

Assessment of Indoor Air Quality and Associated Health, Environmental and Social Risks in Academic Laboratories of Educational Institutions

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ABSTRACT

Nowadays Indoor Air Quality (IAQ) has become a growing concern due to increased indoor activities, combustion processes, and poor ventilation. Testo IAQ Sensor Kit has been used to focus on monitoring and evaluation of IAQ across five laboratories (Thermal, Welding, Carpentry, Chemical, and Concrete) at GCT, Coimbatore. Monitoring has been done during September (60–80% RH) and October (81–93% RH). Weekly variations with respect to humidity were assessed, and comparison between September and October were made. To assess overall air quality and pollutant levels in each laboratory, Indoor Air Quality Index (IAQI) was calculated. It was found that Pollutant concentrations have been increased in October compared to September with rising humidity, except for CO, which decreased due to enhanced oxidation. Due to the absence of combustion activities, CO emissions were negligible in the Concrete, Carpentry, and Chemical labs. The Thermal Lab recorded the highest pollutant levels, followed by Carpentry, Concrete, Chemical, and Welding. Pollutant dominance followed the order $PM_{2.5}$ ($932 \mu\text{g}/\text{m}^3$) > TVOC ($8.303 \text{ mg}/\text{m}^3$) > HCHO ($3.404 \text{ mg}/\text{m}^3$) > CO₂ (790 ppm) > CO (301 ppm), identifying $PM_{2.5}$ as the most critical pollutant. According to IAQI results, the worst air quality was found in the Thermal Lab (≈ 500 , hazardous), followed by Carpentry (≈ 460), Concrete (≈ 410), Chemical (≈ 370), and Welding (≈ 320). The impact of IAQI came after $PM_{2.5}$ > TVOC > HCHO > CO₂ > CO. IAQ considerably worsened from September to October due to increased humidity, with thermal lab being the most affected and $PM_{2.5}$ as the main pollutant highlighting the necessity of adequate ventilation, humidity control, and routine IAQ monitoring. Subsequently, health risk, environmental risk and social impact assessments were also carried out with recommendations for proper mitigation measures

Keywords:

Indoor air quality, IAQI; carbon monoxide (CO); carbon dioxide (CO₂); Formaldehyde (HCHO); Total volatile organic compounds (TVOC); Particulate matter ($PM_{2.5}$); Health risk assessment; Environmental impact and social impact assessment

I. INTRODUCTION

In occupational and educational environments, Indoor Air Quality (IAQ) has become a critical determinant of human health, comfort, and cognitive performance particularly as individuals spend approximately 80–90% of their daily time indoors, increasing the likelihood of prolonged exposure to indoor-generated pollutants [1], [15]. Due to intensive practical activities such as combustion experiments, welding, machining, sanding, and chemical handling, Academic institutions, especially engineering colleges, comprise laboratories that function as complex indoor microenvironments all of which contribute to elevated concentrations of particulate matter (PM_{2.5}), carbon monoxide (CO), carbon dioxide (CO₂), volatile organic compounds (VOCs), and formaldehyde (HCHO) [2],[3],[4],[5],[11]. Due to high activity levels, dense occupancy, and inadequate ventilation, Numerous investigations have reported that pollutant concentrations in laboratory settings frequently exceed recommended guideline values, thereby increasing the potential for adverse health outcomes [3], [6]. Exposure to PM_{2.5} has been strongly associated with respiratory and cardiovascular morbidity, while VOCs and formaldehyde are linked to mucosal irritation, neurological effects, and long-term systemic health impacts under prolonged exposure conditions [5], [13], [17]. Indoor pollutant behaviour are modified by enhancing chemical off-gassing and particulate persistence, leading to increased inhalation exposure in tropical and subtropical regions such as India [5], [8], [19].

Indoor Air Quality Indices (IAQIs) have been developed by integrating concentrations of multiple pollutants into a single numerical indicator representing overall indoor air status to effectively interpret and communicate complex multi-pollutant indoor environments [4], [16]. IAQI frameworks, often adapted from the US EPA outdoor Air Quality Index, enable simplified comparison between indoor spaces, identification of high-risk environments, and effective communication of air quality conditions to non-expert stakeholders [4], [16]. Several studies have demonstrated the applicability of IAQI in educational and laboratory environments, where combined effects of PM_{2.5}, VOCs, and CO₂ were shown to significantly influence indoor air classification under varying ventilation and humidity conditions [1], [6], [12]. However, while IAQI provides an aggregated representation of indoor air quality, it does not directly quantify the associated health risks, highlighting the need for complementary health-based evaluation approaches.

Health Impact Assessment (HIA) offers a robust framework for translating IAQ data into health-relevant risk indicators by incorporating exposure concentration, inhalation rates, exposure duration, and toxicological reference values [1], [6], [13]. Commonly applied metrics such as hazard quotient (HQ) and hazard index (HI) enable the assessment of non-carcinogenic health risks associated with individual and combined indoor air pollutants [5], [20]. Previous studies in educational and occupational environments have reported HI values exceeding acceptable limits due to elevated PM_{2.5} and VOC concentrations, particularly in laboratories and workshops, indicating a significant potential for adverse health effects among students and staff [1], [5], [6]. Despite growing evidence on the importance of integrating IAQ monitoring with Health Impact Assessment, limited studies have systematically evaluated multi-pollutant exposure and associated health risks under seasonal humidity variations in engineering laboratories.

II. MATERIAL AND METHODS

2.1 SELECTION OF STUDY LOCATION:



Fig.1 Selection of Study locations

The study was carried out in five laboratories at GCT Coimbatore, each characterized by distinct pollutant sources as shown in Fig.1. Combustion-based experiments in the Thermal Lab, welding operations in the Welding Lab, woodworking and finishing activities in the Carpentry Lab, chemical handling in the Chemical Lab, and cement-based processes in the Concrete Lab were included. The natural ventilation patterns closely matched those observed in similar laboratory IAQ studies from Thailand [1], Spain [6], and Turkey [3]. Corresponding to seasonal humidity variations, the monitoring was carried out in two phases. A moderate-humidity period with relative humidity ranging from 60% to 80%, was represented by September whereas high-humidity period with levels rising between 81% and 93% was represented by October. This approach mirrored seasonal IAQ methodologies used in London and Middle Eastern studies, where pollutant variation was analysed in relation to climatic fluctuations [10], [19].

