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Quantitative Assessment of IAQ and HVAC Performance in an Office Building at Hyderabad

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***Abstract*—Indoor air pollution has become a serious issue in affecting public health. Since poor IAQ is considered unhealthy as it causes eye irritation, loss of ability to concentrate and even sickness (Sick Building Syndrome), an indoor air quality monitoring system helps in the detection and improvement of indoor air quality. Tightening of building envelopes, reduction of ventilation rates, use of building materials and techniques with unknown consequences and reliance on technology may significantly diminish the quality of indoor air. Hence, there is a significant need in IAQ research.**

In this project, an impact of HVAC system on IAQ has been studied. For this study, Prajay constructions syndicate Ltd., head office at Banjara Hills, Hyderabad, a commercial office building which is centrally Air-Conditioned is selected. This research study involved taking the parametric measurements like temperature, relative humidity and carbon dioxide levels at different locations of each floor which are the key parameters to decide the IAQ in the space with the help of CO2 measuring meter.

This study also involves a Questionnaire of the Building Occupants to know their comfort levels with the building indoor environment. Moreover at the end, a checklist for HVAC systems is also added and recommendations are suggested at the end of the report

***Keywords*— Indoor Air Quality, HVAC System, Building Environment, Sick Building Syndrome, Ventilation**

I. INTRODUCTION

Indoor Air Quality (IAQ) goals in designing and operating buildings focus on providing healthful and comfortable indoor buildings environments. These goals are pursued by providing outdoor air ventilation to dilute internally generated contaminants to levels that are not harmful to human health and that do not negatively impact occupant perceptions of the indoor environment.

A building without heating and cooling system would be inhabitable. Furthermore, IAQ is significant determinant of healthy life and human’s wellbeing as much of the human’s lifetime is spent in the indoor area. And improper operation or failure of the HVAC system may lead to poor ventilation which in turn causes Sick Building Syndrome (SBS). This SBS develops when the indoor air contaminants build up and subsequently resulting in poor health and low productivity. The symptoms of illness related to SBS include eye, nose throat irritations: skin allergy: mental fatigue and headache and difficulty in concentration. Further it was found that the failure to respond to the problem of poor indoor air quality can bring the disastrous impacts towards human health.

All modern sophisticated buildings employ some type of Heating, Ventilation and Air-Conditioning (HVAC) system and its main purpose being to provide a thermally comfortable environment with good Indoor Air Quality (IAQ) that is conductive to health and productivity. These systems play a vital role as many people spend most of their time indoors and the air they breathe has to pass through these systems. Hence we can say that these systems act as lungs to the buildings.

On the other hand there has been considerable focus on the energy conservation measures in time. The HVAC systems have to balance between the two often opposite strategies for the energy conservation and IAQ, without compromising the human comfort, health and their performance. Hence, a properly designed, maintained and operated HVAC system is essential that consists of suitable components, approaches and strategies. This project reviews knowing the IAQ by measuring the parameters like temperature, relative humidity and CO2 levels of a conditioned space and analyzing the space to be a consist ant of good Indoor Air Quality or not by comparing with ASHRAE standards by taking the values of these parameters in the air-conditioned space by a CO2 reader.

II. RESEARCH METHODOLOGY

While investigating any IAQ situation, be aware of entire picture/view of the space upon which the IAQ is being investigated/checked as many parameters affect the overall quality of air. Also note that it is not uncommon to find multi number of problems; moreover finding one problem and solving it may not get the root cause of the problem. Investigation is just like peeling an onion; as a layer of it is removed, another is exposed. Be sure to understand the exact time and place that problems are suspected since indoor air quality problems are transitory. Working with common sense along with proper tool is must and keep investigating until the complaints of IAQ stop or come to minimum. Facility Managers along with residents can find it challenging to determine if their buildings have exceptional, fair or poor IAQ. Measuring and Testing IAQ is an imperfect science with many variables, and the path to establishing whether or not a building has healthy indoor air is rarely clear cut. Sensory organs like eyes, ear and nose in proper conditions are some of the most important natural means of tools in evaluating IAQ. However there are additional measurements that can access IAQ in building with its design and some electronic instruments as it is done in this work with electronic CO2 sensing metre which predicts the levels of CO2, RH and Temperature which are the key parameters to know the air quality

In this project, quality of the air is checked in the three perspects where one of it involves technically taking the three important parameters- CO2, Relative Humidity and Temperature in each floor at different locations with the help of electronic CO2 measuring meter and observed whether they are under the comfort or permissible limits as prescribed by ASHRAE Standards.

The other involved walk through inspection where physically, the building is observed for it proper design and maintenance which also affect to Air Quality and suggestions are made.

Finally, Interaction with maintenance person of HVAC System is involved which plays a vital role which is aslo a major cause of Air Quality and Recommendations are made at the end to achieve the best Quality of Air.

III. Walk Through Inspection

It is seen that ground floor is well ventilated and has opening at the entrance with the greenery surrounding the building which enumerates the high quality ventilation inside the building. The continuous opening of the incoming main door allows the fresh air inside the office building. As the building is located at a place where there are no high storeyed buildings, besides a considerable corridor left around the building allows light inside the building from the transparent glass walls. No foul smell of washrooms sensed as it is well designed for the requirement of the building occupants along with fresh air allowed continuously inside the space. There is also a well-designed gathering room of the employees as shown in the pictures above with the parameters assessing air quality under safe conditions of air quality. There seems the requirement of fresh air to be allowed as the office space in the second floor seems to be little high denser by the occupants/employees. It allows the occupants to feel fresher with fresh incoming air continually. Coming to the flooring design, it is all laid by well-furnished carpets inside the office which retains a lot of dust inside it. This indirectly further lowers the air quality by increasing the pollutants in the air space.

