INDOOR AIR QUALITY ASSESSMENT DURING SEASONAL VARIATIONS IN DIFFERENT SITES AT JADAVPUR UNIVERSITY, KOLKATA

A thesis

Submitted in partial fulfilment of the requirements for the award of the degree of
Master of Technology in Environmental Biotechnology

by

DIPANJAN GAIN
Environmental Biotechnology

Roll Number: 002130904004
Exam Roll Number: M4EBT23010

SCHOOL OF ENVIRONMENTAL STUDIES

FACULTY OF INTERDISCIPLINARY STUDIES, LAW AND MANAGEMENT (F.I.S.L.M)

JADAVPUR UNIVERSITY

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CERTIFICATE

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It is hereby certified that this thesis titled "**Indoor Air Quality Assessment During Seasonal Variations in Different sites at Jadavpur University,Kolkata** " has been prepared and submitted for the partial fulfilment of the continuous assessment of Master of Technology in Environmental Biotechnology course of Jadavpur University by Dipanjan Gain (Roll No: 002130904004), a student of said course for the session 2021-2023 under the supervision and guidance of Dr. Subarna Bhattacharyya, Assistant Professor , of School of Environmental Studies , Jadavpur University.

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I hereby declare that the thesis entitled "**Indoor air quality assessment during seasonal variations in different sites at Jadavpur University, Kolkata"** submitted to the Department of Environmental Studies, Jadavpur University in partial fulfilment of the requirements for the award of Master of Technology, is my original work and has not previously formed on the basis for the award of any degree or diploma or fellowship or any other similar title.

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Final examination for
evaluation of thesis

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Signature of Examiner

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ABSTRACT

In the current study, indoor air quality (IAQ) in six different interior microenvironments of Jadavpur University is evaluated for seasonal and spatial variation from August 2022 to June 2023. Indoor environmental quality (IEQ) variables such as particulate matter (PM_{10} and $PM_{2.5}$), formaldehyde(HCHO), carbon dioxide (CO_2), were monitored during the monsoon, winter, and summer seasons. It was discovered that the IAQ varied considerably ($P< 0.05$) between the examined microenvironments. While the greater HCHO levels with above the threshold limit were recorded in the classroom, the highest concentrations of indoor PM_{10}, $PM_{2.5}$, and CO_2 were discovered in AC canteen with concentrations beyond the suggested guidelines values and standards. Additionally, it was discovered that the ventilation rate in the examined workplaces and lecture rooms was lower. Strong seasonal change was evident in the indoor concentrations of PM_{10}, $PM_{2.5}$($P <0.05$). Wintertime levels of PM_{10} and PM_{10} HCHO and CO_2 were found to be greater. Seasonal and geographic variation in indoor microenvironments was caused by indoor activities, ventilation, and occupancy.

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LIST OF ABBREVIATIONS

$PM_{2.5}$– Fine particulate Matter

PM_{10} - Coarse Particulate Matter

PM_1 – Ultra Fine Particulate Matter

IR- Infrared radiation

UV – Ultra violet radiation

PAN – Peroxacyl nitrate

NO – Oxides of Nitrogen

VOC- Volatile Organic Compound

CPCB- Central Pollution Control Board

WBPCB- West Bengal Pollution Control Board

WHO – World Health Organization

NAAQS – National Ambient Air Quality Standard

USEPA- United States Environmental Protection Agency

LIST OF SYMBOLS

μg -Micro gram.

$\mu g/m^3$ -Microgram per meter cube.

CHAPTER 1:INTRODUCTION

When dangerous compounds or pollutants are present in the atmosphere of the planet, it is referred to as air pollution. These pollutants can have a negative impact on people's health, the environment, and their general quality of life. These pollutants, which can be gaseous or particulate, are mostly discharged into the atmosphere by human activities like traffic, industrial processes, and the combustion of fossil fuels.

Carbon monoxide (CO), Nitrogen Oxides (NOx), Sulphur Oxides (SOx), Volatile Organic Compounds (VOCs), particulate matter (PM), and different dangerous substances are examples of common air pollutants. Vehicle emissions, power plants, industrial facilities, agricultural operations, and home heating and cooking are only a few of the sources of these pollutants. These pollutants can have a number of negative impacts when they build up in the atmosphere. Respiratory issues like asthma, bronchitis, and other chronic obstructive lung disorders can be brought on by air pollution. Lung cancer, allergies, and cardiovascular problems can all be exacerbated by it. In addition, air pollution can influence the balance of greenhouse gases in the atmosphere, degrade ecosystems, lower crop yields, and accelerate climate change.

Promoting cleaner technology, enhancing transportation infrastructure, and increasing public understanding of the value of decreasing pollution are all part of efforts to tackle air pollution. As part of broader environmental protection efforts, international agreements and initiatives, including the Paris Agreement on climate change, strive to reduce air pollution.

Nowadays Air pollution is a major problem and familiar environmental health hazard. Brown haze settles over a city, exhaust below surge across a highway or flame of smog rises from a smokestack are easily seen nowadays. We can’t see all types of air pollution but intense smell alerts us.

It is a fiercest threat to global health and living being. It is responsible for more than 6.5 million deaths each year globally, this number increased over the past decades .Many sensitive ecosystem are getting affected due to this air pollution, it’s also effects atmosphere chemistry, crops. The term of air quality used to express the suitability air to sustain different process but the quality of air becoming progressively worse day by day across the planet. At first Air pollution are bothered in a city areas but last two decades it’s increased in rural areas. Two types of pollutant are exists. 1. Gaseous and 2. Particulate matter. Gaseous air pollutants present in air like gaseous form. Some microscopic solid or liquid suspended particulate matter.

Air pollution has obtain a great concern globally due to evolution of technological in various fields in addition to diverse activities of human beings for the quality of being sophisticated. The burning of fossil fuels spreads various kind of air pollutants like Sulphur dioxide , Nitrogen dioxides, Carbon dioxide, Carbon monoxide, Unburned hydrocarbon, hydrogen fluoride and particulates can effects.

Air pollution changes the earth's system on a planetary system. Global warming is responsible for climate change. Greenhouse effects, ozone layer depletion .Global warming is a long process and this change happens gradually , It's also caused of polar ice melting and ocean water level rising. So global warming is directly responsible for all drowned on the banks of the river. Carbon emission is major caused of temperature rising, dangerous radiation like IR, UV, are trapped by various kind of gasses like carbon dioxide, CFC, Nox and this phenomenon increased the temperature of earth atmosphere. As a result it effects on weather change and seasonal change. Ozone layer protect us from harmful effect of Sun's UV radiation with catastrophic imparts but now days global warming cause of ozone depletion or ozone hole.

Oxide of sulphur and nitrogen is formed sulphuric acid and nitric acid due to atmospheric oxidation. Acid rain formed due to this acid mixed with rain form of precipitation It effects buildings , monuments which is made of marble materials it is called "Marble cancer" .This acid rain also effects both terrestrial and marine aquatic ecosystem.

1.1 Types of air pollutants

1.1.1 Primary air pollutants:

Substances that are immediately emitted into the atmosphere as a result of human activity or natural processes are referred to as primary air pollutants. These pollutants may be hazardous to the environment, human health, and overall air quality. Primary air contaminants include the following:

- Sulphur dioxide (SO_2) is primarily created when fossil fuels, especially coal and oil, are burned. In addition to contributing significantly to acid rain, SO_2 can harm the lungs and cause respiratory issues.
- Nitric oxide (NO) and nitrogen dioxide (NO_2) are examples of nitrogen oxides (NOx). They are mostly released from fossil fuel combustion in power plants and automobile

exhaust. NOx can play a role in the development of smog and respiratory problems. Nitric oxide (NO) and nitrogen dioxide (NO_2) are examples of nitrogen oxides (NOx). They are mostly released from fossil fuel combustion in power plants and automobile exhaust. NOx can play a role in the development of smog and respiratory problems.

- Carbon monoxide (CO) is a colourless and odourless gas that is created when fossil fuels burn partially, most frequently in motor vehicles and industrial processes. Since high amounts of CO make blood less capable of carrying oxygen, they can be fatal.
- Volatile Organic Compounds (VOCs): At room temperature, VOCs are organic compounds that readily evaporate. They come from things like paints, solvents, burning fuel, and industrial processes. Ground-level ozone, a significant contributor to smog, is formed when VOCs combine with other contaminants. Although its emissions have greatly decreased over time, lead (Pb) is still regarded as a major air contaminant. Leaded gasoline, industrial operations, lead-acid batteries, and other sources all emit it. Serious health consequences of lead exposure can affect the nervous system in particular.

These primary air pollutants can interact chemically with one another in the atmosphere to produce secondary pollutants including ground-level ozone, acid rain, and fine particulate matter, which aggravate the effects of air pollution.

1.1.2 Secondary air pollutants:

When primary pollutants interact with other chemicals or change chemically in the atmosphere, secondary air pollutants are created. Photochemical reactions and other atmospheric processes frequently fuel these reactions. Secondary pollutants are created within the atmosphere itself, as opposed to primary pollutants, which are immediately released into the atmosphere.

Following are some instances of typical secondary air pollutants:

- Ozone (O_3): Ozone is a secondary pollutant generated in the presence of sunlight by the interaction of nitrogen oxides (NOx) and volatile organic compounds (VOCs). It is a main component of smog and can cause respiratory problems as well as plant damage.
- Nitrogen Dioxide (NO_2): Nitrogen dioxide is primarily emitted as a primary pollutant from combustion processes. However, it can also form as a secondary pollutant

through the oxidation of nitric oxide (NO) in the atmosphere. NO_2 is a respiratory irritant and contributes to the formation of acid rain and photochemical smog.

- Sulphuric acid (H_2SO_4) is generated through the oxidation of sulphur dioxide (SO_2), a principal pollutant emitted by industrial activities, power plants, and volcanic eruptions. Sulphuric acid is a primary component of acid rain, which can harm ecosystems, structures, and human health.
- Particulate Matter (PM): Particulate matter is made up of small, airborne particles. While some particles are released into the atmosphere directly as primary pollutants (such as soot from combustion operations), secondary particles are created when gases like Sulphur dioxide and Nitrogen Oxides interact with other components in the atmosphere such as ammonia, organic compounds, and other gases. When inhaled, fine particulate matter ($PM_{2.5}$), which is the result of these processes, can have harmful consequences on human health.
- Formaldehyde (HCHO): When volatile organic compounds (VOCs) are exposed to sunlight, they oxidize, creating formaldehyde, a secondary air pollutant. Common sources of its release include construction materials, motor vehicle emissions, and industrial activities. A proven human carcinogen and respiratory irritant, formaldehyde.

It is significant to remember that a variety of factors, such as primary pollutant emissions, atmospheric conditions, and geographic location, influence the creation and existence of secondary pollutants in the atmosphere. The generation of secondary air pollutants must be minimized through efforts to lower primary pollutant emissions and enforce air quality standards.

1.3 Sources of air pollutants:

A multitude of natural and man-made factors, as well as one another, contribute to air pollution. Some of the main causes of air pollution are listed below:

- ❖ Transportation: The burning of fossil fuels produces air pollutants such nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), and particulate matter (PM) when they are used to power automobiles, trucks, buses, airplanes, and ships.

- Industrial Emissions: As a consequence of the manufacturing process, factories and industrial facilities emit pollutants such sulphur dioxide (SO_2), NOx, particulate matter, and different harmful compounds.
- Power generation: Electricity is produced by power plants that burn coal, oil, and natural gas. These facilities release a lot of pollutants, such as mercury, SOx, NOx, and greenhouse gases like CO_2 and methane.
- Agriculture: Activities related to agriculture, such as raising animals and using chemical fertilizers and pesticides, are a major source of ammonia (NH_3) emissions and other pollutants.
- Disposal of Waste: Poor waste management, such as the open burning of rubbish and emissions from landfills, releases dangerous chemicals and worsens air pollution. Burning wood, charcoal, coal, and other solid fuels in homes for heating and cooking can release dangerous pollutants, especially in places with poor ventilation.
- Natural Sources: The atmosphere can get contaminated by particulate matter and other pollutants when wildfires, volcanic eruptions, and dust storms occur naturally.
- Construction and Demolition: The dust and fumes produced by these activities can contaminate the air locally.
- Chemical and oil refineries: During the refining process, harmful and VOC-containing air pollutants are released into the atmosphere.
- Smoking: A variety of toxic chemicals and particulates are released when people smoke cigarettes and produce other tobacco-related emissions.
- Paints: Certain paints, solvents, and other volatile chemicals can release VOCs into the atmosphere when used.
- Air Conditioning and Refrigeration : Older air conditioning and refrigeration systems may generate hydro-chlorofluorocarbons (HCFCs) and chlorofluorocarbons (CFCs), which contribute to the ozone layer being depleted and climate change.
- Indoor causes: Tobacco smoke, fossil fuel-powered cooking and heating equipment, construction materials, cleaning supplies, and other household chemicals are all causes of indoor air pollution. Poor ventilation can cause an accumulation of contaminants within, which will have a detrimental effect on the air quality.

To improve air quality and safeguard both the environment and human health, it is crucial to address these sources and put in place efficient pollution control methods. Together, governments, businesses, and people can reduce emissions and adopt greener practices and technologies.

