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ASSESSMENT OF INDOOR & OUTDOOR AIR QUALITY OF SCHOOL BUILDINGS LOCATED CLOSE TO URBAN ROADWAY IN MANIPAL (KARNATAKA)

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ABSTRACT

Investigation of indoor air quality in classroom of school buildings is consider as prime concern because of its adverse effects on students health and performance. Students spend their most amount of time (6-7 h per day) in schools. Current study is investigation of indoor and outdoor air quality in school buildings during winter season. In this study indoor and outdoor air quality parameters in naturally ventilated school building located near to urban roadway in Manipal. Monitoring was done during winter season (32 days). The objectives of the present study are monitoring indoor and outdoor parameters like PM10, NO_2, SO, and CO_2 during winter season and suggesting mitigation measures for proper air quality. Relative humidity, temperature and classroom characteristics such as size of room, occupancy level also monitored during school hours.

Results show that CO2 concentration in classroom over 1000 PPM during winter season due to small size of classrooms and more occupancy rate as per ASHRAE standards. Closing doors and windows can prevent only entry of outdoor PM concentration in inside room. For proper indoor air quality in school buildings mechanical ventilation system with proper air purification should be provide, also plantation of some indoor plants such as Anthurium, Dumb Cane, Golden Pothos, Kadaka Fern, Prager Plant, Spider Plant, and Syngonium etc. so it will help to reduce the indoor CO_2.

Key words: Indoor and outdoor air quality, school building, children, urban roadway, classroom, indoor plant.

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1. INTRODUCTION

Quality of indoor air (IAQ) is defined as "air is an occupied space towards where substantial majority of occupants express no disinfection and in which there are likely to be known contaminants at concentration leading to exposures that having significant health risk" [3]. Proper quality of air is depending on the required components which are present in suitable quantity, generally occupant is the best who judge its quality. This is due to air which we breathe is perceived absolutely through the sense. But building does not forever guarantee protection of occupants from the air pollution. A person spends his most of time (90%) in indoor environment. So the indoor environment can consider as "habitat" or "ecosystem". It is complicated habitat that consists of different attributes, such as occupants and their actions, the air pathways and condition of ventilation etc. According to various scientific studies they found that indoor air may be more polluted than the outdoor air. According to WHO Indoor air pollution is mainly responsible for 2.7% of the total world's burden of illness [16].

Over the last few decades, considerable attention has been directed toward the problems of indoor air quality. In recent years more studies have focused on indoor air in non residential & non industrial building. Among these studies much more concern about air quality in school building. Proper indoor air quality (IAQ) is essential to a good learning environment & contributors to the health of all building occupants. The association between the utilization of building either as office or a residence could also be reason behind discomfort & symptoms results in health problem. Contamination of various pollutants in indoor environment is the main problem & this pollutant contamination is usually referred as "Poor quality of indoor air". The adverse effect of bad indoor air quality of various buildings affects many people quality, since peoples in the city spends their most of time in indoor environment so they having more risk to get affected by the pollutant. Recently according to a study conducted by center of science & environment New Delhi. Indoor air pollution is a leading cause of death after tobacco smoking, obesity, high blood pressure & poor nutrition in India.

Most schools of urban area are located close to the busy roads. Vehicular emission from outdoor can enters into indoor air through ventilation intakes and open doors and windows. Various studies show that outdoor air quality has a significant impact on indoor air quality. The acceptable IAQ may be refer as, air within building and occupied space where there are no contaminants in concentrations leading to exposure that may lead to health risk [11]. Children may be more adversely affected due to indoor air pollution than the adults. Because Children breathe a greater volume of air relative to their body weight & this may lead to more harmful effects of pollutants on their bodies. The school going children spend comparatively more time in school especially in classrooms. As such classrooms are second most important indoor environment for children after their homes. The classrooms are characterized by high pollution density compared to other occupancies. Research has shown that poor indoor air quality in school building can cause reduction in student's performance & may increase health related problems. Therefore healthy indoor environments of school are required to reduce health risks & for better performance. Under the scope of this study it is proposed to investigate IAQ of school buildings located closed to urban roadway in Manipal city.

