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Improvement of air quality for office buildings in northern Indian cities

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Abstract - *In this era, a human spends most of their time indoors. Office buildings are such cold hermetic spaces that are formal and create a lot of psychological stress and pressure on minds. It is also one of the most important spaces where people spent their time indoors.*

The need is to study the alternative active and passive solutions in the existing structure which improve the indoor air quality of the building without changing the existing structure and function of the space. The extent of the study is limited to the interior space of the air-conditioned office building in northern Indian cities. Way to introduce the solutions from the building codes and research solutions.

This condition is regarded to be one of the factors impacting employee job productivity and stress levels. Nonetheless, this study was able to provide more insight and important information on how indoor air quality influences the psychological performance and health of office building occupants. Recommendations are provided to improve indoor air quality performance to provide a comfortable working environment for employees.

Key Words: Indoor Air Quality, IAQ Pollutants, Building Codes, Recommendations….

1. INTRODUCTION

Indoor air quality (IAQ) is a general term that describes the conditions inside buildings that may have an impact on people's health, comfort, and productivity. The number of contaminants in indoor air and temperature and humidity are all factors in IAQ. Indoor air quality isn't just a health hazard; it also affects employee productivity, leaving a company reliant on a sick workforce. Sick leave and absenteeism, productivity, decision-making, and staff retention are all factors that affect office operations. Improving indoor air quality not only benefits your inhabitants' health, but it also benefits you in terms of productivity and profits. Air quality has deteriorated in most portions of the Indo-Gangetic plain, including major cities in North India such as Delhi, Lucknow, and Kanpur, due to a combination of unique geology and rising pollutants. Air pollution kills 4.2 million people per year, according to the World Health Organization (WHO), with the majority of these fatalities occurring in poor nations. Carbon monoxide (CO), Sulphur dioxide (SO2), nitrogen oxides (NOx), volatile organic compounds (VOCs), ozone (O3), and respirable particulate matter (RPM) are the principal air pollutants that characterize the air quality over an area (PM2.5 and PM10). According to the EPA, IAP is one of the top five environmental health threats to the public. According to the World Health Organization (WHO), IAP kills 14 times more people than outdoor pollution. 15% reduction of employees' productivity by low indoor IAQ.

When employees complain that the office is too hot, too cold, too humid, or too dry, or that their eyes, throats, and skin are constantly dry and irritated, poor air quality can have measurable consequences such as:

- Diminished concentration
- Diminished problem-solving abilities
- Lack of focus
- Decreased energy
- Decreased job satisfaction and morale
- Decreased work efficiency and productivity
- Increased use of sick days

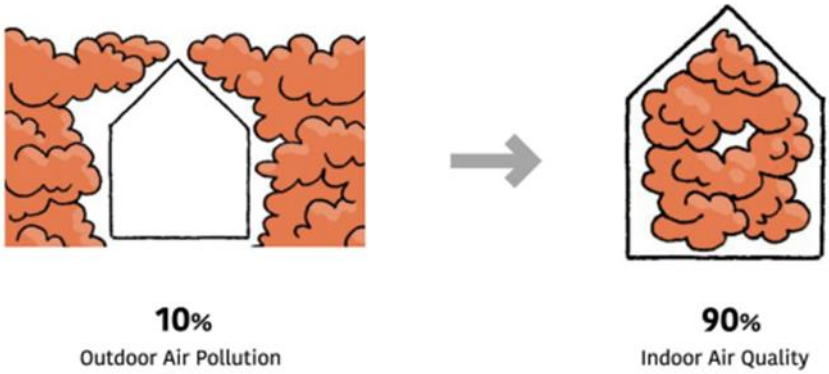

Fig -1: percentage of indoor air quality (source-https://www.archdaily.com/938491/how-to-transform-a-polluted-indoor-environment-into-a-healthy-home)

1.1 INDOOR AIR POLLUTANTS

1.2 COMMON INDOOR AIR POLLUTANTS IN OFFICE BUILDINGS:

TRICHLOROETHYLENE: Printing inks, paints, lacquers, varnishes, adhesives, and paint removers all include this chemical. Excitation, dizziness, headache, nausea, and vomiting, followed by sleepiness and coma, are all symptoms of short-term exposure.

