Review

Quality of Indoor Air in Educational Institutions and Adverse Public Health in Europe: A Scoping Review

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Posted Date: 17 December 2024

doi: 10.20944/preprints202412.1395.v1

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Quality of Indoor Air in Educational Institutions and Adverse Public Health in Europe: A Scoping Review

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Abstract: Indoor air quality (IAQ) at educational institutions has emerged as an important public health issue, affecting the health and cognitive performance of school-aged children, students, and faculty alike. This scoping review study seeks to investigate and synthesize current literature on the factors influencing the current state of research on indoor air quality in educational institutions, as well as its implications for public health. The technique thoroughly investigated peer-reviewed journals, international organizations, and government reports, as well as case studies on IAQ in educational contexts. Using keywords such as "indoor air quality," "educational institutions," "public health," " Europe, " and "adverse health outcomes," the study's inclusion and exclusion criteria, as well the criteria use of quality assessments. The results show that low IAQ is connected with a variety of public health issues, including health difficulties and cognitive impairments, particularly in vulnerable populations such as children and teachers. Inadequate ventilation, the presence of volatile organic compounds, mold growth, and external contaminants are all common causes of poor indoor air quality. Monitoring and management measures are required to improve IAQ in schools, encouraging students health and academics performance, also policy implications importance of the interdisciplinary approaches in addressing this public health concern.

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1. Introduction

Assessing indoor air quality (IAQ) in educational institutions is one of the most effective preventive measures to avoid adverse public health effects. It is crucial to prioritize the well-being of individuals within these educational settings, as indoor air pollution has emerged as one of the top five environmental risks to public health worldwide[1]. In recent years, the concern over poor indoor air quality IAQ has grown significantly in Europe, with alarming consequences for the health of its population[2]. Prosecutable cases of indoor air pollution not only endanger physical health but also have profound implications for emotional well-being and behavioral patterns[3,4]. It is particularly distressing that IAQ issues disproportionately affect vulnerable groups, such as children, pregnant staff, and individuals already grappling with pre-existing health conditions[3,5]. The impact of IAQ extends beyond these immediate health concerns and permeates into other critical aspects of life[6]. Moreover, the influence of IAQ on the learning and achievement levels of individuals, as well as

 doi:10.20944/preprints202412.1395.v1

laboratory animals, cannot be overlooked[7]. The educational environment serves as a hotspot for community infections and chronic exposure to environmental hazards[8]. Hence, it becomes imperative to comprehensively comprehend the direct consequences of IAQ on students' health, educational capabilities, and the occupational performance of the dedicated educational staff. Understanding the adverse implications of IAQ on individual learning not only highlights the urgency in addressing this issue but also emphasizes the need for proactive measures to mitigate its effects[9]. The quality of the air that we breathe indoors, especially in educational institutions, does matter tremendously, directly affects the health and well-being of students and staff, making it crucial to prioritize and improve[10]. Poor air quality within schools can have a multitude of negative effects on the health of the upper respiratory system, cognitive functions, and absenteeism rates[11]. The significant impact air quality has on the well-being of individuals is evident in the data, as schools with lower levels of air quality often experience higher sick leave rates compared to those with better air quality[12]. Unhealthy buildings pose a considerable threat to both teachers and students, spend the majority of their time inside these structures, thus becoming highly susceptible to the physical and psychological factors that can intensify stress levels[13,14]. The detrimental consequences of poor indoor air quality can manifest in various ways, affecting the physical health and mental well-being of those within, and strive for optimal indoor air quality in order to create a conducive environment that fosters learning, growth, and overall vitality[15,16]. Focus on IAQ extends physical, chemical, and biological pollutants, although these are undoubtedly crucial factors, on specific IAQ components, including but not limited to allergens, cultures, parasitic diseases, unsafe environmental viruses, toxic fungi, volatile organic compounds, bacteria, formaldehyde, endotoxins, carbon monoxide, and microscopic fungi[17]. It is equally important to consider room factors that contribute to IAQ, such as hydrothermal information and humidity information, among others[18]. Several recent research studies have pointed out that indoor air quality plays a very important role in the environment in which individuals live, are perceived as indicative of good or bad air quality, denoting positive or negative environmental influences on the quality of life and health of the population[19-21]. Indoor air quality IAQ is crucial for health, especially in educational settings like schools. High occupancy rates and varying ventilation standards in European institutions can exacerbate IAQ issues, affecting respiratory issues, allergies, and cognitive impairments [22]. Throughout Europe, in educational buildings, several factors contribute to indoor air pollution, which may result in an imbalance of the quality of the indoor air relative to outdoor air, which negatively impacts the health and quality of life of students and educators[23]. It is appropriate to provide the students with a good classroom environment, where the indoor air quality meets comfort requirements and the performance of students is at an optimal level[24,25].