2. OBJECTIVES OF THE STUDY

- The main objective of the study was to identify schools located close to road and monitor indoor and outdoor air quality at those schools
- To monitor indoor air pollutants like PM10, CO_2, SO_2, NO_2 along with temperature and humidity during winter season.
- To monitor Outdoor air pollutants like PM10, CO_2, SO_2, NO_2 along with temperature and humidity during winter season.
- Suggest mitigation measures to improve the existing conditions based on findings.

3. METHODOLOGY

3.1. Study Area

Manipal city is fast growing and situated at latitude 13.3605º N & longitude of 74.7864º E. in Karnataka state. Manipal city is considered as one of the biggest education hub in India. There are many school buildings in city, constructed keeping in mind the byelaws but consideration given to IAQ may be questionable. There are some government's schools in city limits which cater the low income group, lack of maintenance & no consideration given to personal hygiene & health aspects. Also new school buildings are constructed in recent years. In this study it was proposed to investigate indoor and outdoor air quality of the schools located near to the urban road. The data pertaining to AQ of these schools is not available. This work will help to understand the present condition of air quality in schools. The research will create baseline data which further help to promote research to know nature of pollutants; probable contribution, health impacts etc.

This study is proposed to collect the information regarding the pollutant concentration in indoor air within in the classroom and also compare it with the outdoor air quality. In relation with this, influence of classroom occupancy, room size, ventilation and metrological parameters, were also investigated to study its impact over Air quality.

3.2. Reconnaissance Survey

The main objective of the study was to identify schools located close to urban roadway and monitor indoor and outdoor air quality at those schools. To achieve this aim the recognizing survey of various schools located close to road in Manipal city was carried out using questionnaire method. The survey was conducted in total 15 schools among the city. Then schools are identified and monitoring at those schools was carried out. The data collection sheet was prepared. Various details were collected during the survey which included zone in which school is located, building details, area of classrooms, ventilation source, school timings, no of stff, and total students in each classroom, presence of ground within vicinity, presence of roads near the school building, type of traffic, plantation in the vicinity. The actual monitoring was then carried out at these schools.

3.3. Identification of Schools

There are no studies for Manipal and nearby city reveling indoor as well as outdoor air quality at schools and its pollution level in air. Hence in the study the focus is on to investigate the indoor air quality of the schools located close to urban road in the city. At the beginning of this study, the schools were identified depending on their location. The survey of total 15 numbers of schools was done. After studying details of schools the two schools were selected for study. More details of selected schools were than collected. The details of school timings, lecture timings, break timings etc., accordingly the monitoring time and duration was fixed.

Monitoring frequency, sampling duration was then decided and accordingly monitoring at schools was done. Details of the schools selected for monitoring is given below in table 1.

Table 1 School Description

Sl No.	Name of school	School description
1	School No 1	It is located in commercial zone in Manipal city. Various commercial activities like, colleges, post office, police station. Also backside of school contains residential area. School surrounded by roads and contains heavy traffic intensity. classroom on the first floor was selected for study as it is close to the road and playground
2	School No 2	It is located in commercial zone in Indrali. Various commercial activities like bank, railway station, variety of shops. School very near to Manipal – Udupi highway so it contains heavy traffic intensity. classroom on the first floor was selected as it is very close to the road and playground

The characteristics of the classroom selected for the study is presented in table 2.

