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Innovations in Strategic Management: Navigating Complexity and Driving Organizational Success

A complete review on enhancing air circulation and filtration for improving internal air quality in a healthy school environment

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Abstract The health of staff and students is impacted by Indoor Air Quality (IAQ) in educational environments. A healthy atmosphere depends on good IAQ, yet millions of students worldwide might develop respiratory illnesses due to poor air quality. Immediate action is required to alleviate the burden of IAQ consequences in the pandemic-dominated period. This detailed evaluation focuses on techniques for improving air circulation and filtration systems to meet the critical demand for improved IAQ in schools. This research demonstrates the negative impacts of inadequate IAQ on students and educators' cognitive capacities, health and performance based on an extensive examination of current records. A healthy learning environment, on the other hand, can minimize absenteeism, raise test results and increase pupil/teacher education/teaching productivity. This review explores the effectiveness of different ventilation as well as filtration methods, such as air purifiers, mechanical ventilation, natural ventilation and advanced filtration systems, in lowering airborne pollutants like particulate matter, volatile organic compounds (VOCs) and microbiological contaminants. This study reviews current information, emphasizes recent findings along with options and provides guidelines for the future of education. It underlines the limits of previous studies, gives ideas for further research and indicates a path forward for more enhancements to the air quality in schools. Comprehensive analysis with greater sample numbers is required to evaluate student performance, indoor contentment and environmental health exposure. On-site measurements are essential for comprehending the properties of contaminants. Intricate mitigation strategies must take health impacts, IAQ and energy efficiency into effect.

Keywords: Educational Environments, Students, Indoor Air Quality (IAQ), Air Circulation and Filtration

1. Introduction

The indoor environmental quality (IEQ) of any structure directly impacts how people learn and accomplish different occupations. A good IEQ in educational facilities improves learners' academic capacities and promotes profitability and effectiveness. Long-term functionality, indoor temperature regulation, electromagnetic radiation level, internal air purity, natural convenience, furniture arrangement, creature convenience, and size and appearance factors contribute to the general interior atmosphere of a utilized vacuum (Labib et al 2022). The IEQ in ventilation-efficient classrooms is an important consideration given that students between the ages of 3 and 18 spend a considerable amount of time for approximately 4 to 7 hours. NV occupies the vast majority of school structures in India, with mixed-mode ventilation accounting for a fraction. The analysis of NV educational facilities remains in its initial phases and requires additional IEQ studies (Banerjee et al 2021). Maintaining convenience and good health is highly important to those who utilize the facility. Interior environmental quality pertains to the condition of the built environment for the people who reside in the institution, emphasizing safety and well-being. The IAQ, density of people, interior lighting, sound impairment, natural light, respiration, ambient temperature, hygiene, humidity inside and biomechanics are some of the complicated trends that make up the IEQ. The IEQ emphasizes the role that construction development plays in affecting the health of people inhabiting or working in structures (Abdulaali et al 2020).

The industrialization of world air quality has improved in developing nations, and air pollution levels are increasing. The World Health Organization (WHO) created criteria for the air purity of various substances to measure air pollution. Statistics released by the WHO show that nine or more people consume polluted air (Tiotiu et al 2020). Environmental issues exist in educational facilities as an effect of the insufficient management and maintenance that affect these structures. As a result, school environments must be modified to guarantee that users have suitable circumstances to perform their responsibilities (Yuanet al 2019). Problems with breathing, such as wheezing, dyspnea, coughing and lung tightness, are caused by variable exhalation restriction of airflow, and they are symptoms of asthma, a chronic, inflamed respiratory illness. Estimates for the prevalence of asthma in various countries range from 1 to 18%. Statistics have shown that air pollution negatively impacts individuals worldwide and children with asthma and accounts for 13% of the global prevalence of asthma in children, which can be attributable to traps (Shin et al 2020). Numerous studies have proposed efforts to evaluate the impact of a learning environment on the well-being and productivity of students as well as faculty. It is evident that the quantity of time spent on school grounds impacts the IEQ of the building and, consequently, impacts the students' fitness, mentality and educational achievement. Children are susceptible to the negative effects of indoor pollutants from inadequate academic air hygiene (Coronado et al 2021). Estimating the impact of air circulation, purification and optimizing interior air quality for healthier school sustainability and a healthy atmosphere for learning can reduce sickness absence, enhance evaluations and increase student education along with teacher performance.

