CORRELATION BETWEEN INDOOR AIR POLLUTANTS AND ASTHMA: A CASE STUDY IN KUET

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ABSTRACT

Polluted air, whether outside or inside a building, can potentially aggravate asthma and allergy symptoms in the human body. In addition to dust mites, pet allergens, and mold, chemical pollutants such as nitrogen dioxide, sulfur dioxide, ozone, particulates, and volatile organic compounds are known to trigger asthma attacks. Because students spend an average of 10–14 hours inside the classroom each week, they are subjected to a significant amount of polluted indoor air, which poses a significant threat to their overall health. There has not been a lot of research done on the connection between the indoor air quality (IAQ) of educational institutions and the allergens that students are exposed to, as well as the health of their respiratory systems. This research project focuses on the classrooms at the Civil Engineering Department at Khulna University of Engineering and Technology and the quality of the indoor air was investigated to discover whether or not certain air contaminants are responsible for triggering asthma attacks. To query about the pupils' respiratory health, a questionnaire was handed out to each of them. Portable air analyzers were used to determine the level of cleanliness of the air inside. The concentration of carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) were all measured by this apparatus. Using the concentration of the air pollutants present in the classroom, the Air Quality Index (AQI) was calculated with the National Ambient Air Quality Standard.

A total of around 26% of the students who took part in the survey were diagnosed with asthma, and 35% of the students had a family history of asthma. The Air Quality Index (AQI) values for sulfur dioxide (SO_2), particulate matter ($PM_{2.5}$), and particulate matter (PM_{10}) were 63, 96, and 90, respectively, suggesting minor respiratory discomfort. According to the findings of this study, there is a possibility that asthma could be triggered by exposure to air pollution that is present in the classroom. This is the conclusion drawn from the data of the study. Within the classroom located in the Civil Engineering building, an assessment was carried out to determine whether or not the classroom was qualified for WELL Certification. There is a scorecard system, and the minimum number of points necessary to become eligible for the certification in the air category is 17. Based on the findings of the investigation, the classroom received just 4 points, which indicates that the classes do not meet the requirements for certification. For enhanced indoor air quality, the study recommends WELL Building Standard classroom improvement.

Keywords: *Asthma, Indoor Air Pollutants, Air Quality Index, WELL Certification*

1. INTRODUCTION

Asthma affects millions worldwide, including many children. One of the most common chronic illnesses in children, asthma affects 6.2 million US children, according to the CDC. Poor classroom air quality is linked to students' asthma. Classroom air quality is affected by inadequate ventilation, outdoor air pollution, and cleaning agents. Indoor pollution can inflame airways, causing asthma episodes and hospitalizations.

Indoor air quality helps students learn in a healthy environment. Numerous studies have examined how indoor air pollution harms students' health and academic performance. Poor indoor air quality in school may slow cognitive functions like memory and attention and increase absenteeism. Pulimeno et al. (2020) found that students in classes with weak IAQ performed 4% worse on standardized examinations. Poor IAQ courses had 20% more respiratory illness-related absenteeism, according to the study. Children exposed to indoor air pollutants like NO_2 and $PM_{2.5}$ are more likely to develop asthma. Ambient $PM_{2.5}$ exposure causes 10% of childhood asthma cases worldwide, according to Sun et al. (2022). Chatzidiakou et al. (2015) found that children who attend schools near refineries and chemical companies are more likely to have asthma. Classroom air quality affects students' health, well-being, and study ability. As allergy and respiratory difficulties develop, indoor air quality (IAQ) must be improved. In addition, seasonal variations have an impact on the indoor air quality of a room. The cold air of winter can trigger breathing problems in an asthma patient. Also in winter people have to spend more time indoors which may expose people to indoor allergens like mold, pet dander, dust mites, etc. In spring pollen levels are high which can trigger allergic reactions in individuals with asthma problems. Damp conditions in the rainy season can cause mold growth in the room.

