
Indoor Air Quality in Schools: A Review Based Study

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Abstract

There is a sudden increase in public and media attention on the incidences of increasing ambient air pollution in India and its potential influence on infants and children. But, the fact that children spend as much as 80-90% of their time indoor, either at school or at home, must drive attention of researchers to also study indoor air pollution with the same vigour and concern. The present study discusses the current scenario of indoor air quality (IAQ) in learning institutions, mainly school environment in India and world over. Review of literature showed that there is a very limited research data available in India on IAQ of schools. However, scientific evidences around the world claim poor state of schools in terms of indoor environment and air quality which may trigger serious health concerns that directly or indirectly affect health and well-being of children.

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1. Introduction

The poor quality of indoor air in schools can be of particular concern for children's health who spend approximately 30% of their time inside school buildings, only second to their homes [1]. A number of research studies indicate that school air may be a source of a wide spectrum of air pollutants. Ventilation rate (flow of outdoor air to a space) and ambient air quality are the most important factors that affect IAQ. Due to inefficient ventilation system, increase in particulate matter and other toxic materials, accumulation of carbon dioxide (CO₂), reduction in oxygen (O₂), and increase in temperature and humidity may lead to building related health problems in occupants [2].

Studies on the status of indoor air quality have received increased attention of the researchers, government bodies and policy makers over the last few years due to its association with the adverse health effects and occupants' discomfort [3]. Thus this study embarks on the objective of assembling, evaluating, and summarizing existing research based literature on indoor air quality in schools, with special emphasis on ventilation, CO₂, PM_{2.5} and PM₁₀ concentrations in schools

2. Research Method

The research methodology of this paper included in-depth analysis of research papers and media reports which were indexed in various journals on e-web portals, and research reports by the Government and International organization. The reviewed literature from these papers regarding the state of poor school environment and exposure on children's health due to poor state of indoor air provided a very eloquent picture of indoor air quality and its possible effect on occupants, especially on infants and children. The original scientific researches pertaining to the indoor air quality employed a variety of study designs ranging from cross-sectional multi-building surveys to on-site-inspections and experimental studies using appropriate measuring tools.

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3. Results and Analysis

This review based research paper provides a perspective on IAQ in Indian as well global school buildings.

3.1. What is indoor air quality?

There is no single internationally accepted authoritative definition of indoor air quality. This paper uses a broad definition of IAQ given by Central Pollution Control Board's (CPCB, India) Indoor Air Pollution Report 2014, Indoor Air Quality (IAQ) refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health and performance of occupants [4]. Wesolowski (1987) defines IAQ as being 'the totality of attributes of indoor air that affect a person's health and well-being' [5].

3.2. A scenario of Indoor Air Quality (IAQ) in Schools in Indian Cities

The existing body of published literature in IAQ in India has mostly focused on indoor air pollution due to the burning of biomass fuels in cook stoves in rural, semi urban areas or in urban slums. However, there is still dearth of researches to study indoor air quality and related pollution issues caused due to other developmental factors like increased vehicular traffic, industrial pollution etc in urban areas. Indoor air pollution (IAP) in rural and urban areas may differ due to the different economies and lifestyles. Children in urban areas spend most of their time indoors, which means that their primary exposure to air pollution may come from the air inside homes and schools rather than outdoors. While reviewing the literature, it was found that only a handful of published literature was available on IAQ in Urban Schools in India. However, it is anticipated that researches in this area will gain momentum at a very fast pace in near future due to increased public attention on air pollution episodes in urban areas frequently reported by media.

3.2.1 Media coverage about air pollution in India

The media coverage have played an important role in bringing immediate attention of government and people on the increasing air pollution in India and the hazards associated with it. The connection between air pollution and various respiratory diseases is being repeatedly brought out in the Indian and International media (table 1).

Table 1: School related air pollution reports in leading newspapers/ news portals in India between 2015-2017