IV. Field Measurements

TABLE I. Measurements taken on Day-1 (4TH June 2015) are as follows

	Outdoor				Location-1			Location-2			Location-3			Location-4		
	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	36	41.1	391	10:00	30.7	40.1	405	32.2	36.3	407	30	36.3	418	33.1	30.1	508
	43.1	27	397	12:00	30.3	38.4	434	30.3	38.8	438	28.8	41.6	449	29.8	40.5	449
	39.5	27.7	404	14:00	32	36.5	466	32	36.6	468	29.7	40.5	440	31.1	38.7	458
	37.3	30.3	416	16:00	32.1	33.4	500	32.1	38.2	455	28.3	41.5	453	29.3	40.8	468
	Outdoor				Location-1			Location-2			Location-3			Location-4		
FLOOR 1	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	36	41.1	391	10:00	30.9	43.7	413	30.5	44.5	410	28.6	44.2	435	28.2	43.3	423
	43.1	27	397	12:00	28	36.2	435	27.6	37.4	427	27.3	38.4	423	26.8	38.7	417
	39.5	27.7	404	14:00	29.5	31.3	435	28	33.9	417	27.6	35.2	431	27	35.6	417
	37.3	30.3	416	16:00	29.6	33	421	26.9	36.4	427	26.6	37.2	425	26	38.5	423
	Outdoor				Location-1			Location-2			Location-3			Location-4		
FLOOR 2	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	36	41.1	391	10:00	29.8	45.5	400	28.8	47	405	29.6	48.4	465	30	46.9	416
	43.1	27	397	12:00	28.5	45.7	463	27.8	48.5	438	27.6	49.6	460	26.6	51.4	486
	39.5	27.7	404	14:00	32.2	34.4	434	30.7	37.5	440	29.7	40.3	455	27.3	43.5	494
	37.3	30.3	416	16:00	31.2	33.8	476	29.7	41.3	447	29	43.4	456	27.7	46.9	473

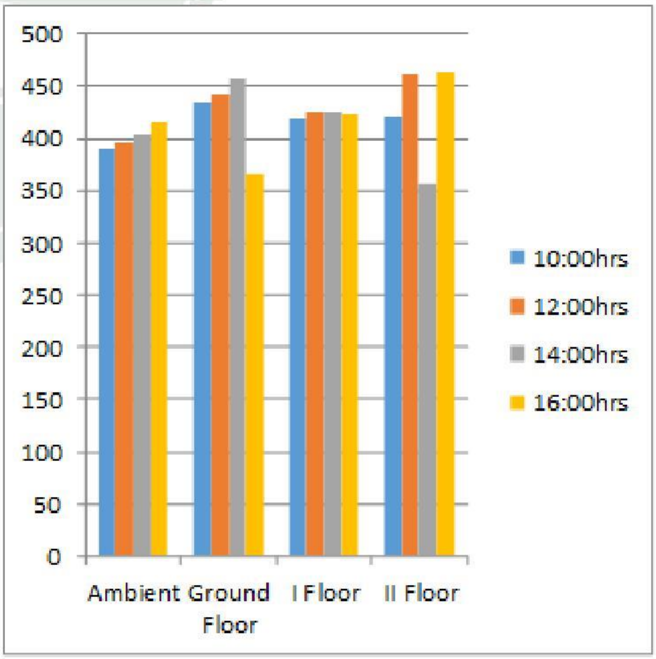


Chart. 1. Day-1, CO2 levels.

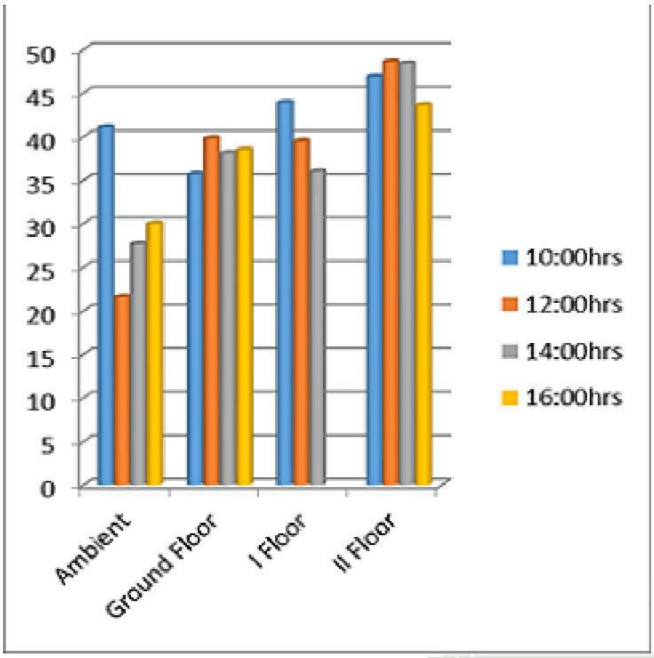


Chart. 2. Day-1, Relative Humidity.