FORMALDEHYDE: Paper bags, waxed papers, face tissues, paper towels, plywood paneling, and synthetic textiles have all been found to contain this substance. Short-term exposure irritates the nose, mouth, and throat and enlargement of the larynx and lungs in severe instances.

BENZENE: It's present in tobacco smoke, glue, and furniture wax, and it's used to manufacture plastics, resins, lubricants, detergents, and medications. Short-term exposure can cause eye irritation, tiredness, dizziness, headaches, elevated heart rate, disorientation, and in rare circumstances, coma.

XYLENE: Rubber, leather, cigarette smoke, and car exhaust all include this substance. Short-term exposure can cause mouth and throat irritation, dizziness, headaches, disorientation, heart issues, liver and kidney damage, and coma.

AMMONIA: Window cleaners, floor waxes, smelling salts, and fertilizers all include it. Eye discomfort, coughing, and a sore throat are all symptoms of short-term contact.

NITROGEN DIOXIDE (NO2): Emissions from automobiles and industry during the combustion of fuel produce this hazardous gas. It has a high prevalence in areas where automobiles and traffic are concentrated. The gas irritates the lungs and causes harm to the cardiovascular and respiratory systems. It has been shown to promote airway irritation in healthy people.

SULPHUR DIOXIDE (SO2): The combustion of fuels in enterprises and factories produces sulfur dioxide, a highly reactive gas with a strong and disagreeable odor. Its presence in the air irritates the lungs, throat, and nose lining, worsening the symptoms of individuals with respiratory disorders, including asthma and other cardiovascular issues.

SUSPENDED PARTICULATE MATTER: SPM, or suspended particulate matter, refers to solid and liquid particles floating in the air that are too tiny to be seen with the human eye. Its short-term consequences include ocular and respiratory irritation, with long-term exposure leading to asthma and weakened cardiovascular function.

1.3. PARAMETERS OF INDOOR AIR QUALITY (IAQ)

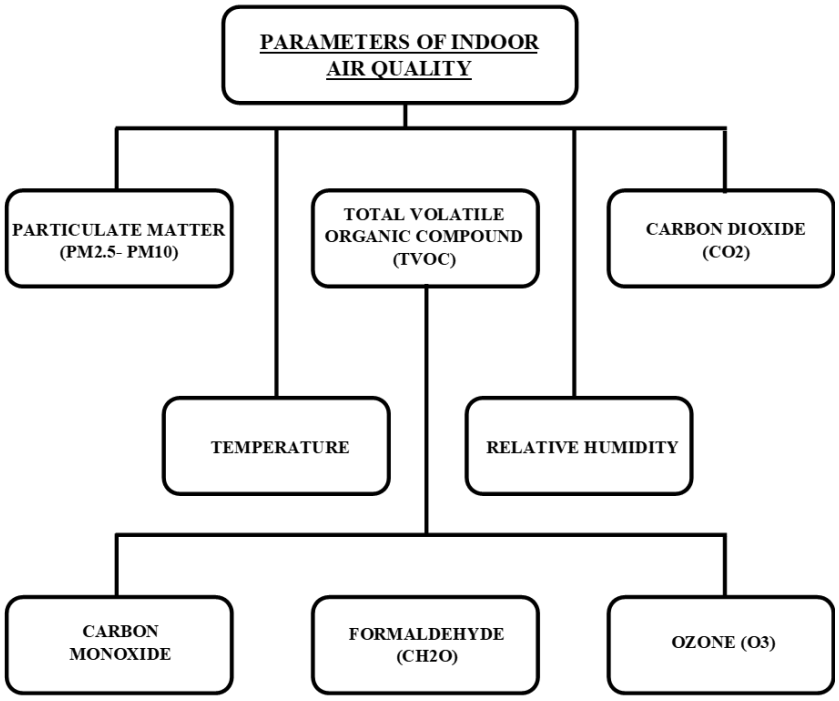

Fig -1: parameters of indoor air quality

1.4. BUILDING CODES

NAAQS: The Indian government has established National Ambient Air Quality Standards. The National Ambient Air Quality Standards (NAAQS) were established in 1982 and amended in 1994 and 2009 to include eight principal pollutants: particulate matter (PM 2.5 and PM 10), nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, benzene, and ammonia.