Source	Date	Article	Key points
Hindustan Times	8-11-2017	Delhi air pollution: Govt orders closure of all schools till Sunday [6]	<ul style="list-style-type: none"> All schools closed due to deteriorating air quality in the Delhi. Indian Medical Association said the Delhi witnessing a "public health emergency".
The Times of India	07-11-2017	All Delhi primary schools closed on Wednesday as air quality worsens [7]	<ul style="list-style-type: none"> Delhi government closed all primary schools due to air pollution and smog. Proposed odd-even formula for vehicles. People asked to not burn crops, wood and residues.
News18	06-11-2017	Delhi Air Pollution: Here's Why They Are Keeping The Schools Shut [8]	<ul style="list-style-type: none"> Children are particularly vulnerable to hazards of air pollution as their bodies are still developing. They have weaker immunities, vulnerable biologies, susceptible brains and lungs. Keeping confined indoors is tricky due to the build-up of indoor air pollutants and gases. Air pollution is a major contributing factor in the deaths of around 600,000 children under five every year. Air pollutants can cross the blood-brain barrier and permanently damage developing brains.
Hindustan Times	04-11-2017	Delhi's air quality causes schools to suspend outdoor activities [9]	<ul style="list-style-type: none"> Experts suggested that all outdoor activities to be restricted if the AQI reaches a range of 301 to 400. Schools suspended sports and outdoor activities
The New York Times	08-11-2017	In India, Air So Dirty Your Head Hurts [10]	<ul style="list-style-type: none"> Delhi pollution reached 30 times limit set by WHO. Around 4000 schools shut due to smog. People complaining of throat irritation, headache, coughing.
Times of India	12-11-2016	Delhi a wake-up call for world on air pollution: UNICEF [11]	<ul style="list-style-type: none"> Delhi's smog worst in 17 years. Over 5,000 schools declare holiday to minimize exposure of children to the polluted air. Approx. 4.41 million children missed 3 days of school. PM levels hit $999\mu\text{g}/\text{m}^3$, more than 15-16 times the safe limit.
CNN	8-11-2016	New Delhi is the most	<ul style="list-style-type: none"> US Embassy in Delhi put the city's Air Quality Index at 999.

		polluted city on Earth right now [12]	<ul style="list-style-type: none"> • Use of anti-pollution masks on rise. • Schools shut down.
The Guardian	6-11-2016	Indian government declares Delhi air pollution an emergency [13]	<ul style="list-style-type: none"> • Delhi schools closed for three days. • Building work halted. • PM_{2.5} level more than 16 times (more than 999µg/m³ safe limit in Delhi). • People advised to stay home. • Hospitals reported increased admissions of people suffering from respiratory diseases. • Children are particularly vulnerable. • Half of the city's 4.4 million schoolchildren have stunted lung development.
News18	06-11-2016	Delhi Air Pollution: Here's Why They Are Keeping The Schools Shut [14]	<ul style="list-style-type: none"> • Children more vulnerable to hazards of air pollution as their bodies still developing, have weaker immunity, susceptible brains and lungs. • Schools shut from 4th to 7th November 2016. • Keeping children confined indoors is also tricky due to the buildup of indoor air pollutants. • Children's respiratory tracts more prone to infections due to air pollution & have increased risk of asthma, bronchitis and chronic cough. • Pollutants can cross the blood-brain barrier and permanently damage children's brains.
NDTV	04-12-2015	Indoor Air Quality in Delhi Schools Very Bad, Says Green Body [15]	<ul style="list-style-type: none"> • 24-hour monitoring of IAQ carried out by GreenPeace, India for 7 days in 7 schools based in Delhi revealed PM_{2.5} levels to be 5 times above Indian safety limits and as much as 11 times that of the WHO's safety limits.
Mail Today	05-05-2015	Nearly HALF of Delhi's children suffer 'severe' lung problems due to air pollution [16]	<ul style="list-style-type: none"> • Delhi's children have the weakest lungs compared to youngsters from other metros. • Acc. to HEAL Foundation and Breathe Blue- 4 out of 10 children have severe lung problems. • 35% of school-going children fared badly in the Lung Health Screening Test. • According to WHO air pollution is a major environmental health risk.

It is evident from the frequency of media reports that school children are particularly vulnerable to increasing pollution episodes, especially in urban areas like Delhi. Predominant cause of increasing respiratory diseases in children can be contributed to dangerous level of air pollution in the cities. While some attribute worsening of air quality in to the use of firecrackers during Diwali, other factors could be burning of solid waste in and around Delhi, vehicular emissions, dust by the roadside and around construction sites in Delhi and stubble burning in Punjab and Haryana.

3.2.2 Glimpses of Research Studies conducted in India on IAQ in schools

Studies on the status of indoor air quality in India have received increased attention of the researchers, government bodies and policy makers over the last few years due to its association with the adverse health effects and occupants' discomfort [3].

The research studies by Chithra and Shiva Nagendra [17], Habil and Taneja [18], Sireesha and Padmavathi [19], Goyal and Khare [20], SGS India Pvt. Ltd. [21] and Energydesk Greenpeace [22] indicated poor air quality in schools in urban area. The results of their studies are highlighted in table 2.