In response, the International WELL Building Institute (IWBI) produced the WELL Building Standard to guide the design and maintenance of healthy buildings. Effective ventilation, low-emitting materials, and frequent cleaning can improve classroom IAQ, according to Bayoumi et al. (2021). Classrooms may have poor IAQ due to high occupancy and insufficient ventilation. WELL, accreditation provides a framework for creating classrooms with optimal IAQ, emphasizing non-toxic materials, efficient ventilation, and air quality monitoring. The impact of WELL certification on classroom interior environmental quality was studied by Matthaios et al. (2022). The study found that WELL-certified classrooms had lower carbon dioxide, volatile organic compounds, and particulate matter and better lighting and thermal comfort. WELL-certified classrooms also improved student satisfaction.

Again, Johnson et al. (2018) examined how ventilation and air purification affected classroom IAQ. Air purifiers and increased ventilation minimize air pollutants, according to the study. The study noted that classroom size and occupant count may affect these tactics' effectiveness. Wargocki et al. (2020) examined how the WELL Building Standard influenced health and well-being in schools and other institutions. WELL certification improves indoor air quality, reduces sick days, and boosts productivity, the study found. Sadrizadeh et al. (2022) found that increasing ventilation rates improve indoor air quality and reduces respiratory symptoms including coughing and wheezing. Indoor air pollution can be reduced by reducing cleaning products and smoking. Vinegar and baking soda are safe environmental cleaners for schools. Classrooms can ban smoking and perfumed goods, which can worsen asthma symptoms.

In poor air quality classrooms, students, especially asthmatics, are at risk for health issues. Indoor air pollution can induce asthma, poor academic performance, and absenteeism. This study will assess the indoor air quality of Khulna University of Engineering and Technology's Civil Engineering building classrooms to determine how indoor air pollutants affect asthma. A survey will determine how classroom indoor air quality affects students' health. The KUET Civil Engineering Building classrooms will be analyzed to see if they meet the WELL Building Standard for air and what efforts need to be taken to get WELL-Certified

2. RESEARCH METHODS

2.1 Population and Survey

A questionnaire has been prepared to explore detailed information on students' health and how it is affected by the indoor air quality of classrooms. The question mainly covered the health-related problems associated with indoor air pollution, past health records, comfort in the classroom, and further improvement ideas to improve the air quality of classrooms.

2.1.1 The site and student selection

The study was carried out in the building of the Civil Engineering Department of Khulna University of Engineering & Technology. The study was conducted on randomly chosen 100 undergraduate students of 3rd year and 4th year. Among them, the number of male participants was 60 and the number of female participants was 40. The students belonged to the age group of 22-24 years. The selected site for the survey was classrooms of 3rd year and 4th year. The questionnaire includes the International Study of Asthma and Allergies in Childhood (ISAAC) core health questions and additional questions regarding housing, life habits, and outdoor environment.

2.1.2 Questionnaire design

The questionnaire includes the International Study of Asthma and Allergies in Childhood (ISAAC) core health questions and additional questions regarding classroom air quality, comfort in the classroom, and suggestions for improvement of the classroom environment. The questions covered age, gender, frequency of nose congestion, wheezing, and cough, breathing difficulties, flu in one month and twelve months, and frequency of waking up at night due to coughing. Another important question was if the cough stayed for more than 10 days. According to ISAAC answers to two questions can give an idea if a person has Asthma. If a person wakes up at night due to coughing and the cough stays for more than 10 days it indicates that the person may have asthma. The questionnaire also included parental asthma history, past asthma treatment history, classroom environment, lighting facilities, classroom cleanliness, and ventilation. Students also suggested what should be done to improve the quality of the classroom environment.

2.1.3 Analysis of the questionnaire survey

The procedure for the questionnaire survey was very simple. First, the class representatives of 3rd year and 4th year were contacted. They consulted with the interested students and fixed a time for filling up the questionnaire. Upon the agreement of the students, the questionnaire was distributed among the interested students in the classroom. They filled out the paper and submitted it on time. Then the data were input in an EXCEL sheet and were analysed statistically.

2.2 Air Quality Measurement

Using a Portable Air Quality Analyzer, the quality of the air inside the classroom of B section in the Civil Engineering Department was measured. The Air Quality Analyzing equipment must first go through the calibration process before it can be used. For warming up the portable air quality analyzer, three minutes is needed. At the study site, the quality of the air was evaluated in different positions of the classroom and then the results were averaged.