RESET: RESET Air is an indoor air quality standard. Which is the world's first sensor-based, performance-driven data standard and building certification program. The RESET Standard is a series of recommendations for data quality, monitoring, and benchmarking.

WHO: The World Health Organization's new air quality guidelines (WHO AQG) are ambitious and reflect air pollution's significant impact on global health. They propose aiming for yearly mean PM2.5 concentrations of no more than 5 g/m3, NO2 concentrations of no more than 10 g/m3, and an 8-hour ozone concentration of no more than 60 g/m3 during the summer.

OSHA: OSHA regulates workplace air pollution to safeguard employees from chemical and particle hazards in the air they breathe. Permissible exposure limits (PEL) based on a time-weighted average (TWA) over an 8-hour workday are widely used to manage employee exposures.

EPA: Carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide are six of the most common air pollutants for which the EPA has established national ambient air quality standards (NAAQS).

ASHRAE: The ANSI/ASHRAE Standard 62.1-2019, Ventilation for Acceptable Indoor Air Quality, establishes minimum ventilation rates and other requirements for new and existing buildings to guarantee acceptable IAQ for human occupants while minimizing negative health effects.

WELL: The WELL Building Standards (WELL) is a set of recommendations for buildings that promote healthy indoor air and reduce or eliminate sources of indoor pollution.

LEED: The US Green Building Council launched the Leadership in Energy and Environmental Design (LEED) rating in 2000 to improve the environmental impact of built structures.

TABLE I- BUILDING CODES

S.NO.	PARAMETERS					
	PARAMETERS	**NAAQS INDIA (2009)**	**RESET (2021)**	**WHO (2021)**	**OSHA (2011)**	**EPA (2020)**
1	Particulate Matter (PM2.5- PM10)	40 µg/m3 60 µg/m3 60 µg/m3 100 µg/m3	< 35 µg/m3	Annual- 5 µg/m3 24 hrs.-15 Annual- 15 24 hrs.- 45	35 µg/m3 150 µg/m3	35 µg/m3 150 µg/m3
2	Total Volatile Organic Compound (TVOC)		< 500 µg/m3		5000 ppm	5,000 ppm
3	Carbon Dioxide (CO2)		< 1000 ppm			
4	Temperature		Monitored			
5	Relative Humidity		Monitored			30% - 50%
6	Carbon monoxide	2.0 (8 hrs.) µg/m3 4.0 (8 hrs.) µg/m3	< 9 ppm		50 ppm (8 hrs.)	9 ppm (8 hrs.)
7	Formaldehyde (CH2O)					0.1 ppm
8	Ozone (O3)	100 (8 hrs.) µg/m3 180 (8 hrs.) µg/m3		Peak season- 60 µg/m3 8 hrs. -100 µg/m3	0.1 ppm	0.75 ppm

TABLE II - BUILDING CODES

S.NO.	PARAMETERS					
	PARAMETERS	**ASHRAE (2019)**	**WELL (2020)**	**LEED (2021)**	**IDPH**	**ISHRAE (2019)**
1	Particulate Matter (PM2.5- PM10)	< 65 µg/m3 < 150 µg/m3	< 15 µg/m3 < 50 µg/m3	< 35 µg/m3 < 50 µg/m3	65 µg/m^3 150 µg/m^3	< 15 µg/m3 < 50 µg/m3
2	Total Volatile Organic Compound (TVOC)		< 500 µg/m3			< 200 µg/m3
3	Carbon Dioxide (CO2)	1000ppm (8-hr)			1,000 ppm	350 ppm
4	Temperature	68°F – 74.5°F (20-23.6oC)(winter) 73°F – 79F° 22.8-26.1oC)(summer)			68° - 75° (winter) 73° - 79° (summer)	
5	Relative Humidity	30% - 65%			20% - 60%	
6	Carbon monoxide	9ppm (8-hr)	< 9 ppm	9ppm (8-hr)	9 ppm	< 2 ppm
7	Formaldehyde (CH2O)	<0.1 ppm	< 0.027 ppm	< 0.016 ppm	0.1 ppm	
8	Ozone (O3)	.08 ppm	< 0.051 ppm	.07 ppm	0.08 ppm	< 50 µg/m3