2.2 MONITORING OF INDOOR AIR POLLUTANTS USING AQM SENSORS:



As shown in Fig.2, Testo 440 multifunction IAQ meter was used to record CO, CO₂, humidity, temperature, and air velocity. NDIR sensor for CO₂ and an electrochemical sensor for CO, ensuring high accuracy comparable to sensor performances reviewed by Amin Beighetal.[14] was incorporated by this device. Key indoor air-quality parameters, including CO, CO₂, humidity, temperature, and pressure Can be measured as the device weighs 250 gram. It operates efficiently within a wide temperature range of -20°C to $+50^{\circ}\text{C}$, making it suitable for diverse environmental conditions. Humidity measurement ranges from 0 to 100% RH, with an accuracy of $\pm (1.5\% \text{ RH} + 0.7\% \text{ of the measured value})$, ensuring reliable data

Fig.2 Testo 440 multifunction IAQ meter to record CO, CO₂, humidity, temperature



As shown in Fig.3, To measure PM_{2.5}, TVOCs, and formaldehyde, A semiconductor-laser-based air detector was employed as shown in Fig.3. It's measurement principles align with IAQ monitoring approaches validated in previous studies using IAQ meters and optical sensors [18]. To capture maximum exposure scenarios, consistent with monitoring strategies outlined by Ismail et al. [9] and Abbas et al. [12], all data collection was performed during peak laboratory occupancy. The sensors were placed at a standardized breathing-zone height of approximately 1.2 meters and positioned away from windows and doors to minimize external influence. For comprehensive pollutant assessment across varying concentrations, test range of 0–1.999 mg/m³ for formaldehyde, 0–9.999 mg/m³ for total volatile organic compounds, and 0–999 µg/m³ for PM_{2.5}. Using semiconductor sensing technology combined with laser scattering, ensuring reliable detection and accurate monitoring of gaseous pollutants and fine particulate matter was operated by the instrument.

Fig.3 A semiconductor-laser-based air detector to measure PM_{2.5}, TVOCs, and formaldehyde

2.3 CALCULATION OF INDOOR AIR QUALITY INDEX(AQI):

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}$$

Where I_p = the index for pollutant p
 C_p = the truncated concentration of pollutant p
 BP_{Hi} = the concentration breakpoint that is greater than or equal to C_p
 BP_{Lo} = the concentration breakpoint that is less than or equal to C_p
 I_{Hi} = the AQI value corresponding to BP_{Hi}
 I_{Lo} = the AQI value corresponding to BP_{Lo}

Fig.4 Formula to calculate IAQI

IAQI Range	Category
0–50	Good
51–100	Moderate
101–150	Unhealthy for sensitive groups
151–200	Unhealthy
201–300	Very unhealthy
301–400	Hazardous
401–500	

Fig.5 Central Pollution Control Board Air Quality Standards

As shown in Fig.4, To calculate IAQI the following formula was used and as shown in Fig.4, By modifying the US EPA's outdoor AQI, Indoor Air Quality Index (IAQI) was created. Based on the formula, IAQI was developed which was used for the calculation of outdoor air quality index. As shown in Fig.5, According to Central Pollution Control Board Air Quality Standards, IAQI of 0-50 was classified under 'good' category, 51-100 was classified as 'moderate' category, IAQI of 101-150 was classified under 'unhealthy for sensitive groups' category, IAQI of 151-200 was classified under 'unhealthy' category, IAQI of 201-300 was classified under 'Very unhealthy' category, IAQI of 301-500 was classified under 'Hazardous' category.

2.4 EVALUATION OF HEALTH RISK ASSESSMENT:

Evaluation of Health risk assessment was done by Hazard Quotient (HQ) from exposure to respiratory air pollutants. By age range, three main groups of people (Children, teenagers, and adults) were classified and this study interested in people who had activities in these study areas. HQ is the ratio of potential exposure to pollutants and its level without adverse health effects was determined using Equation (1)

$$HQ = ADD / RfD \quad (1)$$

Where ADD is an average daily dose of inhalation exposure (mg/kg per day) and RfD is an inhalation reference dose (mg/kg per day), which can be used to estimate level of human daily intake without adverse health effects during a lifetime. The hazard level was classified by the HQ value as follows: no hazard results for HQ values less than 0.1, acceptable risk to human health for HQ values in the range of 0.1 to 1.0, hazard risk to human health for HQ values more than 1.0. Based on standard values of air pollution exposure parameters from the EPA (US. EPA, 2011), ADD was calculated from age ranges of children, teenagers, and adults. The ADD value was determined using Equation (2)

$$ADD = \frac{C_{air} \times InhR \times ET \times EF \times ED}{BW \times AT} \quad (2)$$

Where ADD is for pollutants and C_i is the concentration of air pollutants (mg/m³), which was calculated from an average of that pollutant concentrations, InhR is the inhalation rate of the group (m³/hour), ET is the exposure time (hours/day), EF is the exposure frequency (days/year), ED is the exposure duration (years), BW is the body weight (kg) and AT is the average time (days). The RfD value was determined using Equation (3). Average standard reference concentration of inhalation exposure is 8 hours (based on standard values for The Office of Environmental Health, Department of Health of Thailand).

$$RfD = RfC \times IR \times ET \times EF \times ED / BW \times AT \quad (3)$$

Additionally, to estimate the risk from exposure to many pollutants at the same time [9], the total non-carcinogenic risk was calculated by the hazard index (HI) using Equation (4)

$$HI = HQ_1 + HQ_2 + \dots + HQ_n \quad (4)$$

where 1–n: specified pollutants in the air.

2.5 EVALUATION OF ENVIRONMENTAL RISK ASSESSMENT:

By applying a prioritisation factor (PF) to the environmental risk (ER), the significance (S) of an impact is determined. The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact, Consequence is determined. The consequence of the impact or the purpose of this methodology was determined using Equation (5):

$$C = \frac{(E+D+M+R)}{4} \times N \quad (5)$$

Evaluation of impact assessment was done using four main criteria: nature, extent, duration, and magnitude/intensity. Whether an impact is negative (−1) or positive (+1) is identified by nature. The spatial influence, ranging from activity level (1), site level (2), local level within 5 km (3), regional level between 5–50 km (4), to provincial or national level beyond 50 km (5) was defined by the extent. The time span of the impact, from immediate impacts under one year (1), short-term impacts of 1–5 years (2), medium-term impacts of 6–15 years (3), long-term impacts lasting throughout the project life (4), to permanent impacts (5) was defined by the duration. Severity, where minor impacts (1) cause negligible effects and low impacts (2) result in slight environmental, cultural, or social changes was defined by the Magnitude or intensity measures. The likelihood of occurrence on a scale of 1–5, ranging from improbable (1) to definite occurrence (5) was defined by the Magnitude or intensity measures.