Table 2: Summary of IAQ related research studies in Schools in India

Researcher and year	Place	Significant findings	Exceeding WHO limit
SGS India Pvt. Ltd. (2014)	Delhi, India	Satisfactory results for IAQ except PM ₁₀ and PM _{2.5}	Yes
Greenpeace, India (2014)	Delhi, India	Air pollution inside all schools exceeded safety levels set by Indian authorities and WHO.	Yes
Sireesha and Padmavathi (2014)	Hyderabad, India	Air quality parameters different in indoors and outdoors, however, respirable and non- respirable particles remained same. The difference in the indoor air quality across the schools located in different environments.	-
Habil and Taneja (2013)	Agra, India	PM concentration varied extremely during winter, monsoon, and summer season. PM higher in winters, lower in summers, and moderate during monsoons. Ventilation rate have direct influence on the I/O ratios of particulate matter Indoor PM ₁₀ exceeded from four to five times and PM _{2.5} by two to three times the WHO standards.	Yes
Chithra and Shiva Nagendra (2012)	Chennai, India	PM ₁₀ and PM ₂ levels exceeding NAAQS. High I/O value of PM ₁₀ . Low I/O values of finer particles.	Yes
Habil and Taneja (2011)	Agra, India	The mean indoor PM ₁₀ , PM _{2.5} and PM _{1.0} concentrations in winter season exceeded NAAQS The I/O ratios were found to be >1	Yes
Nagendra and Harika (2010)	Chennai, India	Hourly CO ₂ concentration below 1000ppm. Almost 50% of students suffering from minor health problems.	-
Goyal and Khare (2009)	Delhi, India	Indoor PM ₁₀ , PM _{2.5} and PM _{1.0} concentrations higher than outdoors.	Yes

3.3 Indoor Air Quality (IAQ) in Schools: A Global Scenario

Researchers also increasingly taking interest in studying air quality in educational premises as schools are densely occupied and children are more susceptible to air pollutants. There are a large number of research publications available world over which provides insight into the indoor air quality in schools and the problems associated with it. These research studies have also highlighted the possible effect of poor IAQ in schools on students' health and well-being [19], [23], [24].

Majority of the existing published literature reviewed in this study reported the CO₂ concentration in classrooms often exceeding 1000ppm, the limit recommendation by American Society of Heating, Refrigerating and Air-conditioning Engineers- ASHRAE- standard 55/ 62-2004 (ASHRAE, 2010) [25]. In the research studies by Yang et al. [26], Hou et al. [27], Elbayoumi et al. [28], Fuoco et al. [29], Jurado et al. [30], Fadeyi et al. [31], Bako´ -Biro´Zs. et al. [2], Froome et al. [32], Godwin & Batterman [33], and Lee and Chang [34], indoor CO₂ concentrations were outside the permissible limit exposing students to unhealthy learning environment. Particulate matter concentrations and dust were also seen to be a cause of concern in a large number of studies [28], [30], [32], [34], [35]. The summary of the research studies published worldwide is highlighted in table 3.

Table 3: Summary of research studies published worldwide on IAQ in educational institution

Researcher and year	Place / Country	Number of selected schools/colleges	If exceeding WHO/ASHRAE/EPA standard	Parameter outside limits
Yang et al. (2015)	Malaysia	School classrooms	No	CO ₂ , PM ₁ , PM _{2.5} PM ₁₀
Hou et al. (2015)	Beijing, China	2 primary schools	Yes	CO ₂
Fuoco et al. (2015)	Cassino, Italy	6 classrooms from 3 schools	Yes (in winter)	CO ₂
Elbayoumi et al. (2015)	Gaza	12 naturally ventilated schools	Yes (CO ₂ exceeded in winter season)	CO ₂ , PM ₁₀ PM _{2.5}
Madureira et al.	Porto, Portugal	73 classrooms from 20 public primary	Yes	PM _{2.5} PM ₁₀

(2015)		schools		
Jurado et al. (2014)	Brazil	15 air-conditioned and 15 naturally ventilated university classrooms	Yes	PM CO ₂
Mohammadi (2014)	Sari, Iran	15 preliminary schools	Yes	PM _{2.5}
Fadeyi et al. (2014)	United Arab Emirates	16 schools	Yes	CO ₂ PM
Alves et al. (2013)	Aveiro, central Portugal	1 kindergarten and 8 elementary school classrooms	Yes	CO ₂ PM
Bako´-Biro´ et al. (2012)	England	8 primary schools	Yes	CO ₂
Lee and Chang (2000)	Hong Kong	School classrooms	Yes	PM ₁₀ CO ₂
Froome et al. (2007)	Munich city	65 schools	Yes (in winter)	CO ₂
Godwin and Batterman (2006)	Michigan	64 elementary and middle school classrooms	Yes	CO ₂

4. Conclusion

Healthy school environments are tremendously important to children's health and academic success. Review of research highlighted poor state of indoor air in the school environment. Studies showed that poor indoor air quality in schools could result in more illness, absenteeism and asthma attacks. Problems such as exposure to chemicals, toxic building materials and infiltration of outdoor air pollutants contribute to unhealthy indoor air quality that can negatively affect children's ability to consistently attend school and learn. As children are more susceptible to environmental pollutants, there is a need to shift focus on the research area pertaining to school build environment. Integration of three simple steps namely eliminating pollutants from indoor air, ventilating classrooms and educating school administrators, faculty, students about IAQ issues can play a proactive role in improving air quality in schools. More research studies are also needed on studying the relation of indoor environment quality in schools with health and well-being of its occupants.

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