Ramya et al. (2021) estimated that indoor air pollution (IAP) is thought to be the cause of 3.8 million diseases worldwide, according to WHO estimates. Initiatives carried out by residents, such as preparing, smoking, using electronics, utilizing appliances, or emitting emissions from interior construction components, are possible IAPs, provided that the majority of people's entire lives are spent indoors, primarily inside at work. The internal environment benefits human health. Hazardous materials include microbiological substances, pollutants, particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs) and others. Kelly and Fussell (2019) explained the state of people's health in environments in which individuals operate and work is impacted by the interior atmosphere. The industry has to maintain a moral obligation to offer wholesome environments that people and employees consider satisfactory, as well as circumstances for prosperity. Over the past few years, there has been a pattern in building design in which stresses reduce energy usage and minimize the environmental effects of structures. Heracleous and Michael (2019) analyzed a combination of their underdeveloped immune and respiratory systems, lack of muscle indices and abnormal breathing patterns and found that students are more susceptible than adults to the negative consequences of air pollution. Due to the amount of time children spend in classrooms, indoor environmental conditions are one of the main sources of their overall exposure to various air contaminants. Paleologos et al. (2021) described the greater risk of pollution in the atmosphere, chronic sickness for children, staff members and insufficient IAQ as impacting children's academic performance, satisfaction level and behavior in school. They decrease instructor productivity and increase the number of sick days. The detection of various indoor air pollutants and their impact on both measured and interpreted IAQ in school environments is a crucial ecological issue, considering the potential long-term detrimental implications of consumption.

Ismaeelet et al. (2023) reported that the structures under research seemed most thoroughly understood by interior atmosphere experts and individuals who consulted from various fields because they had complete control over the associated information, such as IAQ inquiries, building technology data, issue reports, maintenance and repair activities, IAQ estimations and occupation evaluations. Dimitroulopoulou et al. (2023) represented the values of relative humidity (RH), temperature (T) and CO2 content, as well as their effects on good space design, which were chosen as the air quality and comfort features for the present research. The CO concentration is included because carbon monoxide is an ordinary contaminant of the environment that is created when fossil fuels are burned erroneously and consumed primarily from car exhaust fumes on roadways. Pamonpol et al. (2020) determined that the number of chemicals that are excreted through evaporation can decrease as a result of unfortunate evaporation of sweat from the surface of human skin in environments with high RHs. Similarly, it has been discovered that exposure to high T causes symptoms such as mental wear and alterations in cardiovascular health, along with effects on productivity at work. Moreover, a state referred to as an acidic condition that occurs when the blood pH is below 7.35 can be produced by breathing in an excess of CO2 above 10,000 ppm. The condition increases the defenses of the body, leading to increased respiratory quantity, frequency, arterial level and cardiac beat.

Kishi and Araki (2020) assessed the IAQ requirements that need to be observed systematically and strictly, as difficulties with breathing produced by constant air conditioning and careless use of unsuitable materials for finishing developed, and issues with IAQ are steadily declining and posing a health risk to inhabitants. The immune system of residents can be reduced by prolonged exposure to polluted air, which can cause problems with breathing, hypersensitivity, allergies and viral vulnerability. Seseña et al. (2022) analyzed the most frequent signs of decreased IAQ, including a few nebulous sensations such as headache, irritated eyes or nose, eruptions, itching, sickness, or difficulty concentrating. These symptoms cannot be linked to a single cause, and their occurrence is referred to as sick-building syndrome (SBS). Significant health concerns, such as those affecting respiratory and cardiovascular systems; sensory defects; reproductive issues; allergic diseases; and potential malignancy, are possible issues that might occur due to prolonged interactions with indoor pollutants. Zhang et al. (2021) examined the importance of monitoring indoor air pollution patterns for the effective analysis and forecasting of these patterns. Low-cost air pollution monitoring methods and laser-based semiconductor approaches have become popular. Exploring the correlations between interior and outdoor air quality using real-time measurements has gained increasing attention. The IAQ has been predicted using various prediction models based on environmental factors.