The Environmental Risk Score (ER) determines overall risk, where scores below 9 indicate low risk, 9–<17 indicate medium risk, and ≥17 indicate high risk requiring stronger mitigation and monitoring. Additional criteria include Public Response (PR), Cumulative Impact (CI), and Irreplaceable Loss of Resources (LR), each rated from low (1) to high (3). The final impact priority was determined using Equation (6)

$$\text{PRIORITY} = \text{PR} + \text{CI} + \text{LR} \quad (6)$$

which determines the prioritisation factor (PF): low priority (PF = 1), medium priority (PF = 1.5), and high priority (PF = 2). By multiplying PF with the post-mitigation ER, the final impact significance is obtained, allowing impacts with higher public concern, cumulative effects, or resource loss to receive greater importance.

Environmental Significance Ratings guide decision-making, where scores below 15 indicate low significance, 15–<30 indicate medium significance, and ≥30 indicate high significance requiring strong consideration in project planning. These ratings, combined with professional judgement, enable both quantitative and qualitative comparison of project alternatives and help to identify the most suitable implementation option.

IV. RESULTS AND DISCUSSION

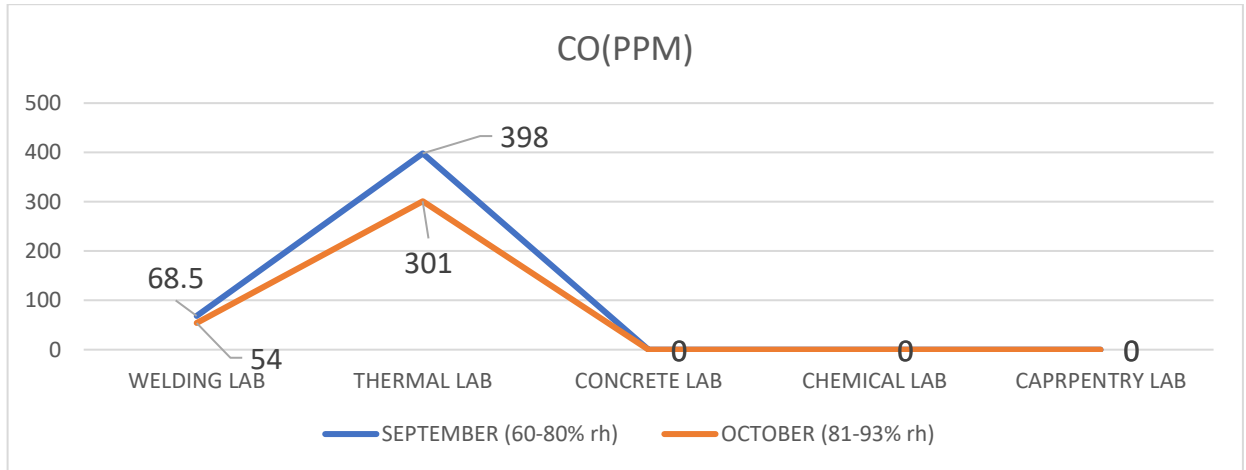


Fig.6 Comparson of CO between September and october

As shown in Fig.6, Clear variation with humidity levels was exhibited by CO. In the Thermal Lab, due to combustion activities, CO concentrations were high in September (up to ~398 ppm) but as humidity increased, CO concentration decreased to ~301 ppm in October in consistent with humidity-driven CO oxidation reported in IAQ studies [19]. Similarly, welding lab showed a reduction from ~68.5 ppm to ~54 ppm. In contrast, Carpentry, Concrete, and Chemical labs recorded negligible CO aligning with findings in non-combustion educational environments due to the absence of combustion sources [3,6].

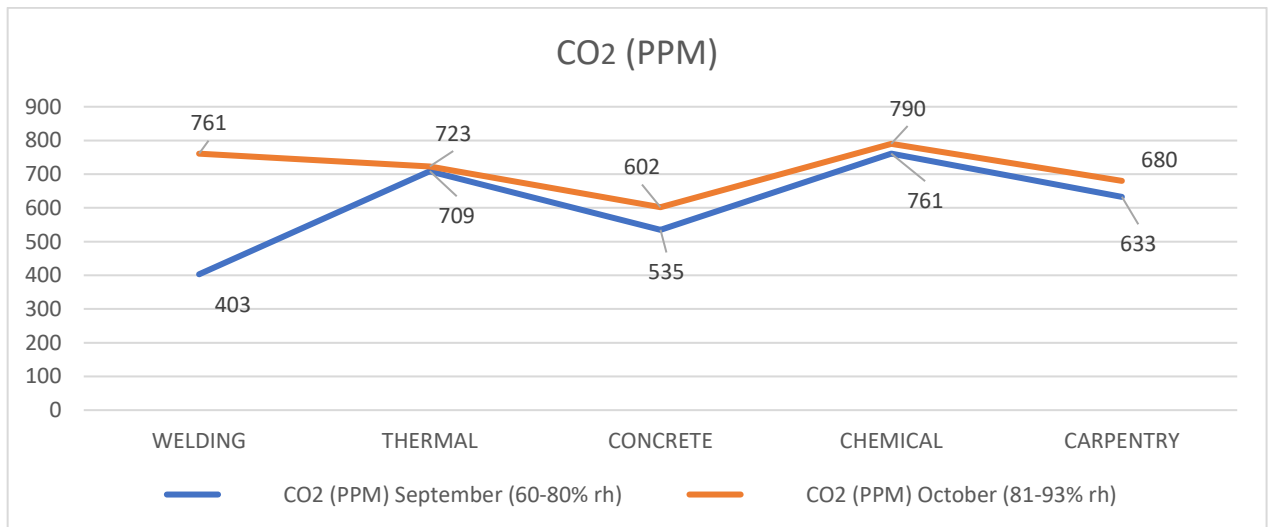


Fig.7 Comparison of CO₂ between September and October

As shown in Fig.7, In October, CO₂ concentration increased across all laboratories due to reduced ventilation and high humidity. The Welding Lab rose from mid-400 ppm in September to over 760 ppm in October, while the Chemical Lab reached nearly 800 ppm during high occupancy. This trend aligns with studies linking elevated CO₂ levels to restricted ventilation during humid seasons [2,8].