For measuring the air quality a portable air quality analyzer which is a product of AEROQUEL was used. It has a base machine that gives all the readings on the screen and a head is attached to the base which collects the air pollutants sample and gives the readings of concentration of the air pollutants. The Indoor Air Quality Test Kit (Starter) comes with Aeroqual's portable monitor, which can be used to measure a variety of pollutants by merely exchanging the sensor heads for the pollutant to be monitored. This allows the monitor to be used for a wide range of applications. A sensor for particle matter (PM) ($PM_{2.5}$, PM_{10}) sensors for two criterion pollutant gases (NO_2 and O_3) and a sensor that measures CO_2, SO_2, and VOCs are also included in the Indoor Air Quality Test Kit.

The values were taken during the class time in the morning. Real-time concentrations of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter ($PM_{2.5}$, PM_{10}), and volatile organic compounds (VOCs), ozone (O_3) were measured. Using the concentration of these air pollutants Air Quality Indexing (AQI) was done.

2.3 Air Quality Index (AQI) Calculation

The AQI values were derived using air quality data measurements, allowing for a more realistic comparison of the pollutants that affect air quality. The concentration of each value was averaged, and the levels of air pollution were compared to Bangladesh's National Ambient Air Quality Standard. The average period was 24 hours. A formula was used to determine the AQI for each air contaminant. The AQI value was compared to the category that reflects each air pollutant's health impact.

The index is derived by using this formula:

$$AQI(pollutant) = \frac{Polluted\ Data\ Reading}{Standard} \times 100$$

2.4 WELL Certification of Classroom for Air Category

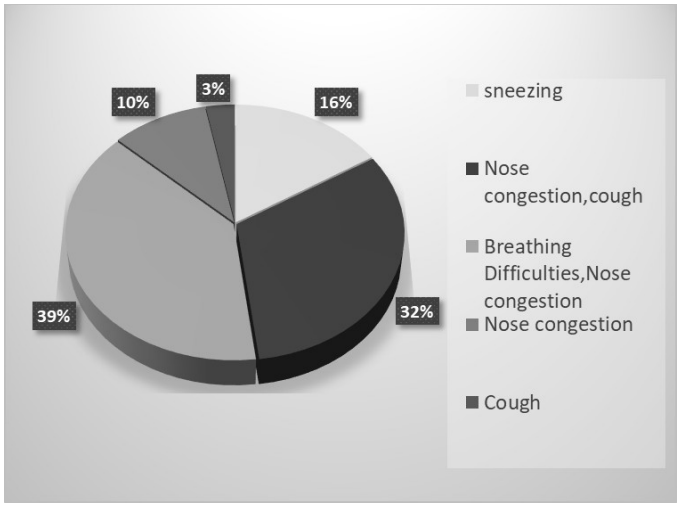
The purpose of this research is to determine whether all of the standards for the air category have been completed for a classroom to be certified. A scorecard based on The WELL Building Standard v2® was used to accomplish this. To qualify for the air category, a total of 17 points must be obtained and certain threshold conditions being met. If all of these standards are completed, the classroom can be declared qualified to get the well certification. Each criterion was evaluated using this scorecard, and points were assigned based on how well it satisfied the criteria. The parameters of air quality were tested using a handheld air quality analyzer. The levels of pollutants in the air were determined using this equipment. Following that, the complete classroom was inspected to determine whether or not it met all of the standards specified on the WELL Building Standard v2 scorecard.

3. RESULTS AND DISCUSSION

3.1 Findings from the Questionnaire Survey

100 students filled out the questionnaire form. Among them 60% of students were male and 40% of students were female. The age range of the participants of the study was between 22 to24. The answers were put into an EXCEL worksheet and the data were analyzed. The questionnaire survey was conducted to find information about student’s health and find if it is correlated with the indoor air quality of classrooms. From the survey, various pie charts were figured out.

Figure 1 shows the information on students' health during cold. The large area of the pie chart shows that about 39% of students suffer from breathing difficulties and nose congestion during cold. And the small area shows that about 3% of students have only coughed during the cold. 10% of students have nose congestion. On the other hand, 32% of students have both nose congestion and cough. The remaining 16% of students only sneeze during cold.