TABLE III - COMPARATIVE STUDY OF ALL OFFICES ON ASPECT OF INDOOR AIR QUALITY

S.NO.	OFFICE BUILDINGS				
		COFCO LANDMARK	**CENTER FOR INTERACTIVE RESEARCH ON SUSTAINABILITY**	**AUSGRID LEARNING CENTER**	**EICHER GOOD EARTH OFFICE**
1	Indoor quality	Air quality testing system monitor Smart office working system (COFFICE)	100% natural light **100% ventilation** Control glare and heat gain Passive environmental strategies	Daylighting usage Appropriate ventilation Moisture control Non-emission materials	No smoking zone 30% extra fresh air (as per Govt. of India) 75% natural daylight
2	Solutions for improvement of IAQ	Air quality monitoring system (CO2, VOC, and PM2.5)	The expressed wood structure consumes 600 tons of CO2.	Air exchange effectiveness (ACE) for at least 90% of the nominated area meets the recommended criteria. CO2 and VOC monitoring system. Internal temp. fall 90% (ASHRAE 55-2004) 90% adhesive and sealants meet the TVOC limit (IEQ-4.2) Mechanically A.C. ventilation system control humidity. 60-80%.	No smoking zone 30% extra fresh air (as per Govt. of India) All paints and sealants used are low VOC. Temperature and humidity are maintained throughout the year as per ASHRAE 62.1.
3	Used material	Material low heat transfer Reflecting glazed strip Floating glass box	Effective U-factor Recycled material Wood Construction waste recycled Recycled concert	Re-used materials Sustainable timber Wood products have low formaldehyde emission All carpets meet the TVOC emission limit.	Low VOC paints and sealants, 30% material (local), 10%% material recycled
4	Landscape	Roof garden Indoor courtyard	Green roof provide a meadow environment	Green roof Local plants in channels	Green area
5	Parameters	Co2, VOCs, PM2.5, temperature	Formaldehyde, Co2, VOC, temperature	Co2, VOCs, temperature, TVOC, low formaldehyde, humidity	VOC, temperature, humidity, CO
6	Certificate	BREEM	LEED	GREEN STAR	LEED

TABLE IV - COMPARATIVE STUDY OF ALL OFFICES ON ASPECT OF INDOOR AIR QUALITY

S.NO.	OFFICE BUILDINGS				
		ANCORA 40 OFFICE BUILDING, SPAIN	**ATECH SOLUTIONS OFFICES / STUDIO 4A**	**WV STATE OFFICE BUILDING 5,6 & 7**	**M MOSER OFFICE**
1	Indoor quality	Maximum natural light Noise reduction technologies	Natural light **100% ventilation** Control glare and heat gain	Daylighting usage Smoking prohibited. Moisture control Non-emission	No smoking zone

			Passive environmental strategies	materials	
2	Solutions for improvement of IAQ	Air cleaning system (30% improvement) as per RITE norms based on ASHRAE standard 62.1-2010. The ventilation system is as per RESET norms. Humidity control and air filter (filter out virus and minute particles)	Plants that help to reduce IAQ pollutants. Bamboo palm Peace lily Chinese evergreen Taro plant Pothos Money plant Coleus	IAQ management plan before construction. All paints and sealants used are low VOC. Mechanical filters should be replaced at least once a year.	Ultraviolet lamps in air conditioners. HVAC system (positive-negative pressure). RESET Air Certification for Commercial Interior v2.0. RESET Material (v1.0) Certification.
3	Used material	Reused materials (Low environmental effect materials). Wood and steel. High transmittance glass	exposed brick wood, and concrete	Re-used materials Wood products have low formaldehyde emission All carpets meet the TVOC emission limit.	Low VOC paints and sealants.
4	Landscape	Green roof	Green space near the working area.		
5	Parameters	Co2, VOCs, PM2.5, temperature	Co2, VOC, temperature.	Co2, VOCs, temperature, TVOC, low formaldehyde, humidity	Co2, VOCs, temperature, TVOC, humidity
6	Certificate	LEED, RESET		LEED	RESET, LEED & WELL

2. RECOMMENDATIONS

The most essential way of avoiding and managing the growth of indoor air pollution is through good architecture and design. Architects should consider a variety of factors while designing a home or building to guarantee the comfort and well-being of its residents.