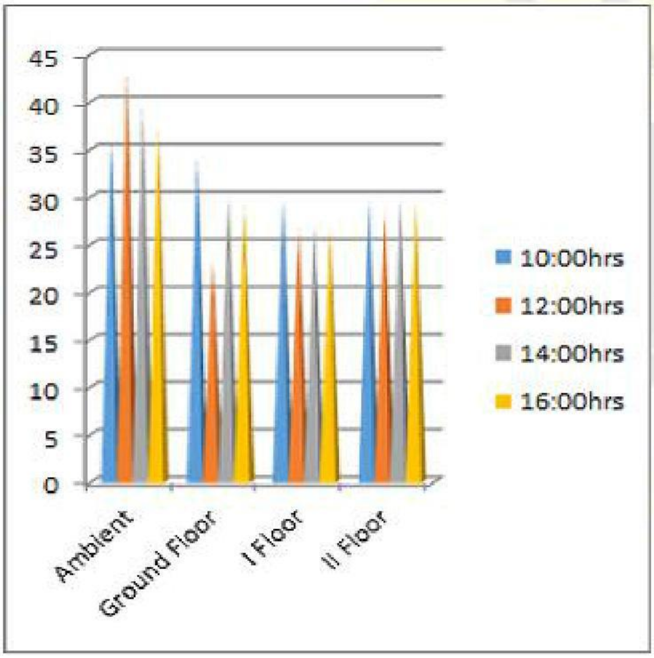


Chart. 3. Day-1, Temperature.

TABLE II. READINGS NOTED ON DAY-2 ARE AS FOLLOWS(12TH JUNE'15)

	Outdoor				Location-1			Location-2			Location-3			Location-4		
	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	32.2	53.1	444	10:00	29.8	52.7	451	26.3	55.1	445	28	57	440	29.3	59.5	444
	34.2	46.8	496	12:00	32.5	46.1	556	25	43.5	507	27.8	55.5	500	30.5	56.6	490
	34.9	46.8	490	14:00	32.5	42.7	508	27	46.3	501	28.2	51	486	29.5	50.8	490
	26.3	97.9	478	16:00	25.3	79.6	484	23.1	66.2	485	23.9	86.2	480	25.3	81.8	478
	Outdoor				Location-1			Location-2			Location-3			Location-4		
FLOOR 1	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	32.2	53.1	444	10:00	26.9	46.6	422	25.7	48.8	414	25.6	48.9	420	25.2	47.8	413
	34.2	46.8	496	12:00	27	46.4	466	25.6	49.9	455	26.1	49.8	448	25.6	50.6	448
	34.9	46.8	490	14:00	25.3	42.5	473	26.9	48.7	460	26.1	50.4	463	26	52.1	457
	26.3	97.9	478	16:00	25.8	54.8	486	25	55.5	484	24.9	53.2	485	24.2	54.9	490
	Outdoor				Location-1			Location-2			Location-3			Location-4		
FLOOR 2	Temp	RH	CO2	Time	Tem	RH	CO2	Temp	RH	CO2	Tem	RH	CO2	Temp	RH	CO2
	32.2	53.1	444	10:00	28.5	58.6	444	28.4	58.5	442	27.6	54.1	487	27	56.1	480
	34.2	46.8	496	12:00	29.1	54.8	480	28.7	54.5	471	27.8	52	475	28	54	474
	34.9	46.8	490	14:00	30.1	52	475	28.3	57.9	497	29	49.9	538	28	52.7	512
	26.3	97.9	478	16:00	27	56.2	518	27.1	61.5	497	27.6	61.9	504	26.4	57.2	517

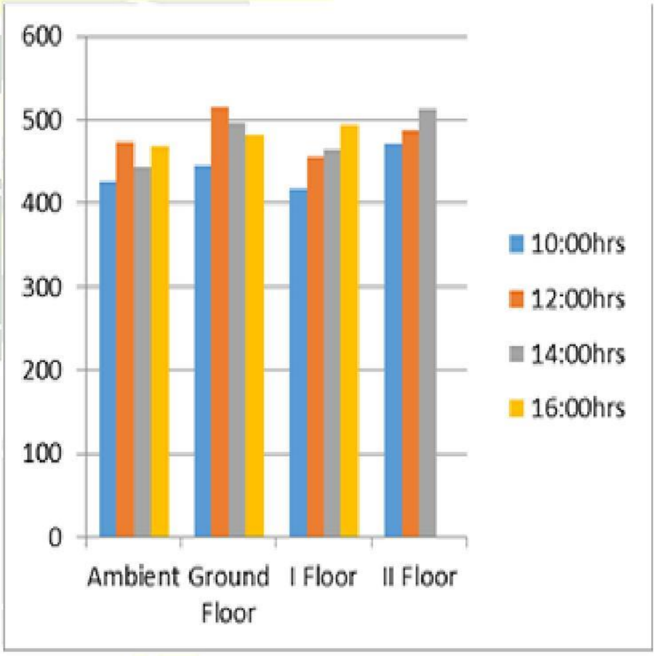


Chart. 4. Day-2, CO_2.