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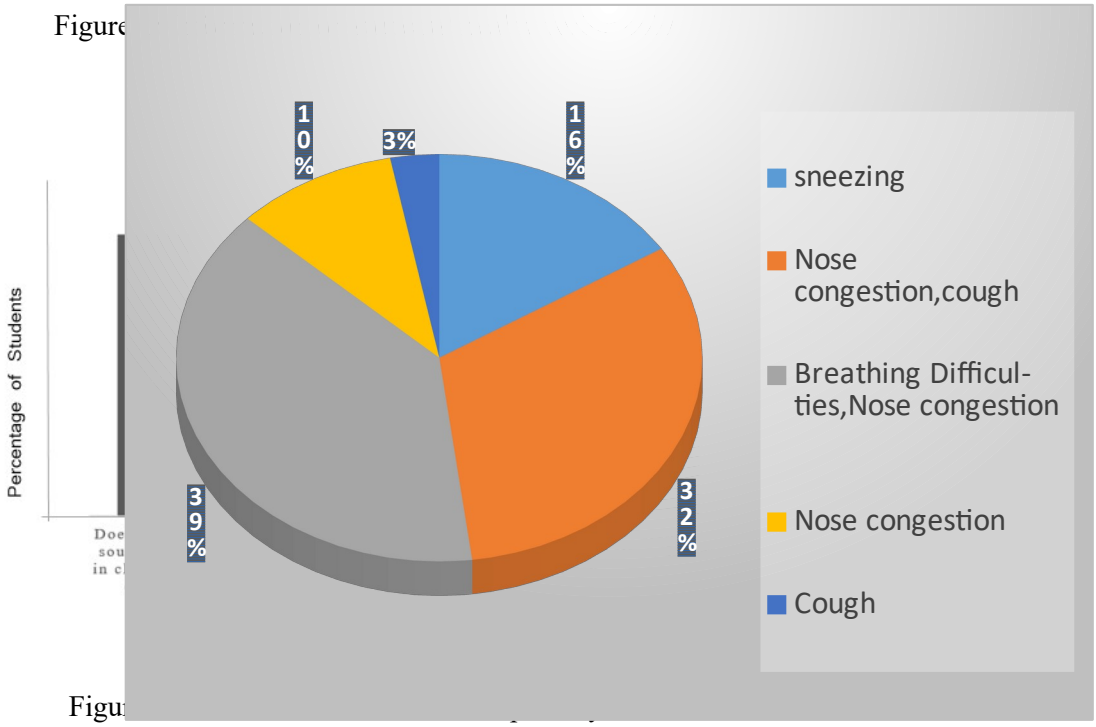

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Figure 2 shows the information on students' respiratory health details. About 53% of students informed that whizzing sounds happen in their chests during the cold. This sound indicates that the patient has a bad cough. About 40% of students wake up from sleep due to coughing and breathing when they suffer from cold. And the cold lasted for more than 10 days for 35% of students. According to The International Study of Asthma and Allergies in Childhood (ISAAC) if the patients' cold lasts for more than 10 days and the patient wakes up from sleep due to coughing and breathing difficulties the patient may suffer from serious respiratory health problems like asthma. From the bar chart, it shows that about 35% of students have asthma or had asthma in the past. It also shows about 35% of students have a parental asthma history.

It is very hard to correlate asthma or sickness with indoor air quality. Further detailed study needs to be done to surely say that. This questionnaire study showed the detailed respiratory health information of the students who participated in the study. 26 people had asthma among 100 students. It's a matter of great concern. Even though this study does not surely prove classroom indoor air quality is the reason behind asthma and other respiratory problems it shows that indoor air pollution may be a potential factor for asthma or other respiratory problems.

3.2 Assessment of Indoor Air Quality in Classroom

AEROQUEL's portable air quality analyzer was used to measure the concentrations of air pollutants present in the classroom. The device had sensors for measuring SO_2, NO_2, CO, O_3, CO_2, $PM_{2.5}$, PM_{10}, and VOC. The sensor was attached to the monitor which showed the real time concentration of the air pollutants.