RódenasGarcía et al. (2022) reported that awareness of air quality (AQ)-related issues has grown with the rapid advancement of technology, which has led to the development of low-cost sensors (LCSs) and detectors that can regulate the demand of people for real-time, internet-based information on the environment as part of their digital ecosystem. The qualities of LCSs, which can offer high-density geographic pollutants, align with that desire, which has contributed to the rapid proliferation of LCSs over the past few years. LCSs remain uncertain to the parties in agreement. Marques et al. (2019) explained the effective identity of passive ultrahigh frequency (UHF) for UHF transmission detection with an infrared transmission individual, a creative detecting component with minimal external effect detectors, a microcontroller unit (MCU) and an RF force harvester that can monitor indoor air quality in real time. IAQ monitoring is a necessity for human health worldwide, and utilizing precaution for advancing inexpensive, open-sourced tracking devices for IAQ oversight is a crucial problem. Silva et al. (2021) examined how the IAQ can be improved by comprehending the users and the dynamics of the environment. In speculation, one of the key factors is sources, which might include building materials, furniture materials, decorations, consumer goods such as air conditioning systems, and the occupants themselves and their activities. The effectiveness of regulation measurements has increased over the past few decades. Many chemical substances are limited, and numerous additional substances appear to replace prohibited substances.

2. Methods for optimizing and improving indoor air quality sources

This section explains the air circulation in the classroom as well as the exposure sources for prevalent air pollution that has an impact on IAQ.

2.1. Circulation of air in classrooms

A school ventilation system is essential for establishing a safe, comfortable and hygienic interior environment. Temperature, warmth and suitable IAQ are necessary to establish an environment that promotes excellent education and health. Classroom air quality (CAQ) is difficult and unsuitable, as indicated by previous research conducted at schools. These factors increase the risk of respiratory infections and other health-related illnesses. The causes of pollutants, both interior and exterior, as well as the dilution and extraction of chemicals through ventilation, affect the CAQ. Air quality is affected by the ventilation system used to ensure that air is distributed inside the classroom (Sadrizadeh et al. 2022). The IAQ criteria are contrasted in Table 1 below.

2.2. Exposure Sources for Prevalent Air Pollution

Several factors influence how students perceive the quality of the indoor environment, yet climate control and indoor air quality are the most important variables that impact how students perceive their residences. The main elements involved in establishing IAQ are both interior and exterior contaminants, as well as the reduction and elimination of chemicals achieved through ventilation. The air purity force can be impacted by the ventilation system to ensure that air circulates inside the classroom. A preliminary search using a list of keywords was performed across different databases (n=150), and the elements were selected despite removing duplicates (n=65). The collected materials were evaluated and found to be pertinent to the research (n=20). Publishing data and regulations were included in the study description (n=9). The method combined the selection criteria with an overview. The flowchart that illustrates the phases required for integrating an article of study appears in Figure 1 and Table 1.

2.3. Exposure Sources for Prevalent Air Pollution that Affects IAQ

Numerous common air contaminants have a major impact on indoor air quality (IAQ) and have the potential to affect people's physical and mental well-being. Therefore, it is imperative to understand these contaminants to improve IAQ. These are a few typical air contaminants that impact IAQ: O3, CO, CO2, SO2, NO2, PM and VOCs are the most common air contaminants that affect IAQ (Tran et al 2020).

2.3.1. Ozone (O3)

A supply of oxygen is converted into O3 gas using high-voltage electric discharge. It is a powerful oxidant with a potency 52% greater than that of chlorine. It develops in the stratosphere, yet it might build due to chemical and photochemical reactions in the upper atmosphere. Inhalation is the usual method of ozone absorption. The tear glands and the uppermost layers of skin are affected by ozone (Manisalidis et al 2020).

2.3.2. Carbon Monoxide (CO)

CO is a poisonous substance that lacks any taste, color, or smell. Gas can originate from a number of sources, including combustion engine equipment, obsolete or improperly maintained combustion devices, tobacco smoke, leaky chimneys, furnaces, unvented fuel, gas-type radiators, burning wood chimneys and gas-powered equipment. It can result in exhaustion, angina, breathing problems, diminished mental abilities, blurred vision, nausea, flu-like symptoms, disorientation and infant mortality, among other symptoms (Sahoo et al 2022).

