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Indoor Air Quality Assessment in College Classrooms and Labs

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ABSTRACT: The health and academic performance of students are significantly impacted by air quality in classrooms. The current research work is to analyze experimental analysis of indoor air quality status to evaluate the presence of air pollutants, particulate matter (i.e. PM_{2.5}, PM₁₀), CO₂, volatile organic compounds (VOCS), temperature and humidity. The findings highlight variations in IAQ based on room usage, ventilation, and occupancy, and propose sustainable, low-cost solutions to enhance indoor air environments. Parameters are analysed by visual inspection, the collected data were evaluated against established guidelines from reputable authorities, including the World Health Organization (WHO), the United States Environmental Protection Agency (EPA), and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The findings indicated that a significant number of monitored spaces exceeded recommended thresholds for carbon dioxide (CO₂) and particulate matter (PM), particularly during periods of high occupancy and in rooms with inadequate ventilation or outdated HVAC systems. Classrooms with closed windows and no mechanical ventilation exhibited rapid CO₂ accumulation, a condition known to impair cognitive function, induce drowsiness, and negatively impact academic performance. In laboratory environments, intermittent elevations in volatile organic compound (VOC) concentrations were observed, largely attributed to the use of chemical reagents and solvents. The pollutant concentration is higher in entrance of the institute due to closer exposure to the road as compared to classrooms, the labs have high concentrations of VOCS and CO₂ due to differences in ventilation, equipment usage, occupancy levels and elevated zones etc. This study focuses on improving natural and mechanical ventilation, implementing air purification systems in the classrooms by maintaining a healthy indoor environment in the classrooms and laboratories by installing sustainable equipment to destabilize the particulate matter in the classrooms. Overall, this research emphasizes the vital role of indoor air quality management in educational settings. Ensuring clean and well-ventilated indoor environments is not only essential for the physical health and safety of occupants but also for fostering a more effective and engaging learning experience. As colleges and universities strive to create sustainable and student-friendly campuses, prioritizing IAQ through consistent monitoring, policy enforcement, and infrastructure upgrades should be regarded as a foundational aspect of institutional development.

KEYWORDS: Air Quality, Pollutants, Elevated Zones, Purification.

I. INTRODUCTION

Indoor Air Quality (IAQ) is defined as the representation of pollutant concentrations and thermal conditions that could have a negative impact on the health, comfort, and efficiency of building occupants. In the last decades, the air quality of indoor areas became of primary importance because of its effect on human health. India ranks as the fifth country worldwide that had the most polluted air in 2024 according to Switzerland based air quality monitoring company IAQ. Telangana's air quality, particularly in Hyderabad, has been identified as a major source of air pollution in India. The closure of natural openings of buildings affects the air drastically. There are several studies showing how poor IAQ in classrooms and labs have a negative impact on student learning. IAQ can be affected by chemicals from labs or materials in furniture. In college classrooms, poor IAQ can result from overcrowding, insufficient ventilation, or outdated HVAC systems. One common issue is the buildup of carbon dioxide (CO₂), which naturally increases as people exhale. If ventilation is poor, CO₂ levels can rise throughout the day, leading to symptoms such as headaches, fatigue, drowsiness, and reduced ability to concentrate. Over time, these conditions can contribute to decreased academic performance and discomfort for both students and instructors. Laboratories pose additional challenges. In these environments, air quality can be affected using chemicals, solvents, biological agents, and specialized equipment.

If these are not properly contained or ventilated, they can release pollutants such as volatile organic compounds (VOCs), ozone, nitrogen dioxide (NO₂), and fine particulate matter (PM_{2.5}/PM₁₀). Exposure to these substances even at low levels can cause respiratory irritation, allergic reactions, or long-term health concerns. In some cases, improper IAQ management in labs may also raise safety risks, including fire hazards or accidental exposure to toxic materials. Some of the methods for analyzing air quality are monitors, sensors and visual inspection. Since classrooms and labs often have a high number of occupants that generate pollutants. Poor air quality causes severe health problems such as headaches, respiratory issues and heart diseases. Simple steps such as ensuring proper ventilation, using air purifiers can significantly improve air quality. Ventilation plays a crucial role in maintaining air quality by continuous exchange of fresh air and removing indoor air pollutants. Humidity and temperature are also critical components of IAQ. Regular assessments and improvements can significantly enhance air quality. This study aims to evaluate the indoor air quality in college classrooms and laboratories, identify key pollutants and contributing factors, and provide recommendations for improving ventilation and environmental conditions to promote a healthier and more effective learning environment.

