Impact of Air Pollution on Children's Physical and Mental Health

Young Researchers for Social Impact

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2.1 Introduction

Air pollution is the release of those elements into the air which pose a threat to human health and the planet. Air is said to be polluted when there is a disturbance to its natural composition due to the addition of harmful substances. Air pollution is caused by human activities such as burning of fossil fuels, industrial emissions such as power generation, unsustainable agricultural practices such as slash and burn agriculture. Common air pollutants include sulphur dioxide, carbon monoxide, lead, nitrogen oxides, and ground-level ozone.

While there has been a global decline in air pollutant emissions over the past five decades, air pollution remains one of the world's largest health and environmental problems.[1] Annually, air pollution kills an estimated 7 million people worldwide.[1] 91% of the world's population breathes air below WHO's quality limits.[2] In India, 12.55% deaths are caused by air pollution.[2] Air pollution has been linked to life shortening effects.

Long-term exposure to pollutants can increase respiratory illnesses such as asthma, bronchitis, lung cancer, emphysema. It increases the risk of chronic illnesses such as cardiovascular diseases. Children, the elderly, people with comorbidities, and minority and low-income communities are particularly vulnerable to adverse health outcomes due to air pollution. Children breathe more rapidly than adults and live closer to the ground, hence are more prone to the risks of air pollution than adults. In children, air pollution can cause infant mortality, childhood cancer, asthma and more. Lesser known are air pollution's impacts on children's psychological and mental health. Air pollution adversely impacts cognitive ability and slows neurodevelopment.

In recent years, extensive research has been conducted on the impact of air pollution on human health. However, few studies focus specifically on its impact on children's physical and mental health. This research project will examine existing evidence regarding this issue, survey relevant stakeholders to gauge common sentiments and develop a case study on air pollution in the Delhi NCR region.

The effect of COVID-19 on air pollution, children's health, and the changes in policies because of it have also been taken into consideration throughout this paper. This element is considered to be prudent as the pandemic has irreversibly changed the state of the world for the better or worse.

2.2 Impact of Air Pollution on Children

2.2.1 Impact of Air Pollution on Children's Physical and Mental Health

Around 93% of the world's child population lives in places where air quality exceeds the WHO guidelines.[3] It was reported that both ambient and household air pollution contributed to 543,000 deaths of children under the age 5 in 2016.[3] This devastating situation has raised red flags for not only parents but also concerned citizens. It is an unequivocal consensus that the enormous toll of disease and death revealed by these new data should result in an urgent call to action for the global community. This section will be divided into two subsections- discussion of physical effects of air pollution, and discussion of mental and neuro-developmental disabilities in children.

There are majorly two sources of air pollution that affect children- ambient (outdoor) air pollution and household (indoor) air pollution. It estimated that in 2016, 286,000 children under the age of 15 years died from exposure to unhealthy levels of ambient air pollution.[3] In an urban setting, the main sources are fossil fuel combustion, transport, and waste incineration. For rural areas, the primary sources are burning of kerosene, biomass and coal for cooking, heating and agricultural waste incineration. As for household air pollution, in 2016, it was estimated that 403,000 premature deaths in children under the age of 5 was caused by indoor pollutants.[3] It is common in rural areas. Its main sources are burning of fuels for cooking, heating, chimneys, and stoves. It is important to note that poverty is also a major determinant of the exposure to air pollution in children. Low income communities within high income countries disproportionately suffer the effects of air pollution.

[1] Ritchie, H. and Roser, M., 2017. *Air Pollution.* [online] Our World in Data. Available at: https://ourworldindata.org/air-pollution.

[2] Who.int. n.d. *Air pollution.* [online] Available at: https://www.who.int/health-topics/air-pollution#tab=tab_1

[3] 2018. *Air pollution and child health: prescribing clean air.* [ebook] WHO. Available at: <https://www.who.int/publications/i/item/air-pollution-and-child-health>

While the exposure to air pollution has a deteriorating impact on the health of people of all ages, the most susceptible are children. According to WHO this is because of three reasons: children are especially vulnerable during foetal development and in their earliest years while their lungs, organs and brains are still maturing. They breathe faster than adults, taking in more air and consequently, more pollutants. Children are closer to the ground where some pollutants reach extreme concentrations. This combination of behavioural, environmental, and physiological factors in children may lead to illnesses and other health burdens that can last a lifetime.

2.2.1.1 Impact of Air Pollution on Children's Physical Health

The most visible and prominent effect of air pollution on children is the weakening of their physiological health. Air pollution is linked not only with fatal diseases, but also with poor health and underdevelopment among millions of children. Studies show air pollution is linked with asthma, bronchitis, airways inflammation, eye irritation, wheezing, coughing and phlegm production.[4] Children who breathe polluted air are at higher risk of potentially severe health problems, in particular, acute respiratory infections such as pneumonia. Even if these diseases are not fatal, they still severely affect their overall health and development. Exposure can also affect lung growth among children, as the cell layer on the inside of the respiratory tract is more permeable among young children.[5] It can also undermine normal lung antimicrobial defence functions. Air pollution may cause the development of subclinical atherosclerosis (plaque builds up inside the arteries) in younger populations.[6] These health complications can then last throughout the rest of their lives.

If we look at the present-day scenario, where COVID 19 cases are still on the rise, people are at a risk. It is crucial to understand the current impact of air pollution on the severity of COVID 19 in order to provide quick relief to the people affected/ will be affected. A study from Harvard T.H Chan School of Public Health found an association between air pollution over many years with an 11% increase in mortality from COVID 19 infection for every 1 microgram/ cubic meter increase in air pollution.[7] In a podcast by WHO, Dr. Maria Neira elucidates that COVID 19 specifically is a respiratory tract infection, so the susceptibility of catching infections by people exposed to air pollution increases. As children are extremely vulnerable to air pollution, this is especially concerning.[8]

As for the long term effects of COVID-19 on children, conclusive research on it is yet to be available. Apart from Multisystem Inflammatory Syndrome there is no heavy impact on children's organs as such. What must be noted is that the lockdowns have decreased the exposure of children to the various microbes and allergens in nature. This has reduced the overall immunity of children, thus making them extremely pregnable to air pollution related disorders in the long term as well.