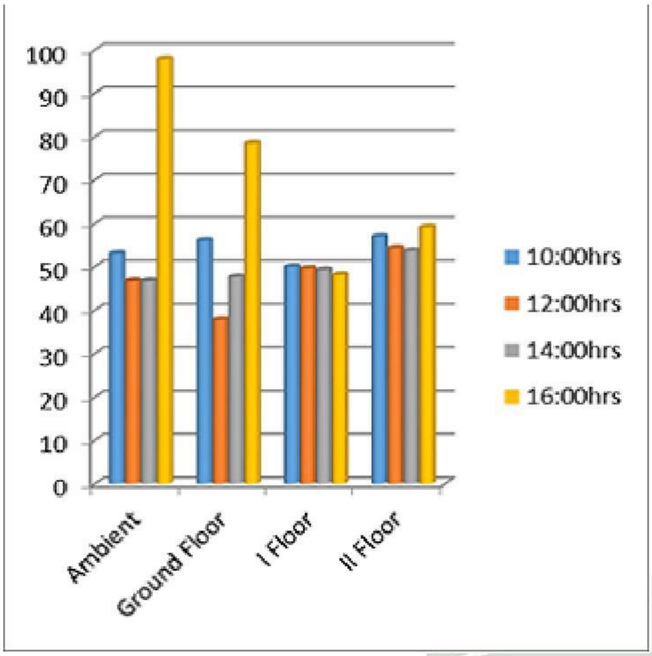
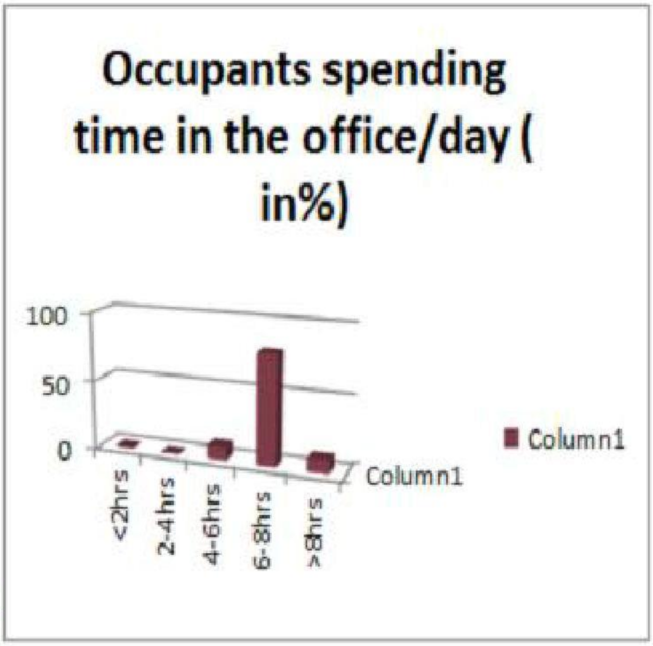


Chart. 5. Day-2, Relative Humidity.



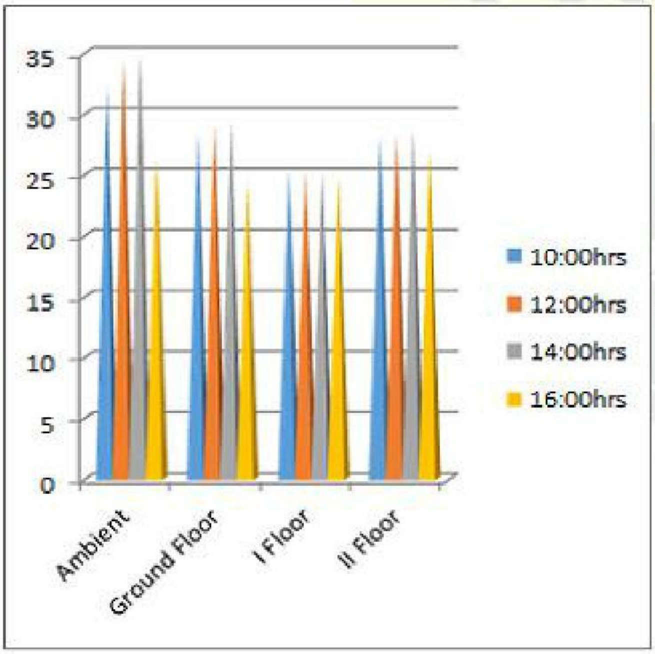
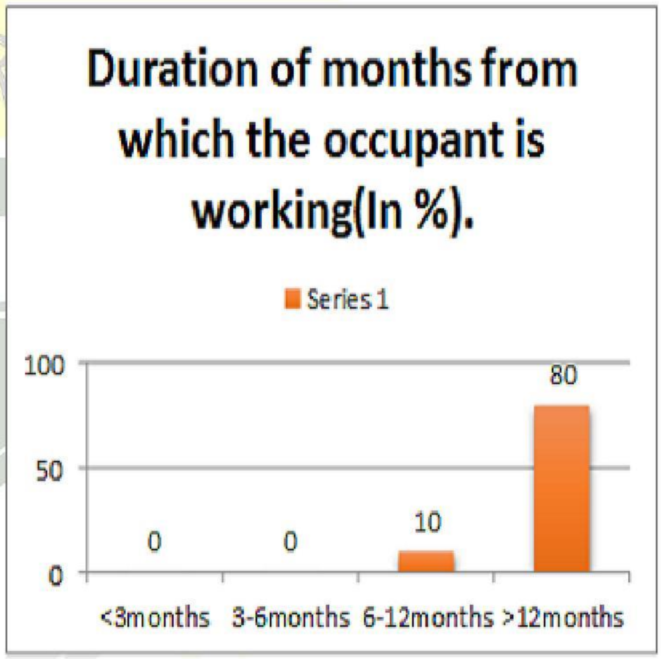
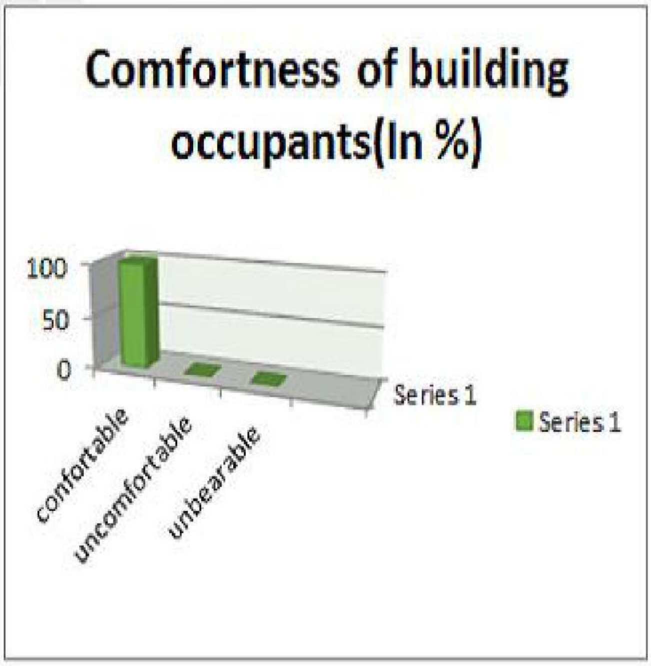