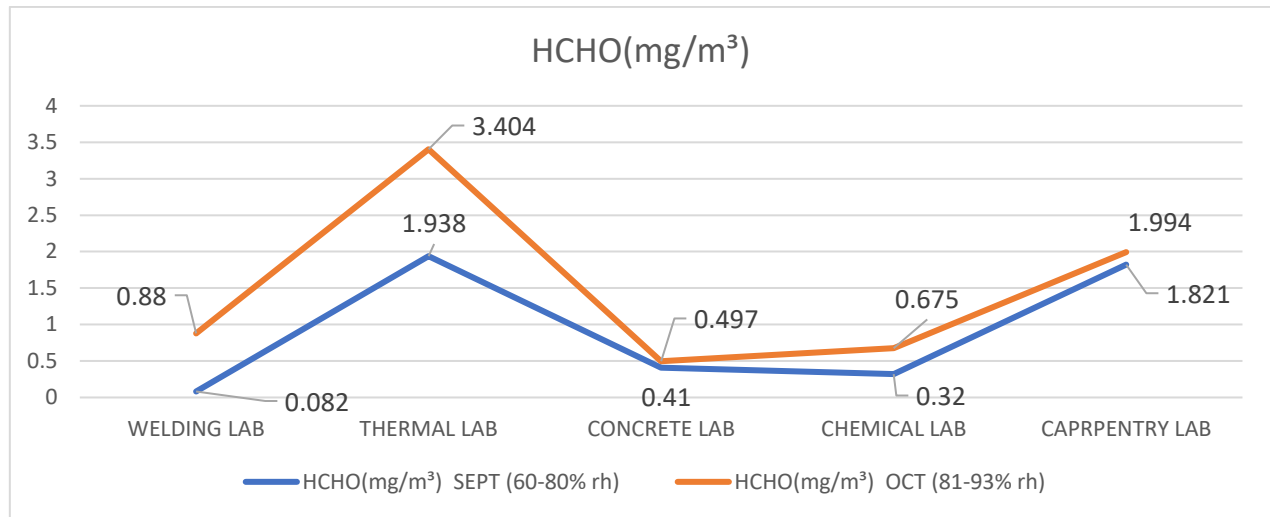


Fig.8 Comparison of HCHO between September and October

As shown in Fig.8, The strongest humidity sensitivity was exhibited by Formaldehyde among all pollutants. Thermal lab exhibited October peaks of nearly 7.8 mg/m³, reflecting both fuel-associated emissions and humidity-enhanced off-gassing which was consistent with VOC emission studies that show steep increases under high humidity, such as the Dubai school studies [10] and perfume formaldehyde investigations [20]. Varnished wood and adhesive-treated surfaces of carpentry lab, recorded steadily increasing HCHO values throughout October, approaching the upper sensor limit of 1.999 mg/m³.

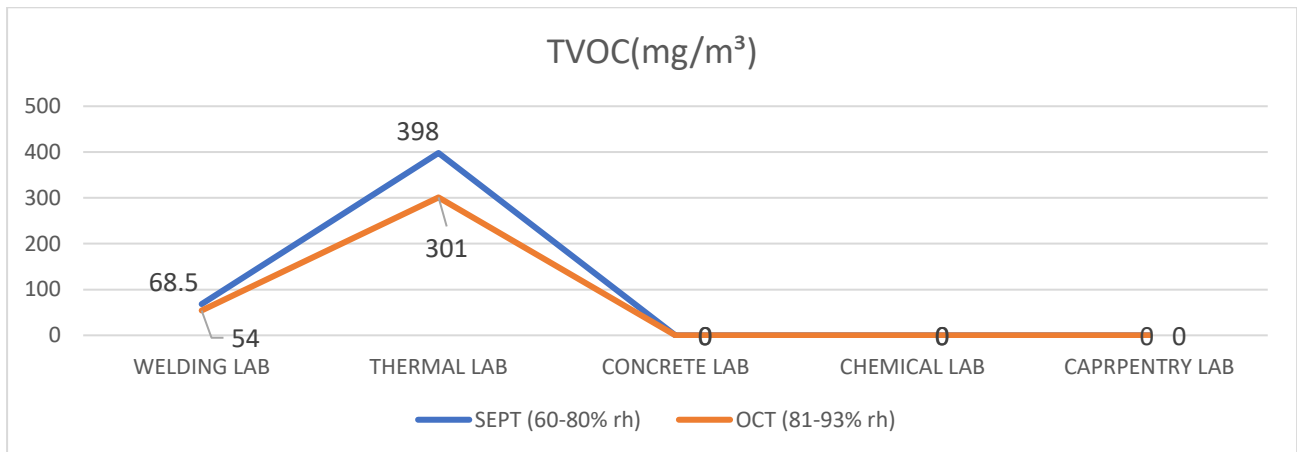


Fig.9 Comparison of TVOC between September and October

As shown in Fig.9, TVOC concentrations increased dramatically in October, especially in the Carpentry and Chemical laboratories. In both cases, readings consistently reached the maximum sensor limit of 9.999 mg/m³. The humidity-driven VOC amplification observed aligns directly with the behaviour described in educational and refurbished building IAQ reviews from Europe and the Middle East [7], [10]. Due to secondary emissions from oils, lubricants, adhesives, and cement-based materials Noticeable increase in October was observed in Thermal and Concrete labs, which are not primary VOC sources

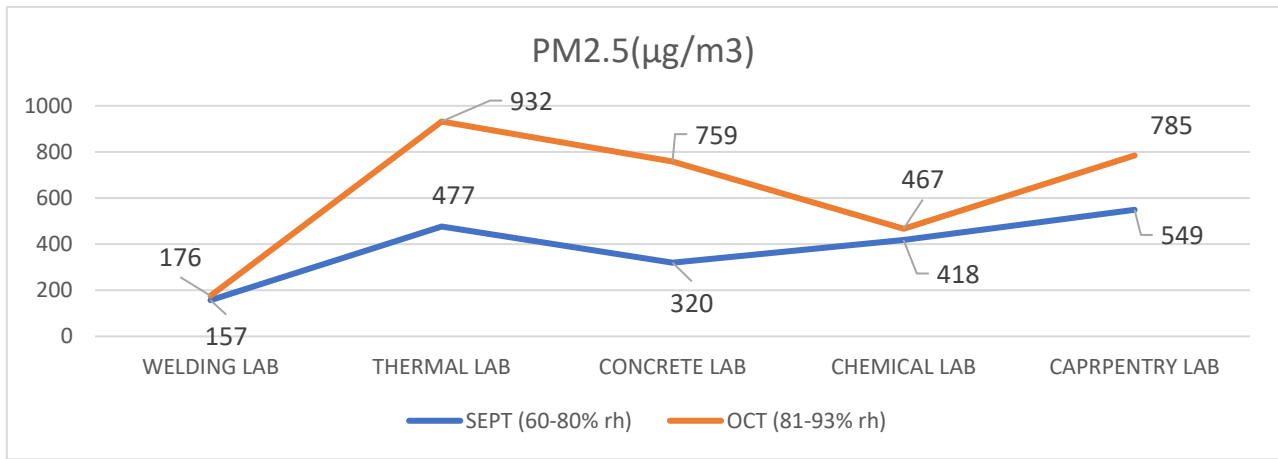


Fig.10 Comparison of PM_{2.5} between September and October

As shown in Fig.10, PM_{2.5} emerged as the most significant pollutant, across multiple laboratories, reaching extremely high values. During October's peak humidity levels, PM_{2.5} concentrations exceeding 900 µg/m³ in the thermal lab. sawdust emissions, sanding, cement mixing, and abrasive processes were driven by High concentrations of PM_{2.5}, displayed by carpentry and concrete laboratories. These findings parallel measurements were reported in welding workshop exposure studies [11], university laboratory assessments in Turkey [3], and naturally ventilated laboratories in Spain [6]