To summarize the overall physical effects:

1. **Cardiovascular-**
   a. Subclinical atherosclerosis and stroke
   b. High blood pressure
2. **Respiratory tract-**
   a. Airways inflammation
   b. Coughing, wheezing
   c. Nose and throat irritation
   d. Impaired immune responses
3. **Lungs-**
   a. Acute respiratory infection (including bronchitis and pneumonia)
   b. Chronic respiratory infection (including asthma)
   c. Chronic obstructive Pulmonary disease
   d. Impaired lung growth
   e. Lung cancer

[4] Jiang, X., Mei, X. and Feng, D., 2016. *Air pollution and chronic airway diseases: what should people know and do?*. Journal of Thoracic Diseases.

[5] The Conversation. 2021. *London air pollution is restricting children's lung development – new research*. [online] Available at: <https://theconversation.com/london-air-pollution-is-restricting-childrens-lung-development-new-research-106909>

[6] Farzan, S.F., Habre, R., Danza, P. *et al.* Childhood traffic-related air pollution and adverse changes in subclinical atherosclerosis measures from childhood to adulthood. *Environ Health* 20, 44 (2021). https://doi.org/10.1186/s12940-021-00726-x

[7] C-CHANGE | Harvard T.H. Chan School of Public Health. 2021. Coronavirus and Air Pollution. [online] Available at: <https://www.hsph.harvard.edu/c-change/subtopics/coronavirus-and-pollution/>

[8] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/media-resources/science-in-5/episode-9---air-pollution-covid-19

4. **Brain-**
    a. Impaired cognitive development
5. **Covid-19-**
    a. Decreased immunity
    b. Increased vulnerability

2.2.1.2 Impact of air pollution on Children's Mental Health

Through recent studies it has been somewhat understood that there is a relation between mental health and air pollution. A systematic review of 63 articles published between 2000 and 2018 investigated six physical and neurodevelopmental outcomes among infants and children exposed to air-borne pollutants associated with fossil fuel combustion. [9] The review provided indubitable evidence that exposure to air pollution is detrimental to the physical and neurodevelopmental health of infants and children.

According to IACAPAP (International Association for Child and Adolescent Psychiatry and Allied Professions'), Mental health for children and adolescents can result in the following conditions in children - (i) neurodevelopmental disorders; (ii) disruptive, impulse-control, and conduct disorders; (iii) depressive disorders; (iv) anxiety disorders; or (v) substance disorders. [10]
Air pollution also impacts children's brain development in several ways. First, pollutants can cause inflammation in the brain by damaging the blood-brain barrier, which is a thin, delicate membrane that protects the brain from toxic substances. Ultrafine pollution particles (particulate matter that is equal or less than 2.5 microns in diameter) can easily enter the bloodstream and travel through the body to reach the brain.[3] Second, specific air pollution particles, such as magnetite, create 'oxidative stress' – which is often a cause of neurodegenerative diseases.[3] Third, several studies also show that polycyclic aromatic hydrocarbons (PAHs), a specific class of pollutants released from fossil fuel combustion and vehicles, contribute to a loss of or damage to white matter in the brain.[3] White matter contains nerve fibers that are critical in helping neurons communicate across different parts of the brain and provides the foundation for continued learning and development.

Fortifying the neurological evidence, studies have found connections directly between air pollution exposure and cognitive development, including verbal and nonverbal IQ and memory, reduced test scores, grades among school children, as well as other neurological behavioural problems. Research shows an association between prenatal exposure to high levels of air pollution and underdevelopment at age three, as well as psychological and behavioural problems later in childhood, including symptoms of attention deficit hyperactivity disorder (ADHD), anxiety, and depression.[11]

However, it is worth noting that there is a dearth of comprehensive research that draws a direct connection between early childhood exposure to air pollution and the mental health of children. The lack of research can perhaps be attributed to data constraints since mental health, especially in children, is a less-talked-about issue in society. That being said, an experiment conducted by Randy Nelson, PhD, a professor of neuroscience at the Ohio State University,[12] demonstrates how exposure to particulate matter induced depression in mice. On comparing the polluted mice's brain and the control mice's brain he found physical changes to the nerve cells in the mouse hippocampus, a region known to play a role in spatial memory. He also observed that the pollutant-exposed mice showed signs of the rodent equivalent of depression. In all it was hypothesised that pollutants cause depression and other mental health disabilities. This was the closest research available that showed a direct connection between mental health (not just cognitive disabilities) and air pollution.

COVID 19 has undeniably affected the mental health of children. Grief, fear, uncertainty, social isolation, increased screen time, and parental fatigue are the primary causes.[13] Thus the gravity of children's mental health must be paid regard to, for the pandemic has only worsened the same.
The cognitive disorders can be summarised as below-

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[9] Systematicreviewsjournal.biomedcentral.com 2021. [online] Available at: <https://systematicreviewsjournal.biomedcentral.com/track/pdf/10.1186/s13643-021-01639-z.pdf> [Accessed 24 July 2021].

[10] *Rey J. IACAPAP textbook of child and adolescent mental health: International Association for Child and Adolescent Psychiatry and Allied Professions; 2015. Available from https://iacapap.org/english/*

[11] 2017. *Danger in the air: How air pollution can affect brain development in young children - World.* [online] Available at: <https://reliefweb.int/report/world/danger-air-how-air-pollution-can-affect-brain-development-young-children> [Accessed 1 August 2021].