The scope of this study to implementing effective strategies to enhance indoor air quality, minimize the constraints imposed on schooling and unlock the full potential of every student. It is evident that the detrimental effects of IAQ permeate every aspect of educational institutions, encompasses all staff members within educational institutions, adopting preferential actions is the key to safeguarding the health, well-being, and future success of communities. This comprehensive and thorough scoping review study aims to provide extensive information and compelling evidence in response to the following key questions that have been raised. It is vital to highlight that IAQ encompasses a wide range of effects, and despite extensive research and studies, consequences and associations with numerous health problems have to be fully identified.

This study aims outlines the identification of pollutants affecting IAQ in educational institutions, their health implications, current policies for improvement, and gaps in existing literature for future inovation research.

2. Materials and Methods

2.1. Methodology

 doi:10.20944/preprints202412.1395.v1

The study identified and analyzed using a scoping review process methodology, an examination of literature systematically for mapping the existing literature and finding significant themes, gaps, and opportunities for future research. The study investigated factors related to specific objectives. The search strategy on the Databases such as PubMed, Scopus, and Google Scholar, Web of Science, using keywords related to indoor air quality, educational institutions, and public health in Europe.

The search terms included "indoor air quality," "schools," "health effects," "Europe," "pollutants," " educational" institutions and " health outcomes." Studies upon recently years has published, articles, guidelines, reports, and conference proceedings papers that reflects the most current research. The data flow from record identification to inclusion followed the PRISMA statement principles [26] .

2.2. Materials and the Design of the Study

It's an examination of literature systematically with scoping review methods of this research analysis.

The study investigated factors related to:

1. Identify key pollutants affecting IAQ in educational institutions.

2. Examine the health implications associated with poor IAQ.

3. Discuss current policies and recommendations for improving IAQ in all Educational Institutions.

4. Highlight gaps in the existing literature and suggest areas for future research.

2.3. Literature Search Selection of the Studies

The inclusion criteria for the study are the ones that follow:

All studies included were published in peer-reviewed journals, conferences proceedings, and reports guidelines for International and National Organizations.

All studies included were in the English language.

All studies included addressed sample of IAQ.

The studies where included have assesses though self-reported instruments, and consequences.

The studies included assess features as regards the IAQ in all Educational Institutions.

The exclusion criteria at sampling of the study are the follow:

a)*The language of the study except for English.*

b)*Studies with sample except for outdoor air quality and not examined health outcomes related to IAQ for educational institutions, were not included or analyzed.*

c)*The study selection that not procedure was attended by all authors.*

d)*Synthesis of results, and thematic analysis mapping of the findings to identify trends, gaps, areas for future research not evolve from all of the authors.*

Important Implications and Concerns on Health Impacts

The study indicates that exposure to poor IAQ can lead to various Health issues among students and staff. Also studies have shown a correlation between high levels of Health Risk Factors and decreased cognitive performance and environmental hazards. Additionally, respiratory problems, have been linked to exposure to indoor hazards. Figure 1, shows the flow chart diagram of the study using PRISMA guide lines and regulations for scoping reviews studies [26].