1.4 Air pollution criteria

The set of recognized principles or standards used to evaluate and control air quality are referred to as air pollution criteria. These standards are intended to safeguard the environment and public health from dangerous air pollutants. Governmental or environmental bodies normally decide and set the criteria after conducting in-depth scientific study and health evaluations. Among the most important factors in air pollution are these:

- Particulate Matter (PM_{10} and $PM_{2.5}$): Small solid particles and liquid droplets suspended in the air make up particulate matter (PM_{10} and $PM_{2.5}$). Particles with a diameter of 10 µm or less are referred to as PM_{10}, while those with a diameter of 2.5 µm or less are referred to as $PM_{2.5}$. Both kinds of particles have the potential to have detrimental impacts on health by entering the respiratory system deeply.
- Ground Level Ozone (O_3): Ozone at ground level (O_3) is a secondary pollutant that is created when sunlight reacts with volatile organic compounds (VOCs) and nitrogen oxides (NOx). For sensitive groups like children, the elderly, and people with respiratory diseases, high quantities of ozone can cause respiratory problems.
- Nitrogen Dioxide (NO_2): This reddish-brown gas is predominantly produced when fossil fuels are used in motor vehicles and industrial processes. It may aggravate pre-existing respiratory disorders and irritate the respiratory system.
- Sulphur Dioxide (SO_2): Sulphur dioxide is a gas that is created when sulphur-containing fossil fuels like coal and oil are burned. It can irritate the respiratory system and help particulate particles to develop.
- Carbon monoxide (CO) is a colourless, odourless gas that is created when fossil fuels burn partially. It has the potential to hinder the body's ability to transfer oxygen and is particularly dangerous in small areas.
- Lead (Pb): Lead is a poisonous heavy metal that can be dispersed into the air by a variety of activities, including those used in industry and gasoline. Lead exposure can affect neurological development, especially in young children.

The requirements for each pollutant's exposure or concentration are typically determined for particular time intervals (such as hourly, daily, or annual averages). These requirements differ from nation to nation and are periodically revised in light of fresh scientific findings and medical investigations. Implementing emission controls, air quality management programs, and other steps to lower pollution levels and safeguard public health are frequently necessary for compliance with these criteria.

Table 1 : Air quality index as per WHO

POLLUTANT	STANDARD VALUE
$PM_{2.5}$ (µg/m³)	25 µg/m³
PM_{10} (µg/m³)	50 µg/m³)
CO_2 (ppm)	1000 ppm
HCHO (ppm)	0.1ppm

Source- WHO, World Health Organization (WHO), Global Update 2005, Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide, World Health Organization

1.5 Air pollutants characteristics:

1.5.1 Physical characteristics:

Air pollutants are compounds in the atmosphere that can be dangerous to other living things, the environment, and human health. These contaminants may exist naturally or may be produced by human activity. Depending on their composition and source, air pollutants' physical qualities might differ greatly. Following are some typical physical attributes of air pollutants:

- ✓ Particle size: Airborne particles can range in size from coarse (more than 10 µm) to small (less than 2.5 µm) to ultrafine (less than 0.1 µm). The distance the particles may travel through the air and the depth to which they can enter the respiratory system when inhaled depend on their size.
- ✓ State of Matter: Air contaminants can be found in solid, liquid, or gaseous phases. When compared to gases like carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen oxides (NOx), and Ozone (O_3), Particulate matter (PM) and some Volatile Organic Compounds (VOCs) are often found in solid or liquid states.
- ✓ Density: Different air pollutants have different densities, which has an impact on how they move and disperse in the atmosphere. Pollutants that are heavier have a tendency to settle closer to the ground whereas those that are lighter may spread across wider distances.

- ✓ Volatility: At room temperature, chemicals known as volatile organic compounds (VOCs) readily evaporate into the atmosphere. Their erratic behaviour impacts their capacity to produce ground-level ozone and contribute to smog.
- ✓ Solubility: Acid rain is created when certain pollutants, such as sulphur dioxide (SO_2) and nitrogen dioxide (NO_2), react with moisture in the air and dissolve in water vapour.
- ✓ Reactivity: Air pollutants have the potential to react chemically with other elements in the atmosphere to produce secondary pollutants. Ozone, for instance, is a secondary pollutant that is produced when sunlight reacts with volatile organic compounds (VOCs) and nitrogen oxides (NOx).
- ✓ Colour and Odour: Some contaminants may have distinguishable colours and odours that aid in locating them. For instance, Hydrogen Sulphide (H_2S) creates a distinct smell of rotten eggs, and nitrogen dioxide (NO_2) can give the air a brownish hue.
- ✓ Persistence: Some air pollutants have the ability to linger in the atmosphere for a long time, which could cause long-distance transport and have global effects. Examples of long-lasting greenhouse gases include carbon dioxide (CO_2).

It is crucial to remember that the negative effects of air pollutants on human health and the environment rely on a variety of factors, including their concentration, length of exposure, and individual sensitivity. In order to determine and manage the effects of air pollution on ecosystems and public health, regulatory authorities and environmental experts continuously monitor air quality.

1.5.2 Chemical characteristics:

Air pollutants are elements in the atmosphere that can harm other living things, the environment, and human health. They may be discharged as a result of human or natural activity. Following are a few typical chemical traits of air pollutants:

- ✓ Tiny solid or liquid particles suspended in the air are known as particulate matter, or PM. PM can be several shapes and compositions. Typical sources include industrial pollution, construction and agricultural dust, and vehicle exhaust.
- ✓ Nitric oxide (NO) and nitrogen dioxide (NO_2) are both considered to be nitrogen oxides (NOx). They are created during combustion processes, which are found in industrial facilities, power plants, and automobile engines.

- ✓ Sulphur dioxide (SO_2) is a gas that is created when sulphur-containing fossil fuels like coal and oil are burned.
- ✓ Ozone (O_3): While ozone in the upper atmosphere (stratosphere), which shields us from damaging UV rays, is beneficial, ozone at ground level is a dangerous air pollutant. In the presence of sunshine, it is created by chemical interactions between NOx and volatile organic compounds (VOCs). VOCs are produced by industrial operations and by-products like the fumes of gasoline.
- ✓ Carbon monoxide (CO) is a colourless, odourless gas that results from incomplete burning of carbon-containing fuels including gasoline, wood, and coal. Common sources include home heating systems and vehicle emissions.
- ✓ Volatile Organic Compounds (VOCs) are a class of compounds that include carbon and are easily evaporative into the atmosphere. They come from a variety of sources, such as industrial operations, paints, solvents, and automobile emissions.
- ✓ Ammonia (NH3): A gas produced by agriculture, ammonia.
- ✓ Lead (Pb): Lead emissions were once a substantial air pollutant from sources including leaded gasoline and industrial operations, but they have significantly decreased as a result of regulatory actions.
- ✓ Mercury (Hg): Coal-fired power stations and specific industrial operations may emit mercury. It is an extremely dangerous heavy metal that can build up in the food chain.
- ✓ Radon (Rn): From the ground, radon is a radioactive gas that can penetrate into structures. It is a severe health problem and a natural contaminant.

1.5.3 Biological Characteristics:

Because air pollutants can have a wide range of biological properties, they can interact with living things in a variety of ways and have a negative impact on health. Following are some typical air contaminants and their biological characteristics:

- ✓ Small solid or liquid particles suspended in the air are referred to as particulate matter (PM). PM_{10} particles, or those with a diameter of 10 µm or less, and $PM_{2.5}$ particles, or those with a diameter of 2.5 µm or less, are two examples of the various sizes of these particles. PM can cause breathing and cardiovascular issues when it is breathed into the respiratory system. Even in the bloodstream, ultrafine particles can harm different organs.

- ✓ Three oxygen atoms make up the highly reactive gas known as ozone (O_2). When ozone (stratospheric ozone) is present at high altitudes.
- ✓ Nitrogen Dioxide (NO_2) is a reddish-brown gas that is produced as a result of emissions from industrial activities, power plants, and automobiles. It can result in respiratory issues, particularly in those who already have respiratory diseases like asthma.
- ✓ Specifically in power plants and industrial processes, burning fossil fuels produces sulphur dioxide (SO_2), a strong gas. It can irritate the respiratory system and help particulate particles to develop.
- ✓ Carbon monoxide (CO) is a gas that has no colour or smell and is created when carbon-containing fuels burn partially. When it binds to hemoglobin in red blood cells, it lessens the capacity of those cells to carry oxygen. Headaches, light-headedness, and in extreme circumstances, death, can all be brought on by high CO levels.
- ✓ VOCs, or volatile organic compounds, are a class of organic substances that can vaporize and disperse into the atmosphere. They originate from a variety of places, including solvents, consumer goods, and vehicular emissions. VOCs may cause harm to the liver, kidneys, and central nervous system in addition to irritation of the eyes, nose, and throat. They can also contribute to the creation of ground-level ozone.
- ✓ Leaded gasoline (though its use has greatly declined) and industrial operations are two sources of lead (Pb), a heavy metal contaminant that can enter the air. Lead dust inhalation can cause neurological damage, especially in children, which can result in behavioural and developmental problems.

1.6 Sources of air pollution in Kolkata:

In Kolkata, transportation is the primary source of pollution. There are a lot of vintage gasoline and diesel vehicles on the road nowadays. These cars are unregulated and produce a lot of dangerous emissions. Over 95% of the population, according to some sources, is caused by diesel-powered cars and trucks. Numerous other modes of public transportation, including open buses, trams, and cars, are also available but are in bad shape. In addition, the large number of vehicles, both personal and commercial, contributes to traffic and congestion, which increases fuel waste and commute times.

Thermal power facilities that are located in and around the city pollute the air and the water. The city region is home to a large number of small-scale companies, which contribute to pollution and make it difficult for those nearby to breathe.

One of the other problems in Kolkata is the use of plastic, despite numerous government attempts to forbid it. The same has been implemented more slowly in Kolkata. Many individuals use plastic bags every day, and they either burn them or throw them into water. Burning plastic releases toxic fumes into the air as well as a foul smell.

It is common practice to burn trash. There are enormous dumpyards where massive amounts of waste are burned frequently, polluting the air.

Construction dust, including cement, wood waste, and other building materials, are produced as a result of new structures being built due to population growth and urbanization. Trees are being cut down to make room for new buildings, which does not provide any fresh air.

Domestic combustion largest single source of $PM_{2.5}$ and PM_{10} close stove and open fires responsible for 38% of $PM_{2.5}$.

70% to 80% of $PM_{2.5}$ made up fine particulate matter like Nitrate, Sulphates, Ammonia, Elemental Carbon, Organic Carbon 40% to 50% of course particulate matter are made up by Aluminium, Sulphur ,Potassium , Calcium , Iron, which is diameter of 10 µm>2.5 µm.

The Particulate matter have diameter with 10 µm are removed by human nostrils during inhalation but some particulate matter's less than 10 nm can enter our respiration system.

The composition of particulate matter cause visual effect , it can reduce visibility of yellow colour. It causes lungs cancer , asthma ,premature mortality. Ambient level of $PM_{2.5}$ should be less than 25ug/m³ according to WHO. In India level of $PM_{2.5}$ is 40ug/m³ at annual average and 60 ug/m³ at the daily average according to CPCB.

Ambient particulate matter may be carries of heavy metals, acid and carcinogenic , organic compound may have negative effect on human health and ecosystem, vehicular emission is responsible for high level of air pollutants like SPM,RSPM, NOx and other organic and inorganic matter that can effect human and environmental health. Motor vehicle emission consider as a major cause of urban areas pollution.

1.7.Health Effects:

- **Cardiovascular Disease:** An increase of 10ug/m³ in $PM_{2.5}$ increased heart failure, fine particulate matter can block blood vessel and its short term daily exposure by post menopausal women to NOx and increases risk of hemorrhagic stroke also increases a pregnant woman’s risk for dangerous chances in blood pressure .In India ,22% of deaths from ischemic heart disease are attributable to outdoor fine particles.

- **Respiratory Disease:** Air pollution can effect lung development. Some particles pollutants enters through nostril then its can enter by particles deposited in respiratory rout in sufficient amounts can induce inflammation. Inflammation may damage or kill cells , also can damage lung system aggravates .Air pollution also causes of reduction in pulmonary function and increased airway inflammation and responsiveness. It can also cause of COPD and respiratory infection.
- **Effects on Children:** Main reason lead to to more school absence due to higher level of air pollution cause of short-term respiratory infection. Pregnant woman exposed in air pollution it should be cause of premature birth, low weight birth children..

CHAPTER 2:OBJECTIVE

The objectives of the present study are-

1. To assess the spatial variation of indoor air quality parameters.
2. To investigate the seasonal variation (Monsoon , Summer and Winter season) of indoor air quality parameters.