Table 2 Classroom Characteristics

Classroom Characteristics	School No 1	School No 2
Number of occupants	43	41
Volume (m^3)	220	175
Floor area (m^2)	63	50
Number of windows	3	3
Area of windows (m^2)	1.8	1.6
Number of door	1	1
Area (m^2)	2.52	2.52
Number of fans	4	2
Board	Blackboard	Blackboard
Cleaning frequency	Daily	Daily

3.4. Sampling Methodology

Measurement was conducted in winter season i.e month of November-December 2017. The monitoring time was fixed according to school timings. 24 hours monitoring at each school was carried out at regular intervals. The sampling time decided was morning 8:00 am to 8:00 am i.e 24 hours. As this time provided the data for both when the schools were vacant and when the schools were occupied. 4 hours monitoring interval for NOx and SO_2 was carried out and 8 hours mass concentration for particulate matter was done. CO_2 was analyzed by handy meter. When school was unoccupied during that time only cleaning of the classroom was observed which may have contributed to particulate matter concentration. The traffic density is also less during the morning section but then it gradually increases as the time proceeds due to office timings, transport service etc., the monitoring during school timings helped to study pollutant concentration in the classroom. Temperature and relative humidity was also noted down as to see its effects on pollutant concentration. The indoor air pollutants are also affected by these metrological parameters. As mentioned earlier the standards for temperature, relative humidity and ventilation rate suggest that if these parameters are properly maintained within indoor atmosphere that good IAQ may be achieved.

3.5. Sampling Location

3.5.1. Indoor Sampling Location

Sampling location was selected according to WHO and ASHRAE standards. So according to the standards samplers placed at least 1m from wall and at least 1.5m height from the floor. Samplers placed at higher position from floor and closer to the wall. The samplers were placed near the wall as the dust from blackboard could be measured. Also window is close to the sampling location. So

3.5.2. Outdoor Sampling Location

To achieve the objectives, the outdoor sampling was also done and the outdoor sampling location was chosen as suggested by WHO and ASHRAE. At least one outdoor air sample should be collected at each school for each pollutant. So according to these standards one outdoor sampling location was selected for study.

3.6. Parameters Used For Monitoring

Table 3 Parameters Used For Monitoring

Sr No.	Parameter	Method	Instrument / Equipment
1	PM	Gravimetric method	APM 550 fine particulate sampler
2	SO_2	Improved west and grake method.	APM 433 gaseous pollutants sampler
3	NO_2	Modified Jacobs and hochheiser method.	APM 433 gaseous pollutants sampler
4	CO_2	NDIR Sensor	Lutron MCH-383SD handy meter.
5	Temperature	NDIR Sensor	Lutron MCH-383SD handy meter.
6	Relative Humidity	NDIR Sensor	Lutron MCH-383SD handy meter.