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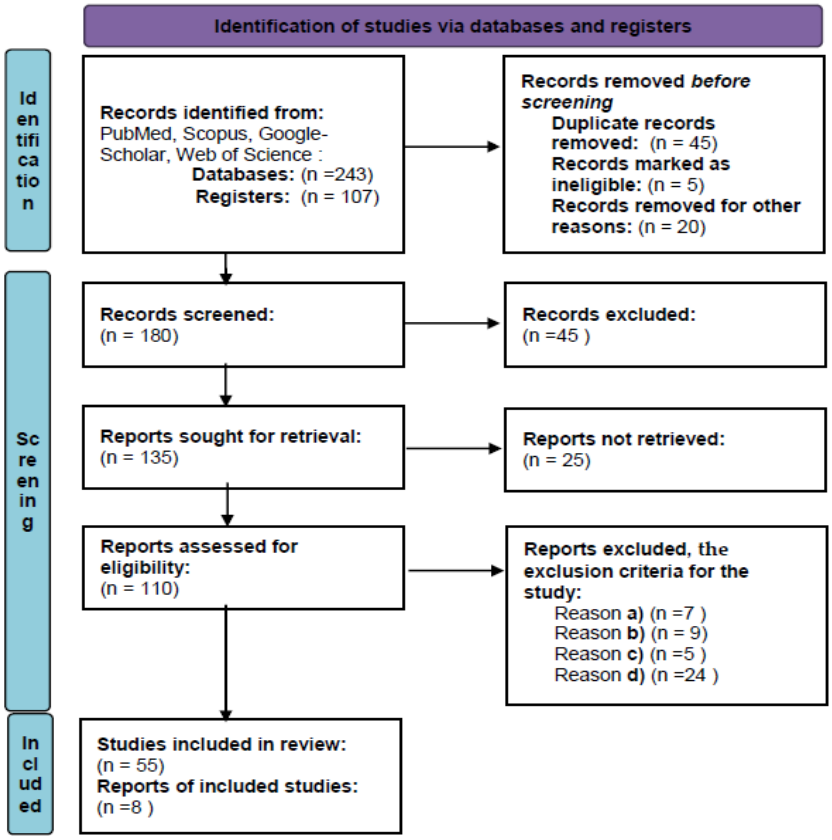

Figure 1. Flow chart diagram of the study PRISMA.

3. Results

Due to the large number of people they accommodate on a daily basis, educational institutions are considered public buildings, and the level of indoor pollutants has important public health implications. Under, this subsection this study adverse health effects arising from exposure to them. In light of modern society's concern for physical and cognitive development to ensure prosperity, it becomes crucial for the health of school-age children, students, teachers, staffs of all Educational Institutions correlated IDAQ with public health and well-being of specific populations. Poor indoor air quality can cause regular cases of "sick building syndrome" and can increase the incidence of upper respiratory tract infections, allergies, asthma in children, building-related diseases, and even death in cases of long-term exposure to large amounts of pollutants[27]. Children are more vulnerable because they are less able to remove pollutants from their bodies than adults[28,29]. Another mechanism of indoor irritants on health is their potential effect on the brain, which may interfere with cognitive function or even promote the development of neurological diseases, leading to negative consequences in their education[30]. Regarding particulate matter concentrations, all chemical and physical hazards included from environment associated risks[31], provided the categorization of measures and average above from recent literature [32-35]. The Table 1, indicate the measurement ranges for each of the five air quality categories for specific pollutants, the averaging times for each pollutant, and the Air Quality standard average measures from Global Organization Government, and non-Government regulations and guidelines.

Table 1. Measurement ranges for Air quality categories, average times, targets, distinguishing Fair and Poor categories.