II. LITERATURE SURVEY

Sushma R shows that different human activities mostly increase the concentration of gas parameters. The peak values of CO₂ determined in canteen and computer laboratory were reported higher than found in any other microenvironment [1]. Michal Kraus shows that indoor air quality in university classrooms based on students' subjective evaluations before and after lessons. Results showed a deterioration in air acceptability, odour intensity, thermal comfort, and noise load, especially in the computer classroom [2]. Grant Erlandson shows that indoor air quality across three types of college campus buildings—LEED-certified, retrofitted, and conventional—by measuring particulate matter, formaldehyde, carbon dioxide, and nitrogen oxides. It found that occupancy and building zones significantly affected air quality, with higher levels of contaminants during occupied periods [3]. Ida Munfarida shows that the analysis on carbon dioxide (CO₂) concentration, relative humidity (%RH), temperature (°C) has shown that the indoor air does not exceed the standard according to ASHRAE standard and Health Ministry Regulation with the maximum concentration was 444,3 ppm [4]. T. Catalina shows that the paper aimed to determine the reduction of pollutant concentration in an educational indoor space related to the mechanical ventilation with outdoor fresh air [5]. Nishant Raj Kapoor shows that IEQ parameters in Indian school classrooms are unsystematic, scattered, insufficient, and unorganized. She also said that there is no well-established method to assess the indoor environmental condition of classrooms in school buildings in India [6]. Nur Batrisyia Azlan shows that the results were compared to the Department of Occupational Safety and Health standard (DOSH). Based on correlation between IAQ and SBS symptoms, poor IAQ and SBS symptoms among occupants may impact teaching and learning process in the university [7]. Grace Michael Ikon shows that microbial quality of indoor air in Obong University's laboratory sections. The indoor air quality was generally low in bacterial and fungal pollution. He recommended controlling factors that promote microbial growth to protect the health of individuals in the University laboratories [8]. Farzaneh Aliakbari shows that the research found a considerable gap between acceptable ranges and the classroom's indoor air and light quality. This discrepancy was linked to health issues among students, including skin and eye irritation, and increased dissatisfaction [9]. Aditya Kumar shows that particulate matter concentrations, especially in heavy equipment labs, exceeded prescribed limits. TVOC was higher in material-based labs, while CO₂ levels were generally around 4000 ppm across labs. Correlations between pollutants varied, with particulate matter showing strong correlations within labs but weaker correlations between labs [10]. Md. Bashirul Islam shows that primary school classrooms had the highest mean values of PM_{2.5} and PM₁₀, while the school and college had the highest CO, light, temperature, and noise levels. University classrooms showed the maximum concentrations of CO₂, TVOC, and relative humidity. PM_{2.5}, PM₁₀, and noise levels exceeded WHO-recommended limits in all institutions [11].

III. MATERIALS & METHODOLOGY

MATERIALS

I. Location and parameters

Classroom:

- a) Location: Second floor
- b) Area: 637.24 ft²
- c) Flooring: Ash ceramic tiles
- d) Ventilation: Two operable windows

- e) Occupancy Level: Approximately 40 students
- f) Materials: wooden table, benches, projector, chalk and board.
- g) Usage: Regular academic teaching and group discussions.

Laboratories:

Two laboratories located on the ground floor were included:

Geotechnical laboratory:

- a) Location: ground floor
- b) Area: 1302 ft²
- c) Flooring: Ash ceramic tiles
- d) Ventilation: Two operable windows with 2 doors
- e) Occupancy Level: Approximately 40 students
- f) Materials: Soil samples, aggregates, basic Geotech lab equipment's
- g) Usage: Testing of soil samples.

Concrete laboratory:

- a) Location: ground floor
- b) Area: 1332 ft²
- c) Flooring: Ash ceramic tiles
- d) Ventilation: Two operable windows with 2 doors
- e) Occupancy Level: Approximately 40 students
- f) Materials: Cement, paints, additives and other construction materials
- g) Usage: Handling of construction materials, paints etc.