[12] *https://www.apa.org/monitor/2012/07-08/smog*

[13] *Unicef.org, 2021. The impact of COVID-19 on children's mental health. [online] Available at: <https://www.unicef.org/india/impact-covid-19-childrens-mental-health> [Accessed 25 July 2021].*

1. Reduced Verbal and non verbal IQ
2. Memory and attention deterioration
3. Difficulty in decision making

The psychological disorders associated with air pollution can be summed up as-

1. Visible problems
   Eg.- Conduct disorder(antisocial behaviour)
2. Internalising problems
   Eg- Anxiety, depression
3. Delusions or hallucinations –
   Eg- Thought Disorder Symptoms (disorganised type of thinking)

2.2.2 Studying Impact Based on Economic Class

A paper studied the impact of socio-economic status on air pollution's health effects.[14] It was found that exposure to air pollution does in fact depend on socio-economic and socio-cultural differences.[15] Most of the urban slums in India are located near industrial areas and highways. Therefore, people living in slums are more susceptible to higher exposures from industrial and vehicular emissions.[16,17] Densely populated localities with no exhaust vents, along with the use of low-quality domestic fuels like biomass, and the presence of unpaved roads further worsens indoor air quality in slums.[19,20]

A study carried out by Kulshreshtha et al. (2008)[18] identified differences of 110-175 μg/m^3 in indoor PM concentrations between low- and high-income houses. Another study carried out in Mumbai also reported higher indoor pollutant concentrations in low-income houses than affluent ones.[19]

A recent study used multivariable statistical analysis to study a similar correlation in India.[20] The results indicated that there were higher $PM_{2.5}$ concentrations in districts with higher percentages of Scheduled Castes (SCs), young children, and households in poor condition and without toilets. Additionally, higher $PM_{2.5}$ increases in less urbanized districts with higher percentages of SCs, females, children, people with disabilities, and households with no toilets. These results put a spotlight on the need to weigh the role of air pollution in aggravating the repercussions of social disadvantages in India.

One of the studies observed the need for more studies which quantify the role of socio-economic disparities in air pollution exposure, to bring to light what is currently a hidden environmental justice issue.[19] We found that, in particular, there was a lack of data that studied the effect of socio-economic class on the impact of air pollution on children's physical and mental health. In particular, we found that there was no data for children. From the existing research, we can say that children are affected along the same lines since affected individuals are in the same households as children.

[14] Pollution, A., Health in India: A review of the current evidence and opportunities for the future July 2017. *Public Health Foundation of India/Centre for environmental Health, India*, pp.1-64.

[15] Pant P, Guttikunda SK, Peltier RE. Exposure to particulate matter in India: A synthesis of findings and future directions. Environ Res. 2016;147:480–96.

[16] Saksena S, Singh PB, Prasad RK, Prasad R, Malhotra P, Joshi V, et al. Exposure of infants to outdoor and indoor air pollution in low-income urban areas—a case study of Delhi. J Expo Sci Environ Epidemiol. 2003;13(3):219–30.

[17] Sharma S, Sethi GR, Rohtagi A, Chaudhary A, Shankar R, Bapna JS, et al. Indoor air quality and acute lower respiratory infection in Indian urban slums. Environ Health Perspect. 1998;106(5):291.

[18] Kulshreshtha P, Khare M, Seetharaman P. Indoor air quality assessment in and around urban slums of Delhi city, India. Indoor Air. 2008;18(6):488–98.

[19] Kulkarni MM, Patil RS. Monitoring of daily integrated exposure of outdoor workers to respirable particulate matter in an urban region of India. Environ Monit Assess. 1999;56(2):129–46.

[20] Chakraborty, J. and Basu, P., 2021. Air quality and environmental injustice in India: Connecting particulate pollution to social disadvantages. *International Journal of Environmental Research and Public Health*, *18*(1), p.304.

2.2.3 Studying Impact Based on Geographical Location

Air pollution in a region could be impacted either by its geographical characters or activities performed at such locations. For example the states in the east of India, such as Bihar, West Bengal, Jharkhand, Orissa, and Chhattisgarh, harbor large coal mines and power plants in conjunction with extensive biomass use, which have made these areas in the list of most polluted ones.[21] Geographical features may aid the pollution level in a region too. For example ,mountains stop the horizontal transport of smog, or divert it in another direction, unless the wind that crosses a region has a greater force to blow it over . The statement above could easily be understood with an example of Delhi NCR which lies to the south-west of the Himalayas. Winds arrive Delhi from the coast with pollutants which further get trapped right before the Himalayas, making Delhi region the worst sufferer.

Distance from coastal regions also plays a significant role in determining air pollution of a region since it impacts direction and speed of the wind of that place .Winds originating from coastal regions help to carry away pollutants, thereby reducing overall air pollution of a location. For example , Chennai stands the third highest in owning the number of automobiles in India, next to Delhi-NCR and Bangalore. But, since Chennai is a coastal city, it doesn't face the same complications of pollution as that of the Delhi-NCR.[22]

Studies have shown that more than three-quarters of the people in India are unmasked to pollution levels higher than the suggested by the National Ambient Air Quality Standards in India and is also comparatively higher than the levels suggested by the World Health Organization. The monitoring of air pollution levels is restricted to large urban and developed areas in India and virtually absent in small towns and rural areas. The Central Pollution Control Board of the Government of India and its corresponding state-level boards currently manage to have 92 PM2.5 and 573 PM10 monitoring stations all over the country. This is grossly inadequate for a country with a land area of 3.3 million km2 and a population of over 1.3 billion.[20] There has been a lack of data resulting in a minimal understanding of spatial patterns of air pollutants at local and regional levels due to the sole reason that small or developing, rural regions and cities do not have a proper management that keeps a check on current status of air pollution levels in that specific region.

2.3 Delhi NCR: A Case Study

According to IQAir, a Swiss group that measures air quality, New Delhi ranked as the world's most polluted capital for the third straight year in 2020. As per 2019 data, the aggregation of PM10 in ambient air in India's capital territory of Delhi is over 210 ug/m3, close to 4 times higher than the recommended WHO threshold (below 54.0 ug/m3).[23] India's Ministry of Earth Sciences published a research paper in October 2018 which attributed 41% of the total air pollution in Delhi to vehicular emissions, 21.5% to dust and 18% to industrial emissions.[23] The urban air database released by the World Health Organization in September 2011 reported that Delhi surpassed the maximum PM10 limit by almost 10 times at 198 ug/m3.[24] In December–January 2015, Delhi had an average PM2.5 level of 226 µg/m3. For comparison, the average level in Beijing for the same period was 95 µg/m3, implying that Delhi's air was twice as bad as Beijing.