CHAPTER 3: REVIEW OF LIERATURE

3.1 National Scenario:

Daisey*et al.*,2003, identified the most frequently reported building-related health complaints involving schools by reviewing the literature on indoor air quality (IAQ), ventilation, and building-related health issues. They analysed evidence on the causative links between pollutant exposures and health symptoms as well as existing data on ventilation rates, carbon dioxide (CO_2) concentrations, and indoor air pollutants that are related to symptoms. Data on CO_2 levels and reported ventilation clearly suggest that many classroom's ventilation is insufficient, which could cause health issues. Design or restoration efforts should put a lot of emphasis on providing adequate ventilation. Formaldehyde (HCHO), total volatile organic chemicals, and microbiological pollutants are recorded. Low HCHO levels (<0.05 ppm) were possibly associated with elevated risks for cancer, chronic irritation, and allergy sensitivity, but were not expected to produce acute irritating symptoms. Allergens were among the reported microbiological pollutants.

Kosonen *et al.*, 2004 discussed in his study that productivity loss in air-conditioned office buildings in relation to perceived indoor air quality. The impact of increased ventilation efficiency on productivity is calculated using a new productivity calculation model that is based on pollution loads and contaminant removal efficacy. The results demonstrate that, in various types of office work, the proportion of dissatisfied is a good predictor of productivity loss caused by indoor air quality. The percentage of dissatisfaction can be calculated using units. By boosting exterior airflow rate, reducing pollutants, and enhancing ventilation efficiency, such as via displacement ventilation, productivity may be increased. When there is one person per 10 square feet (0.1 olf/m^2) and little air pollution, the overall sensory There is a 0.2 olf/m^2 pollutant load. In office areas, the minimum permitted outdoor airflow rate ranges from 0.5 to 1.5 l/s per m^2. This suggests that when employing the minimal airflow rate design method, a productivity loss of 5–9% should be accepted. Comparing displacement ventilation to a standard mixing system, it is possible to dramatically boost production while improving indoor air quality between various systems employing the same airflow rate, the impact of the pollutant removal efficacy on the productivity loss ranges from 0.5 to 2%.

Mendell *et al.*, 2007 showed the comparison between employees with and without eczema for the indoor work environment. At 56 locations, exposure was measured, and 173 workplaces were modelled. In addition to assessing the stability of the tear film, lysozyme in nasal lavage, immunoglobulin E (IgE), and phadiatop, questionnaires were also used to obtain data on symptoms and perceptions. In order to account for age, gender, strain, current smoking, and respiratory illnesses, multiple regression models were used. Eczema sufferers thought the temperature was too high yet this perception was unrelated to the actual temperature. They reported higher general and mucosal symptoms, increased lysozyme in nasal lavage linked to increased air temperature differential between 6 and 10 am, and "dry or flushed facial skin" linked to PM_{10} (airborne particulate matter smaller than 10 millimeters in diameter). PM_{10} had the biggest impact.

Wargocki *et al.,* 2008 designed a study in five pairs of mechanically ventilated classrooms that received only external air in the winter and early spring of 2005. Two separate field intervention trials with a combined total of around 190 students were conducted. Each set of classrooms was in a different institution. When measuring student performance, electrostatic air cleaners were deployed in classrooms and either turned on or off to change the particle concentrations. While the filters used in other schools were not altered, in one school the utilized supply-air filters in a ventilation system without recirculation were also replaced with new ones to alter the quality of the air in the classroom. Blind crossover research on ten to twelve-year-old children was used to determine the conditions for one week at a time. Students participated Six exercises that were part of regular lectures and illustrated various areas of coursework asked students to describe their perceptions of their surroundings as well as the severity of any symptoms. Soon after the students left, an adult sensory panel evaluated the air quality in the classrooms. The amount of particles in the classrooms was significantly reduced when the electrostatic air cleaners were operating. The impact increased as the outdoor air supply rate decreased. This reduction had no discernible influence on how well the students performed on their assignments, how the kids felt about the classroom, how intense their symptoms were, or how the sensory panel assessed the air quality. This shows that particle removal outside of the pollen season has no immediate (acute) consequences. The results varied after the installation of new filters, however this is thought to be caused by the orderly and imbalanced display of filter conditions as well as the fact that the filters in use only retained a little amount of dust.

In Delhi City, a study (**Goyal *et al.,* 2009**) on indoor-outdoor RSPM mass concentration monitoring was conducted in a classroom of a naturally ventilated school building next to an urban street. In order to account for hourly, daily, weekly, monthly, and seasonal variations in pollutant concentrations, the monitoring has been scheduled to take place for a year beginning in August 2006 and ending in August 2007. Weekdays Monday, Wednesday, and Friday and weekends Saturday and Sunday from 8:00 a.m. to 2:00 p.m. are included in the monitoring schedule. To correlate the concentrations of indoor-outdoor RSPM with meteorological characteristics, such as temperature, rH, pressure, wind speed and direction, and traffic parameters, such as its kind and volume, have been recorded simultaneously. In order to determine the relationship between ventilation rate and indoor a concentration of particles. The study's findings show that RSPM concentrations in classrooms frequently exceed allowable levels during all monitoring times, including weekends and holidays, and that this could constitute a health risk to students if they are exposed. I/O is larger than 1, indicating that the building envelop does not offer protection from external contaminants for all particle sizes. Additionally, a considerable impact of traffic, ventilation rate, and meteorological conditions has been seen on I/O. Higher I/O for PM_{10} indicates that indoor sources are present in the classroom, and that everyday activities have a significant impact on indoor concentrations of these sources.

The study's (**Saraga *et al.*, 2011**) main objectives was to pinpoint the primary causes of indoor air pollution in three diversely used interior environments: a museum, a printing factory, and an office. Particulate matter (TSP, PM_{10}, and $PM_{2.5}$), inorganic pollutants (NOx, SOx, and O_3), and organic pollutants (BTX, and formaldehyde) were also tracked for this reason. There were significant differences between the three sites in regards to elements including the type of indoor activities, the emissions from the existing equipment, the quantity of inhabitants, the ventilation pattern, and the outdoor background. While all of them were assessed in the experimental campaigns, the average levels of $PM_{2.5}$ (151 g/m³), benzene (69.4 g/m³), toluene (147 g/m³), SO_2 (47 g/m³), and NO_2 (96.6 g/m³) were the highest values in the printing sector. In the museum, formaldehyde had the highest concentration (50.5 g/m³). The non-smokers' office was determined to have the highest concentration of O_3 (238 g/m³), while the printer presser industry (11.0 g/m³) had the lowest. It appears that the sites' geographic location also has a big impact. The benzene/toluene ratio pointed to traffic as a significant cause. In addition, the printer factory and the museum both in urban areas had modest amounts of ozone, while offices in suburban areas had significantly greater levels, indicating that the substance originated outside.

Majumdar *et al.*, 2012 conducted a study by using three different types of chalk sticks on a board, airborne PM_1, $PM_{2.5}$, PM_5, and PM_{10} are produced. The particle size distribution of chalk dust that falls when writing and dusting the board was investigated by a portable aerosol spectrometer and particle size analyzer. While using 'Clean-Write' chalk during writing, 'Local Gypsum' chalk caused the greatest rise in airborne particle matter. 10% of the chalk dust particles best for writing came from "Clean Write" (0.5 m), followed by "Abroad Quality" (0.67 m), and "Local Gypsum" (1.15 m), while 50% of the chalk dust particles came from "Abroad Quality" (0.67 m) of the particles best suited for writing came from "Abroad Quality" (5.12 m), followed by "Clean Write" (6.36 m), and "Local Gypsum" (77.65 m). 'Clean Write' had the finest 10%, 50%, and 90% of particles in dusting samples, followed by 'Abroad. 'Quality' and 'Local Gypsum' chalks. The amount of PM_1, $PM_{2.5}$, PM_5, and PM_{10} created by "Clean Write" chalk was the least overall during writing. Although there may not be much risk for long-term exposure in classrooms, short-term exposure to airborne tiny chalk particles may be minimal. This research's goal was to give information that would help policymakers take action to reduce the health risk posed by chalk dust in schools.

Goyal *et al.*, 2013 showed the indoor-outdoor (I/O) correlations of particulate matter 10 m (PM_{10}), 2.5 m ($PM_{2.5}$), and 1 m (PM_1) in a mix-use commercial building in Delhi. It was investigated using three naturally and six mechanically ventilated microenvironments (MEs). Investigations are also conducted into the effects of environmental and occupancy factors on PM concentrations during working and non-working hours (i.e., activity and non-activity periods, respectively). The average outdoor PM_{10} and $PM_{2.5}$ concentrations were discovered to be higher above the 24-hour averaged national standard values, indicating a polluted environment around the investigated building. In the chosen MEs, indoor PM concentration was found to be 6–10 times higher during working hours, whereas $PM_{2.5}$ and PM_1

concentrations were 1.5–2 times higher. When compared to $PM_{2.5}$, PM_{10} indoor concentration changes were the greatest (17.1-601.2 g/m³).

There is limited and conflicting epidemiological evidence on the relationship between coarse particles (PMc; particulate matter with an aerodynamic diameter between 2.5 and 10 m) and respiratory morbidity (**Qiu *et al.*, 2014**). Pneumonia is an infection-related lung inflammation that can be aggravated and provoked by exposure to PMc. Hospitalizations for emergency pneumonia were substantially correlated with PMc and $PM_{2.5}$ levels. The number of emergency hospitalizations for pneumonia increased by 3.33% (95% CI 1.54% to 5.15%) for every 10 g/m³ increase in PMc over the previous 4 days (lag_0-lag_3). The effect estimates of PMc were resistant to changes in $PM_{2.5}$, NOx, or SOx, but were diminished by the addition of O_3. It's possible that women, kids, and older persons are more susceptible to PM exposure.

The goal of the study (**Almeida *et al.*, 2016**) was to evaluate how vulnerable groups were exposed to chemical components in air particles and how much of those chemicals they ingested. Particles were collected from gyms, senior living facilities, and schools, and their chemical composition was ascertained using the k 0-INAA method. Results reveal that although all of the microenvironment's outdoor levels of similar elements were measured, the inhaled doses experienced by each of the vulnerable population groups varied significantly. This suggests that measurements of outdoor air concentrations do not accurately represent population exposure to particles and particular elements and the corresponding dose.

Chamseddine *et al.*, 2019elaborated several air quality indicators, including carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM_{10} and $PM_{2.5}$), and total volatile organic compounds (HCHOs) to measure seasonal exposure in a hospital environment. With a focus on capturing seasonal fluctuations, we looked studied the distribution and variance of indoor and outdoor pollutant concentrations in 12 working areas across three hospitals. To measure the relative impact of interior sources on air quality compared to outdoor sources, we examined correlations between observed indoor and outdoor levels. Our findings showed that while measured $PM_{2.5}$ and PM_{10} concentrations at some locations above the limits by a factor of two to three, indoor and outdoor CO levels were below air quality standards/guidelines. Generally speaking, throughout the summer season, we recorded higher indoor PM levels. Especially during localized desert storm incidents. High correlations between indoor and outdoor $PM_{2.5}$ (r between 0.83 and 0.92) and PM_{10} (r between 0.74 and 0.86) levels, In contrast, interior CO_2 and HCHO levels were higher than outdoor levels during both the warm and cold seasons, with I/O ratios more than 1 at all sampling sites. The ramifications of excessive PM exposure are discussed in our paper's conclusion, along with a suggested management approach for reducing such exposure in hospitals.

Shrubsole*et al.*,2019 showed poor indoor air quality can have a number of harmful implications on health. Buildings are typically exposed to high amounts of pollution from both indoor and outdoor sources. Despite the fact that there are a variety of indoor airborne contaminants, the current review concentrates on volatile organic compounds (VOCs) and takes into account the current Total Volatile Organic Compounds (HCHO) regulations in addition to additional guideline values to manage levels in the indoor environment. We looked at the most recent scientific evidence demonstrating the presence of different VOCs in buildings across the globe as well as the available toxicological evaluations for the specific VOCs that may pose a threat to human health. For each component, including acetaldehyde, pinene, d-limonene, formaldehyde, naphthalene, styrene, tetra-chloroethylene, and toluene, we looked at existing health-based general population indoor guidelines for long- and short-term exposure with a combination of xylenes.

A study by **Deng *et al.*, 2019** evaluated how the ambient particulate matter or particles have been linked to morbidity and death all around the world. Predicting the deposition of particles from various sources in the human lung is the goal of this investigation. A one-dimensional lumped "trumpet" model with a variable cross-sectional size was used to represent the entire lung, which consists of 24 generations of branches from the trachea to the alveoli. To examine the transit and deposition of particles in the lung model, the aerosol dynamics equation was numerically solved using the finite difference method. The size and density of particles from diverse sources were assumed to vary. We discovered that, generally speaking, coarse particles (> 2.5 m) were the predominantly through sedimentation and diffusion in the pulmonary (P) area, while small particles (2.5 m) were deposited in the trachea-bronchial (TB) region by impaction. However, sedimentation can deposit low density coarse particles in the P zone compared to traffic particles, which are fine and have a high density, our findings showed that soil particles, which are coarse and have a low density, were deposited in the deep lung more frequently. Modelling of particle deposition in the human lung revealed that the health risks posed by coarse particles produced by crustal sources may be on par with those posed by fine particles produced by combustion sources.