WITH RESPECT TO INDOOR AIR QUALITY INDEX:

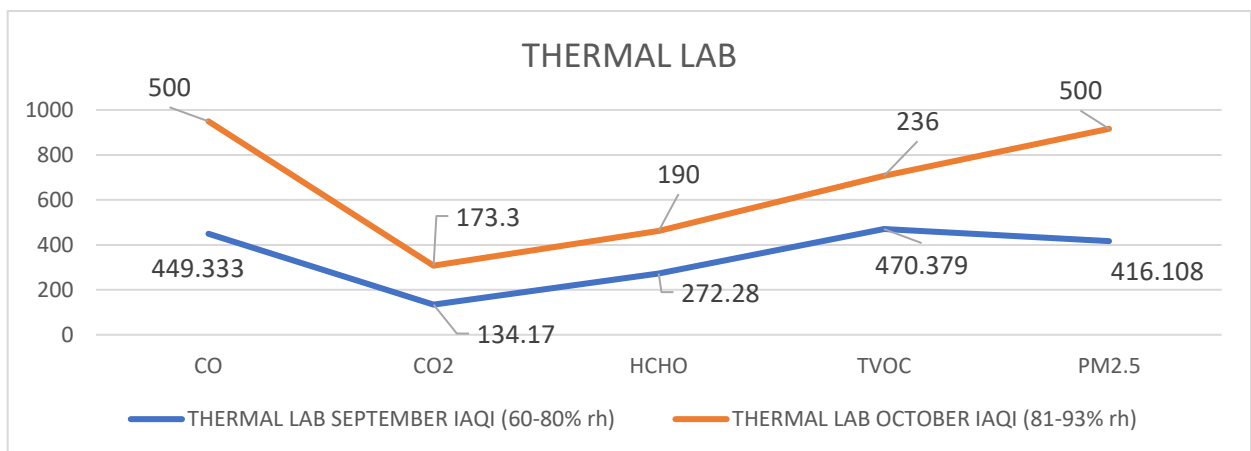


Fig.11 Comparison of IAQI of Thermal lab between September and October

As shown in Fig.11, Critically poor indoor air quality was exhibited by thermal laboratory with pollutant levels worsening from September to October across both months, due to increased humidity. CO, TVOC, and PM_{2.5} were hazardous, while CO₂ and formaldehyde were unhealthy, indicating strong emissions and inadequate ventilation in September. High humidity (81–93%) intensified pollutant buildup, raising CO and PM_{2.5} to the maximum IAQI of 500 and shifting CO₂ to the unhealthy category by October. Although HCHO and TVOC slightly decreased, they remained in unhealthy to very unhealthy levels, indicating continuous off-gassing and solvent emissions. This trend is consistent with previous studies reporting that increased humidity reduces ventilation efficiency and enhances pollutant retention in indoor environments [1], [3], [5], [6], [7], [10], [19].

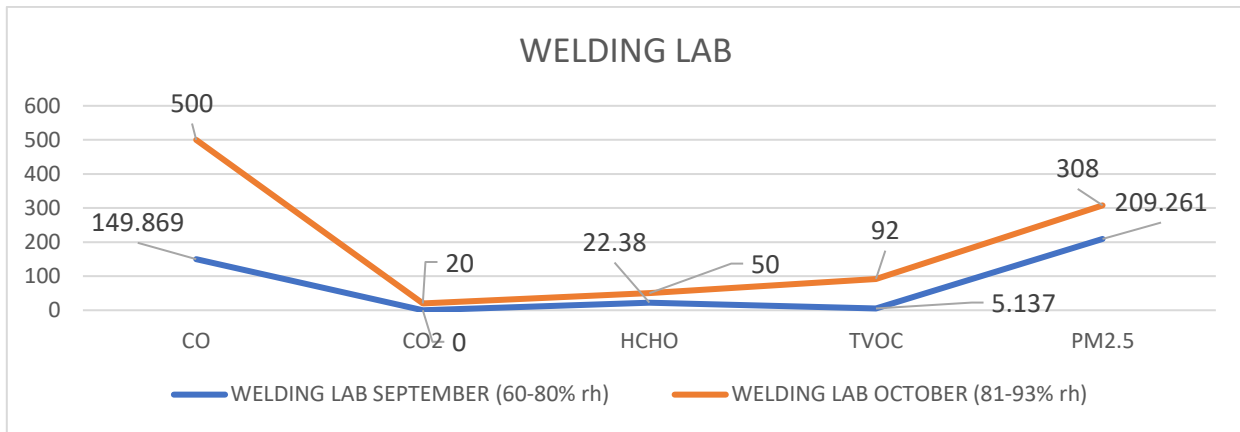


Fig.12 Comparison of IAQI of Welding lab between September and October

As shown in Fig.12, In welding lab, A clear shift toward more severe pollution is observed when comparing laboratory air quality between the two periods. CO was “unhealthy for sensitive groups,” PM_{2.5} was “very unhealthy,” while CO₂, HCHO, and TVOC remained in the good range, indicating effective ventilation for chemical pollutants. CO and PM_{2.5} escalated to hazardous levels, with CO reaching the maximum IAQI of 500 and PM_{2.5} rising to 308, showing severe pollution conditions in the second period. TVOC increased from good to moderate levels, while CO₂ and HCHO remained within safe limits. This deterioration aligns with previous studies reporting that changes in laboratory activities, ventilation efficiency, and environmental factors strongly influence pollutant buildup [1], [3], [5], [6], [7], [10], [19].