II. Instruments

- 1. Flashlight- bright light to check dark corners, ceilings, under desks
- 2. Extendable Rod- to look behind furniture, inside vents, or hard-to reach spots
- 3. Camera or smartphone- to take pictures for documentation- mold, stains.
- 4. Tape- measuring room size, ceiling height and vent location.

1. Participants

A cross-sectional study was conducted among 40 occupants with age range of 19 - 45 years old in the higher educational building located in Aziz Nagar. The occupants asked to answer questions about their health during study hours. Four locations are selected in this study were two classrooms and two labs.

2. Visual Inspection Checklist

A standardized IAQ visual inspection checklist was developed based on recommendations from the U.S. Environmental Protection Agency (EPA), ASHRAE, and WHO guidelines. The checklist was used to evaluate the following parameters:

- i. Ventilation (Natural and Mechanical)
- ii. Cleanliness and Dust Accumulation
- iii. Presence of Moisture or Mold
- iv. Odor and Chemical Smells
- v. Material Storage and Emission Sources
- vi. Occupant Behavior and Ventilation Practices

3. Data Collection

Measurements were taken during morning, mid-day, and evening sessions over one week.

4. Analysis Tools

Microsoft Excel (for data visualization). Systematically record observations, measurements, and inspection notes.

IV. METHODOLOGY

Indoor air quality (IAQ) plays a crucial role in the health, comfort, and productivity of building occupants. Four locations are selected in this study were two classrooms and two labs. The walls and ceilings are fitted with a classic internal plaster with cream paint. Flooring is ceramic. There are two windows for each selected location. The classroom equipment consisting of tables, chairs, board and projector.

The survey was conducted during April. The climate in Aziz Nagar (Hyderabad) during April is hot and dry weather with high temperatures and clear skies. Temperatures typically range from 24.4°C to 36.9°C (76°F to 98°F). Higher temperatures can lead to increased pollen production, allergies, and can also increase the growth of mold, which thrives in warm, moist conditions. Additionally, the heat can cause more ozone to form in the air, which can negatively impact air quality both indoors and outdoors.

To assess the IAQ in our college's classrooms and laboratories, a combination of visual inspection and electronic monitoring was employed. While advanced methods such as mobile apps and sensor-based systems are available, our current methodology focuses on practical and accessible tools to understand and improve air quality.

Visual Inspection

A comprehensive visual inspection was conducted across multiple classrooms and laboratories. A standardized checklist was used to ensure a consistent and thorough approach. This checklist included observations of ceilings, walls, floors, ventilation systems, windows, and doors. Inspectors looked for mold growth, water stains, condensation, excessive dust accumulation, and blocked or dirty vents.

Photos were taken wherever necessary to document findings. For example, thick layers of dust on ceiling fans, light fixtures, and grills indicated poor filtration or long-term neglect in cleaning practices. These particles can become airborne, increasing the presence of allergens and particulate matter (PM).

The smell test was also used as a supplementary method to detect the presence of chemicals, mold, or stale air, which may suggest poor ventilation or the presence of volatile organic compounds (VOCs). Furthermore, occupant feedback was considered an indirect indicator of IAQ. Reports of frequent sneezing, coughing, itchy eyes, headaches, or respiratory discomfort among students and staff often correlate with elevated levels of allergens, dust, and VOCs. Observations such as sparkly dust floating in sunlight beams also indicated high PM concentrations, particularly PM_{2.5}. Visual inspection of an indoor environment can help identify potential sources of air pollution, but it cannot directly measure the concentration of pollutants. To overcome this situation we suggest air quality testing and monitoring, to get a comprehensive understanding of the air quality in a building. Indoor pollutant detectors, like air quality monitors and sensors, use various principles to detect pollutants like particulate matter, VOCs, and gases like CO and CO₂. These devices often employ optical, electrochemical, or infrared sensing technologies to measure pollutant concentrations and alert users to potential hazards.