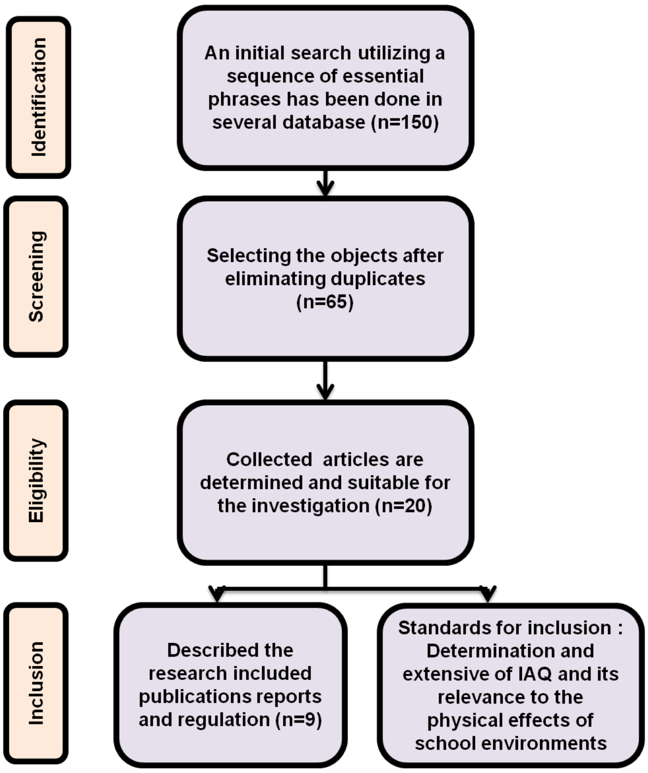

Figure 1 Flow diagram illustrating the steps taken to include a research paper [Source: Author].

Table 1 Global Standard for IAQ [Source: Author].

Pollutant	Global Standards for IAQ
	10 ppm
Carbon Monoxide (CO)	8.6 ppm
	20 ppm
	9 ppm
	0.053 ppm
Nitrogen Dioxide (NO2)	0.075 ppm
	0.21 ppm
Carbon dioxide (CO2)	1000 ppm
	0.08 ppm
Formaldehyde (CH2O)	0.1 ppm
	4.0 Pci/L
Radon	0.15 mg/m^3
	2.0 Pci/L
Total Suspended particle (TSP)	0.1–0.12 mg/m^3
	150 µg/m^3
	300 µg/m^3
Volatile organic compounds (VOCs)	
	0.2–0.6 mg/m^3

2.3.3. *Carbon dioxide (CO2)*

Elevated and consistent CO_2 concentrations in the classroom are ensured by measuring the CO_2 that declines in subsequent educational sessions. A testo-ambient CO_2 detector was used to determine the CO_2 concentration. The air value of the environment (n) preserved is calculated using the exponential modular formula because the level of CO_2 in the space is homogeneous, yet a lack of reaction between the carbon dioxide and various compounds is anticipated.

$$n = \frac{1}{\Delta t} - In \frac{CO_{2-peak} - CO_{2-out}}{CO_{2-final} - CO_{2-out}} \quad (1)$$

where CO_2-peak, CO_2-final and CO_2-out denote the peak, final, and outdoor CO_2 concentrations, respectively, and Δt denotes the duration to CO_2-final along with the CO_2-peak. The temperature difference between the two types of space can impact the rate of air exchange, and an increase in the variation in the degree between two locations can lead to an increase in the variety of air that is transferred. (Stabile et al 2019).

2.3.4. Sulfur Dioxide (SO_2)

In comparison, a higher SO_2 concentration was detected at both locations in 2020–2021; the use of combustible sulfur-containing fuel or other types of coal was limited, which resulted in a decrease of 30–86% in the overall level of SO_2 at both sites compared with the level in the base year. This indicates a decline in the dependence of smaller-scale industrial firms on charcoal as a power resource, such as the production of transportation products and the burning of biodiesel. During the combustion of fuels containing sulfuric acid, such as charcoal and gasoline, the majority of sulfur dioxide comes from fossil fuels that are used in power plants, factories and vehicles. Anthropogenic SO_2 emissions are highest in India (Zhao et al 2019).