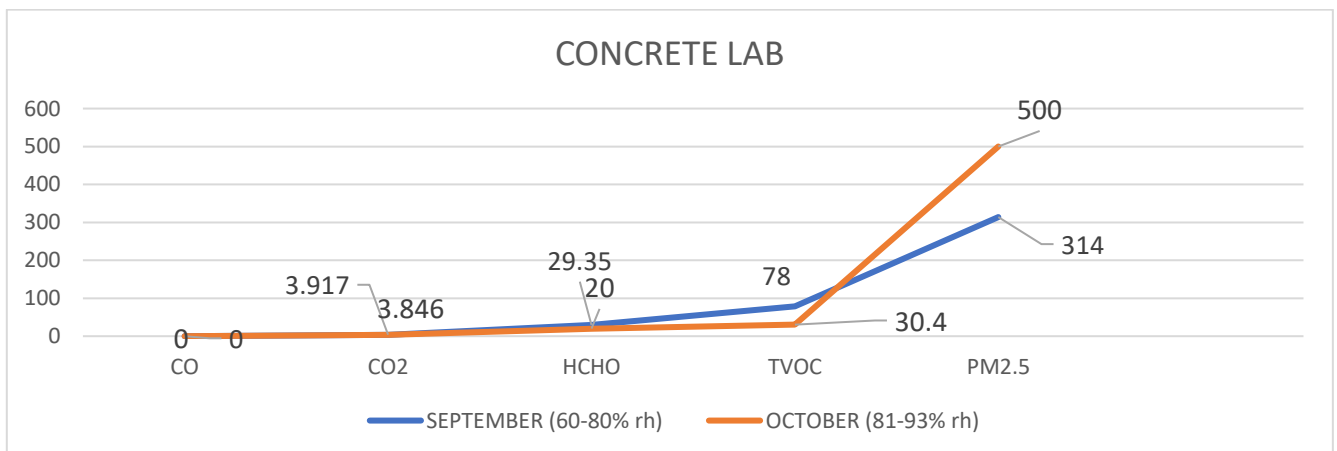


Fig.13 Comparison of IAQI of Concrete lab between September and October

As shown in Fig.13, When comparing September and October, Gaseous pollutants largely remained in the “good” category, while particulate matter showed major deterioration. CO, CO₂, and HCHO were good, TVOC was moderate, but PM_{2.5} was already hazardous, indicating strong particulate generation from laboratory activities in September. CO, CO₂, HCHO, and TVOC stayed within safe limits, with TVOC further decreasing, showing stable gaseous conditions in October. PM_{2.5} rose to the maximum hazardous IAQI of 500 due to higher humidity and reduced dispersion. Particulate levels are strongly influenced by humidity, ventilation, and indoor activity intensity which aligns with previous studies [1], [3], [5], [7], [10], [19].

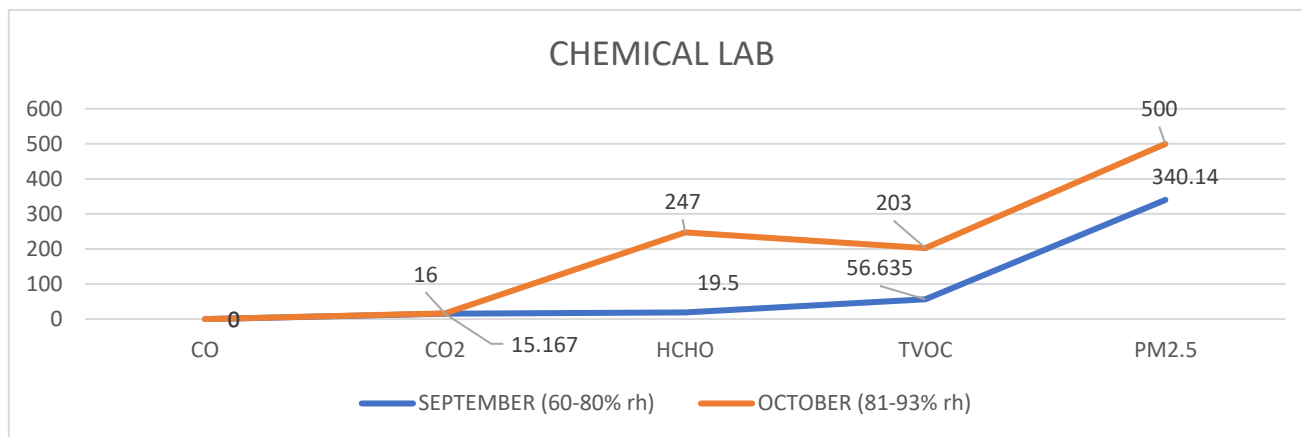


Fig.14 Comparison of IAQI of chemical lab between September and October

As shown in Fig.14, CO, CO₂, and HCHO in the “Good” category, and TVOC in the “Moderate” range, indicating limited gaseous pollution [1],[2],[3] the laboratory showed generally satisfactory air quality during September. However, PM_{2.5} was extremely high at 340.14 µg/m³, falling under the “Hazardous” category [2,4]. By October, CO and CO₂ remained “Good,” but HCHO and TVOC rose sharply to “Very Unhealthy” levels, suggesting increased emissions and ventilation inefficiency [1,3,5]. PM_{2.5} further escalated to 500 µg/m³, confirming severe particulate contamination [2,4]. Overall, September showed concern mainly for PM_{2.5}, while October reflected widespread deterioration in indoor air quality.

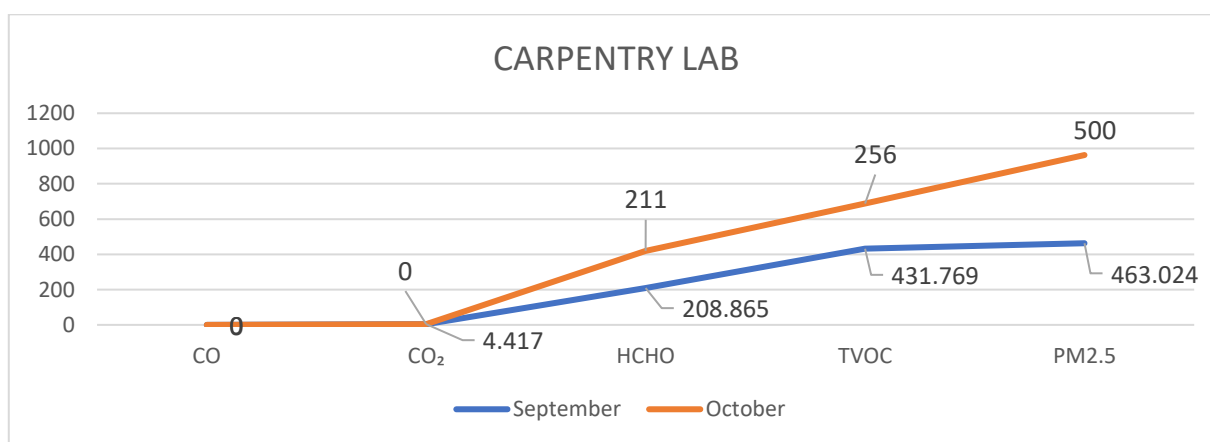


Fig.15 Comparison of IAQI of chemical lab between September and October

As shown in Fig.15, In carpentry lab indicating adequate ventilation and no combustion-related pollution [1,2] in both September and October, CO and CO₂ remained in the “Good” category. HCHO and TVOC levels stayed in the “Very Unhealthy” to “Hazardous” range, emissions from wood materials, adhesives, and solvents [3,6,7,11,12,13]. PM_{2.5} was extremely high in both months, consistently classified as “Hazardous,” due to intensive dust-generating workshop activities, [6,12]. Overall, despite safe CO and CO₂ levels, severe pollution from HCHO, TVOCs, and PM_{2.5} persisted, with October showing slightly lower VOCs but worse particulate conditions.