Shriram *et al.*, 2019 illustrated Carbon dioxide (CO_2) and human bio-effluents accumulation in constructed settings as a result of lower ventilation rates and increasing occupant density. Researchers have looked into the correlation between impaired cognitive performance and CO_2 and bio-effluents utilizing physiological measurements. The fundamental mechanism for the decline in cognitive performance when exposed to elevated CO_2 concentrations with bio-effluents has not, however, been revealed by any study. It is hypothesized that the decline in cognitive function is caused by CO_2 retention in humans, which is brought on by a decreased gas transport in the lungs. The study's objective was to measure lung function at various CO_2 concentrations with bio-effluents and look into how those bio-effluents affected the gas exchange mechanism. Eight healthy male subjects participated in a spirometric analysis.

Lueker *et al.*, 2020 conducted an experimental examination on the level and causes of home air pollution in two types of low-income dwellings in Mumbai . In Dharavi, one of the biggest slums in the world, and two adjoining settlements that exemplify Mumbai's current slum redevelopment program, experiments were conducted. To comprehend the facets of tenant behaviour that affect indoor air quality, household surveys were done. To measure the levels of CO and particulate matter ($PM_{2.5}$), multi-pollutant logging sensors were placed outside and inside of the units. Although it is frequently believed that gas cook-stoves and rehabilitation architecture offer better indoor air quality than in traditional slums, field monitoring and occupant behaviour surveys showed that indoor pollution levels remained constant in both typologies even after infrastructure improvements and widespread use of gas cook-stoves.

Measurements of indoor $PM_{2.5}$ ranged from 150 to 300 g/m³ , which is significantly higher than recommended levels by the World Health Organization (WHO). The relevance of particle deposition phenomena and ambient-sourced $PM_{2.5}$ in indoor environments is highlighted by the fact that $PM_{2.5}$ indoor/outdoor (I/O) ratios rose during cooking times but were otherwise less than 1.0 in more than half of logged instances in rehabilitation units. This study highlights the need for architectural design principles and improved indoor air quality treatments in order to reduce the impact of both indoor and outdoor pollution sources while respecting culturally-normative occupant behaviour.

In a study (**Asif *et al.*, 2020**) indoor CO_2, temperature, and relative humidity levels were monitored during a two-season period winter and summer in naturally ventilated classrooms of a primary school. For one week, parameters including occupancy and non-occupation hours were recorded at 1-min intervals. For a sizable portion of the occupancy period, CO_2, T, and RH exceeded ASHRAE suggested limits. Air exchange rates (AERs) and minute-by-minute ventilation (VRs) were co2mputed for the hours of occupancy. The results revealed a significant difference in indoor characteristics between hours of occupancy and non-occupancy ($p< 0.05$). Thermal comfort measures showed a substantial difference between the two seasons even if indoor CO_2 levels did not change. Average AERs and VRs were found to be far below recommended ASHRAE levels, ranging from 1.4 to 10.6 h-1 and 1.1 to 6.3 l/s/person, respectively. In the study, a system dynamics (SD) based model was created and utilized to generate VRs (minute-by-minute and averaged) in order to estimate indoor CO_2 concentrations. The findings of the created SD-based model shown strong correlation (>0.98 for all classrooms, utilizing minute-by-minute VRs) and minimal root mean square error with observed CO_2 concentration. Similar to this, minute-by-minute VRs fed into models demonstrated more realistic simulation than VRs averaged across a session. The final step was to CO_2 concentration using ASHRAE and REHVA suggested VRs (8 and 3 l/s/person, respectively), where the former successfully kept CO_2 levels below 1000 ppm while the latter failed to sustain claimed limits of 1500 ppm.

Stamp *et al.*, 2020 In a case study involving a hospital, school, and office building that represents a cross-section of the UK non-domestic sector, long-term, continuous air quality monitoring has been conducted alongside seasonal passive sampling. The goal of this strategy was to use cutting-edge sensor technology to better understand how changes in indoor air quality over time relate to both building operations and occupant behaviour. The findings of how the interaction between indoor and outside air changes significantly over short and long periods of time, with distinct behaviours then being observed across various sources of pollution with extremely low interior $PM_{2.5}$ concentrations, the mechanically ventilated hospital and school buildings show the efficiency of particulate filters. However, rapid breathing rates and a lack of oxygen. The hospital had the greatest indoor NO_2 concentrations and the highest corresponding indoor-outdoor ratio due to the lack of any filtration of NO_2. NO_2 levels can peak indoors in the morning and the evening due to traffic, with the penetration of these peaks depending on the provided ventilation rates. In polluted metropolitan areas without complete filtration, this illustrates the effects of using high ventilation rates during times of high traffic as well as the drawbacks of CO_2 based demandcontrolled ventilation systems. The naturally ventilated office then exhibits considerable seasonal fluctuations, with increased ventilation apertures leading to indoor NO_2 concentrations exceeding those in the winter despite large drops in ambient levels. On the other hand, greater ventilation rates are shown to result in lower concentrations of indoor pollutants, highlighting the delicate balance between the dilution of indoor pollution and the intrusion of external sources. All formaldehyde measurements in the naturally ventilated office exceeded guideline values despite significant reductions from the winter to the summer 21.6 to 11.2 g/m³ . This suggests that improved guidance and product labelling schemes may be needed to achieve these guideline concentrations and reduce associated health risks.

3.2 International Scenario:

Chaloulakou *et al.*, 2002 conducted a field research to look at the carbon monoxide (CO) concentrations inside and outside of a public school in Athens, Greece. A non-dispersive infrared analyzer was used to detect the CO concentrations both indoors and outside simultaneously. In May and June 1999, measurements of the mean hourly CO concentrations within and outside the sampling chamber were made every 24 hours. In December 1999, they were made every 14 hours. The study's goal was to look into the building's attenuation pattern of external pollution levels. According to diurnal concentration fluctuations reported for several days of the week, inside CO concentrations are typically lower than corresponding outdoor levels, and the morning peaks of indoor In comparison to the morning peaks of outdoor concentrations, concentrations display a delay of 1 hour or less. Seasonal variations can be seen in the concentration ratios of indoor and outdoor measurements. A computer program is built and tested using experimental data to assess an indoor air quality model for the prediction of indoor concentration levels created by Hayes. Although there are certain instances when the model is unable to effectively account for abrupt variations in outdoor concentration, overall, the model outputs and indoor concentration measurements show good agreement. The difference between the daily maximum indoor concentration as anticipated and as measured varies between 0.88 and 1.23. The regression line connecting hourly measurements to model predictions Indoor concentrations have a slope of 0.64 and a coefficient of determination (R^2) of 0.69 during a continuous 96-hour period

Guo *et al.*, 2008 conducted a study in September 2006, where a primary school undertook a 2-week intense measurement campaign of interior and outdoor air pollution to look at indoor-outdoor correlations of particle number (PN) concentrations and the effect of air exchange rate (ACH) on the indoor PN concentration. The ACHs in the classroom were examined under various settings related to window opening, air conditioner (A/C) operation, and fan operation. The windows were closed, the A/C and fans were turned off, and as expected, the lowest ACH was discovered. On the other hand, while the windows were open and the A/C, fans, and lights were all on, the greatest ACH was recorded. In the absence of indoor sources, the examination of the PN I/O ratios at various ACHs reveals found when the windows were closed, the A/C and fans were turned off, the mean I/O ratio was 0.6210007 ; 0.5240.023; and 0.5020.029, respectively, when the windows were closed, the A/C was turned off, and the fans were turned on. The effect of outdoor PN concentration on I/O ratios at various ACHs was examined to better understand the connection between indoor and outside PN concentrations. It was discovered that the I/O ratio and outdoor PN concentration at various ACHs had a power trend-line relationship with the equation I/O ratio=A PN out B (A and b are coefficients, and PN out is outdoor PN concentration), which suggested that the penetration efficiency decreased with rising outdoor PN concentration. The first time ever We discovered that the concentration of nano-particles, which have been shown to have higher deposition rates and lower penetration efficiencies, increased in tandem with an increase in the outdoor PN concentration. The study demonstrated a considerable impact of ACH on indoor PN concentrations under steady outside PN concentrations based on the aforementioned equation. Generally speaking, the indoor PN concentration decreased with increasing ACH.

A study (**Missia *et al.*, 2010**) was carried out as part of the BUMA (Prioritization of Building Materials Emissions as Indoor Pollution Sources) initiative, which is sponsored by Europe and aims to measure exposure to substances released into indoor air. Field campaigns were conducted in five different European cities: Milan, Copenhagen, Dublin, Athens, and Nicosia. These initiatives included weekly measurements of concentrations in each city's two public buildings and two private homes. Passive sampling was used to measure BTEX, terpenes, and carbonyls at two locations inside the structure and one outside. The Field and Laboratory Emission Cell (FLEC) has also been used to measure the VOC emissions from a number of different building materials. The findings regarding indoor concentrations of substances like formaldehyde (1.2-62.6 g/m^3) and acetaldehyde (0.7-41.6 g/m^3) Depending on the building style, age, etc., indoor sources of toluene (0.9-163.5 g/ m^3), xylenes (0.2-177.5 g /m^3), and acetone (2.8-308.8 g/ m^3) have varied and been somewhat considerable. Depending on the age and nature of the structure, different indoor concentrations of these chemicals exist. A little over 40% of the indoor air quality levels were caused by building materials.

Branis *et al.*, 2011 looked at the mass concentration, mineral makeup, and shape of particles that kids in Prague, Czech Republic's, urban, suburban, and rural elementary school gyms re-suspended during class-time physical instruction. The particle matter was sampled using cascade impactors. Gravimetry, energy dispersive X-ray spectroscopy, and scanning electron microscopy were used to quantify two fractions of coarse particulate matter (PM_{10} and $PM_{2.5}$). The number of pupils participating in physical exercise and the quantity of physical education hours were also tallied as markers of human activity. The average $PM_{2.5}$ 2.5 concentration and PM_1 1.0 mass concentration were lower outside (4.1-7.4 g/m^3 and 2.0-3.3 g/m^3 , respectively) than indoors (13.6-26.7 g/m^3 and 3.7-7.4 g/m^3 , respectively). On days when physical activity was planned, the indoor concentrations of coarse aerosol were higher.

Prior research provided strong support in the first decade of the twenty-first century that fine particulate matter pollution had a negative impact on both children's and adults' health. Wide-ranging effects include decreased lung function, acute and chronic bronchitis, bouts of asthma, and a rise in hospitalizations for respiratory and cardiac conditions. Due to an increase in fine particulate matter in the ambient air, the rates of prior diseases have risen in the Gaza Strip over the past ten years. The objectives of the study (**Elbayoumi *et al.*, 2013**) was to track the mass concentrations of fine particulate matter ($PM_{2.5}$, PM_1) indoors and outdoors in 12 naturally ventilated schools (36 classrooms) in the Gaza Strip and evaluate the impact of outdoor pollutant concentrations on the indoor concentrations using to calculate the probability of fine particulate inhalation during student activities. For one and a half months of 2012's winter, measurements of fine particles $PM_{2.5}$ and PM_1 were made between the hours of 7:00 am and 12:00 am, measurements of fine particulate matter in each classroom and outdoors were made. In the meantime, information about student's after-hours activities was acquired. According to the findings, interior $PM_{2.5}$ and PM_1 concentrations were 197.4 and 34.6 g/m³ , respectively, while outdoor $PM_{2.5}$ and PM_1 concentrations were 134.7 and 32.3 g/m³ . Additionally, the data demonstrate that while the I/O ratios were generally close to unity throughout the school, there were statistically significant differences in the mean I/O values for both $PM_{2.5}$ and PM_1 among various buildings.

Jurado *et al.*, 2014 in his study compared 30 classrooms—15 air-conditioned (AC) and 15 naturally ventilated (NV)—to assess the indoor air quality at Brazilian institutions. Indoor carbon dioxide (CO_2), temperature, relative humidity (RH), wind speed, viable mould, and airborne dust levels were the relevant variables. Compared to the AC rooms, the NV rooms had a higher concentration of mould (1001.30 125.16 and 367.00 88.13 cfu/m³ , respectively). In both NV and AC classrooms, the average indoor airborne dust concentration was higher than the Brazilian norms (80 g/m³). The CO_2 concentrations in the AC rooms (1433.62 252.80 and 520.12 37.25 ppm, respectively) were substantially higher than those in the NV rooms. Student's health is impacted by the indoor air quality in Brazilian university classrooms. As a result, interior air pollution must be taken into account.

Ahmed *et al.*, 2015 in his study used standards and recommendations were established by numerous international organizations to assess an acceptable level of air quality in both indoor and outdoor areas. This paper's major goal was to create a thorough evaluation of the Indoor Air Quality (IAQ) standards and other values that are already in use. The current study served this objective by summarizing the major criteria and recommendations for significant indoor air contaminants and degrees of thermal comfort created by several international organizations. These organizations and agencies include the World Health Organization (WHO), the National Health and Medical Research Council (NHMRC) of Australia, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Hong Kong Environmental Protection Department (HKEPD), and others.