4. RESULTS AND DISCCUSION

4.1. Winter Air Quality Results

4.1.1. School 1- Indoor Air Quality Results

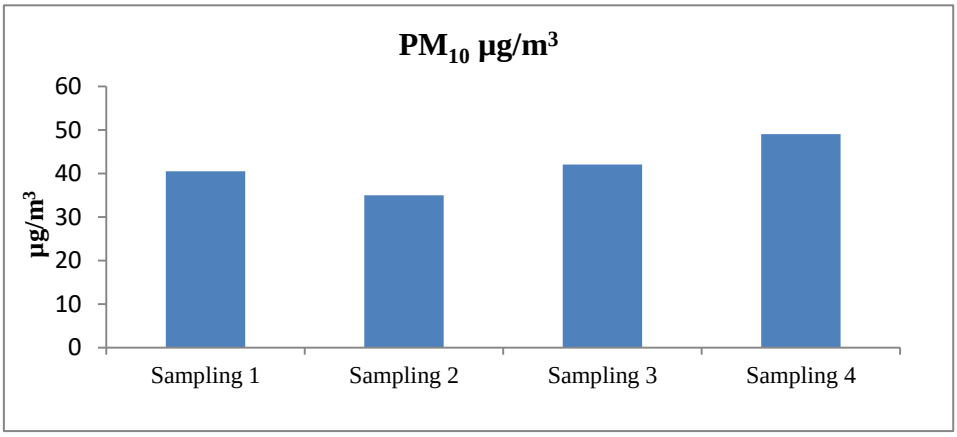

Figure 1 School 1 indoor winter PM_{10} concentration

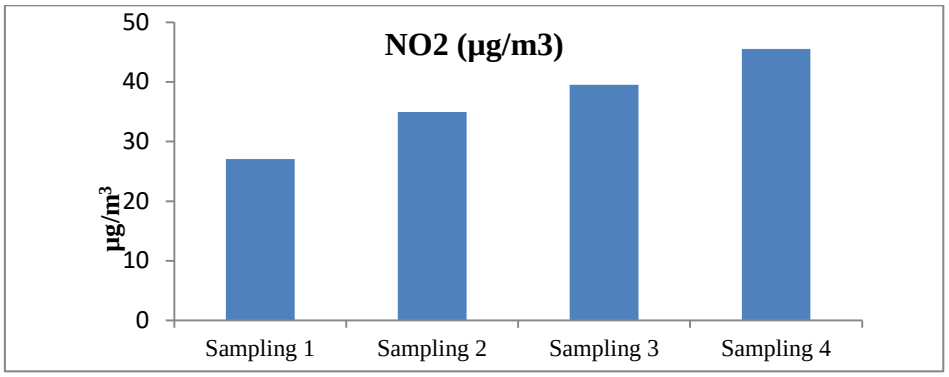

Figure 2 School 2 indoor winter NO_2 concentration.

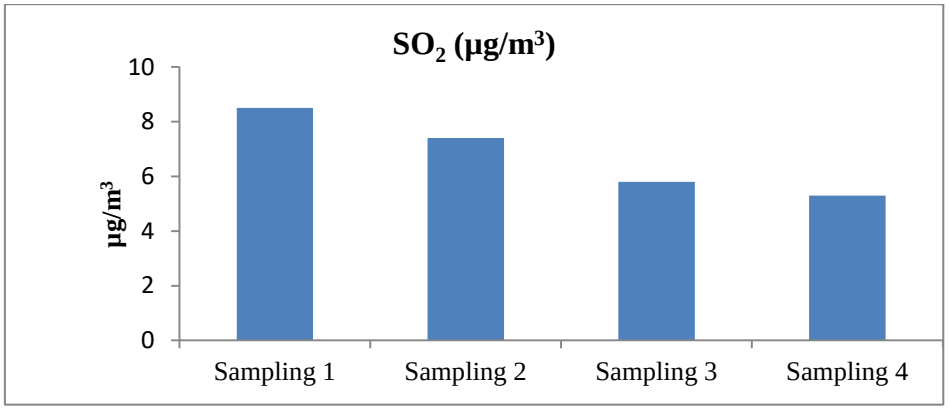

Figure 3 School 1 indoor winter SO_2 concentration

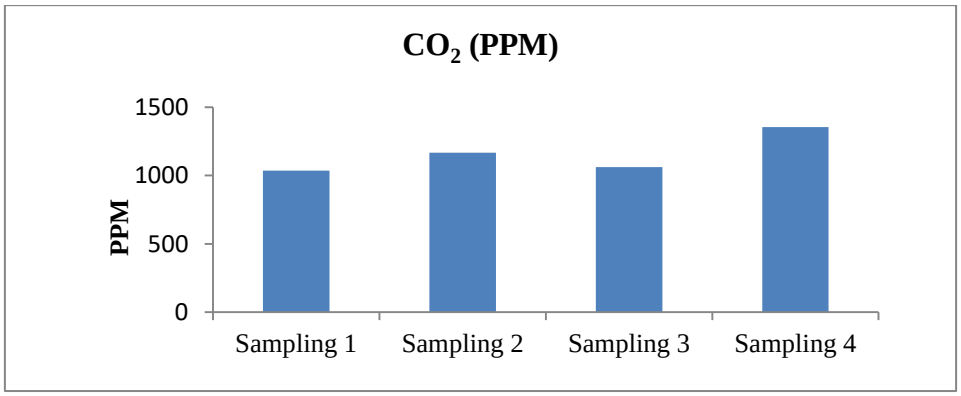

Figure 4 School 1 indoor winter CO_2 concentration

Table 4 School 1 indoor winter temperature and humidity results

Sample no	Temperature	Relative Humidity
Sampling 1	28.5ºC	55 %
Sampling 2	29.5ºC	60%
Sampling 3	30ºC	57%
Sampling 4	28.5ºC	62%