The Delhi Chief Minister, Mr. Arvind Kejriwal, recently referred to the capital city as a 'gas chamber' as the air pollution in the city continues to rise despite several efforts taken to abate the pollution levels in the city.

2.3.1 Causes of Air Pollution in Delhi

There are several reasons that contribute to the rising levels of 2.5PM and 10 PM in Delhi. Some of the major reasons include the following:

Crop Burning - Crop burning is a major cause for air pollution in Delhi. Pollution due to burning crops typically peaks during the first week of November, a time when many farmers set fire to fields. Close to 39 million tonnes of paddy on average are burnt every year, resulting in a dense layer of smog over the Northern Plains, including Delhi NCR.[23] This peak juncture of the

[21] Doi.org. 2021. ambient air pollution. [*online] Available at:_<https://doi.org/10.1016/j.iatssr.2021.03.004>*

[22] Gordon, T., Balakrishnan, K., Dey, S., Rajagopalan, S., Thornburg, J., Thurston, G., Agrawal, A., Collman, G. and Guleria, R., 2021. *Air pollution health research priorities for India: Perspectives of the Indo-U.S. Communities of Researchers. [online] Air pollution health research priorities for India: Perspectives of the Indo-U.S. Communities of Researchers. Available https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6489448/*

[23] Chatterji, A., 2021. Air Pollution in Delhi: Filling the Policy Gaps | ORF. [online] ORF. Available at: <https://www.orfonline.org/research/air-pollution-delhi-filling-policy-gaps/> .

[24] Rizwan, S., Nongkynrih, B., & Gupta, S. K. (2013). "Air pollution in Delhi: Its Magnitude and Effects on Health". Indian journal of community medicine : official publication of Indian Association of Preventive & Social Medicine, 38(1), 4–8. https://doi.org/10.4103/0970-0218.106617

burning phase, has many times accounted for more than 50% of Delhi's total air pollution, according to data from System of Air Quality and Weather Forecasting And Research (SAFAR).

Industrial Pollution - Assessments made by the Central Pollution Control Board (CPCB) show that the national capital is home to and is surrounded by highly polluted industrial clusters that exceed the limits set by the government on air, water or soil emissions. The industries situated along the Delhi-National Capital Region (NCR), contribute to 18 percent to the air pollution in the location.[27]

Vehicular emissions - The transport sector is the major cause for PM2.5 emissions in Delhi (28 percent of all PM2.5 emissions). Apart from this, Overall vehicular emissions account for about 41 percent of total air pollution level in Delhi.[27]

Construction Sites - A mixture of hazardous gases or smog is released by the construction sites, which deteriorates the overall air quality of Delhi. According to Delhi Pollution Control Committee (DPCC) officials, construction sites contribute to almost 30 percent of air pollution in the city.[25]

2.3.2 Impact of air pollution on children

Exposure to air pollutants have been associated with a wide variety of detrimental health impacts in children. These include increase in mortality in very severe episodes; an increased risk of pre- neonatal mortality in regions of higher pollution, increased acute respiratory disease morbidity; aggravation of asthma.[26]Many studies were undertaken in Delhi to determine the effect of air pollution on respiratory functions and the associated morbidity.

One such significant study which was conducted by The Central Pollution Control Board in 2008 concluded that there were notable associations with all relevant adverse health outcomes.[27] The findings revealed that Delhi had 1.7-times higher prevalence of respiratory symptoms in comparison to control groups. Prevalence of current asthma (in the last 12 months) among the participants of Delhi was significantly higher than in controls. Apart from this, lung function was also reduced in 40.3% individuals of Delhi.

Another study concentrated on the impact of pollution on the health of children in Delhi revealed significant correlation between particulate matter in ambient air and attention-deficit hyperactivity disorder. One of the studies in Delhi also confirmed the notable relation between vehicular air pollution and increased blood levels of lead (a potential risk factor for abnormal mental development in children)[28]. High ambient air pollution also showed a significant association, with a risk of developing vitamin D deficiency rickets among children , in a study conducted in Delhi.[29]

"Air Pollution is stunting our children's brains, affecting their health in more ways than we suspected" as stated Environmental and Social Determinants of Health at WHO. Children are particularly at risk to the effects of air pollution because they breathe more rapidly than adults thereby absorbing more pollutants. They also live closer to the ground, where some pollutants reach peak concentrations – at a time when their brains and bodies are still developing. According to a report About 600,000 deaths in children under 15 years of age were attributed to the joint effects of ambient and household air pollution in 2016 in India . The brief summary of our present understanding of the impact of air pollution on children shows without doubt that comparatively lower levels of pollution helps to increase morbidity and even mortality in children. Also ,there is also convincing evidence that current levels of fine particulate matter are responsible for increasing asthma symptoms and respiratory illness. Considering the large

[25] Abelsohn, A., & Stieb, D. M. (2011), 'Health effects of outdoor air pollution: approach to counseling patients using the Air Quality Health Index'. Médecin de famille canadien, 57(8), 881–e287

[26] Epidemiological Study on Effect of Air Pollution on Human Health (Adults) in Delhi, Environmental Health Series: EHS/1/2008, Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India. 2008. Aug, [last accessed on 2011 September 20]. Available from: http://cpcb.nic.in/upload/NewItems/NewItem_161_Adult.pdf .

[27] Epidemiological Study on Effect of Air Pollution on Human Health (Adults) in Delhi, Environmental Health Series: EHS/1/2008, Central Pollution Control Board, Ministry of Environment & Forests, Govt. of India. 2008. Aug, [last accessed on 2011 September 20]. Available from: http://cpcb.nic.in/upload/NewItems/NewItem_161_Adult.pdf .