The main goal of this study (**Sarbu *et al.*, 2015**) was to evaluate thermal comfort using subjective and experimental measurements in two air-conditioned classrooms at a university, where the air-exchange rate is guaranteed by natural ventilation, based on the predicted mean vote (PMV) and predicted percent dissatisfied (PPD) indices. The interior environmental conditions were good, and every circumstance fell within the comfort range. In both seasons, the mean PMV index values vary from 0.55 to 0.69, and the mean PPD index values range from 11.66 to 15.04%. In situ measurements are also used to look into the impact of the air conditioning system and manually operated windows on CO_2 concentration and thermal comfort metrics during the cooling season. When there is no cooling the air temperature is higher than the 27 °C comfort threshold due to the ventilation system and rates. Additionally, the CO_2 concentration rises above the permitted limit, reaching a value of 2400 ppm, and the PMV and PPD indices have values of 0.87 and 21%, respectively. When the windows are manually opened, the CO_2 level significantly drops to 1500 ppm. When the cooling system is on in the room, thermal comfort is noticeably increased (PMV = 0.34, PPD = 7.4%). The creation of a prediction model for academic achievement during the cooling season is the paper's secondary goal. Application of this model reveals that learning outcomes can be significantly impacted by the indoor environment. Last but not least, a simulation model for the PMV-PPD's Transient System Simulation (TRNSYS) application.

Morawska *et al.*, 2017 demonstrated that one of the biggest environmental concerns humans face is exposure to airborne particulate matter. Since most individuals spend their time indoors, it is important to know where the particles are coming from in order to reduce this danger. Furthermore, as the PM mass/number size fractions come from many sources, this question needs to be addressed independently for each of them. Numerous research had been carried out for particular indoor settings or conditions. Here, our goal was to look beyond the peculiarities of particular research and determine whether there are any trends in exposure routes that may be generalized to houses.

Mandin *et al.*, 2017 showed that the European project OFFICAIR sought to increase knowledge about indoor air quality (IAQ) in modern office buildings, that is, buildings that had recently been constructed or renovated. In the summer campaign (2012), 37 office buildings took part, while in the winter campaign (2012–2013), 35 office buildings did. For each building, four rooms were looked into. Twelve volatile organic compounds, seven aldehydes, ozone, nitrogen dioxide, and particulate matter with an aerodynamic diameter of less than 2.5 m ($PM_{2.5}$) were the targeted pollutants. The concentrations of benzene, toluene, ethyl-benzene, and xylene in OFFICAIR buildings were lower than in other studies of office buildings, whereas the concentrations of - and d-limonene were higher and the concentrations of aldehyde, nitrogen dioxide, and $PM_{2.5}$ were of the same magnitude. Summertime concentrations were found to be substantially greater than Wintertime values. for benzene, d-limonene, and nitrogen dioxide in the summer, for formaldehyde and ozone, and in the winter. No of the season, there was heterogeneity in the amounts of terpene and 2-ethylhexanol within the structures. The concentrations of acetaldehyde and hexanal tended to rise by 4-5% on average with each floor level increase when the average concentrations of the summer and winter concentrations were taken into account, while the concentration of nitrogen dioxide tended to fall by 3% on average with each floor level increase. A first assessment of IAQ's possible effects on irritability and respiratory health was made. Acrolein and d-limonene concentrations were below their projected criteria for irritating and respiratory effects, and formaldehyde and ozone concentrations were below their respective WHO air quality guidelines over the course of five days. Indoor $PM_{2.5}$ values exceeded the 24-hour and yearly WHO ambient air quality recommendations.

Vilsekova *et al.*, 2017 depicted that indoor air pollution can hurt people for a long time if they live in a structure. So, the purpose of his study was to look at the indoor air quality of family homes. 25 homes in various cities throughout the Republic of Macedonia were studied for their interior air temperature, relative humidity, total volatile organic compounds

(HCHO), particle matter (PM), and sound pressure level. The average indoor air temperature and relative humidity were respectively between 18.9 °C and 25.6 °C and 34.1% and 68.0%. Regarding HCHO, it may be said that an overwhelming amount of incidence was observed. 50 to 2610 g/m³ was the range of mean values. In 32% of homes, the recommended amount (200 g/m³) for human exposure to HCHO was surpassed. The concentrations of $PM_{2.5}$ and PM_{10} are calculated to be respectively 16.80 g/m³ to 30.70 g/m³ and 38.30 g/m³ to 74.60 g/m³ . The average sound pressure level was between 29.8 and 50.6 decibels . The relationship between measurement data for temperature, relative humidity, HCHO, $PM_{2.5}$, and PM_{10} and building parameters was examined using R software. Smoke dependence on HCHO and $PM_{2.5}$ is demonstrated by the Vander Waerden test. The impact of the interaction between Renovation and Smoke is demonstrated through permutational multivariate analysis of variance.

Shi *et al.*, 2018 examined mechanical ventilation systems which were not present in buildings with split air conditioners, or SAC buildings. These structures' primary sources of fresh air are natural ventilation and air infiltration, both of which have the potential to bring indoor environments contaminated with particulate matter (PM) from the outside. Two indoor air purification systems, air purifiers (APs) combined with open-window ventilation (AP-Mode) and fresh air units (FAUs) combined with positive pressure control (FAU-Mode), can be used to simultaneously satisfy the fresh air and indoor PM concentration requirements. In order to ascertain which of the two solutions is more suited for various types of SAC buildings, research is necessary. First, a novel approach to estimating the mechanical fresh air supply rate required to maintain a for SAC structures, positive room pressure is recommended. It is determined that if mechanical fresh air supply rate exceeds 3.2 times natural air infiltration rate (i.e., air infiltration rate when a room is not supplied with mechanical fresh air), positive room pressure can be maintained. Then, under various PM2.5 I/O ratios and fresh air supply rates, the clean air delivery rates (CADRs) for APs used in the AP-Mode and FAUs used in the FAU-Mode are computed. The annual energy consumptions of the two techniques are then compared. This is done based on the mass balance principle of indoor particulate matter. As a result, it is shown that using the FAU-Mode in SAC buildings in Beijing, Shanghai, and other cities typically results in lower annual energy usage. Guangzhou, too. Finally, the AP-Mode should be utilized in rooms with fresh air requirements lower than 1 h1, while the FAU-Mode should be used in other situations, taking into account the room air tightness requirement for positive pressure management and the indoor $PM_{2.5}$ concentration upper limit of 35 g/m³ .

Since most of a person's life is spent indoors, indoor air quality (IAQ) is a key problem for human health. Keeping this in mind, the goal of this study (**Asif *et al.*, 2018**) was to examine and compare the indoor air quality (IAQ) and thermal comfort in classrooms of four buildings belonging to a school that each had a different type of HVAC system. On-site continuous measurements of indoor CO_2, temperature, and relative humidity were taken for both weekdays, including working and non-working hours, as well as weekends, at a 1-minute interval. The analysis also made use of data of the relative humidity and temperature outside taken simultaneously. The statistical examination of each classroom's mean hourly readings revealed substantial differences in CO_2 levels between the workday and the weekend ($p < 0.05$). Similar to this, variation in hourly mean thermal comfort parameter values was also shown to be significantly different ($p < 0.05$) between the buildings as well as over the course of the week. However, for one specific building, the variation in hourly mean temperature over weekdays and for all three parameters over weekends for all buildings was not statistically significant ($p > 0.05$). Buildings with non-centralized systems throughout the occupational period had higher CO_2 levels that exceeded ASHRAE guidelines than buildings with centralized systems, it was discovered. Furthermore, it was discovered that the orientation of buildings and the ambient climate had an impact on thermal comfort characteristics.

Bennett *et al.,* 2019 conducted a study on the school children exposure to air pollution in school environment. Children are especially susceptible to the health impacts of air pollution. For the measurement and control of indoor air pollution, it is essential to comprehend the factors that affect the interior air quality in schools. The concentration and causes of air pollution at a primary urban school (5–11 years old) in Wellington, the nation's capital, were examined in this study. Indoor measurements of particulate matter ($PM_{2.5}$, PM_{10}), temperature, humidity, carbon dioxide (CO_2), and nitrogen dioxide (NO_2) were taken over a three-week period in the spring. Hourly air particulate matter samples ($PM_{2.5}$, PM_{10}-2.5) were also collected indoors and outdoors for elemental speciation analysis. indoor PM_{10} levels during the school day were noticeably (p 0.001) greater than outdoor amounts during the day. compared to 8.9 (1.0-35.0, SD 6.8) g m³ , 30.1 (range 10.0-75.0, SD 1.9) g m³ . The majority of the components in indoor PM_{10}, as determined by elemental analysis and receptor modelling of PM samples, were those found in crustal matter (soil), probably carried indoors on children's shoes. There is a need for mitigation strategies to reduce exposure to indoor air pollution at school, such as improved cleaning procedures, a decrease in the use of carpet in schools, and improved ventilation. The main driver of indoor $PM_{2.5}$ was the infiltration of outdoor pollutants inside, with by-products of motor vehicle emissions being the main contributor to indoor $PM_{2.5}$. Numerous additional public buildings, such as schools, will benefit from this study's findings about heavy foot traffic.

Scibor *et al.,* 2019 examined the association between particulate matter (PM_{10} and $PM_{2.5}$) concentrations outdoors and indoors and assesses the impact of several variables that may affect particle pollution levels in homes. With the aid of personal aerosol monitors, 24-hour measurements of the PM_{10} and $PM_{2.5}$ concentrations were made simultaneously indoors and outdoors in 179 locations across Krakow. A questionnaire was used to gather details about the properties where measurements were made. Despite the fact that daily average outside PM_{10} and $PM_{2.5}$ levels were greater than inside levels (p 0.001), there was a substantial, statistically significant association between outside and indoor PM_{10} and $PM_{2.5}$ concentrations (r = 0.78, p 0.001) and outside and indoor $PM_{2.5}$ (r = 0.82, p 0.001). The greatest predictors of indoor measures after adjusting for outdoor measurements. When urban air quality is improved, interior air quality will also improve because the increase in outdoor PM_{10} and $PM_{2.5}$ concentrations is accompanied by an increase in indoor concentrations. Additionally, modernizing apartments—in particular, removing outdated windows and upgrading the heating system—would help improve indoor air quality and consequently quality of life.

Stamatelopoulou *et al.*, 2019 showed a good correlation between numerous harmful health effects in respect to indoor air pollution. Despite the fact that babies and young children spend the majority of their time indoors, little is known about how much exposure they may have to indoor contaminants. Consequently, the goals of this study were to characterize the particulate matter (PM) and total volatile organic compound (HCHO) concentrations that young children are exposed to define comfort parameters for living rooms and children's bedrooms and identify the determinants of indoor PM and HCHO concentrations and d investigate how resident's socioeconomic status and daily activities affect diurnal variations in these indoor pollutants. In this regard, a study of PM, HCHOs, and comfort criteria was carried out in homes in Athens, Greece with little kids who are under three years old. Real-time monitoring was used during the 6-7 day sampling periods. The average indoor concentrations of PM_1, $PM_{2.5}$, and PM_{10} were 8.1, 10.6, and 20.9 g/m³ , respectively. HCHO mean concentrations were very variable across the investigated homes, ranging from 24 to 890 g/m³ . Carbon dioxide (CO_2) levels above the reference limit of 1000 ppm in several homes, particularly in children's bedrooms. The findings showed that the greatest contributors to both PM and HCHO concentrations were the research participant's indoor activities.

Kim *et al.*, 2020 examined the psycho-physiological impact of interior heat conditions on the academic performance of college students. An experiment was carried out in a climate chamber with 20 participants to achieve this goal. Using the climate chamber, five thermal conditions were produced. The standard of the indoor environment was observed. The subjects were given four cognitive tests to assess their attention, perceptual, working memory, and executive abilities at the same time in order to study their learning performance. Additionally, an electroencephalogram was used to gauge the subject's psycho-physiological reactions, including their mental workload, mental stress, attentiveness, and mental weariness. Meanwhile, one-way repeated-measures ANOVA was used in this study to examine the statistical significance of the various components.

Alves *et al.*, 2020 conducted a study in an unstudied work environment, a university cafeteria where a thorough air monitoring campaign was carried out. Use of passive diffusion samplers allowed the collection of carbonyls and volatile organic compounds. Both indoors and outdoors, temperature, relative humidity, CO_2, CO, and particle matter were continually recorded. Simultaneous PM_{10} sampling was done both during the day and at night using high and low volume equipment with quartz and Teflon filters, respectively. The quartz filters underwent thermo-optical analysis for their carbonaceous content and GC-MS analysis for their organic components. Ion chromatography and PIXE, respectively, were used to analyze the water-soluble ions and elements in the Teflon filters. Poor ventilation is indicated by low air change rates (0.31–1.5 h1) and infiltration coefficients of 0.14 for both $PM_{2.5}$ and PM_{10} particles. The cafeteria had substantially greater levels of gaseous pollutants and particulate matter than the surrounding area, with strong daily changes based on activity levels and occupancy. The amount of PM_{10} produced indoors on average was calculated to be 32 g/m³ . Alkanes, PAHs, saccharides, phenolics, alcohols, acids, alkyl esters, triterpenoids, and sterols were among the organic chemicals found in PM_{10}. The diversity of sources, formation reactions, and removal processes shown by the complex particle composition are still poorly understood. They include dust resuspension, abrasion and off-gassing from building materials, kitchen emissions, tobacco smoke, and a number of consumer items. Personal care items, insecticides, plasticizers, flame retardants, and psychotropic medicines all contain a variety of different substances. Metal and PAH inhalation cancer risks were found to be insignificant.