Monitoring with Air Quality Devices

In addition to inspections, air quality monitors were used to collect data over a week. These devices provided real-time measurements of key IAQ parameters such as carbon dioxide (CO₂), PM_{2.5}, temperature, and humidity. CO₂ levels were found to peak in the afternoons, often exceeding 1000 ppm in closed classrooms, especially when windows and doors remained shut. This indicates inadequate ventilation during peak occupancy. PM_{2.5} levels were notably higher in laboratory spaces. This can be attributed to the presence of chemicals, use of machinery, and limited air exchange. Unlike classrooms, laboratories lack sufficient ventilation and often store materials that release VOCs, further degrading air quality. The data confirmed that comfort conditions acceptable temperature, humidity, and air freshness were not met in approximately 30% of the classrooms assessed. By monitoring and assessing air quality we get a real time data, understanding pollution sources and assessing health risks. The following are the examples and working principles of the different monitors and sensors for detecting indoor air pollutants.

Examples and Working Principles:

1. Particulate Matter (PM) Sensors:

Optical Light Scattering:

These sensors direct a light source onto particles in the air. The light scatters, and the degree of scattering and the number of particles are measured to determine the PM concentration.

2. Carbon Dioxide (CO₂) Sensors:

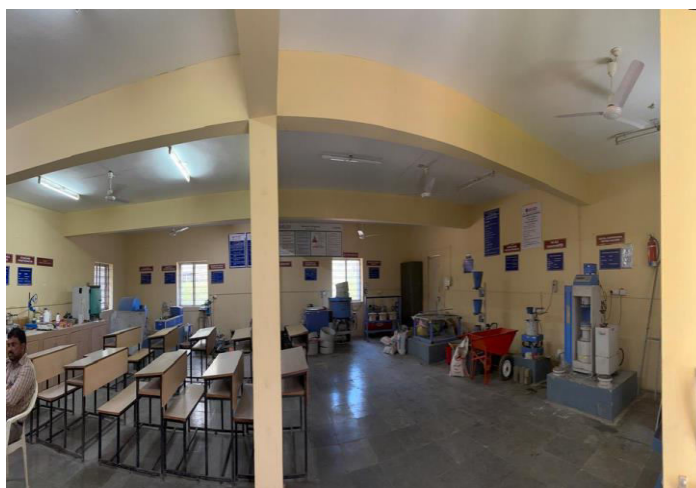
Non-Dispersive Infrared (NDIR) Sensors:

These sensors utilize the principle that CO₂ molecules absorb infrared radiation at specific wavelengths. By measuring the decrease in transmitted infrared light, the CO₂ concentration can be determined.

3. Volatile Organic Compounds (VOCs) and other Toxic Gases:

Photoionization Detectors (PID): These sensors ionize VOC molecules with ultraviolet light, and the resulting ions are collected, generating a signal proportional to the VOC concentration.

SELECTED INFRASTRUCTURE FOR INSTALLATING AIR PURIFIERS:



V. DISSCUSSION

Co₂ Levels: In classrooms and labs, CO₂ concentration should ideally be kept below 800-1000 ppm as per ASHRAE to maintain good air quality and prevent negative impacts on human health and performance. As per our results the CO₂ levels are high in the afternoon session due to high temperature and occupancy levels.

Particulate matter: PM concentrations were higher in labs due to presence of building materials, human activities, ventilation system. High PM concentrations in classrooms and labs can negatively impact student health and academic performance.

Temperature and Humidity: Generally, a temperature range of 20-25°C and a relative humidity range of 30-50% are considered but in case of our study the temperature exceeds the ideal limit which can significantly impact learning and performance of students. Also, the students and staff in these classrooms reported feeling the air was too damp and uncomfortable.

Volatile organic compounds: VOC concentrations are higher in laboratories than in classrooms due to the presence of chemicals, building materials, high indoor temperature. Poor ventilation and high occupancy were the main causes of deteriorated air quality. Labs without proper fume extraction exhibited elevated VOC levels.

VI. SUSTAINABLE RECOMMENDATIONS

Indoor air quality in Delhi is a major concern, with studies indicating that it is often worse than outdoor air quality, especially during winter. While the levels of PM_{2.5} indoors can be higher than government-reported outdoor levels, research suggests that Delhi households are generally not taking proactive steps to improve indoor air quality. Delhi implemented Actions on the ground include the relocation of polluting industrial units away from Delhi, phasing out the use of old motor vehicles, a switchover of all public transport vehicles from diesel to compressed natural gas (CNG), the switchover of private and commercial vehicles to cleaner fuels, the introduction of electric vehicles, the mechanised sweeping of roadsides, the installation of solar power systems, and the installation of air quality monitoring stations.