HEALTH RISK ASSESSMENT:

Varying levels of potential health risk across the laboratory environments was indicated by The Hazard Index (HI) assessment of September. In thermal lab, due to elevated exposure levels, the highest HI value of 28 (>1), indicating a significant hazard risk to human health. Similarly, the Welding Lab showed an HI value of 12.057 (>1), also exceeding the safe limit and suggesting a considerable health risk for occupants. In contrast, the recorded HI values of 0.587 (<1) and 0.39 (<1) were recorded in respectively, which fall below the acceptable threshold, indicating no significant health risk under current exposure conditions. However, HI value of 4.17 (>1) was exhibited by the Carpentry Lab, exceeding the safety limit and highlighting a potential hazard risk to human health. Overall, to reduce health risks associated with pollutant exposure the results suggest that while some laboratories maintain safe exposure levels, the Thermal, Welding, and Carpentry labs require improved control measures and ventilation strategies. Significant differences in potential health risks across the various laboratory environments was revealed by the Hazard Index (HI) assessment of October.

The highest HI value of 28.8 (>1), was recorded by the Thermal Lab indicating a severe hazard risk to human health due to high pollutant exposure levels. Similarly, HI value of 26 (>1), exhibited by the Welding Lab showed an also far exceeding the safe threshold and suggesting considerable health risks for occupants. HI values of 4.9 (>1) and 4.22 (>1) respectively, was recorded by the Chemical Lab and Carpentry Lab both above the acceptable limit, indicating the presence of hazardous exposure conditions that may adversely affect human health. HI value of 0.4 (<1), was exhibited by the Concrete Lab which is within the safe limit and indicates no significant health risk under existing conditions. Overall, the results highlight that most laboratories, except the Concrete Lab, pose potential health risks and therefore require improved ventilation, exposure control measures, and regular monitoring to ensure a safer indoor environment.

The Thermal and Welding Laboratories had Health Indicators of >1 (>1) during both September and October (2nd quarter) indicating significant non-carcinogenic health risks; e.g., Significant Health Risks linked (but not limited to) to Acute & Chronic Respiratory Disorders, & the Development of Asthma, as well as Reduced Lung Function, Inflammation of the Airways, and an Increased Vulnerability to Heart Diseases. The Carpentry & Chemical Laboratories had elevated levels of Volatile Organic Compounds (VOCs) and Particulate Matter (PM_{2.5}), presenting potential health risks primarily including: Signs of Eye, Nose, and Throat Irritation, Allergic Reactions, Skin Sensitivity, and Chronic Toxic Health Effects on the internal organs (liver/kidneys). Elevated levels of PM_{2.5} (by far) were one of the most hazardous from the standpoint of Chronic Respiratory & Cardiovascular Disease caused by extended exposure to PM_{2.5}; resulting in significant health-related issues (e.g., asthma, emphysema, chronic obstructive pulmonary disease (COPD), decreased lung capacity, heart attack, hypertension, & so forth), and the Carpentry and Chemical Laboratories also presented health hazards associated with other VOCs such as TVOCs, Formaldehyde, Carbon Monoxide (CO), and Carbon Dioxide (CO₂), contributing to a variety of symptoms (e.g., irritation, headaches, fatigue, impaired cognitive performance, dizziness, nausea, inability to concentrate, problems with memory, hypoxia in the case of CO exposure, and possible neurological dysfunction). The Thermal Lab has a number of laboratory-specific hazards such as respiratory problems and carbon monoxide exposure that result in a

lack of oxygen, pain in the chest area, confusion, and may, in severe cases, lead to unconsciousness; severe lung conditions from metal fume exposure at the Welding Lab, including metal fume fever, inflammation of the lungs, and long-term pulmonary injury; extended periods of exposure to wood dust and formaldehyde from the Carpentry Lab increases the chances of developing chronic asthma or nasal cancers as well as developing chronic health problems from being exposed to chemicals in the Chemical Lab leading to chronic toxicity to the body and disrupting the endocrine system and causing damage to vital organs (liver, kidney, and nervous system).

ENVIRONMENTAL IMPACT

In the Thermal Lab, measurements from September show that three contaminants had extremely unhealthy concentrations; namely, CO, Total Volatile Organic Compounds (TVOC), and Particulate Matter less than 2.5 microns (PM_{2.5}) measured (Exposure Ratio (ER) = 16.25, Standard Deviation (SD) = ~ 97.50), and HCHO was at a very unhealthy level (ER = 12, SD = 72), while CO₂ was determined to have an unhealthy concentration (ER = 8.25, SD = 49.5), and all four of these pollutants resulted in severely degraded indoor environments, and severe pollutant accumulation, and demonstrated as having been reported in laboratory-based indoor air quality studies [3], [6], [12]. The Welding Lab had reported that PM_{2.5} has a very unhealthy concentration (ER = 12, SD = 72) and CO was at an unhealthy level (ER = 8.25, SD = 49.5), while CO₂, HCHO, and TVOC remained within a normal or good level (ER = 2.25, SD = 13.5), and therefore there was localized particulate air pollution, and metal fume contamination similar to that seen in welding environments [11]. The Carpentry Lab displayed a similar finding where there was high HCHO (ER = 12, SD = 72), and both TVOC and PM_{2.5} were reported as having hazardous concentrations (ER = 16.25, SD = ~ 97.50); however, CO and CO₂ had relatively safe concentrations (ER = 2.25, SD = 13.5), and thus indoor air pollution was caused by dust and chemical emissions, which supports the behaviour of VOC emissions from indoor environments [7], [10]. The Chemical Lab's measure of PM_{2.5} was hazardous (ER = 16.25, SD = ~ 97.50), and TVOC was scored moderate (ER = 5, SD = 30), while CO, CO₂, and HCHO were rated as good (ER = 2.25, SD = 13.5), indicating a moderate level of environmental impacts from chemical exposure behaviour [1], [12].