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CHAPTER 4:MATERIALS AND METHODOLOGY

4.1 Site description:

The Bengal Technical Institute, formerly known as Jadavpur University, is situated in Kolkata, an east Indian city, in the southern part of the city. One of West Bengal's first technical colleges, Jadavpur University was founded in 1955. Jadavpur University's main campus is comprised of 36 academic departments, research centres, laboratories, lecture hall complexes, various residential and recreational buildings, and is located at 22.4989° N, 88.3714°E (Fig.1). Throughout the university campus, six different indoor microenvironments (IMs) were chosen for this study's air quality assessment. Fig. 1 depicts the monitoring locations at the university. The IMs were chosen after extensive research by experts and students to examine potential exposure in various university learning environments. The A.C canteen in IM1 has ceiling fans. At the Central Library, IM2 is a reading room with ceiling fans. The IM3 Gym, which is housed in the Physical Education department building, contains wall-mounted air conditioners as well as open windows for natural ventilation. The Chemical Engineering Department's IM4 chemistry laboratory is outfitted with cutting-edge equipment for material characterisation and precise chemical analysis.IM5 is a classroom with ceiling fans and air conditioning facility. In order to keep the residents' thermal comfort throughout the winter, the room heater was also used in the microenvironments under study. During the monitoring, many window and door openings were seen. Since IM6 is a Post Office Canteen with an open area and natural ventilation, the ventilation mode at these IMs is classified as mixed ventilated.

Fig.1 The monitoring site in the university.

Table2: Characteristics of indoor microenvironments (IMs).

IM'S	Description	Working hours	Floor	Volume(m3)	No. Of occupants
IM1	AC Canteen	13:00-15:00	Ground	2920	50-60
IM2	Central Library	13:00-15:00	Ground	731.2	30-40
IM3	Chemistry Laboratory	13:00-15:00	First	370.17	6-7
IM4	Classroom	13:00-15:00	Second	131.4	18-20
IM5	Gym	13:00-15:00	Ground	3427.5	20-25
IM6	Post Office Canteen	13:00-15:00	Ground	153.36	11-15

Table 2

4.2 Monitoring:

In order to cover the monsoon, winter, and summer seasons, IAQ monitoring for PM_{10}, $PM_{2.5}$, CO_2, and HCHO was conducted in three campaigns from August through September 2022, November through January 2023, and February through April 2023. At each of the chosen indoor microenvironments, continuous measurements with a resolution of 5 minutes were taken over a period of 2 hours on separate days. All IMs and all seasons were monitored indoors in a similar way. In six indoor microenvironments, monitoring was done for a total of 50 days. The absence of multiple samplers prevented this study from conducting concurrent measurement.

4.2.1 Monitoring instrument

Using a portable aerosols spectrometer, the particle number concentrations were measured in real-time. The monitor measures the size of the particles, which range from 0.25 mm to 32 mm. Formaldehyde and CO_2 concentrations, as well as comfort indicators including temperature (T) and relative humidity (% RH), were all tracked using the Temtop M 2000. Each IAQ indicator's corresponding sensor is included in the IAQ monitor. Noise-free monitors were used to take the data at the appropriate location, and a laboratory setting was used for the analysis that followed. The monitors were placed at least 1.5 m away from direct pollution sources and barriers and 1.2 m above the floor (i.e., the breathing zone of a sitting individual). Thus, every component of monitoring was handled in accordance with EN ISO 16000-1: 2006, "Indoor air- Part 1: General aspects of sampling strategies".

Prior to the monitoring program, the monitors were calibrated at the appropriate laboratory. Checks on the instrument's status, including probe stabilization and self-check an activity diary was kept during the sampling days, and the people who lived in the investigated indoor microenvironment went about their daily lives as usual.

Fig.2 Temtop M 2000.

4.2.2 Anemometer:

The sampler had been placed in every sampling site for two hours and after two hours from the graph the data (Velocity of air in indoor microenvironments) was collected by Lutron AM-4201 digital anemometer.

Fig.3 Lutron AM-4201 digital anemometer.

4.2.3 Sampling Period:

The study for assessment of ambient air quality were undertaken during the three season Eg:1) Rainy season – August 2) Winter season – December 3) Summer season – April. Although it is 15 Days were monitored in weekdays. The seasonal variation at the air quality was monitored in 1st shift into 12:00 P.M to 3 P.M.

4.2.4 Statistical Analysis:

The monitoring device's 5-min measurements were used to calculate the 2-h mean and working hour's mean concentrations. Data normality was tested through the Shapiro-Wilk test, and Tukey's quartile method was used to exclude data outliers. A Non-parametric independent sample test was performed to assess the seasonal variability, and Kruskal–Wallis tests were used to examine the spatial variability of IAQ indicators among studied IMs. IBM SPSS Statistic 20 and MS Excel were used to run all statistical analyses for this investigation. To ensure the consistency of the data, missing values and similar cases were removed before to each statistical analysis.

CHAPTER 5: RESULT

The indoor air quality assessment during different seasons has been done in different sites of Jadavpur University. Indoor air quality parameters like Carbon dioxide (CO_2), Formaldehyde (HCHO), PM_{10}, $PM_{2.5}$ concentration was observed during the seasons. The results are discussed below-

5.1 Seasonal Variations:

Assuming the null hypothesis, H0: the mean concentrations of indoor pollutants are the same across the category of seasons, the independent sample test was used to statistically investigate seasonal variations of daily average concentrations of PM_{10}, $PM_{2.5}$, HCHO and CO_2, monitored in studied indoor microenvironments, are shown in Fig.4 . All pollutants had P-values less than 0.05 and a 95% confidence interval. As a result, there were significant seasonal fluctuations in the indoor concentrations of PM_{10}, $PM_{2.5}$, $CO_2$and HCHO ($P < 0.05$).

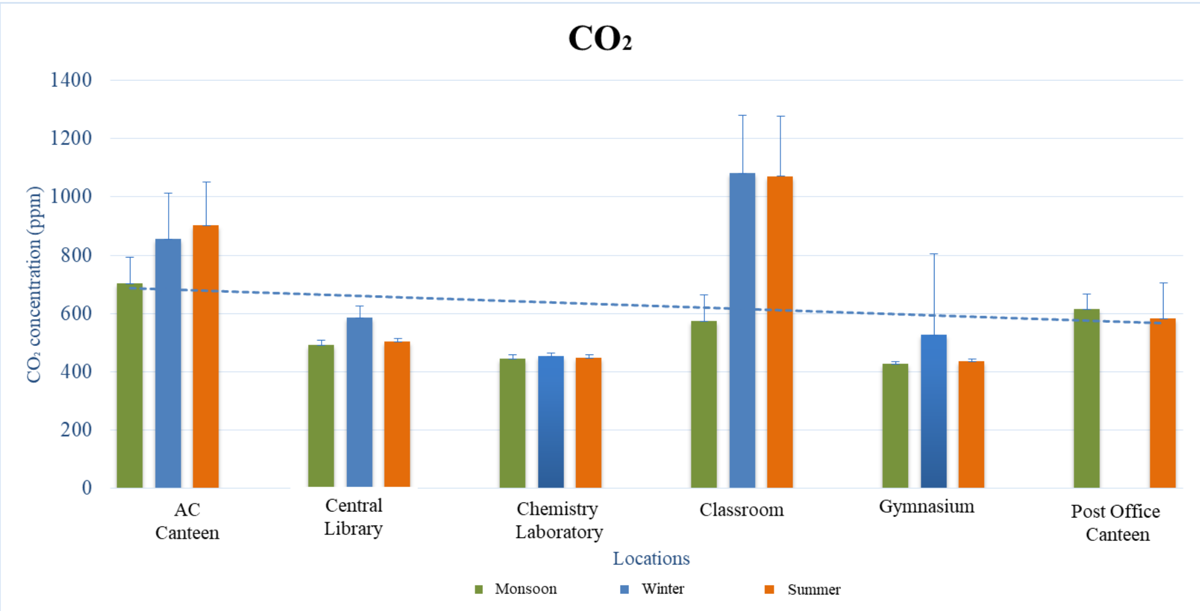

Fig.4 Carbon dioxide concentration(ppm).

This graph shows that the daily average CO_2 concentration is less then the 1000ppm .The maximum CO_2 concentration is in winter season and the minimum CO_2 concentration is in monsoon season. The maximum concentration is in Classroom ranged from CO_2 639ppm to 1270ppm however the minimum CO_2 concentration record in Gymnasium ranged from 414ppmto 439ppm. Cold air is denser than warm air, leading to reduced vertical mixing of atmosphere during the winter. This can trap pollutant including CO_2 near the surface of longer periods, leading to an increase in local concentration.CO_2 concentration is high in classroom due to no natural ventilation and the sampling period is in class time . CO_2 concentration is in lowest in Gymnasium due to natural ventilation and large area and occupied population is lower than other indoor microenvironments.

This suggests that people are the primary source of indoor CO_2 in classroom. However, because these microenvironments were occupied year-round, the CO_2 concentration in classroom with no natural ventilation did not exhibit any significant seasonal variability ($P > 0.05$). This suggests that people are the primary source of indoor CO_2 in classroom.

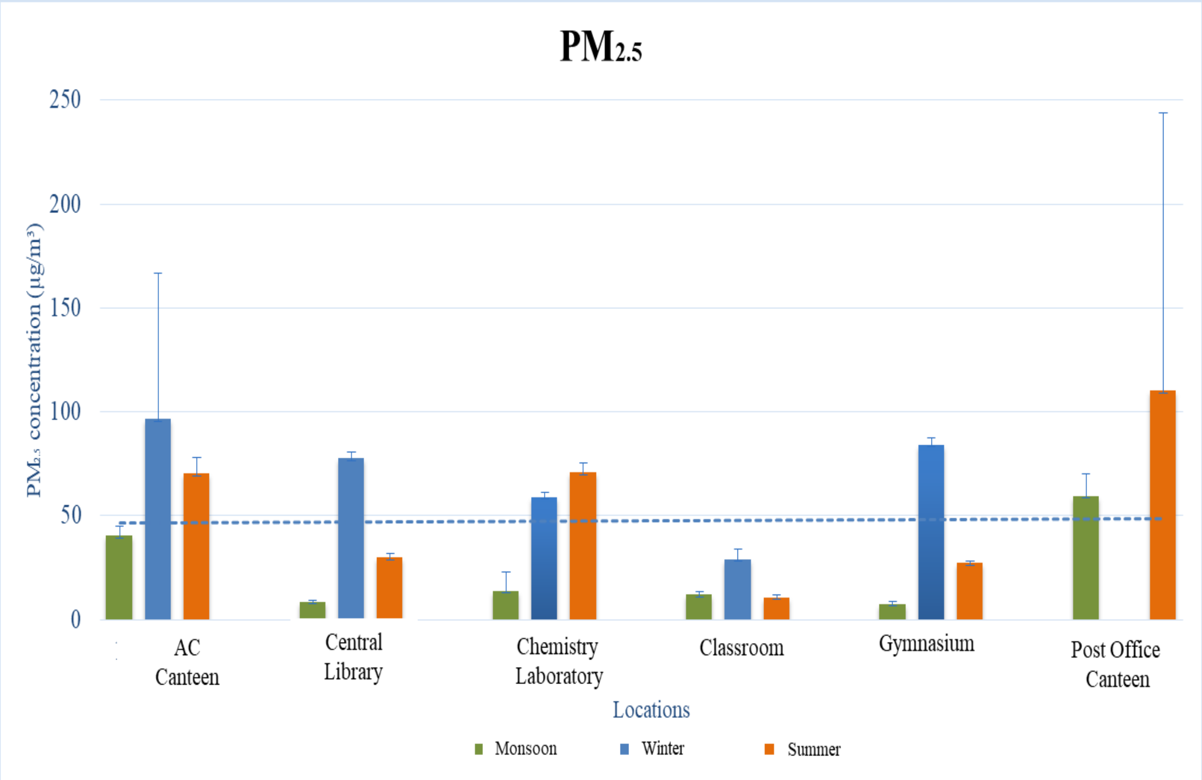

Fig.5 $PM_{2.5}$ concentration(µg/m³).