[28] Agarwal KS, Mughal MZ, Upadhyay P, Berry JL, Mawer EB, Puliyel JM. The impact of atmospheric pollution on vitamin D status of infants and toddlers in Delhi, India. Arch Dis Child. 2002;87:111–3. [PMC free article]

[29] Kalra V, Chitralekha KT, Dua T, Pandey RM, Gupta Y. Blood lead levels and risk factors for lead toxicity in children from schools and an urban slum in Delhi. J Trop Pediatr. 2003;49:121–3. [PubMed] [Google Scholar]

number of individuals (especially children), affected due to air pollution it leads to a significant concern for burden on the health system.

2.3.3 Government Interventions

2.3.3.1 Overarching Interventions

Taking cognizance of the air pollution in the capital city, the government undertook several measures to control the pollution levels. Some of the major overarching interventions are listed below:

Graded Response Action Plan (GRAP)
The Graded Response Action Plan is a programme to control air pollution in Delhi. is referred to as a 'graded' plan, as it functions according to stages. There are specific actions to be taken for certain pollution concentration levels, which can bring about a gradual form of pollution control.

Commission for Air Quality Management in National Capital Region - In January 1998, the Supreme Court endorsed the Central Government's proposal to create an expert authority, the Environment Pollution (Prevention and Control) Authority (EPCA), to improve the air quality in the NCR region. The EPCA was replaced by a more permanent body- the Commission for Air Quality Management (CAQM) in the National Capital Region. While both bodies have similar functions, the CAQM can impose and collect environmental compensation from farmers causing air pollution by stubble burning.

Odd-Even Scheme - The odd-even scheme is a traffic rationing measure begun by the Delhi government, under which private vehicles with registration numbers ending with an odd digit are allowed on roads on odd dates, and those with an even digit ply on even dates. In its introductory phase, the odd-even scheme succeeded in curbing air pollution in Delhi. However, in the long-term its effects were less visible.

The scheme is less effective due to exceptions to the rule such as commercial vehicles. Most IIT-D researchers state that its effectiveness is at 2 -3%. According to a study by the Delhi Integrated Multi-modal Transit System (DIMTS), the overall traffic on roads was only 2-percent less while the odd-even scheme was in place, and the average peak hour speed of vehicles increased by only 5 percent.

2.3.3.2 Child-Based Interventions

In 2019, the government distributed five million N95 masks - capable of blocking at > 95% of PM 2.5 particles - to students of government and private schools. Due to the toxic haze produced by stubble burning, the Delhi government closed schools during October and November months of 2020. However, the Delhi government is yet to take significant child-specific measures against air pollution.

2.4 Global Best Practices

2.4.1 Case Study: Policies in the UK

Air quality is considered to be the biggest environmental health risk in the UK. It shortens lives and contributes to chronic illness. Its effects in children are identical to those seen globally, which is not only concerning but also important to tackle. Keeping this in mind, the UK government came up with the Clean Air Strategy- 2019.[30]
These policies aim to reduce $PM_{2.5}$ concentrations across the UK, so that the number of people living in locations above the WHO guideline level of 10 $\mu g/m^3$ is reduced by 50% by 2025.

Actions to reduce emissions from transport
The UK government has already committed more than 3.5 billion pounds to tackle poor air quality through cleaner road transport. The government has published Road to Zero, which sets their plans to end the sale of new conventional petrol and diesel cars and vans by 2040. Studies show that high degrees of exposure to traffic-related air pollution during early childhood may change the

[30] GOV.UK. 2021. *Clean Air Strategy 2019*. [online] Available at: <https://www.gov.uk/government/publications/clean-air-strategy-2019> [Accessed 26 July 2021].

structure of the brain and lead to neurocognitive disorders. By setting such targets and working to reduce traffic-related air pollution, the government will alleviate these effects on young children.

Children-Specific Measures

The Mayor of London has launched the Mayor's School Air Quality Audit Programme.[31] As a part of the programme, 50 primary schools in London's most polluted localities were audited.

The audits have made suggestions to mitigate emissions and exposure. They include:

- moving school entrances and child play centers away from busy roads
- 'no engine idling' schemes to cut down on automobile emissions
- reducing emissions from household devices such as kitchen systems, boilers,etc.
- changing local roads to include better road plans and designs, restricting high-polluting vehicles around schools and pedestrianisation in the vicinity of school entrances
- adding green infrastructure like 'barrier bushes' along high-traffic roads and in playgrounds to filter dust particles and fumes
- encouraging students to substitute transportation to school with walking and cycling along low-traffic and less polluted routes
- support of funds by Transport for London(TfL) Local Implementation Plans[32] and Clinical Commissioning Groups[33]
- launching Breathe London, [34] a low-cost air quality monitoring system

2.4.2 Case Study: UNICEF and China

In the past 30 years, China has witnessed dramatic economic growth. Its expansion of the gross domestic product (GDP) by a factor of 43 from 1990 to 2017 can primarily be attributed to fossil fuels, particularly coal, the main source of emission of air pollutants. In 2007, China surpassed the United States in CO_2 emissions and in 2009 in energy consumption, becoming the world's largest energy-consuming and carbon-emitting country. Considering the drastic effects air pollution has on children's physical and mental health, young citizens were severely affected during this time period. However, following this, China was able to significantly reduce its air pollution and created a model for other countries facing similar problems to follow. With the help of policies and child-based interventions, they were able to mitigate air pollution.

Over the past three decades, China has made strides towards achieving a society based on sustainable development and ecological civilization. In the 1970s and 1980s, China implemented policies and took measures to control dust emissions at a local level. Following that, acid rain became a serious concern, with SO_2 emissions and NO_x emissions growing continuously. Since then, efforts have been made to mitigate SO_2 emissions, especially from coal combustion. Measures have also been taken to reduce NO_x and $PM_{2.5}$ emissions.

China's new air quality management model has a clear aim: mitigate multiple precursors from multiple sectors through extensive coordination at the regional or national level. China has launched various movements, some of which include the short-term "Blue Sky Defense Battle" between 2018 and 2020 and the long-term "Beautiful China" targets to be achieved till 2035.