Byrnihat, a town on the Assam-Meghalaya border, has the worst air quality in India, with a very high concentration of PM_{2.5}, primarily due to industrial emissions from factories like distilleries and steel plants. To address this, the Meghalaya government is taking steps like inspecting and potentially shutting down factories that violate pollution norms, and the Assam government is also working on joint efforts to improve air quality.

Kolkata's indoor air quality is a serious concern, especially in densely populated areas, with high levels of PM_{2.5} and other pollutants. To improve indoor air quality, a multi-faceted approach is needed, including reducing the use of biomass fuels, increasing ventilation, and using air purifiers. The National Clean Air Program (NCAP) has helped reduce PM_{2.5} levels in the city, but more needs to be done to address biomass burning and other sources of pollution.

While Bengaluru has faced challenges with air quality, government initiatives and individual efforts have helped improve both outdoor and indoor air quality. Government efforts include promoting electric vehicles, stricter emission norms, and enforcing industrial emission regulations. Individuals can reduce indoor air pollution through practices like using air purifiers, maintaining good ventilation, and utilizing natural air purification methods like indoor plants.

Mumbai's indoor air quality is improving through a combination of government initiatives and individual actions. The BMC (Brihan Mumbai Municipal Corporation) is implementing measures like installing air purification systems in public areas and addressing emissions from vehicles and industries. Individuals can also improve indoor air quality by using air purifiers, reducing the use of pollutants like colognes and cigarettes, and promoting ventilation.

As per our research study we suggest to introduce air purifiers, encourage opening windows and doors during breaks, introduce air-purifying plants like spider plants and peace lilies, regular cleaning of air filters and ducts, use dehumidifiers to reduce humidity and prevent mold growth, educate students and staff on the importance of IAQ, use low-VOC paints, glues, and cleaning products whenever possible for improving indoor air quality in classrooms and labs.

VII. CONCLUSION

Indoor air quality (IAQ) in educational settings is increasingly recognized as a fundamental factor influencing health, cognitive performance, and overall well-being. In college classrooms and laboratories, where students and staff spend long hours in enclosed environments, assessing and maintaining good IAQ is not merely a regulatory formality—it is

an essential responsibility. Poor air quality can lead to fatigue, reduced concentration, respiratory issues, and long-term health effects, all of which can impair learning and productivity. Systematic assessment of indoor air through the measurement of pollutants such as CO₂, PM_{2.5}, VOCs, and humidity levels—along with evaluation of ventilation efficiency—provides institutions with vital data to identify and resolve environmental deficiencies.

These assessments not only help in understanding current IAQ conditions but also support evidence-based decision-making for future improvements. To address immediate concerns, practical and low-cost interventions can be implemented. These include encouraging natural ventilation by opening windows and doors during breaks, placing air-purifying indoor plants such as spider plants and peace lilies in classrooms, installing DIY air purifiers in areas with higher pollutant concentrations, and ensuring regular maintenance and cleaning of HVAC systems, air filters, and ducts. Education plays a key role—raising awareness among students and staff about the importance of IAQ can foster proactive and responsible behaviour across campus. In the long term, leveraging IoT-based monitoring systems can provide real-time insights into air quality trends and enable prompt responses to emerging issues. Incorporating IAQ considerations into the design and renovation of campus buildings ensures that future learning environments are healthier and more sustainable.

The adoption of low-emission materials, the formation of departmental IAQ committees or champions, and the inclusion of IAQ education in orientation sessions for new students and staff can help create a culture of environmental responsibility. Moreover, understanding and addressing the mental health impacts of poor IAQ, alongside physical health risks, reinforces the need for a holistic approach to indoor environmental quality. In conclusion, prioritizing indoor air quality is not only a matter of compliance—it is a forward-looking investment in student achievement, staff wellness, and institutional excellence. A clean, healthy indoor environment forms the foundation of effective education, supports long-term sustainability, and reflects a commitment to the well-being of every member of the academic community.

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