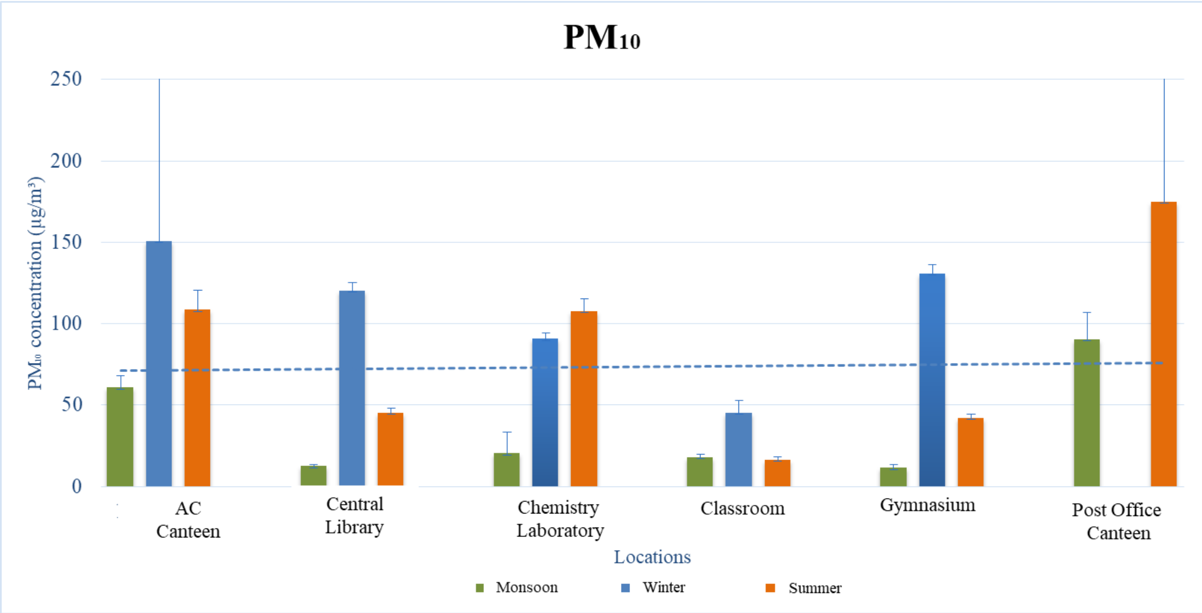

Fig.6 PM_{10} concentration (µg/m³).

The graph shows that the average $PM_{2.5}$ concentration is greater than 25 µg/m³ and PM_{10} is greater than 50 µg/m³.The daily average concentrations of indoor PM_{10} and $PM_{2.5}$ during the winter season were found higher than those recorded during summer and monsoon season, across most of the studied indoor microenvironments.

The maximum PM ($PM_{2.5}$ and PM_{10}) concentration is in winter season and the minimum PM ($PM_{2.5}$ and PM_{10}) concentration is in monsoon season.

The maximum $PM_{2.5}$ is in AC canteen ranged from 60.6 µg/m³ to 84.3 µg/m³ and PM_{10} is 96.2 µg/m³ to 131.4 µg/m³. However the minimum PM concentration found in Gymnasium ranged from $PM_{2.5}$ 6 µg/m³ to 11 µg/m³ and PM_{10} is 9.1 µg/m³ to 17.2 µg/m³.

This canteen has no natural ventilation and the number of occupied population is maximum compared to other Indoor micro environments .

Winter temperatures favour low atmospheric mixing heights, which restrict the dispersion of contaminants. Additionally, the resident's propensity to keep the windows and doors shut in order to create warm microenvironments could trap more pollutants . As a result, indoor PM ($PM_{2.5}$ and PM_{10}) concentrations increased during the winter. The monsoon season's moist deposition and precipitation encourage the washing out of air pollutants. As a result, the monsoon season was when PM ($PM_{2.5}$ and PM_{10}) concentrations were lowest. While in the summer, the high temperature gradient between indoors and outdoors causes more ventilation, which in turn promotes the dispersion of pollutants.

In an Indian classroom study, Chithra & Nagendra (23) discovered comparable seasonal fluctuations while evaluating the impact of climatic conditions on indoor PM. Wintertime indoor $PM_{2.5}$ and PM_{10} concentrations in microenvironments ranged from142.4% to 237.2% and 92.4% to 162..8% higher than the WHO's recommended threshold of 25 µg/m³ and 50 µg/m³. The inhabitants' actions in the microenvironments have been found to be a substantial source of indoor PM (namely PM_{10} and $PM_{2.5}$) during the examined seasons. Additionally, we noticed that for the same interior microenvironment, the daily average indoor $PM_{2.5}$ concentrations had a larger seasonal variability than the indoor PM_{10} concentrations.

However, during both the winter and summer seasons, these concentrations in AC Canteen, Central Library, Classroom and Gymnasium were found to be higher than the WHO's recommended ranges in monsoon season . Nearly all of the examined microenvironments' indoor PM_{10} and $PM_{2.5}$ concentrations were found to be under the recommended WHO guidelines during the monsoon season.

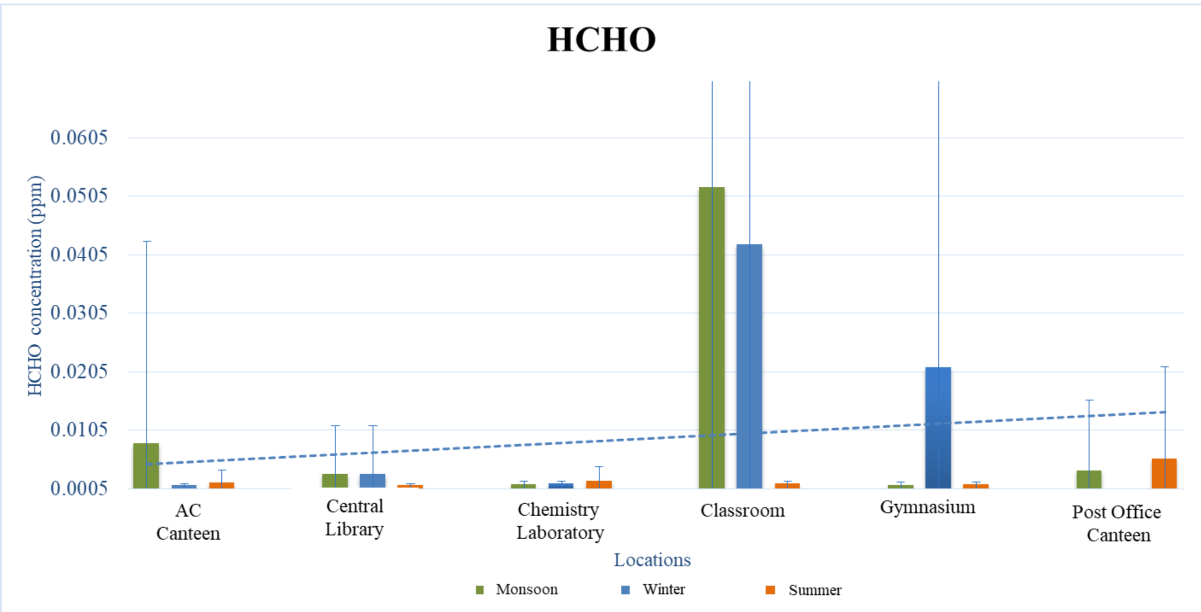

Fig.7 HCHO concentration (ppm).

This graph shows that the Average HCHO concentration is lower the 0.1ppm. Average HCHO concentration is 0.001ppm – 0.007ppm. The classroom microenvironment, was shown to have the highest HCHO concentrations during the monsoon season. Additionally discovered to have considerable seasonal variations were the daily average concentrations of indoor HCHO. The main sources of HCHO in the investigated microenvironment included building inhabitants, construction materials, laboratory chemicals and furniture which is made of plywood, particleboard ,wood products etc. Buildings often have tighter seals during the colder months to retain heat, which reduces airflow. Indoor air contaminants, such as formaldehyde, may collect as a result of the restricted airflow.

Additionally, it was found that indoor microenvironments with open windows for natural ventilation displayed greater seasonal variation than indoor microenvironments with air conditioning, indicating that the impact of meteorology on the air quality of an indoor microenvironment with natural ventilation is significantly greater than that of an indoor microenvironment with air conditioning [23].

5.2 Spatial Variation:

In order to evaluate the spatial variability of IAQ indicators among the various indoor microenvironments of the university campus, the IAQ was evaluated throughout the winter season.

The IAQ was substantially ($P< 0.05$) different across the examined microenvironments, according to the Kruskal-Wallis tests statistics at, 95% confidence interval. This spatial variance can be an indication of how the building's attributes, occupancy, and ventilation affect indoor air quality.

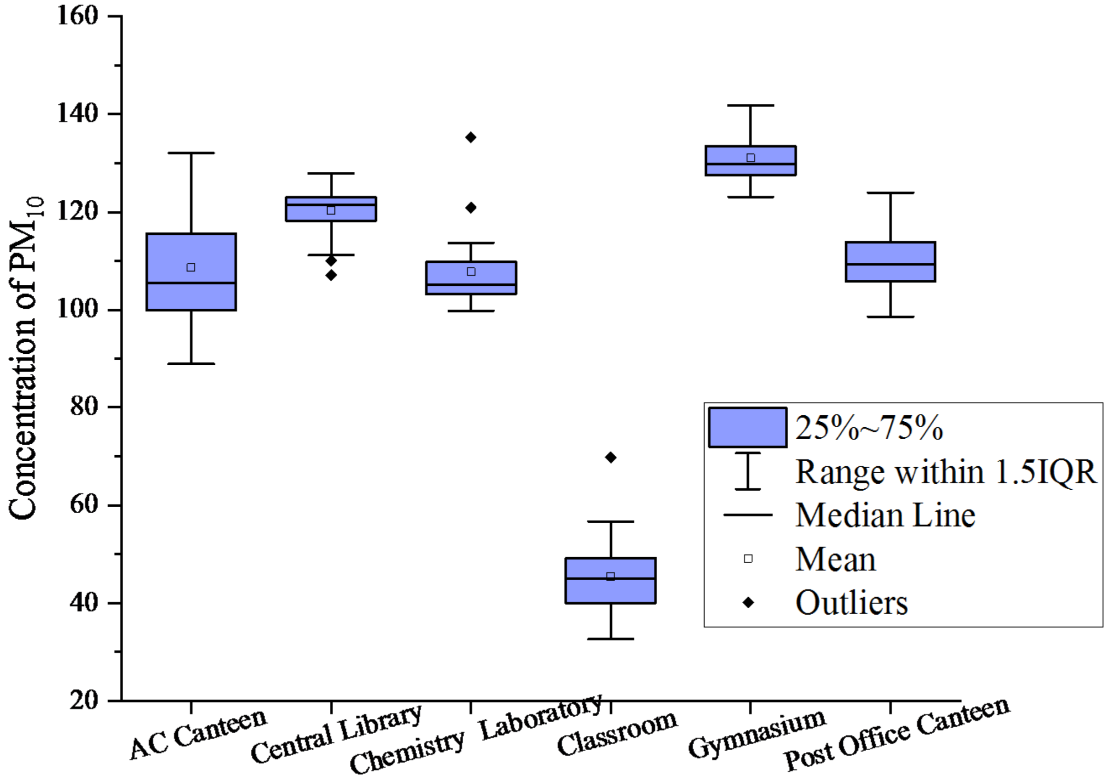

Fig.8 Indoor micro environment PM_{10} concentration(μg/m³).

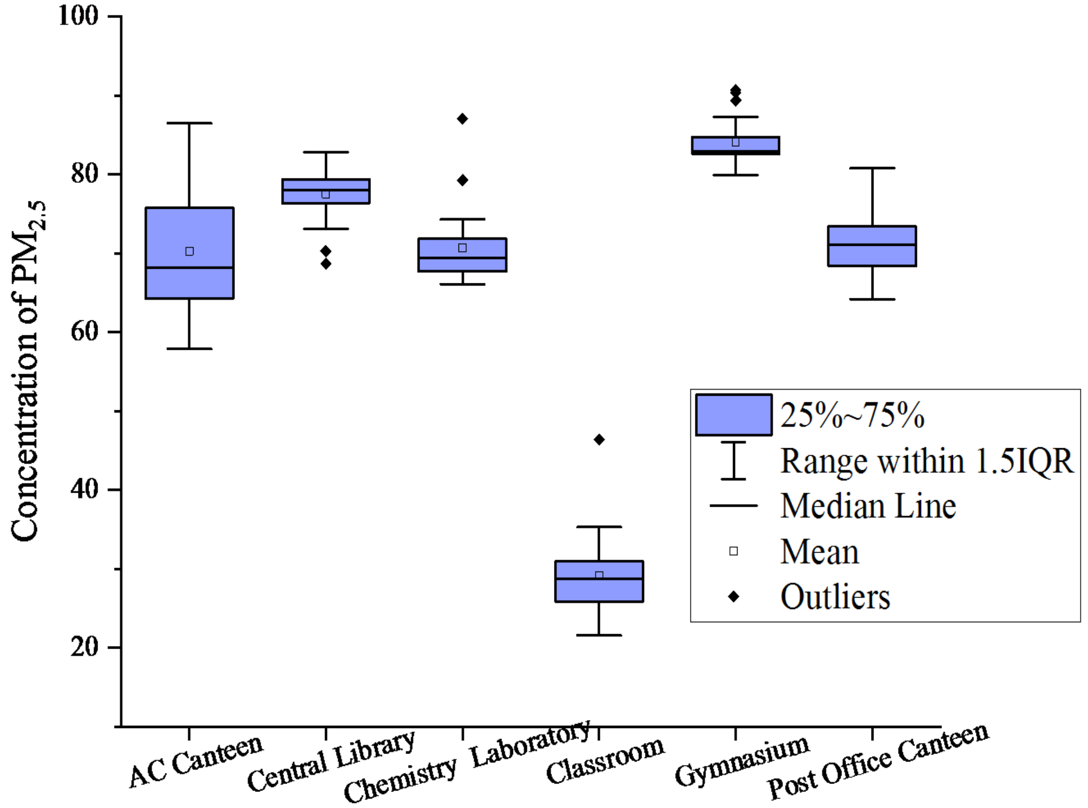

Fig.9 Indoor micro environment $PM_{2.5}$ concentration (μg/m³).