As stated in table no 1, school 1 is located in commercial + residential zone. School has roads on three sides of building and contains heavy traffic on Manipal – Udupi highway which is near to school building. As shown in graph PM10 concentration was more due to student's activity, dust particles of chalk. The higher level in CO_2 is mainly because maximum occupancy in classroom environment than that of recommended by the ASHRAE standard 62-1989 which is 50person/100m^2. The data obtained shows that the pollutant concentration is well within limit as prescribed by WHO and ASHRAE only CO_2 was exceeds.

4.1.2. Outdoor Air Quality Results

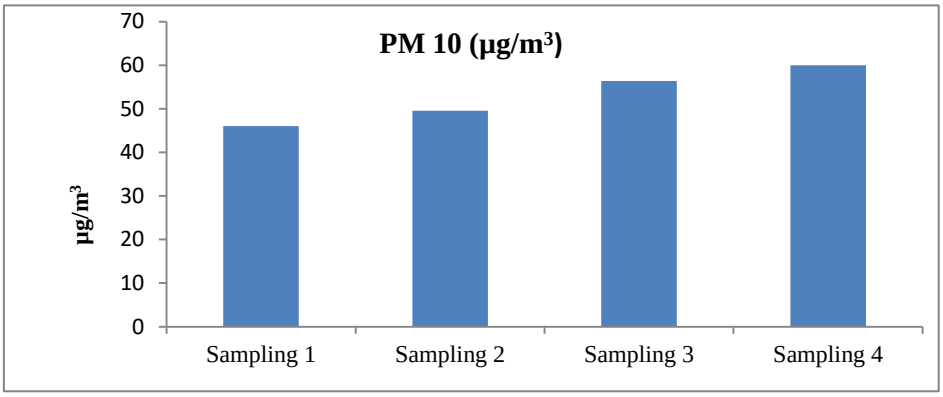

Figure 5 School 1 outdoor winter PM10 concentration

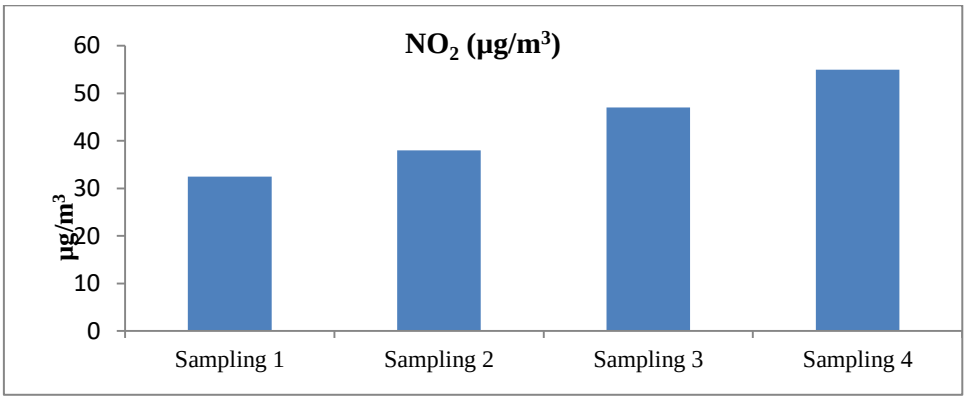

Figure 6 School 2 outdoor winter NO_2 concentration