Table 1: Concentration of Air Pollutants found in the Aeroquel's portable air quality analyzer

SO_2 (µg/m^3)	VOC (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)
70	470	67	131
60	450	64	137
20	430	40	138
10	460	63	132
50	420	64	135
30	390	50	133
60	380	66	141
70	460	75	129
80	450	64	124
40	400	65	136
Avg = 50	Avg = 435	Avg = 62	Avg = 134

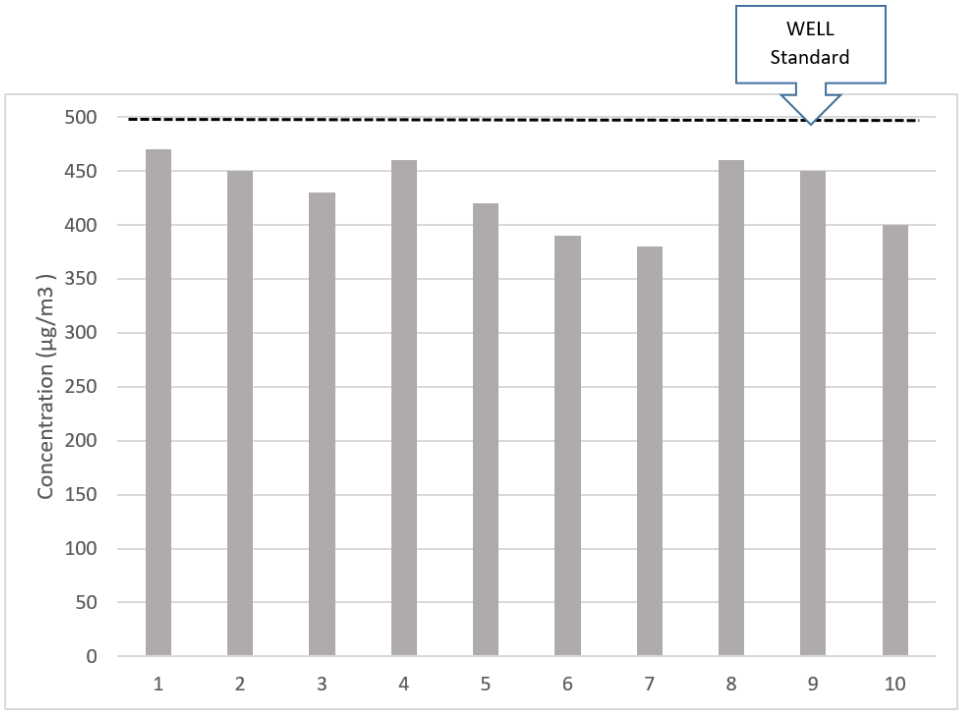

Figure 3: Concentration of VOC

Figure 3 shows the concentration of VOC. Here the maximum concentration is 470 µg/m^3 where the minimum concentration is 380 µg/m^3. The average concentration is 435 µg/m^3. According to the WELL Standard, the concentration of VOC needs to be below 500 µg/m3. The concentration in the graph did not exceed the standard value.

It is found that when the concentration of VOC exceeds 395 µg/m^3 the asthma patient or patient with respiratory problems suffers from the problem of continuous wheezing. Here almost 8 values crossed that concentration limit. It can be said that when the concentration of the classroom exceeds 395 µg/m^3, it may cause wheezing to the students who are suffering from asthma.