When working on any project, proper ventilation, natural light exposure, building envelope insulation, and non-toxic, sustainably produced materials are just a few of the safeguards to consider.

From pre-design through post-handover maintenance, a comfort-based strategy should ideally be employed. A variety of smart design options are available to preserve healthy indoor air quality.

A. PLANTS CLEAN INDOOR AIR QUALITY

NASA and the Associated Landscape Contractors of America (ALCA) collaborated on a Clean Air Study in 1989, which resulted in a definitive list of plants that are most efficient in purifying indoor air. The findings were revealed in 1990.

According to research conducted by Dr. B. C. Wolverton, plants are effective in filtering benzene, ammonia, and formaldehyde from the air, reducing the symptoms of Sick Building Syndrome.

They observed that some tropical houseplants can clean the air by removing formaldehyde, trichloroethane, benzene, and other contaminants and replacing them with breathing oxygen.

Indoor plants provide several benefits that cannot be overstated. Air purification is aided by houseplants. Plants can inhale and exhale. While inhaling carbon dioxide, they exhale oxygen.

Humans and animals both breathe oxygen and exhale carbon dioxide. Bringing plants inside your office creates a symbiotic connection by cleansing the air and providing new oxygen.

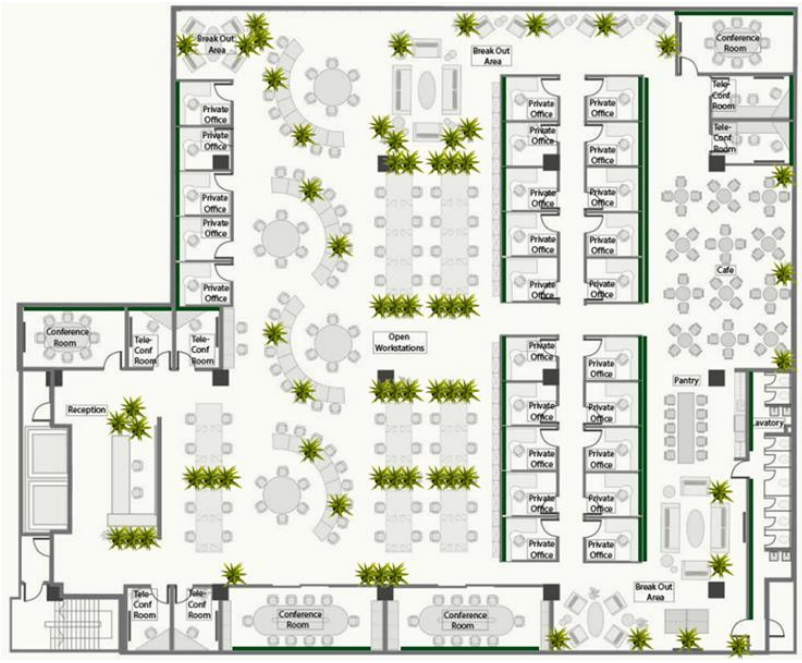

Fig. 2 plants in an office building as per green building codes (source- author)

B. **NATURAL AND MECHANICAL VENTILATION**

When designing an office, one of the first things to consider is proper natural ventilation. The orientation and aperture layout of the structure would allow for optimal airflow throughout the area (cross ventilation, cooling towers).

Installing a working hybrid ventilation system indoors may aid in the diversion of some toxins. While natural ventilation is preferable, any air loss must be restored to maintain a balanced indoor/outdoor air pressure.

It is critical to prevent permitting uncontrolled air penetration, since this may result in the introduction of extra contaminants. The stack effect can be reduced by separating similar portions.