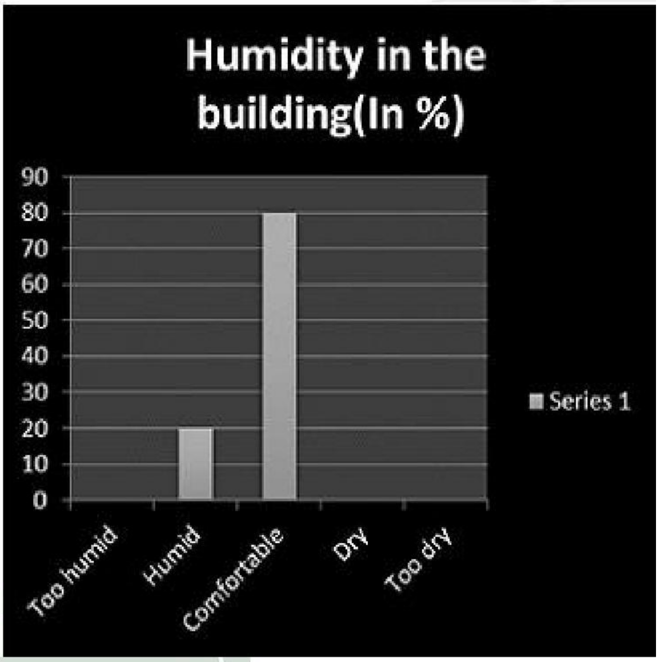
Chart. 6. Day-2, Temperature.