AIR POLLUTANTS	AVERAGE-TIME	UNITS	GUIDELINES	GOOD	FAIR	POOR	VERY POOR	EXTREMELY POOR

 doi:10.20944/preprints202412.1395.v1

Ozone O3	0-7 hours	ppm	0.100/0.065	<0.067/<0.043	0.100/0.043	0.150/0.097	0.200/0.130	0.201/0.131
Nitrogen-dioxide NO2	0-7 hours	ppm	0.080/9.0	<0.053/<6.0	0.053 / 9.0	0.081 / 13.5	0.121/18.0	0.161/18.1
Sulfur-dioxide SO2	0-1 hours	ppm	0.100	<0.067	0.067 /0.100	0.101/0.150	0.151-0.200	0.201
PM.< 10µm	0 /23 hours	µg/m3	100/50	<50/<25	100/25	100.1 - 50.1	600-300	300.1-600.1
PM.2.5 < 2.5 µm	0/23 hour	µg/m3	50/25	<25/<12.5	12.5 - 50	50.1 - 100	300-150	300.1-150.1
T.S.P.	0/23 hours	µg/m3	250/80	<125/<40	125 - 250/40-80	500/80.1	1500/160.1	1500.1/480.1
Visibility	1 hour	Mm-1	235	<118	118 - 235	236 - 470	471-1410	1411-1610

The current regulatory approaches to indoor air quality was conducted, which are applied in a multi-faceted manner across Europe. The investigation considered twenty countries, including all of the Member States of the European Union. The conclusion was that legislation in the field of indoor air quality is fragmented and sometimes lacks the proper application and enforcement. Furthermore, it was found that limited financial and human resources, including in educational buildings, are often considered one of the main barriers to the appropriate management of indoor air quality. In educational institutions and for public health services evolving with inspections, IAQ limits have been established not only for tobacco and CO2, but also for a number of other air pollutants, such as NO2, PM10, PM2.5, benzene, heavy metals, radon, and Aspergillus fumigatus, and also consider the difficult circumstances of the period during COVID-19 Pandemic [7,36-44]. Another fundamental aspect that should be taken into account is the economic one: from specific estimates, it has been calculated that poor indoor air quality could cause a health and economic burden of 0.01–22 billion Euros for each allergen[12,45]. By creating a direct correlation between healthcare costs and lost productivity, it has been estimated that there are signs of a growing number of hospitalizations for asthma linked to environmental factors[26], which could lead to an important economic impact[1]. To reduce these costs and to prevent the onset of indoor air quality-related health problems, it is important to raise awareness among the population about the value of monitoring environmental parameters and taking precautions not to exceed the pollution threshold value[27].

IAQ issues in educational institutions

1. Improved Ventilation: *Reduce pollutant levels and improve IAQ implement mechanical ventilation systems and to promote Physical air circulation.*
2. Regular Monitoring: *Implementing specifics IAQ assessments, identifies and mitigates potential hazards also apply air quality tests to monitor levels of CO2, PM, VOCs, etc.*
3. Education and Training: *Providing training for educational institutions staff of indoor pollutants and best practices for maintaining on IAQ management.*
4. Policy Development: *Governments should establish clear Policies. guidelines and standards for IAQ.*
5. Community Engagement: *Engaging the community in discussions about IAQ a collaborative approach to improving educational institutions environments.*

4. Discussion

All studies and research findings of varying methodologies, IAQ indicators, monitoring periods, education system stages, classroom occupancy ages, and geographic locations serve to highlight the underlying relationships between IAQ, health, and academic performance[18,10,46]. A few studies looking at the health impacts of IAQ interventions in schools, of which included follow-up data on health effects and highlighted improved academic achievement[9,10,47]. The limitations of findings

 doi:10.20944/preprints202412.1395.v1

are not easily scalable across Europe due to the role of numerous confounding local[8], and school-based factors that are not controlled for in observational studies[48,49]. Results can vary from one school to another, and the data from a number of studies were characterized by large variability[50]. Improved IAQ did not lead to improved health or academic outcomes in the intervention studies[51]. It should be noted that case studies of individual schools were valuable in providing a rich[52], in-depth understanding of the approaches and practices used at a local level and provided recommendations for IAQ interventions based on stakeholders' and practitioners' experiences in the field of IAQ management[53]. Over the last two decades, there has been growing research into concrete issues facing the quality of indoor air in schools and associated health concerns, with this subfield even having its own conference series[32]. Much of this research has been conducted in the North America, Australia, Scandinavia, and Central Europe[19,54], but there is good representation of some other Western European countries[20].The specific questions addressed range from the health outcomes associated with exposure to specific pollutants and cumulative exposure indices to the physical environmental conditions that were associated with air quality[54,55], such as outdoor air exchange rates and the variation of indoor CO2 concentrations[56]. The vast of studies in used a mixture of data collection and modeling to assess the quality of the air[57].