Child-Specific Measures

UNICEF China, in collaboration with the government counterpart, is studying the effects of environmental health on children and will support the development of a Child Environmental Health Action Plan as part of the National Environmental Health Action Plan.[35] UNICEF is also engaged in activities to educate youth, raise awareness about climate change and empower children to be future leaders in tackling climate change and environmental issues.

UNICEF is developing strategies and advocating for policies that will replace coal-burning cooking and heating sources with clean-energy appliances. They are also advising parents to keep children away from sources of pollution and ensure better

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[31] 021. The Mayor's school air quality audit programme. [online] Available at: <https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/mayors-school-air-quality-audit-programme> [Accessed 26 July 2021].

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[33] NHS Clinical Commissioners. 2021. *About CCGs - NHS Clinical Commissioners*. [online] Available at: <https://www.nhscc.org/ccgs/> [Accessed 26 July 2021].

[34] Breathe London. 2021. Breathe London. [online] Available at: <https://www.breathelondon.org/> [Accessed 26 July 2021].

[35] Unicef.cn. 2021. *Pollution: 300 million children breathing toxic air - UNICEF report*. [online] Available at: <https://www.unicef.cn/en/press-releases/pollution-300-million-children-breathing-toxic-air-unicef-report> [Accessed 26 July 2021].

ventilation while using coal-burning stoves. The project is also investigating the impacts of introducing chimney ventilation, fans and air purifiers on reducing exposure to pollutants. In addition, the team installed real-time indoor air quality monitors to encourage villagers to take timely actions when the air quality's reading crosses a certain level. The project aims to increase community members' awareness of the adverse health effects of indoor pollution.

Other government policies and measures

China has successfully implemented interventions such as phasing out of leaded gasoline, which rapidly reduced blood lead levels in children. Government action to reduce coal-fired power plant emissions has resulted in direct and immediate health benefits to children.

With all these policies, China was able to establish a model that could be replicated in countries with similar environmental conditions and human factors such as population. By adopting sustainable energy alternatives, China will be able to better protect its children, the future of the country.

2.4.3 Independent Global Organisations working towards clean air specifically for children

Independent organizations working for the reduction of the impact of air pollution in children[36] are as mentioned below:

1. **Coalition for clean air -CCA**

   CCA[37] has been consistently working towards reducing air pollution and increasing air quality monitoring across California(US). Educating school children about air quality monitoring is a key goal of CCA. Their STEM program educates local students about the air in their cities, incentivising them to take that knowledge home to make actual differences. They have also partnered with Sonoma Tech to bring participatory air quality monitoring research projects to California students and empower them with knowledge they can take back home.

2. **Mom's Clean Air Force**

   Mom's Clean Air Force[38] represents a community of over one million parents across the US working to reduce air pollution for the sake of their children's health. They campaign on a number of connected national and local policy issues in their fight against air pollution. They meet with lawmakers at every level of government and on both sides of the political aisle to build support for equitable and healthy solutions to air pollution.

3. **Little ninja**

   Little Ninja[39] was established by a London-based father, David. His organization campaigns for greater awareness in London as to the pollution dangers of idling vehicles, especially for young children. Their programs include: say no 2 idling (petition against idling vehicles), toxic bus shelters (no idling vehicles at kerbside shelters), start stop idling (reduce the number of times a vehicle accelerates and brakes), fight pollutant monsters (comics to increase child awareness),driver awareness, pollution monitoring (measuring local air pollution through 'AQMesh'[40])

4. **Children's environmental Health Network-**

   CEHN[41] is a multi- disciplinary organization whose mission is to protect the developing child from environmental health hazards and promote a healthier environment. It is a key leader on climate change and children's health. It has formulated a parent and educator toolkit that consists of activities to help increase environmental awareness in children.

5. **Chintan-**

   Chintan[42], a well-known environmental organization in India, has been working with various partners to empower the public to understand the science and impacts of air pollution, take action on it and to push for policies that minimise vent

[36] Helen, A., 2021. *Top Influencers, NGOs & Organizations Against Air Pollution in 2021*. [online] Blog.breezometer.com. Available at: <https://blog.breezometer.com/ngos-fighting-air-pollution> [Accessed 25 July 2021].

[37] Climate & Clean Air Coalition. 2021. *Climate & Clean Air Coalition*. [online] Available at: <https://www.ccacoalition.org/en> [Accessed 25 July 2021].

[38] MacEachern, D., Rauch, M. and Yerman, M., 2021. *Moms Clean Air Force: Fighting Air Pollution & Climate Change*. [online] Moms Clean Air Force. Available at: <https://www.momscleanairforce.org/> [Accessed 25 July 2021].

[39] Little Ninja.co.uk. 2021. *Little Ninja – Protecting children from air pollution*. [online] Available at: <https://www.littleninja.co.uk/> [Accessed 25 July 2021].

[40] Air pollution monitoring device

[41] Cehn.org. 2021. *Children's Environmental Health Network – A healthy environment for all children*. [online] Available at: <https://cehn.org> [Accessed 25 July 2021].

[42] Chintan Environmental Research and Action Group. 2021. *Chintan Environmental Research and Action Group*. [online] Available at: <https://www.chintan-india.org/> [Accessed 25 July 2021].

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air pollution and its impact on human health. Chintan focuses on the poor population, children and women, and the marginalised communities.

2.5 Primary Survey

To gauge the perception and awareness of the various physical and mental impacts of air pollution on children in India, we conducted primary surveys and interacted with a diverse set of stakeholders to inform our research. The results of the surveys and interactions are summarized in this section.

2.5.1 Stakeholder Survey (Children)

57 children, ages 10-17, were surveyed to analyze sentiments regarding air pollution and its impacts on children's health. Most of our respondents were based in North India and Western India, there was lesser representation from East India. These results indicate that most children are aware of air pollution (Fig 2.5.1). 97.8% of our respondents have noticed air pollution to some or full extent in their cities. While most children are aware of side-effects to their physical health, fewer are educated about air pollution's impact on their mental health. Only 1.8% of our respondents were aware that air pollution can cause depression and anxiety in children (Fig 2.5.2). A majority of children (93.3%) wish to play a role in reducing air pollution (Fig 2.5.3). These results show that youth can be mobilized to combat air pollution. Awareness regarding its impacts on mental health must be spread.