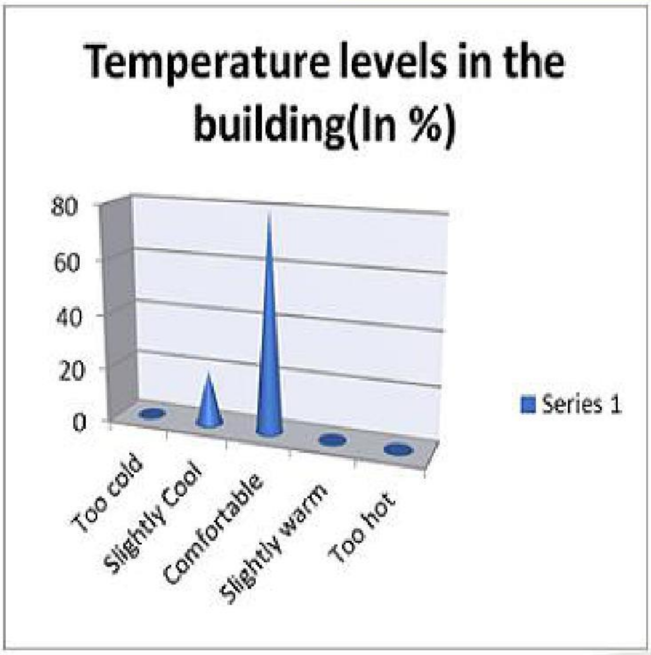


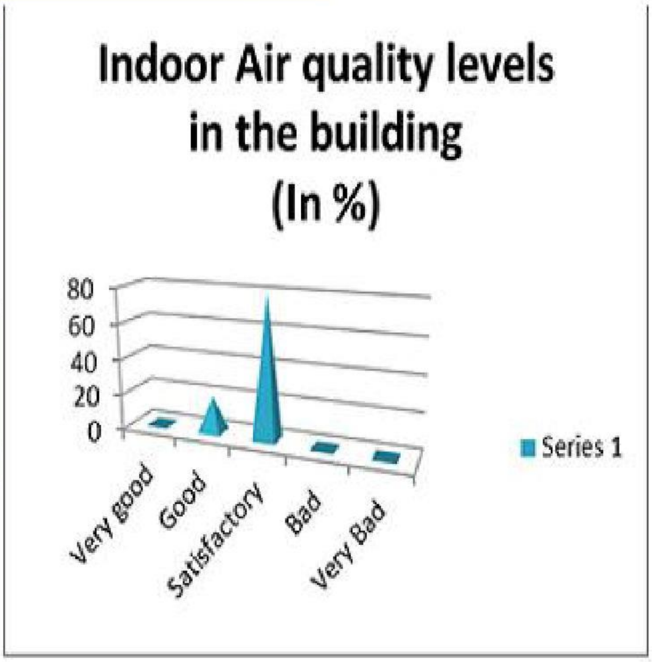
A. Building Occupants survey

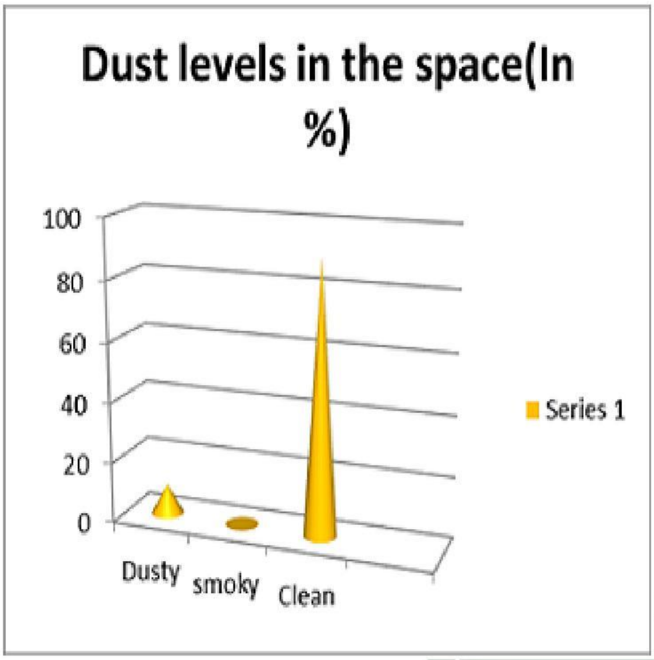
1) Feedback from the building occupants of the office taken in the Research Questionnaire.

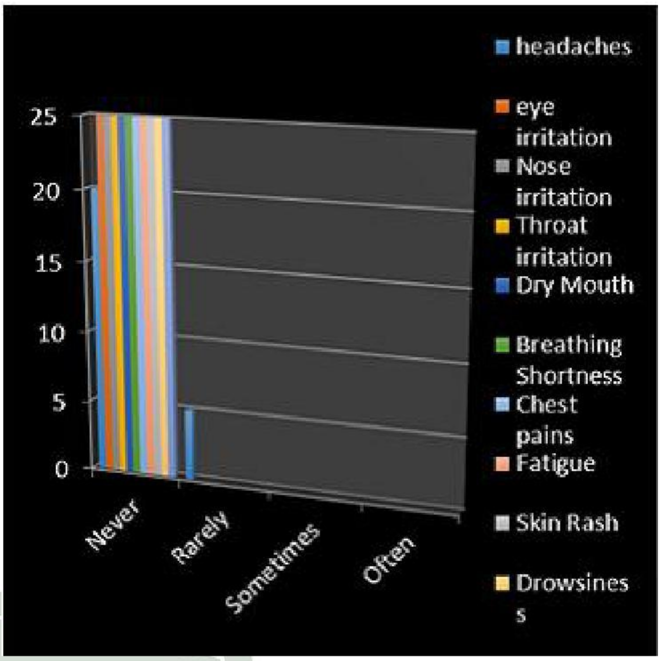

Comfortness of building occupants(In %)
100
50
0
confortable
uncomfortable
unbearable
Series 1
Series 1


Humidity in the building(In %)
90
80
70
60
50
40
30
20
10
0
Too humid
Humid
Comfortable
Dry
Too dry
Series 1

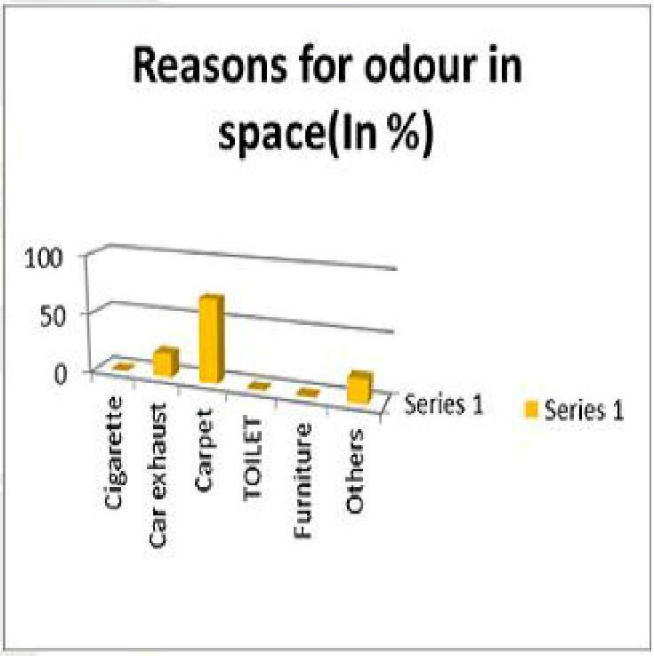

Temperature levels in the building(In %)
80
60
40
20
0
Too cold
Slightly Cool
Comfortable
Slightly warm
Too hot
Series 1

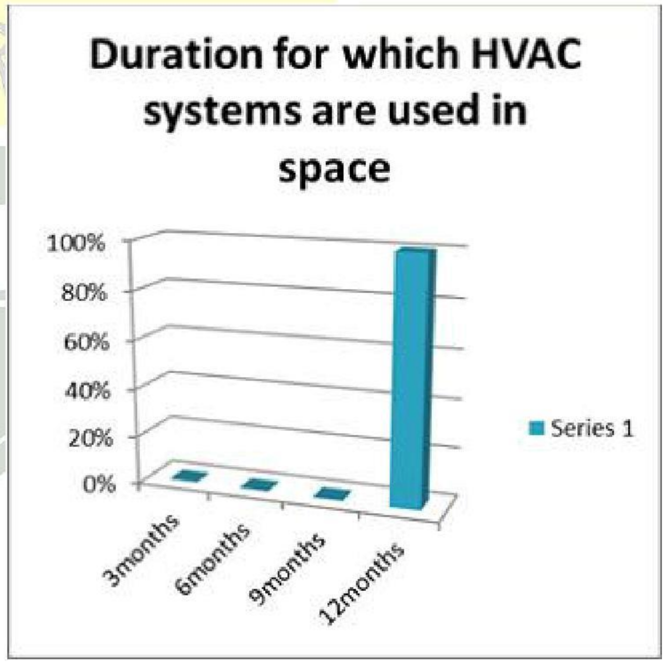

Indoor Air quality levels in the building (In %)
80
60
40
20
0
Very good
Good
Satisfactory
Bad
Very Bad
Series 1