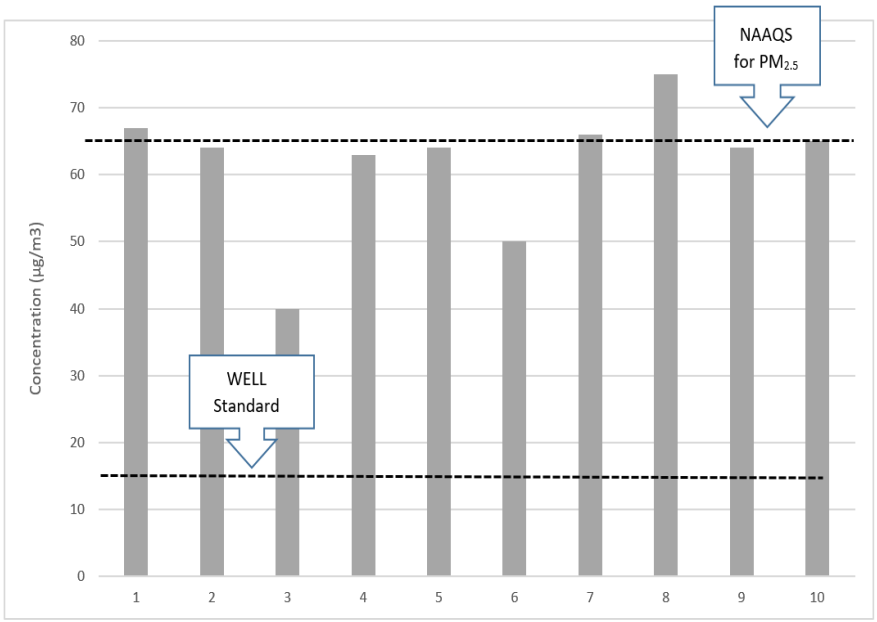

Figure 4: Concentration of $PM_{2.5}$

Figure 4 shows the concentration of $PM_{2.5}$. Here the maximum concentration is 75 µg/m^3 where the minimum concentration is 40 µg/m^3. The threshold value for National Ambient Air Quality Standards for $PM_{2.5}$ is 65 µg/m^3. The maximum concentration crosses the threshold value. Some other values also cross the line. According to the WELL standard minimum air quality standard for $PM_{2.5}$ is 15 µg/m^3. Here all values crossed the threshold value for WELL Standard.

The average concentration is 62 µg/m^3. Where the standard is 65 for 24 hr standard average period. So the AQI Value is 96. It falls into the Moderate category. Which may cause minor breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children, and older adults.

3.3 Air Quality Index in Classroom

The concentration of the air pollutants was averaged and using the concentration of the National Ambient Air Quality Standard (NAAQS), Air Quality Index was measured for each air pollutant. The standard average period is 24 hr.

Table 2: AQI Chart with Category

Air Pollutants	Average Concentration (µg/m^3)	Standard Average Period	Standard Concentration(µg/m^3)	AQI	Category
$PM_{2.5}$	62	24hr	65	96	Moderate
PM_{10}	134	24hr	150	90	Moderate
SO_2	50	24hr	80	62.5	Moderate
NO_2	<1	Annual	100	1	Good
O_3	<1	8hr	157	1	Good
CO	<10	8hr	10000	1	Good

From the chart, it is found that the AQI value of SO_2, $PM_{2.5}$, and PM_{10} is 63, 96, and 90. The AQI category for these air pollutants is Moderate. The health implication for this category is people with asthma or any other respiratory problem may face minor discomfort during breathing. As earlier it was found from the questionnaire survey that about 26 students have asthma among 100 students. This indoor air quality may cause them minor breathing problems as they are already suffering from asthma.

3.4 Eligibility of the Classroom for WELL Certification

The Air category of the WELL Building Standard v2 awards a total of 17 points to a building. In addition, specific criteria for the threshold state must be met. If each and every one of these conditions is satisfied, then it will be conceivable to declare that the classroom is suitable to be awarded the well certification. Using the scorecard, each criterion was assessed, and points were allotted based on how well it fit the criteria. The details of the scorecard is listed below:

Table 3: Scorecard for WELL certification of classroom

Item	Evaluated Result	Points
A01.1 Meet Thresholds for Particulate Matter	$PM_{2.5}$ = 62 µg/m^3 PM_{10}=134 µg/m^3	✗
A01.2 Meet Thresholds for Organic Gases	VOC = 470 µg/m^3	✓
A01.3 Meet Thresholds for Inorganic Gases	CO < 10 µg/m^3 O_3 < 1 µg/m^3	✓
A01.4 Meet Thresholds for Radon	Did not have any device to measure that	-
A01.5 Measure Air Parameters	$PM_{2.5}$ = 62 µg/m^3 PM_{10} = 134 µg/m^3 VOC = 470 µg/m^3 CO < 10 µg/m^3 O_3 < 1 µg/m^3	✗
A02.1 Prohibit Indoor Smoking	Indoor smoking is banned	✓
Item	**Evaluated Result**	**Points**