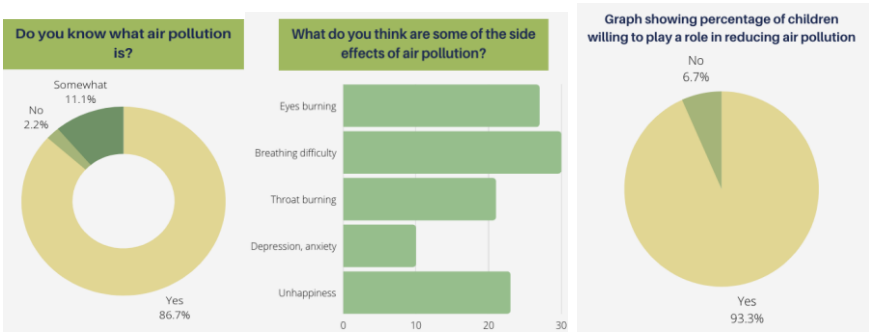

Fig 1.1 Fig 1.2 Fig 1.3

Fig 1. Responses of children to stated questions on the conducted survey

2.5.2 Stakeholder Survey (Parents)

This survey was conducted to understand the awareness in parents about the impact of air pollution on children's physical and mental health and gather potential recommendations that they expect or suggest. 65 parents were surveyed. The geographical distribution of the respondents was fairly equal, though the representation of West India was a little weak. These results indicate that most parents rate their cities air quality at an average of 3.05. Parents are least aware that air pollution causes depression(Fig 2.1). 62.5% of their children have faced issues due to air pollution(Fig 2.2). 50% of parents said that air pollution has impacted their children's daily activities. 57.1% of the parents were aware of the current policies regarding air pollution(Fig 2.3). Out of these parents, 62.5% were not satisfied with those policies (Fig 2.4). "Initiatives are taken but execution must be better" is the common sentiment amongst parents. It has been inferred that parents are not fully aware of the impact of air pollution on children's mental health. Most are not satisfied with the current policies regarding the same and are willing to take action to reduce the impact of air pollution on their children. Awareness regarding the impact of air pollution on mental health should be spread and organisations with parents as members should be formed.

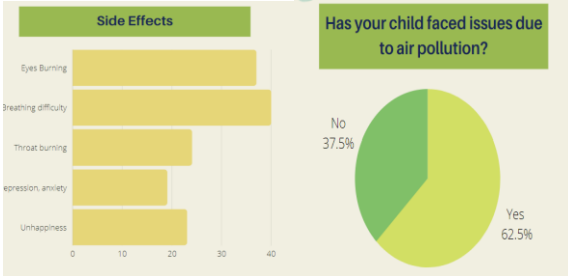

Fig 2.1

Fig 2.2

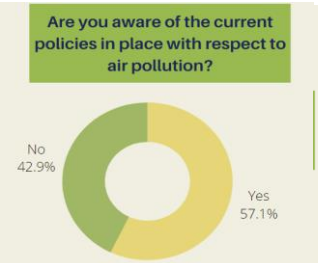

Fig 2.3

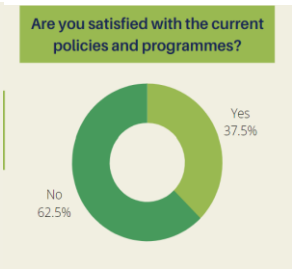

Fig 2.4

Fig 2. Responses of parents to stated questions on the conducted survey

2.5.3 Interaction with stakeholders

The stakeholders we interacted with were teachers, school administrators, NGOs, University students, Medical Practitioners, and experts in this subject.

1. Teachers and school administrators

We interviewed teachers and school administrators from a pre-school based in Ludhiana to understand their opinions. There were 11 interviews conducted in total.

- When asked whether school outdoor activities were affected as a result of air pollution, 9 out of 11 interviewees agreed. Reduced attendance was the main reason associated with the impact of air pollution on school activities.
- 8 out of 11 respondents did not encounter students with respiratory issues as a result of air pollution. This is because they believed that the children were too young to explain their issues.. However, most did know children outside of school or personally who encountered respiratory problems.
- Most were aware of physical effects such as respiratory problems, breathing issues, allergies, eyes burning, and lack of physical activity .The school administrators confirmed that most children owned nebulisers to cope with air pollution issues.
- There was a lack of awareness to some extent about mental health effects of air pollution, although 8 out of 11 respondents believed there was some correlation between mental health and air pollution. Some general mental effects listed were concentration problems, unhappiness, reduced school attendance during seasonal highs in air pollution, laziness, tiredness.
- 9 out of 11 believed that the impact of air pollution on children's health varies based on socio-economic class. The most agreed upon reasons for the difference were the lack of awareness and education in lower socio-economic classes about air pollution and its detrimental effects, lack of resources and opportunities for healthcare, greater population density causing greater spread of respiratory infections, greater exposure to bad air quality for the homeless, lack of greater residential spaces with greenery and trees in the surroundings, absence of air purifiers, and improper gas systems.
- Everyone agreed that the school had taken certain steps to reduce the effect of air pollution on children. Firstly, air purifiers were installed in every classroom. There were a lot of trees in the surrounding area of the school. The school administrators

encouraged carpooling through circulars and parent-teacher discussions. Sensible waste management techniques were followed by the school, including composting and recycling.

- All respondents were unaware of current government policies in place with respect to air pollution, which indicated a general lack of awareness among citizens.
- When asked for suggestions about policies, many said that children's health should be prioritised in air pollution related policies. Another suggestion was child awareness programmes related to air pollution and its effects. Other suggestions included afforestation in school areas, use of electric vehicles, substituting cars with bicycles and walking whenever possible, traffic control, separating residential areas from industrial areas, restrictions on industries, ensuring stricter regulations for car pollution check-ups, and encouragement of school transportation.