2.3.5. Nitrogen dioxide (NO_2)

One of the components of the complicated combination of many pollutants detected in indoor air and the analyses of NO2 exposure comes from unvented combustion appliances, among other sources. This mixture included NO_2. The fact that motor vehicles are the primary source of nitrogen oxides (NOX) that yield NO_2 in most urban areas makes it difficult to comprehend the evidence from NO_2 open-air visibility; after that, NOX is a dependable indication of emissions from vehicles and includes several unrecognized contaminants that sources generate. Precise observations and simulations of the regional distribution and temporal evolution of NO_2 concentrations in the troposphere are of great environmental and scientific interest, as is the impact of NOX on air quality and climate through effects on radiation. The complexity of its chemical activity makes it dependent on a variety of components, including the quantity of atmospheric protection that influences the photolysis of the trace gas and the simulation of NO_2, which is difficult for numerical models (Matthaios et al 2020).

2.3.6. Particulate matter (PM)

It remains difficult to characterize the effect of particulate matter (PM) on indoor air quality in terms of its dimensions and composition and to identify its emission sources. This is relevant in situations where the activities in which individuals interact or the activation of primary and secondary internal sources such as serving, gas-particle transformation into unpredictable natural sources, beginnings, preparation fires and home heating can cause variations in the chemistry of interior PM over time. A reduction in pollutant levels in interior spaces can be attributed partially to occupancy-associated PM (Tofful et al 2021).

2.3.7. Volatile organic compounds (VOCs)

The chemical substances that elute on a gas chromatography column as they span from n-hexane all the way up and include n-hexadecane are called volatile organic compounds (VOCs). Prior to n-hexane, the organic volatile compounds that elute on the liquid chromatographic surface are known as very flammable organic substances. The organic molecules that elute on the gas chromatographic column after n-hexadecane are known as semivolatile organic compounds (SVOCs). The combined quantities are the combined amount of identifiable and total volatile organic compounds (TVOCs). Quantifying VOC concentrations from consumer products is crucial because almost all exploration is conducted after occupancy, and these products contribute to an individual's indoor exposure to VOCs in addition to those released from materials for construction, other sources and activities, including adornment (Shrubsole et al 2019).

3. Result Analysis

This section explains the monthly relative humidity statistics. It identifies the different degrees of indoor pollution affecting microbiological activity, including comparing student monitoring stations to the overall impact of air pollution and quality.

3.1. Monthly Statistics for Relative humidity (RH)

The impact of atmospheric conditions brought on by different groups visiting the classroom at specific times caused the most significant variance in RH to be observed at the minimum levels during the months of fall and winter in 2020. The simplest method to reduce the RH is to include fresh air, maintaining the understanding that the RH might fluctuate frequently or every day. Figure 2 and Table 2 show the monthly findings from the 24-hour IAQ observation information at one-minute intervals.

3.2. Microbiological Activity with Various Indoor Pollution Levels

Pollution increased during the summer, and microbial activity progressively decreased. The variation in microbial activity that occurred after autumn remained the same as that in summer. During summertime, the degree of microbial activity was considerable even though the air quality was excellent and there was a small variance in activity between these two conditions. After the winter, samples taken in closed rooms exhibited a considerable change in microbial activity compared to the samples taken in ventilated rooms. The microbial activity was the lowest in good-air quality air and greatest in slightly polluted or high-quality air under both resolved and ventilated conditions, as shown in Figure 3 and Table 3. The summer conditions with mild pollution had the lowest microbial activity. Furthermore, during winter ventilation, the microbial activity in slightly polluted settings remained lower than that in highly polluted settings. Figure 3 and Table 3 show the seasonal variation in the movement of microbes in PM in indoor air at varying pollutant concentrations.