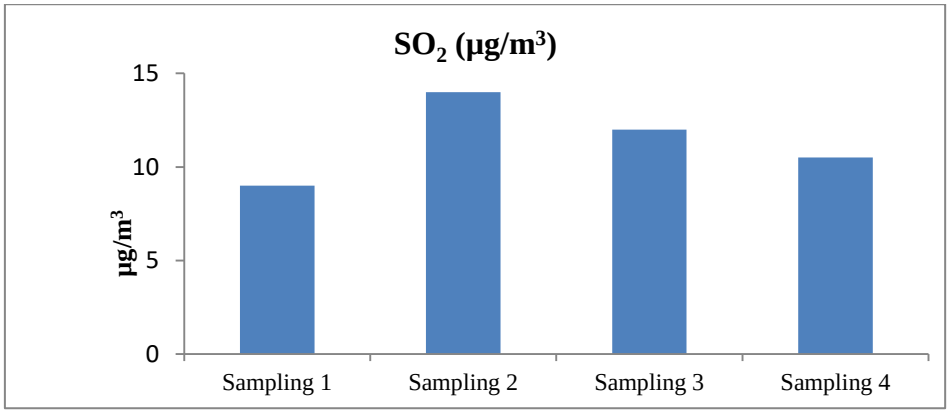

Figure 7 School 1 outdoor winter SO_2 concentration

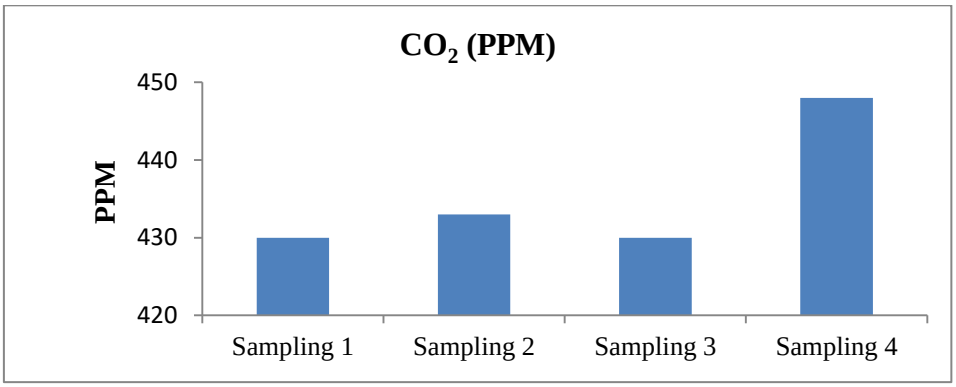

Figure 8 School 1 outdoor winter CO_2 concentration

Table 5 School 1 outdoor winter temperature and humidity results

Sample no	Temperature	Relative Humidity
Sampling 1	29.5ºC	56%
Sampling 2	27.5ºC	60%
Sampling 3	26.5ºC	63.55%
Sampling 4	29ºC	63%

From the graph it is seen that the outdoor air pollution concentration is more and that the indoor air pollutant level is mainly affected by outdoor source i.e., Outdoor vehicular emissions, dust coming indoor due to movement of children's or re-suspension of particles. Similar results have been obtained for the rest of the school which indicate the vehicular contribution being major source of pollution in indoor air.