A02.2 Prohibit Outdoor Smoking	Outdoor smoking is banned	✓
A03.1 Ensure Adequate Ventilation	The classroom has only 2-4 ventilators but do not have proper ventilation system	✗
A04.1 Mitigate Construction Pollution	No such things are provided	✗
A05.1 Meet Enhanced Thresholds for Particulate Matter	$PM_{2.5}$ = 62 µg/m^3 PM_{10} = 134 µg/m^3	0
A05.2 Meet Enhanced Thresholds for Organic Gases	Did not have any device to measure that	—
A05.3 Meet Enhanced Thresholds for Inorganic Gases	CO < 10 µg/m^3 NO_2< 1 µg/m^3	1
A06.1 Increase outdoor air supply	CO_2= 1100 ppm	0
A06.2 Improve Ventilation Effectiveness	No such things are provided	0
A07.1 Provide Operable Windows	Enough windows are provided	1
A07.2 Manage Window Use	Outdoor levels of $PM_{2.5}$ were not measured	0
A08.1 Install Indoor Air Monitors	$PM_{2.5}$ = 62 µg/m^3 PM_{10}= 134 µg/m^3 VOC = 470 µg/m^3 O_3 < 1 µg/m^3,NO_2< 1 µg/m^3	0
A08.2 Promote Air Quality Awareness	No such things are provided	0
A09.1 Design Healthy Entryways	Even though cleaners clean regularly, during the inspection everything was very dusty	0
A09.2 Perform Envelope Commissioning	Did not have any device to measure that	—
A10.1 Manage Combustion	No such things are used	1
A11.1 Manage Pollution and Exhaust	Bathrooms have exhaust fan	1
A12.1 Implement Particle Filtration	Did not have any device to measure that	—
A13.1 Improve Supply Air	There is no Air purifier in the classroom	0
	Total points Earned	4

In order to get WELL Certification for Air Category total 17 points are needed to be earned. By inspecting the classroom total earned points were 4 which is very low. Also the threshold requirements were not met. Among 9 threshold requirement 4 requirements were met. So it can be said that the classroom is not eligible for WELL Certification. A lot of improvement is needed to meet all the requirements and to get 17 points for WELL Certification of classroom for air category.

3.5 Improvement of Classroom Indoor Air Quality

For improving indoor air quality there are various way. Some of these are listed below:

- Keeping the classroom clean and free of dust
- Providing enough ventilation in the classroom so that air can pass and circulate in the classroom
- Providing operable windows so that natural air can enter into the classroom
- Air purifier can be used to filter the air
- Authority should focus on using green cleaning products to reduce the concentration of VOC
- Monitoring indoor air quality of the classroom regularly

4. CONCLUSIONS

According to the findings of this investigation, 26% of students suffer from asthma, and 36% of students have a family history of asthma. From the air quality analyzer concentrations of air pollutants were found. Asthma-triggering air pollutants like SO_2, $PM_{2.5}$, and PM_{10}, VOC are present in the classroom. The concentration of $PM_{2.5}$ crossed the National Ambient Air Quality standard more than one time. The concentration of SO_2 was close to the line.

The AQI values for SO_2, $PM_{2.5}$, and PM_{10} are 63, 96, and 90 respectively, which places them in the moderate category and indicates that breathing may cause some slight discomfort. The highest concentration of VOC was 470 $\mu g/m^3$. Studies showed that a concentration above 395 $\mu g/m^3$ causes continuous wheezing. Even though the indoor air quality of the classroom is moderate it is not good for students suffering from asthma. If the indoor air quality gets worse the students may suffer from various respiratory problems and it may trigger asthma in students who still do not have asthma but have a parental asthma history. The questionnaire survey and the air quality study revealed that the indoor air quality of the classroom had the potential to trigger asthma attacks and other breathing difficulties in the children. That's why improvement of classroom indoor air quality is needed.

An analysis was done to find the eligibility of WELL Certification of classrooms of Civil Engineering buildings for the air category. To get certified 17 points are needed and threshold requirements are needed to be met. From the evaluation classrooms of Civil Engineering building got only 4 points where only 4 requirements met the criteria. The classrooms are not eligible for WELL Certification.
The indoor air quality of the classroom, as well as the pupils' respiratory health, will be improved if the classroom is built by the Well Building Standard and receives the WELL Certification. Several steps should be taken to improve indoor air quality. The use of air purifiers can be promoted, ventilation systems need to be improved, the classrooms should be cleaned regularly, enough windows should be provided in the classroom for entering natural air and light, and air filters can be used. The air quality of the classroom should be monitored regularly and the concentration of particulate matter must be maintained. Classrooms should be designed according to WELL Building standards and this will not only improve the indoor air quality of the classroom but also will improve students' respiratory health.

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