2. Medical Practitioners

The interviewed doctors, primarily from Maharashtra, responded as below-

- On asking about the physical impact of air pollution in children, all of the doctors gave a similar response. Air pollution causes an allergic condition in the respiratory tract of children which worsens into diseases like bronchitis and asthma which can also impact the heart at a later stage. Air pollutants also have carcinogens and the trend of breast and lung cancer in young children in polluted cities has been observed.
- As for the effect on mental health, it was a general consensus that air pollution does impact mental health of children but indirectly as no direct connection is yet to be known. Exposure to air pollutants causes chronic mental fatigue in children. Also, reluctance of parents to send children out in the polluted city increases irritability in children.
- Air pollution related health issues in children have increased by multiple folds in the past ten years.
- The impact of COVID 19 and air pollution on children had different opinions. Some said that air pollution and COVID 19 was the 'worst combination', others said that there was no significant relation between the two and the impact on physical health was not noticeable. But a connection between mental health and air pollution in the pandemic was observed.
- None of the doctors were satisfied with the current actions and policies in India and suggested chest-opening yoga for children, early education in schools regarding air pollution, making comics, cartoons, infographics, having competitions and activities to increase awareness in children, increasing green zones, proper implementation of laws.

3. Experts-

- The sources of air pollution in developing countries like India are primarily from constructions and vehicles. Pollution in Delhi is due to vehicles, heavy and small-scale industries, and brick kilns. The situation in Delhi worsens due to its poor geography as it lies in the trans-continental arc.
- The international models suggested were eco-driving habits, policies from London, Generalised Additive and CALPOC.
- They advocated rapid expansion of innovation, creating a national health database, strengthening policy implementation, installation of air purifying towers, wet cooling towers, contemplated the use of technology and AI, implementation of SDG-11 and increasing awareness in children through the school curriculum and advertisements.

2.6 Recommendations

After extensive research from various papers, case studies, and articles, analysing and imbibing the opinions of our stakeholders and experts, and intensive internal discussion, we have come up with these recommendations that aim to maximally reduce the impact of air pollution on children's physical and mental health.
The recommendations are as below:

Short Term-

- Parent awareness campaigns specifically for mental health
- Child awareness campaigns specifically for mental health
- Volunteer programmes for children
- Competitions and activities for increasing awareness in children (as suggested by stakeholders)
- Green camps for children- summer camps for children in total pollution-free zones with activities aiming at improving their mental health and physical health.
- Organisations for parents, teachers, students (from Mom's Clean Air Force)
- Comics/ cartoons for children to increase awareness about air pollution in children (from Little Ninja, as suggested by stakeholders)

- Addition of air pollution awareness in school curriculum at an early age (as suggested by stakeholders)

Long Term-

- Partner with organisations that encourage children to build their own air quality monitoring devices (from Coalition of Clean Air)
- Increasing green zones (as suggested by stakeholders)
- Zero diesel vehicles in cities (metropolitan)
- Electrification of school vehicles
- Anti-pollution masks (like Prana Air Junior[43]) made available at subsidised rates
- Mandatory installation air filters and detection systems in every school and house with children
- Cost effective air-purifying towers (from China)
- Better implementation of laws and regulations by the government

2.5 Conclusion

Our paper investigates the impact of air pollution on children's physical and mental health. Based on our research, there is a connection between air pollution and extremely damaging physical (respiratory, cardiovascular and developmental) and neurodevelopmental (cognitive and depression) issues. Although, there was a definite dearth of resources regarding the impact on mental health. Other than that, we were able to gather data to show an economic relation between class and race and impact of air pollution. There also seems to be a geographical relation, with varying impacts in different regions of India.

We took a closer look at the Delhi NCR, a region which has been in the spotlight concerning air pollution for a long time. Delhi's children are the most defenceless against its toxic effects as they have developing immune and respiratory systems. In Delhi, air pollutants are, almost literally, forced down children's throats and find their way into the lungs and cardiovascular systems of children, resulting in increased mortality rates, and health issues such as asthma and bronchitis. While Delhi has taken several steps to reduce its air pollution, none of them have been particularly effective. The government must take strong action that not only targets vehicular pollution, but also crop burnings and that from small and large scale industries.

Our paper takes a deeper look at global models for child-based interventions and determines whether they can be replicated in India considering various factors. We took a look at the policies in place in the UK and China. Additionally, we were able to identify successful independent global organisations that work to mitigate the impact of air pollution on children..

We hope that the recommendations from our research can be implemented to mitigate air pollution and its damaging effects on children. Future research may build on our findings to provide more insightful data about the air pollution crisis, especially when the scope is narrowed to children with respect to mental health impacts, socio-economic class, and geographical locations.

[43] Prana Air. 2021. *Adult-Kid Mask (N95) | Prana Air*. [online] Available at: <https://www.pranaair.com/product/junior-pollution-mask/>

Annexure
List of Stakeholders

Name	Profession	Organisation	Designation
Dr. Shailaja Mane	Doctor	Independent	Pediatrician
Dr. Saurabh Varshney	Doctor	Independent	Cardiac Surgeon
Dr. Pallavi Bapat	Doctor	Independent	Developmental, Behavioural Pediatrician
Dr. Meghana Tidke	Doctor	Independent	
Mr. Nehul Shashikanth	Professor	Pune University	Professor of Environmental Studies
Mr. Abhay Pathak	Engineer	Tata Motors	General Manager, Sustainable Development
Mr. Rawat Agrawal	Student	IIT Banaras Hindu University	Majoring in sustainable development
Ms. Tani Sidhu	School Administrator	Little Kingdom Nursery School	Director
Ms. Malvika Sharma	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Sonia Sikka	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Priyanka Aggarwal	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Neharika	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Samiksha Rawat	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Neha Bector	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Shrutika Sharma	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Tanu Gaba	Teacher	Little Kingdom Nursery School	Online Content Teacher
Ms. Srishti Mohindra	Teacher	Little Kingdom Nursery School	Class Teacher
Ms. Vasundhara Kapoor	Teacher	Little Kingdom Nursery School	Online Video Content Teacher