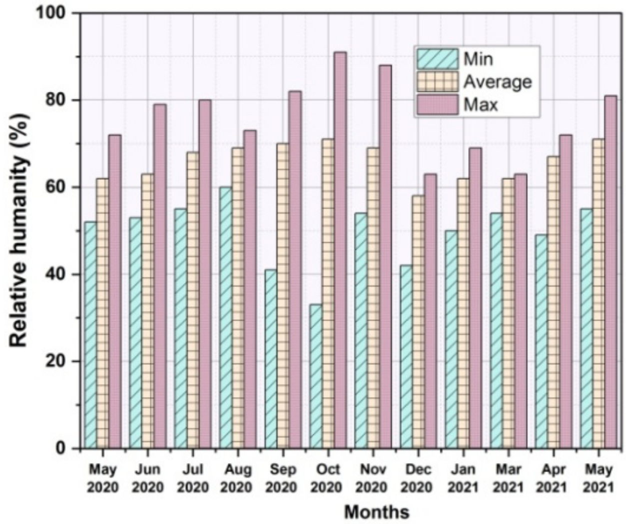

Figure 2 Monthly Statistics for Relative humidity (RH) [Source: Author].

Table 2 Monthly Statistics for RH [Source: Author].

Relative humanity (%)			
Months	Min	Average	Max
May- 2020	52	62	72
June- 2020	53	63	79
July 2020	55	68	80
August - 2020	60	69	73
September - 2020	41	70	82
October - 2020	33	71	91
November - 2020	54	69	88
December - 2020	42	58	63
January - 2021	50	62	69
March - 2021	54	62	63
April - 2021	49	67	72
May -2021	55	71	81

3.3. Comparison of student monitoring stations

The air quality index (AQI), which reflects the extent of polluted air, regular pollution levels and the methods by which specific elements impact human health, is helpful for detecting environmental and healthcare benefits. Most air quality monitoring stations exhibit notable variations in air quality parameters between weekdays and weekends, as depicted in Figure 4 and Table 4. The AQI decreases by approximately 16% on weekends but increases on workdays as factories run at full capacity and traffic is at its highest since people are traveling from work and students are returning to their schools of higher learning.

3.4. The cumulative effect of air pollution and quality

The concentrations of several contaminants, including gases, chemical compounds and particulate matter, as well as climatic elements such as humidity and temperature, were measured. The requirements for air quality and pollution that describe the condition of the air in a particular location, usually the Earth's atmosphere, are closely related. Two frequently used variables, namely, air quality and pollution, are more prevalent. Figure 5 and Table 5 depict the effects of air pollution and air quality.

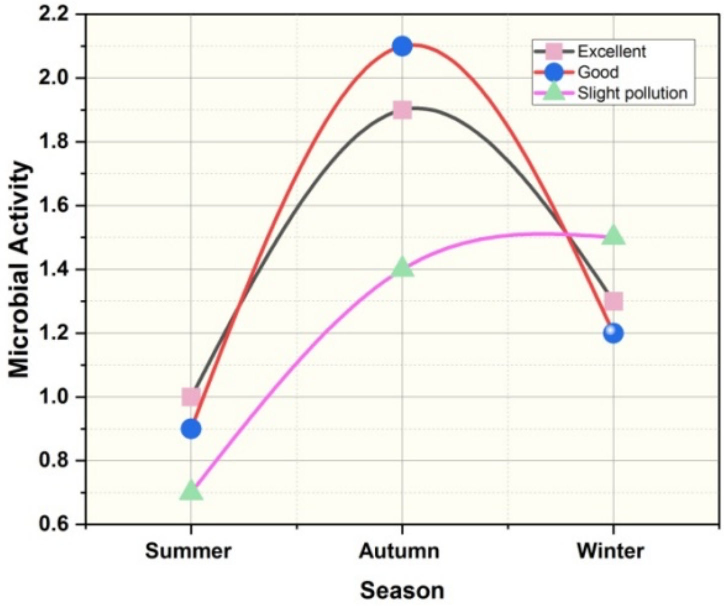

Figure 3 Microbial activities with seasonal variation [Source: Author].

Table 3 Microbial activities with seasonal variation [Source: Author].