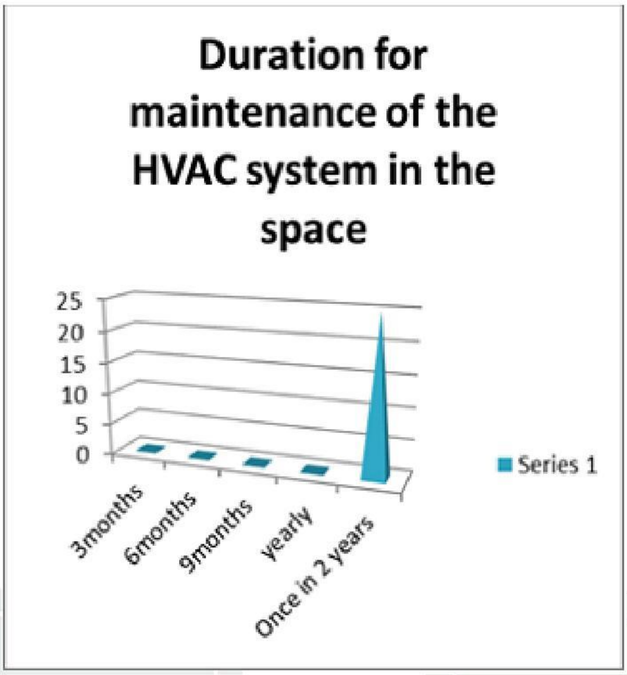
2) HVAC System Information.

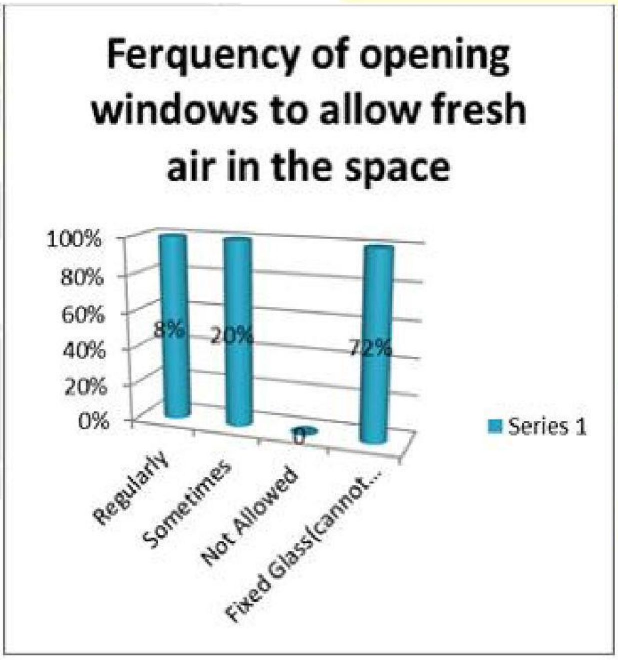




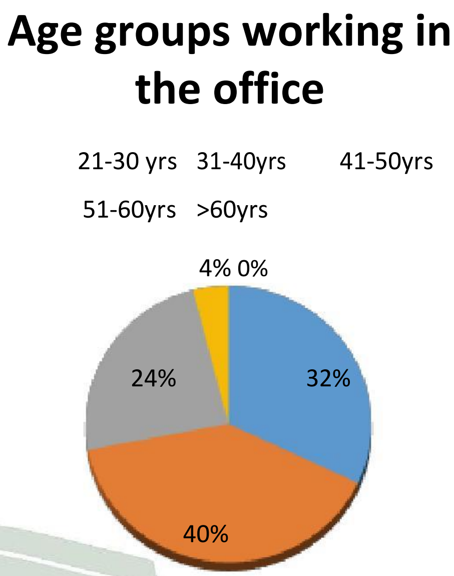
B. Health/ Symptoms Information

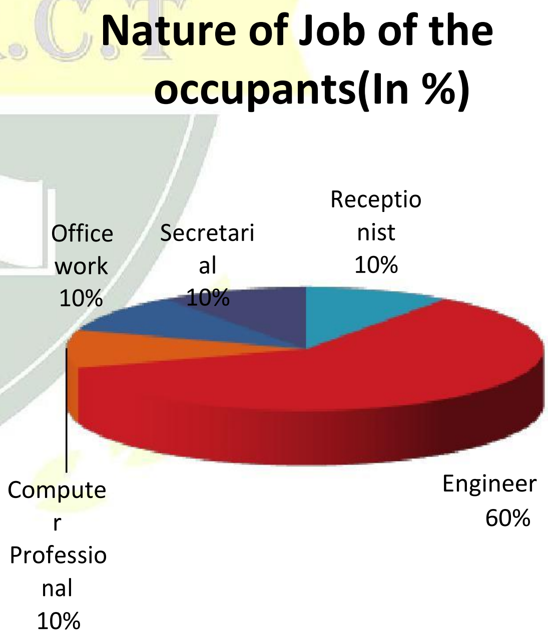
1) Symtoms experienced by the occupants in the working environment.





