composition [24]. The scaling factor-based approach relies on the accuracy of the model or reanalysis-derived scaling factors that are used to convert aerosol optical depth to PM2.5 [25]. Nonetheless, recent studies have shown that the algorithms can be trained to a very high level of accuracy with proper calibration [25]. Since satellite-derived exposure has been available for over two decades in India, they are also used in retrospective cohort design [23]. On the other hand, prospective cohorts and studies focusing on household exposure rely on personal exposure assessment using portable sensors [4]. While this is expected to provide the best exposure estimates, it is challenging to scale it up at a population level, and the sensors need robust calibration with reference-grade monitors.

So far, epidemiological studies in India have examined the impacts of exposure to total PM2.5 or PM10 mass. The differential impacts of individual PM types on child health outcomes are not known. Exposure models need to be developed for individual species, tagged to sectoral emissions. Statistical models based on machine learning techniques [23] and chemical transport models [26], being the two most effective tools to develop sector- and species-specific exposure data. Currently, India does not have any chemical speciation network that can be utilized to evaluate modelled exposure. Although measurements of PM composition are carried out intermittently [27], and measurements of oxidative potential (a proxy for quantifying toxicity of PM species) have recently started in India [28], this must be organized in a coordinated way. This was one of the key recommendations of the environmental science panel of the VAIBHAV India summit in 2020 (*innovate.mygov.in*).

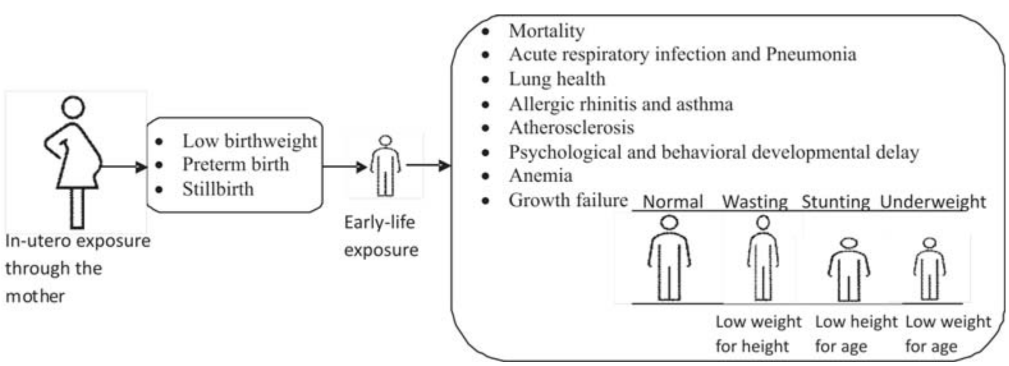


Fig. 2 In utero exposure of the mother to air pollution during pregnancy is a major risk factor for low birthweight, stillbirth, and preterm birth, which can lead to child mortality. Early-life exposure of the child to air pollution can also lead to mortality and negative impacts on multiple health outcomes (for those who survive) and delay in developmental milestones.

Laboratory-based studies done at the cellular level [29] are needed to understand the biological pathways through which exposure to air pollution impacts child health. Further, exposure assessment confined to only ambient or household PM2.5 always has the chance of exposure misclassification and overlaps, and may not capture the true exposure disparity [30]. The personal exposure data collected during recent cohorts (e.g., TAPHE, DAPHNE, CHAI, APPLE, etc.) would be valuable in evaluating such models.

Finally, air pollution is a deadly cocktail of various pollutants, including particulates and gases. Exposure databases do not exist for other criteria pollutants on a national scale, which restricts multi-pollutant epidemiological modelling. Efforts like the creation of the national ambient PM2.5 exposure database [25] are required to address this issue.

WHAT SHOULD WE DO?

India has taken the first step in the right direction by acknowledging air pollution as a national problem, thus gathering momentum for implementing clean air action plans under the National Clean Air Program. However, this is not enough, given the magnitude of the problem.

Evolve a hybrid monitoring approach for improved exposure assessment: Lack of institutional resources and financial constraints prevent India from expanding the ground-based reference-grade monitoring network as per World Health Organization norms of having at least one monitor per million population. So, India can evolve a hybrid monitoring network including reference-grade monitors providing the benchmark data, satellites providing the required spatial coverage, portable sensors (after properly calibrated against reference-grade monitors) providing hyper-local information, and measurements of PM species at strategically suited locations within air sheds [31].

Include health as an integral part of the air pollution management system: Health, to date, is not included in the air pollution management plan as a core indicator. Given that children are more vulnerable to air pollution than adults, environmental policies should urgently be linked to the national health mission.

Strengthen social awareness: General awareness about air pollution is still very poor outside major cities. Though the entire Indo-Gangetic plain, including the rural areas, has PM2.5 levels exceeding the national standards, citizens are not aware of their ill impacts. Physicians would be the ideal ambassadors for clean air advocacy. Unfortunately, most physicians in India are not aware of the multiple health hazards of air pollution beyond respiratory health. The medical curriculum could be more inclusive of environmental health risks.

Invest in air pollution epidemiology research: In the last decade, a plethora of studies came out showcasing the systemic impacts of air pollution on child (and adult) health in India. However, prospective multicentric cohorts with multi-year follow-ups are the need of the hour with a sustained funding commitment from the government.

Focused capacity building promoting interdisciplinary skills: Advancing air pollution epidemiology research in India requires adequately trained human resources. To cater to the need for a focused capacity-building exercise in air pollution epidemiology, the CAPHER-India network has been launched jointly by All India Institute of Medical Science, Delhi, and Indian Institute of Techno-logy Delhi in partnership with the Health Effects Institute, USA. The primary mandate of this network is to provide a platform for researchers from atmospheric chemistry, biostatistics, atmospheric measurement and modelling, epidemiology, medicine, and the public health community to collaborate and provide hands-on training to early-career researchers. The Consortium for climate, health, and air pollution research in India (CHAIR-India), coordinated by the PHFI, is also involved in capacity building.

We must remember that the fight against air pollution is a long-drawn process. Contrary to the general belief that cleaning air could have a negative impact on economic progress, data from developed countries suggest otherwise [32]. We should accept the seriousness of the problem, be prepared mentally, and act with strategic planning, ably supported by science.

Note: The data that is used to generate Fig. 1 has been provided at the GBD India data portal for free use.

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