	Microbial Activity		
Season	Excellent	Good	Slight pollution
Summer	1	0.9	0.7
Autumn	1.9	2.1	1.4
Winter	1.3	1.2	1.5

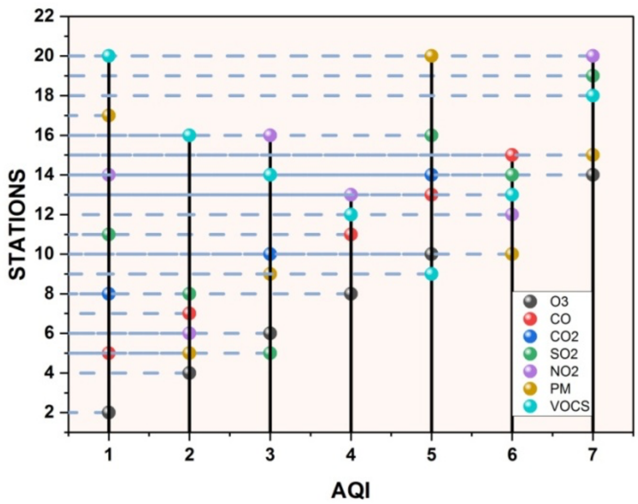

Figure 4 Analysis of AQI with student monitoring stations.

The responsibility of schools is to establish an atmosphere that allows students to have an optimal chance to grow and realize their potential. IAQ is crucial in classrooms because it can impact students' and teachers' comfort, performance, alertness and capacity for concentration. The health of students is considerably threatened by exposure to numerous air contaminants in school buildings because they breathe larger quantities of air than people, which is proportional to their body weight. This matter is crucial, as several investigations have found that school buildings have greater pollution than residential and commercial structures. VOCs are among the most common indoor air contaminants that harm both adults' and children's health. However, many schools have determined that PM contaminants form a single of the essential variables that contribute to polluted air inside buildings.

Table 4 Analysis of AQI with Student Monitoring Stations.

STATIONS							
AQI	O3	CO	CO2	SO2	NO2	PM	VOCS
1	2	5	8	11	14	17	20
2	4	7	6	8	6	5	16
3	6	9	10	5	16	9	14
4	8	11	13	12	13	12	12
5	10	13	14	16	9	20	9
6	12	15	12	14	12	10	13
7	14	18	19	19	20	15	18

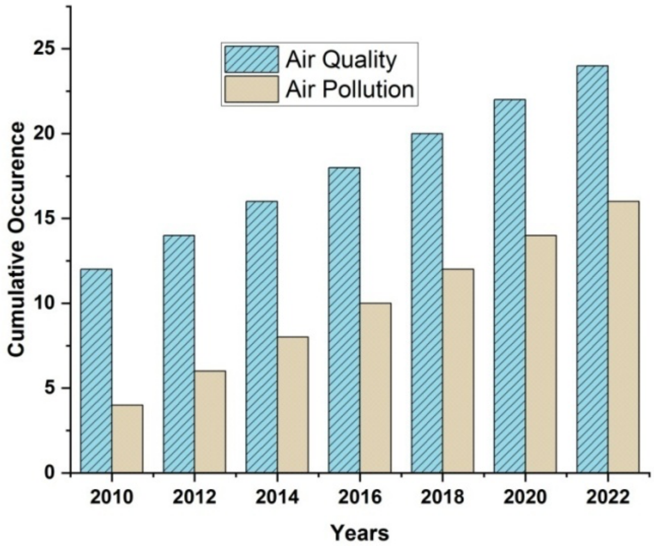

Figure 5 Cumulative occurrences of air quality and pollution.

Table 5 Cumulative occurrence of air quality and pollution.

Cumulative Occurrence		
Years	Air Quality	Air Pollution
2010	12	4
2012	14	6
2014	16	8
2016	18	10
2018	20	12
2020	22	14
2022	24	16

4. Conclusion

The study produced a superior educational environment by improving the indoor air quality and comprehending that the atmosphere and health of students, along with their performance in school, might be negatively impacted by inadequate ventilation in the classroom. The chemical compounds that affect the environment's ventilation and air quality include CO2, O3, NO2, SO2, PM and VOCs. The study's findings are summarized as follows. More specific guidelines for the thoughtful selection and application of construction materials need to be developed with the intention of increasing the interior atmosphere structure and focusing on improving the general health and quality of the school atmosphere. In the future, work will be done to demonstrate improvements in the classroom air circulation and IAQ of the school atmosphere. The causes of SBS, which are exposure sources for widespread air pollution that has an impact on IAQ and other IAQ indicators, should be the primary focus of future research.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare no conflict of interest.

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