TABLE V- VENTILATION RATE PER PERSON

S. NO.	OFFICE BUILDINGS	
	Space	**Ventilation rate / person**
1	Office	20 cfm
2	Conference room	20 cfm
3	Smoking lounge	60 cfm
4	Auditorium	15 cfm
5	Restaurant/cafeteria	20 cfm
6	Retail shop	15 cfm

Fig. 3 ventilation rate/person in an office building as per green building codes (source- author)

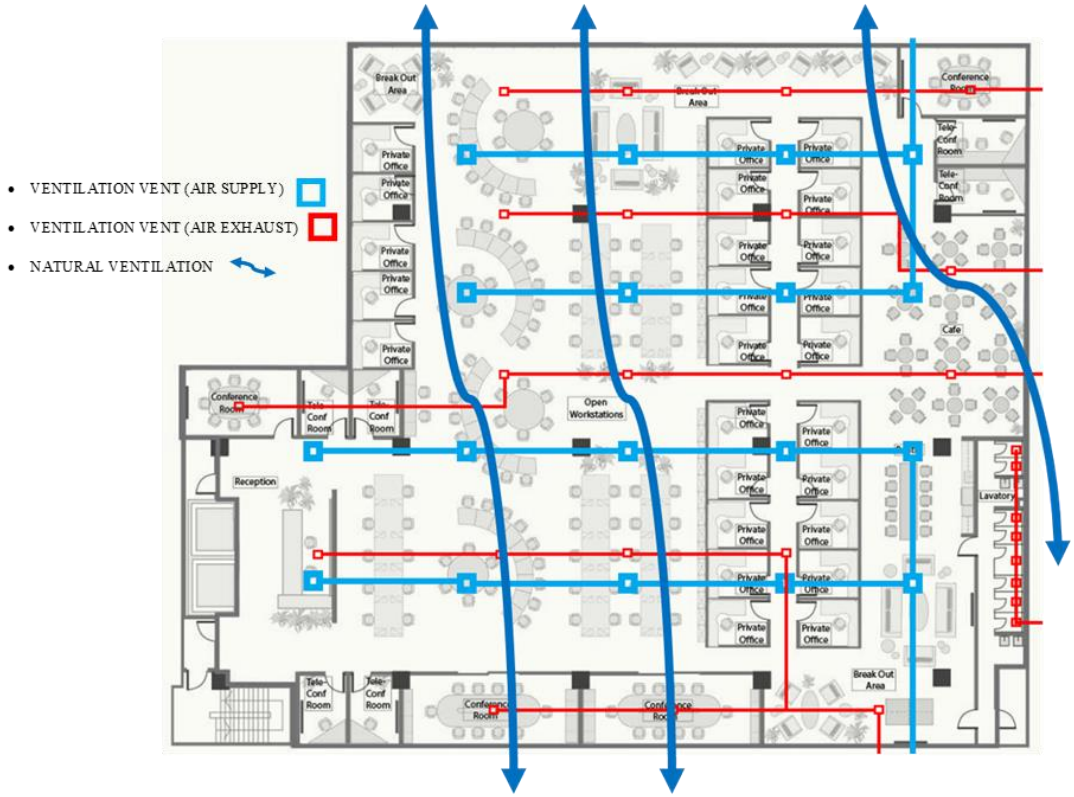

Fig. 4 mechanical ventilation in an office building as per green building codes (source- author)

Monitor system (reset air) – 1 monitor covers 500 sq. mt of space.

Mounted within the breathing zone- 3-6 ft (from the ground)

Located- 16 ft away from operable windows and air filter and fresh air diffusers.

It will monitor PM 2.5, TVOC, CO2, and CO.

The ultra-light air purification system is used which removes PM from the air and also kills microorganisms.

Oxidation and ionization air purifiers not only kill particles in the air within the HVAC system but also clean air throughout the office space. (Viruses, bacteria, VOCs, mold spores, and odors)

Exhaust fans help to reduce the virus particles present in the air.

VRF (variable refrigerant flow) HVAC system detects the requirement of air according to the space in the building and sends the precise amount of air (cooling/heating).

HEPA (high-efficiency particle air) filters used in buildings reduce IAP by trapping 99.97% of pollen, dust, and smoke particles from the air.

HEPA filters are recognized by the EPA and OSHA.

Clean the ducts and filters which help to improve IAQ and also helps to improve the HVAC system efficiency and prevent breakdowns.