Educational facilities can be places where diverse pollutants and other factors will have a major impact on indoor air quality, School-aged children and the staff working within them can be susceptible to some of the harmful effects[27,18,58], such as respiratory health symptoms and performance decrement, both potential health outcome factors of ambient concentration[59]. Focus on indoor air quality within educational institutions, such as schools, colleges, and universities, and review studies that present results only from these environments or, and most have taken place in North America and Europe[60,47]. The relevant investigated air quality assessment components, and closed environments, such as offices, kindergartens, and civil service buildings, have been not be included-removed from the Discussion section of this study. Although most recognized as a problem that predominantly affects students, the poor quality of indoor air can have a broad impact on society beyond the impact of an educational institution [61]. Long-term exposure to indoor pollutants can raise the chance of acquiring health problems, aggravating pre-existing illnesses, and creating productivity losses[62]. Exposure to chemicals detrimental to human health, most acute allergy symptoms are caused by microbiological organisms found inside. Research-portals links provide poor at indoor air quality to the studybdevelopment of chronic illnesses and an increase in the occurrence of respiratory diseases, finally the extreme weather events and climate crisis increase negative public health issues [62,63].

Limitations of the Study and Future Research

The implications of inadequate IAQ in educational institutions go beyond individual health outcomes. Poor indoor air quality can raise healthcare costs, impair productivity, and lower academic achievement, ultimately affecting society as a whole. Addressing IAQ in schools is vital for protecting the health and well-being of both kids and staff. The gaps considering the rising quantity of research on IAQ in educational institutions, numerous gaps exist. More longitudinal studies are required to examine the long-term health impacts of low indoor air quality on children. Furthermore, research on the efficacy of various strategies to promote IAQ in educational institutions, and schools is scarce. Future research should concentrate on producing evidence-based guidelines for schools to implement in order to improve IAQ and preserve student health.

5. Conclusions

The purpose of this study was to offer an overview of ongoing concerns with indoor air quality in European educational institutions. The review indicates that many European children, students, and staff at educational institutions are exposed to extremely poor indoor air quality in buildings, and that there are various health consequences associated with the detrimental influence on academic

 doi:10.20944/preprints202412.1395.v1

performance. Even while some restrictions and recommendations are in place, they may not be adequate to protect this population's health, particularly for air contaminants having co-toxicity effects. The present study and recommendations for interior air quality are based on European standards, with outdoor inputs most typically utilized to establish criteria for indoor air policies. To evaluate health parameters and improve teaching quality, a new set of indoor air quality indices, as well as a new European air quality monitoring foundation, are required. Furthermore, policymakers encourage European member countries to take an integrated approach to Nationwide Cross-sectoral Strategies that address health, education, and control pollution. Harmonized research across Europe, in addition to utilizing research infrastructure and open data in information technology to provide a comprehensive solution for indoor air quality in educational institutions, regaining regulation from harmful indoor settings that require the Public Health's citizens protection.

Author Contributions: Conceptualization, N.S. and I.A.; methodology, L.D., N.S. and I.A.; software, M.M., N.S. and I.A.; validation, G.A., P.T. and I.A.; formal analysis, M.M. N.S. and I.A.; investigation, L.D. N.S. and I.A.; resources, P.T., N.S. and I.A.; data curation, G.A.,M.M., N.S. and I.A.; writing—original draft preparation, L.D., M.M., G.A., P.T, N.S. and I.A.; writing—review and editing, L.D. N.S. and I.A.; visualization, N.S.; supervision, L.D. N.S. and I.A.; project administration, I.A.; funding acquisition, I.A. All authors have read and agreed to the published version of the manuscript.

Funding: Please add: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki. Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors are appreciated and are grateful for invitation from the Editors.

Conflicts of Interest: The authors declare no conflicts of interest.

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 doi:10.20944/preprints202412.1395.v1

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