V. FIELD MEASUREMENTS





VI. FIELD MEASUREMENTS

From the readings noted in the tabular column, most of the values of the parameters (CO_2, RH and Temperature) fall under the comfort level region or they are near to the comfort level values. In general the comfort levels as per the ASHRAE STANDARDS are:

Temperature range: 22^oC - 26^oC

Relative Humidity range: 30% - 60%

CO_2 level: <1000ppm

The only level of RH at 16:00hrs crossed the comfort level noted is 97.9% (>60%). It is due to the rainfall. It can be visualized in the graphs of RH shown in the second day's figures. And all other readings of RH are in the permissible levels under normal conditions. Also it is seen that the levels of CO_2 and temperature are ranging differently which indicates two things. First is the locations with high load conditions are with high values of ppm of CO_2. The second is abnormal distribution of cool air in the space by the HVAC system. Hence it needs proper rotation and distribution of air in the space.

More over from the Research Questionnaire analysis, it seems that the quality of air is better. Further to improve the air quality levels in the space and healthy environment of the occupants, it is necessary to allow the fresh air continually in the Ist and IInd floors which is rectified to be done in the office in walk through inspection. Maintenance and Operation person of the HVAC system need to monitor the proper working of the system from time to time. Cleaning of the carpets is to be done to remove dust formation and accumulation of the pollutants. Also noted that the locations are free from wet or moist with which there are chances of growing fungi which also lowers the quality of air.

CONCLUSION

The results of indoor air quality measurements provided evidence of satisfactory thermal conditions for the commercial building. It was shown that although the overall air-exchange rate was in accordance with the ventilation standards, deficient dilution of indoor air with "fresh" outside air resulted in increased contaminant concentrations. The reported health problems could not be ascribed to any of the contaminants studied, since the values measured lay well below the current health standards for exposure; nevertheless, an insufficient rate of air exchange is commonly found in new or remodelled buildings. We would conclude that although A causative agent was not identified; ventilation deficiencies may be a primary factor contributing to employee discomfort; the establishment of optimal ventilation conditions should not be underestimated in the design of fully enclosed working places. To ensure the quality of work done by the workers is achieved to the employer's satisfaction, it is also important to ensure the quality of environment of the working area satisfies the workers. One of the elements that need to be considered in providing good environmental quality in a building is the indoor air quality including the ventilation and thermal comfort provided in the building such as ensuring the HVAC system provided is functioning well, and the temperature is conducive to building occupants. This is because a temperature that is too high or too low will affect the IAQ and in turn affect employee performance.

Besides, if the IAQ level in a building does not meet the occupants' needs and requirements, several symptoms will occur and affect them such as headache, irritated eyes or nose, blocked nose, and so forth; as the syndrome infects the building occupants, they will feel ill and it will reduce their passion to come to work as they know once they enter the building, they will be having the syndrome and it makes them sick. Besides, it is identified that the occupants' comfort and health level, indoor ventilation satisfaction and the comfort level felt by the occupants are the major factors affecting the occupants' psychology. As shown by the results obtained, it can be concluded that the higher the occupants satisfaction with the indoor air quality in the building, the higher their work productivity and the lower their stress level. So, based on our survey and questionnaire we can conclude that the building is well maintained and properly air conditioned free from pollutants and healthy for the occupants.

A. Guidelines for HVAC Operation & Maintenance Personnel

- Test the volume of air supplied or returned through diffusers to ensure that the system is balanced.
- System operators must be able to respond appropriately to occupant complaints
- Sometimes the problem can be relieved by fine tuning or repairing the HVAC system, but in some cases the system cannot perform as expected, and a long-term solution must be investigated
- Calibrate sensors and devices that control airflow, temperature, and humidity.
- Change air filters, clean dirty air intakes, and prevent leaks. • Inspect drive belts, bearings, motors, and other moving parts. Replace if necessary.
- Clean ductwork and, where ceiling spaces are used as supply or return air plenums, replace. Damaged or missing tiles.
- Clean and disinfect components where standing water may have been present for extended periods or where dirt, slime, or mould is observed. This includes humidifiers, electrostatic precipitators, cooling towers, fan coil units, air supply and exhaust ducts, air intakes, cooling coils, condensate drains, radiators, and induction units.
- Make sure drain traps in mechanical rooms do not go dry.
- Follow proper procedures for housekeeping, handling chemicals, and cleaning up spills.
- Inspect heat exchangers when it is suspected that combustion gases are escaping into the air plenum.

B. Guidelines for HVAC Designers

- All filter banks should be provided with pressure differential indication gauges to indicate the filter dust loading.
- Monitoring of filters should be done at regular intervals in order to prevent excessive filter loading that could force dust particles through the filter media, or could cause the filters to burst, resulting in ambient contamination.
- Where reverse pulse dust collectors are used for removing dust from dust extract systems, these should usually be equipped with cartridge filters containing a compressed air lance, and be able to operate continuously without interrupting the airflow.

- Alternative types of dust collectors (such as those operating with a mechanical shaker, requiring that the fan be switched off when the mechanical shaker is activated) should be used in such a manner that there is no risk for cross contamination. There should be no disruption of airflow during a production run as the loss of airflow could disrupt the pressure cascade.
- Mechanical shaker dust collectors should not be used for applications where continuous airflow is required.
- When wet scrubbers are used, the dust-slurry should be passed to a suitable drainage system.
- The exhaust air quality should be determined to see whether the filtration efficiency is adequate with all types of dust collectors and wet scrubbers.
- Where necessary, additional filtration may be required downstream of the dust collector. In the event of power failure, 'fail-safe' systems should be in place to prevent backflow of residues from the ductwork.

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