Figure 8. depicts the regional changes of indoor pollutants during the winter. Each Box-Whisker plot in the figure represents the daily average concentration for a specific indoor microenvironment. Within the examined microenvironments, it was discovered that the indoor PM_{10} concentration ranged from 32.6 µg/m³ to 132.1 µg/m³ , while Figure 9. depicts the $PM_{2.5}$ concentrations ranged from 21.6 µg/m³ to 86.5 µg/m³.

Gymnasium, had the greatest interior PM_{10} and $PM_{2.5}$ concentrations, whereas classroom had the lowest indoor PM_{10} and $PM_{2.5}$ concentrations. In comparison to other IMs, the PM (PM_{10}, and $PM_{2.5}$) concentrations in AC canteen, central library and post office canteen were observed to be higher. This could be because of the impact of increased occupancy and dust . When compared to classroom were found to have comparatively low PM_{10} and $PM_{2.5}$ concentrations, measuring 32.6 µg/m³ to 69.8 µg/m³and 21.6 µg/m³ to 46.4 µg/m³ respectively. However, there was not much of a difference in occupancy between these microenvironments.

Similar variations have been observed in studied laboratories of different ventilation mode . In addition, lower concentrations of PM were found in chemistry laboratory compared to other indoor microenvironments, and this may likely result from restricted entry along with the smaller number of occupants in these microenvironments.

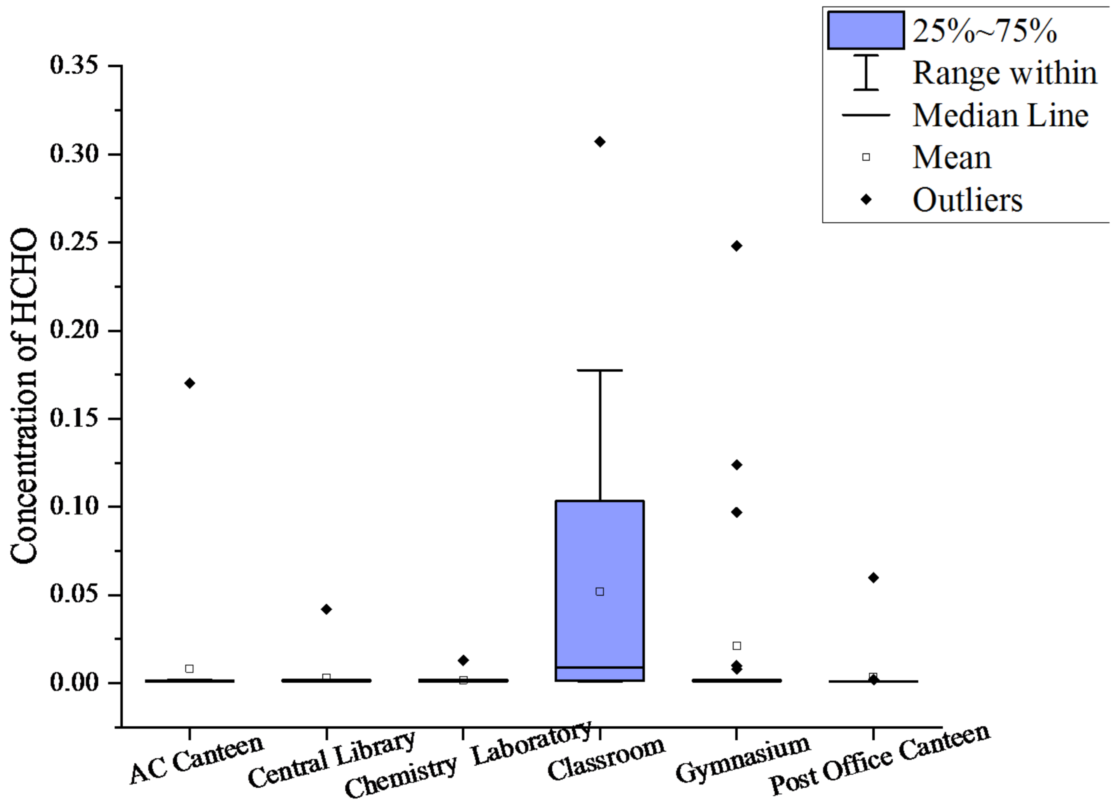

Fig.10 Indoor micro environment HCHO concentration (ppm)

The examined IM's HCHO concentrations ranged from 0.001ppm to 0.3072ppm. When compared to other IMs, the classroom were found to have higher indoor HVOC.

The impact of chemicals used or present during plywood and wood furniture on IAQ may be reflected in the greater HCHO in classroom. According to research, the majority of indoor that were present in the classroom were released by the furniture and construction materials.

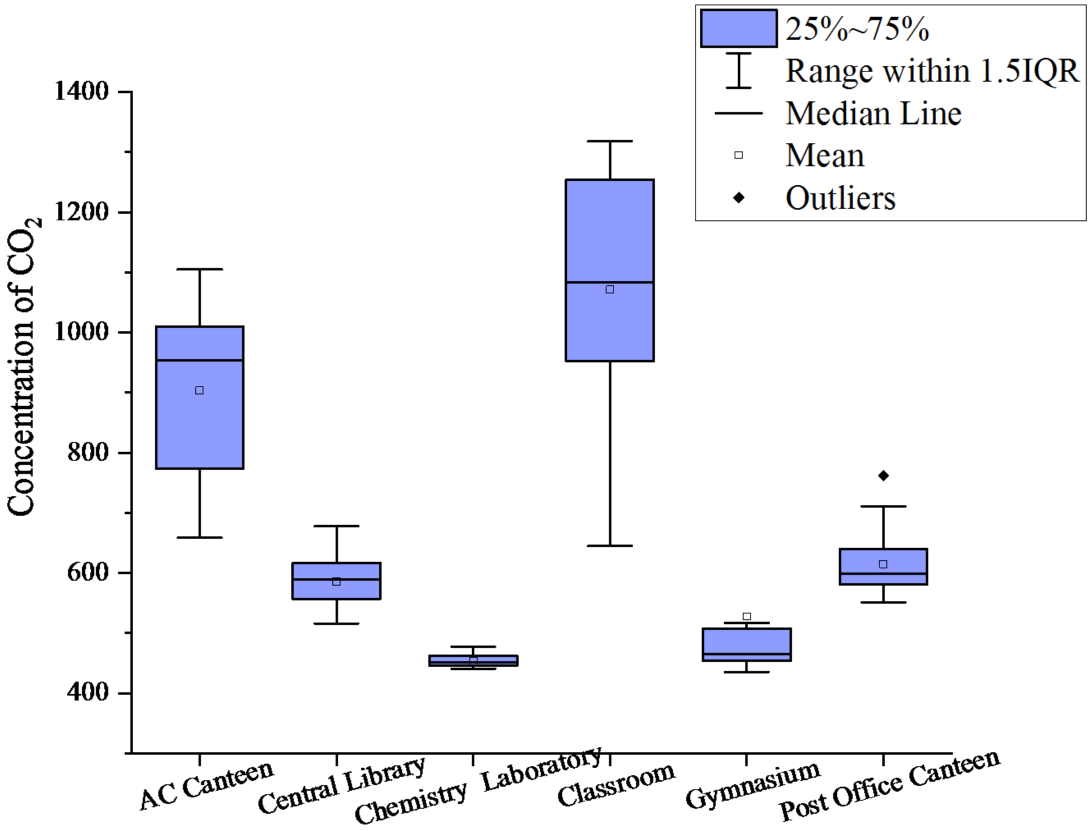

Fig.11 Indoor micro environment CO_2concentration (ppm)

The CO_2 concentrations in classroom and AC canteen were higher and ranged from 645ppm to 1318ppm and 659ppm to 1105ppm according to the spatial variance in CO_2 among the examined IMs. The lower value of CO_2 in the chemistry laboratory ranged from 441ppm to 477ppm demonstrates the influence of proper ventilation in since indoor CO_2 concentrations are thought to be an indicator of ventilation in the microenvironment [35].

Central library and gymnasium had indoor CO_2 values that ranged from 516ppm to 678ppm and 435ppm to 517ppm, respectively. It was discovered that the CO2 concentrations in indoor microenvironments vary depending on the population.

Additionally, it was noted that gymnasium and chemistry laboratory with natural ventilation had lower indoor CO_2 concentrations, which is probably owing to insufficient ventilation in microenvironments with air conditioners.

Keep in mind that mechanical ventilation is not guaranteed by a standard split-type air conditioner unit [51]. Infiltrated or released contaminants from indoor sources may stay there until enough ventilation is offered.

These findings are in line with the research done by Goyal & Kumar [35]. The considerable impact of a building's architecture, air exchange rate, penetration, occupants, and their activities on interior air quality has been documented in other research as well.

5.3 Indoor air quality status:

By comparing the pollutant concentration with the advised recommendations and health standards for indoor pollutants, the IAQ state of a microenvironment can be assessed. Since there are no such criteria or guidelines for India, we have compared the 2 hour average pollutant concentration norms for air quality.

We observed that the indoor $PM_{2.5}$ and PM_{10} concentrations in the Canteens, classrooms, and library were higher than the WHO-recommended limits (50 µg/m³ for PM_{10} and 25 µg/m³ for $PM_{2.5}$).

Numerous studies have demonstrated that people exposed to high CO_2 concentrations in offices and schools had health impacts such fatigue and drowsiness. However, people who are exposed to indoor CO_2 at levels below 5000ppm do not pose a serious health risk. However, it is important to note that sustained CO_2 exposure above 1000ppm may impair occupant's ability to execute basic cognitive functions, scholastic performance, and work productivity.

We compared the measured HCHO concentrations with the safe level of the European standards (i.e., 0.1ppm) since India as of yet has no health regulations for indoor HCHO. Other indoor HCHO values were determined to be within the European guideline range.

However, it has been suggested in a number of studies that increased HCHO concentrations may be taken into account as a potential sign of insufficient ventilation and poor IAQ for operational buildings. The researched indoor microenvironment's indoor environmental quality (IEQ) indicators, such as temperature, relative humidity, ventilation, and occupancy, were also compared.

Nearly all of the analyzed microenvironment's mean interior temperatures and relative humidity levels were found to be within the approved ASHRAE guidelines, which are 20 °C to 24 °C for temperature and 30 % to 60 % for relative humidity.

Based on the CO_2 steady-state technique (Equation (1)), the ventilation rate for the investigated indoor microenvironments was determined.

$Q= N*E/(C_{max} - C_{min})$ ………………………….. Eq. 1

C_{max} and C_{min} are the highest and minimum indoor CO_2 concentrations seen in the relevant microenvironment, respectively, where N is the maximum number of inhabitants present. E stands for the individual CO_2 emission rate, which is 0.3 L/min.

CHAPTER 6:CONCLUSION

In this study, the indoor air quality (IAQ) of ten different indoor microenvironments at Jadavpur University was assessed. Three season's worth of monitored IAQ indicator data ($PM_{2.5}$, PM_{10}, CO_2 and HCHO) were analyzed. Assessing the IAQ variability among the examined microenvironments on the university campus has received particular attention. It was discovered that the IAQ varied considerably ($P < 0.05$) among the examined microenvironments. The greatest indoor $PM_{2.5}$, PM_{10}, and CO_2 concentrations were discovered in AC Canteen and Classroom as well as Post Office Canteen. While the greatest HCHO levels (0.3072ppm) were found in the Classroom, above the reference limit of the European guideline (0.1ppm). In almost all of the microenvironments that were evaluated, the mean indoor temperature and relative humidity were found to be within the ASHRAE comfort range (20 °C to 24 °C for temperature and 30% to 60% for relative humidity). The indoor concentrations of HCHO and CO_2 were lower in the microenvironments with natural ventilation, while the indoor concentrations of PM_{10} and $PM_{2.5}$ were greater. The elements that affect the IAQ of the microenvironment have been identified as indoor activities, ventilation, and occupancy. The IAQ status of indoor microenvironments as perceived by the respondents did not match the IAQ status under observation. Moreover, the seasonal fluctuations in the interior CO_2,PM_{10}, $PM_{2.5}$, and HCHO concentrations were found to be insignificant for the indoor concentrations ($P < 0.05$). In all analyzed indoor microenvironments, the daily average concentrations of indoor $PM_{2.5}$ and PM_{10} throughout the winter season were found to be greater than those observed during the summer and monsoon season. Additionally, it was shown that indoor microenvironments with open windows for natural ventilation displayed greater seasonal variance than those with air conditioning. The current research recommends taking action to ensure appropriate ventilation in order to reduce indoor pollutants and the exposure they cause. The study's findings may be used by the interested parties to create an IAQ management framework and standard IAQ guidelines for diverse indoor environments in India.

CHAPTER 7:REFERENCES

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