Control the humidity by dry construction (steel & timber framing) and finishing materials which help to improve the IAQ.

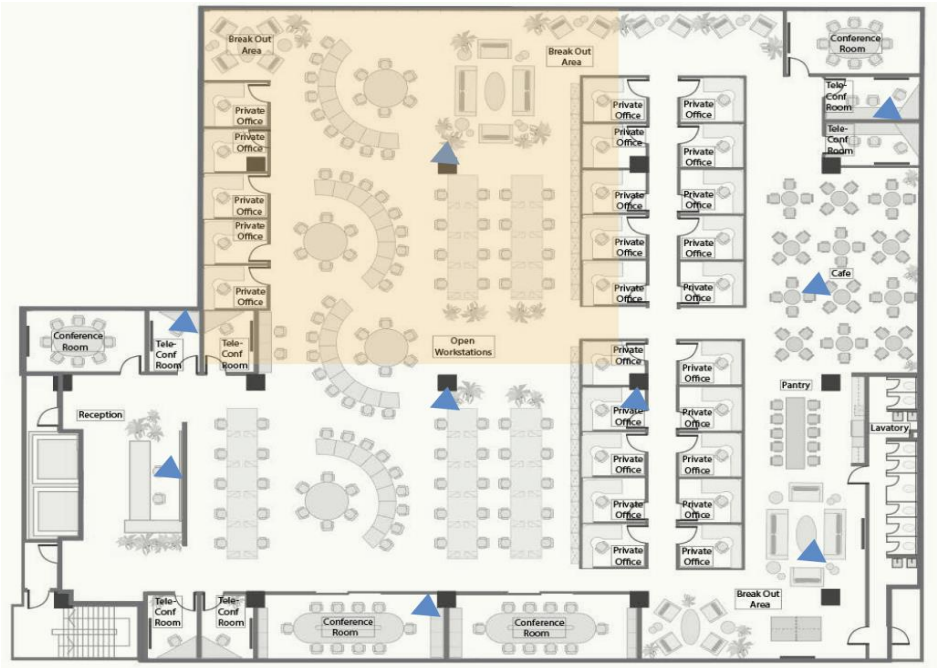

Fig. 5 Monitor system in an office building as per green building codes (source- author)

C. MATERIALS

Nontoxic modern materials help to reduce and remove pollution sources and also provide a safe indoors.

For reducing the effect of indoor air pollution use green-labeled or health-certified materials. (BREEM, LEED, and WELL)

BREEM- points are given for reusing furniture is used, timber like FSC or PEFC certified and furniture items have EPDs. (Environmental product declarations)

LEED- use of a responsible source of raw materials for furniture.

SKA- 70% materials supplied by EPD (environmental product declaration) or cradle to cradle certification.

WELL- focus on the restriction of VOC from furniture, interior products, and architecture.

Low VOC paint. (EPA not more than 250 grams per liter), latex paint- oil (380 g/l).

3. CONCLUSIONS

The accomplishments and level of performance of a company's personnel define its success. That is if the tenants' performance continues to improve, so will the company's performance, and vice versa. As a result, all employees must perform admirably every time they are assigned a task. As a result, to ensure that workers' job quality is good to the employer, the working environment must also be entertaining to the employees. One of the variables to consider while developing a healthy atmosphere in an office building is indoor air quality. The major purpose of this study was to learn more about how active and passive strategies improve air quality and remove pollutants. Office buildings are such cold hermetic spaces that are formal and create a lot of psychological stress and pressure on minds. It is also one of the most important spaces where people spent their time indoors. The extent of the study is limited to the interior space of the air-conditioned office building in northern Indian cities. The employees are dissatisfied with the workplace's indoor air quality (IAQ), which is caused by PM2.5-10, TVOC, CO2, relative humidity, CO, temperature, or ozone. This is because the majority of office workers are unable to manage the temperature and air velocity provided by the workplace's air-conditioning system. According to this study, enclosed places may reduce the dispersion of interior toxins such as gases emitted by paints, cleaning agents, adhesives, air fresheners, cigarette smoke, etc. were removed from the room by providing active and passive solutions in an office building.

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