High levels of CO and PM_{2.5} classified as hazardous (ER = 16.25, S = 97.5), very unhealthy levels of TVOC (ER = 12, S = 72) and unhealthy levels of CO₂ and HCHO (ER = 8.25, S = 49.5) at the Thermal Lab throughout October indicated major indoor environmental deterioration with high humidity levels present, consistent with recent research on humidity's contribution to pollutant accumulation and reduced ventilation efficiency. Chemical Lab measured very unhealthy (ER = 12, S = 72) levels for HCHO and TVOC but good levels for CO (ER = 2.25, S = 13.5) and CO₂ (ER = 2.25, S = 13.5); however, PM_{2.5} levels were at a hazardous level according to the chemical lab results (ER = 16.25, S = 97.5). The high PM_{2.5} levels reflect continuing emissions of chemicals and persistence of indoor pollutants given humid conditions. Concrete Lab recorded high-quality air for CO, CO₂, HCHO and TVOC, (ER = 2.25, S = 13.5); however, PM_{2.5} recorded hazardous levels at ER=16.25, S=97.5. The continuing presence of PM_{2.5} reflects continuing emissions of particulate matter, which is often found in areas where large amounts of dust are present. Carpentry Lab measured good levels for CO and CO₂ (ER = 2.25, S = 13.5), whereas HCHO and TVOC were both very unhealthy (ER = 12, S = 72) and PM_{2.5}

was hazardous (ER = 16.25, S = 97.5). Records indicate significant pollution levels caused from combined VOC emissions and dust, consistent with the findings of previous studies on indoor air quality issue on educational and workshop environments

MITIGATION MEASURES

In the Thermal Laboratory where the greatest potential for environmental hazard is exhibited through emissions from combustion, the focus of mitigation should be complete control of emissions and intelligent management of exhaust. Installation of high-efficiency exhaust chimneys and enclosed combustion systems and sensor-based automatic exhaust ventilation are essential in controlling both CO and PM emissions. Furthermore, multi-stage air filtration systems including HEPA and activated carbon filters can reduce pollutant concentrations significantly. Health-wise, Restricted Access and Time Control on Exposure must also be implemented, as well as the use of advanced respiratory protection devices. Socially, the display of real-time air quality displays and improved thermal comfort conditions will help reduce stress and increase awareness of the occupants, thus enhancing their overall well-being.

Fume and PM_{2.5} exposure is high in the Welding Laboratory. Therefore, it is essential to prioritize pollutant source capture over general dilution for controlling these pollutants. The use of local exhaust ventilation systems and fume extraction torches with movable extraction arms can substantially reduce worker fume exposure near the fume source. Additional health protection measures may include using powered air-purifying respirators and performing routine respiratory health monitoring. Social benefits of these mitigation strategies include better visibility, less worker discomfort, and improved worker productivity, which combine to create a safer and more efficient learning environment.

The Carpentry Lab will need to be controlled for two types of pollutant (particulate matter and volatile organic compounds), as there are high levels of wood dust and bonding agents in the air. Using a central dust collection system and using materials that are lower in formaldehyde and friendly to the environment will significantly reduce the impact on the environment. From a health perspective, using combined dust/VOC protection masks and monitoring for at-risk respiratory problems (e.g. occupational asthma) is critical. From a social perspective, improving indoor air quality will lower irritation levels; provide a more comfortable working environment; and make users feel better about using that space.

At the Chemical Lab where there are substantial risks of exposure to VOC and formaldehyde, containment and controlled handling of emissions should be the principal focus for mitigating such risks. This can be accomplished with advanced fume hood technology, which includes airflow monitoring sensors and the usage of closed systems for chemical handling, thereby minimizing pollutants released in the indoor environment. Health protection measures to be taken include meeting stringent requirements for personal protective equipment use, monitoring potential long-term health effects (such as neurologic effects and organ effects),

and social measures of decreasing odor intensity and perceived level of toxicity in order to increase the trust and comfort level of laboratory users.

The focus in the Concrete Lab should be on minimizing particulate matter, then dust suppression and modification of processes would be the best means to reduce this type of particulate matter. For example, using wet mix techniques, localized dust control systems, and meeting adequate ventilation standards will all help to lower PM 2.5 exposure. In addition to limiting overall exposure to particles through the use of dust masks, the social benefits of cleanliness and reduced particulate matter provide a more pleasant and acceptable working environment for everybody who works in the area

V. CONCLUSION

The project titled “Assessment of Indoor Air Quality at GCT, Coimbatore” highlights how air quality varied across different campus laboratories and how environmental conditions influenced pollutant levels. The study found that pollutant concentrations increased in October compared to September, mainly due to rising humidity, while carbon monoxide (CO) levels decreased because of enhanced oxidation. CO emissions were negligible in the Concrete, Carpentry, and Chemical labs due to the lack of combustion activities. Among all spaces, the Thermal Lab showed the highest pollutant levels, followed by Carpentry, Concrete, Chemical, and Welding labs. The pollutants ranked in dominance as $\text{PM}_{2.5}$ ($932 \mu\text{g}/\text{m}^3$) > TVOCs ($8.303 \text{ mg}/\text{m}^3$) > formaldehyde ($3.404 \text{ mg}/\text{m}^3$) > CO_2 (790 ppm) > CO (301 ppm), identifying $\text{PM}_{2.5}$ as the most critical pollutant. According to the Indoor Air Quality Index (IAQI), the Thermal Lab had the poorest air quality (≈ 500 , hazardous), followed by Carpentry (≈ 460), Concrete (≈ 410), Chemical (≈ 370), and Welding (≈ 320). Overall, air quality worsened from September to October due to higher humidity, with $\text{PM}_{2.5}$ being the main contributor to poor IAQ. The findings emphasize the urgent need for better ventilation, humidity control, and regular indoor air quality monitoring to maintain a healthier indoor environment. IAQI values revealed hazardous conditions in several laboratories, especially the Thermal and Carpentry units, underscoring the need for improved ventilation strategies, pollutant source control, and real-time IAQ surveillance.

The study’s outcomes align closely with global IAQ research trends in educational and laboratory environments [1]–[20], reinforcing the importance of humidity-aware IAQ management to safeguard occupant health and ensure safe learning conditions. To overcome the aforementioned problems, it is necessary to have a comprehensive solution to mitigate them based on the requisite control systems for environmental issues, therefore developing specialized laboratory environments. The lab environments include implementing additional air intake/exhaust systems in thermal and welding labs; dust and VOC (volatile organic compounds) controls in carpentry labs; containment of chemicals during chemical lab processing; dust suppression techniques used during concrete labs operation; and utilizing health related issues ie; more exposure management and use of personal protection equipment (PPE). Finally support for social initiatives should also be procured through PA research and educational programmes on workplace safety, as well as using technology such as real-time Indoor Air Quality (IAQ) monitoring and improved work environments as means to provide support to the laboratories.

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Author contribution:

Keerthika M was responsible for the study conception, design, data collection, analysis, and manuscript drafting.

Rajeshkumar Kadarkarai provided guidance and supervision