4.1.3. School 2 – Indoor Air Quality Results

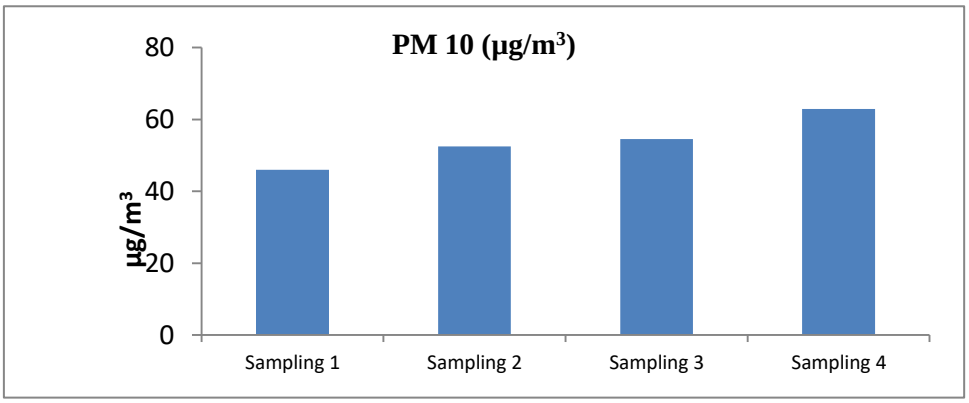

Figure 9 School 2 indoor winter PM_{10} concentration

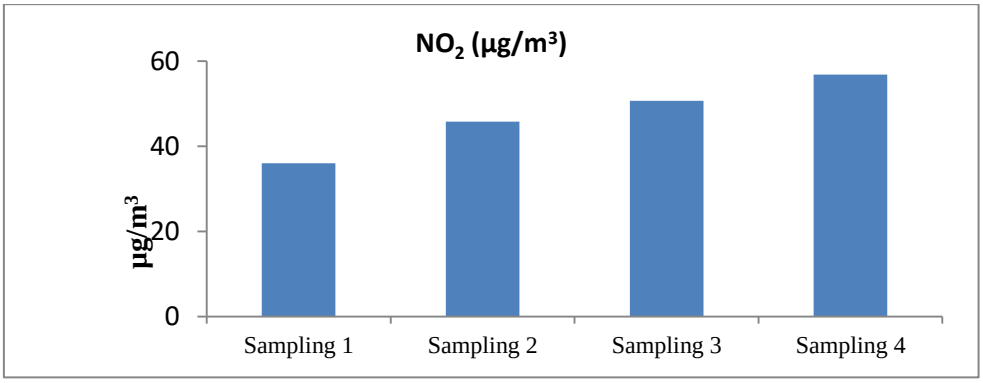

Figure 10 School 2 indoor winter NO_2 concentration

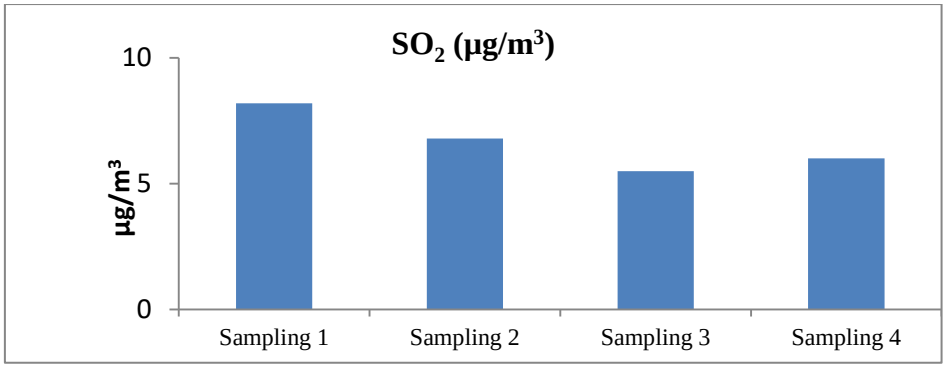

Figure 11 School 2 indoor winter SO_2 concentration

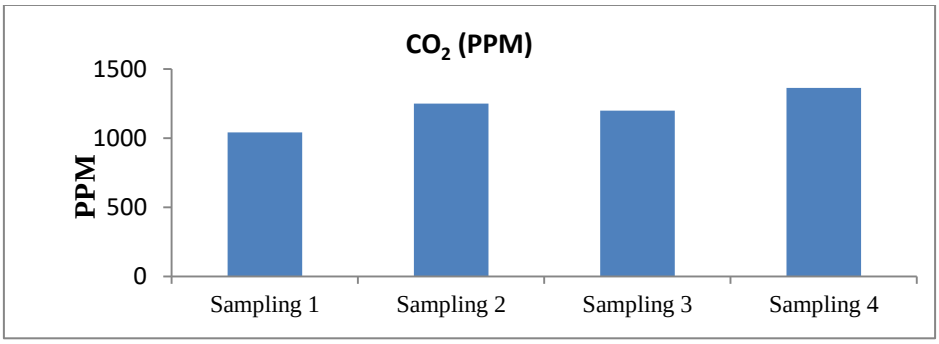

Figure 12 School 2 indoor winter CO_2 concentration

Table 6 School 2 indoor winter temperature and humidity results

Sample no	Temperature	Relative Humidity
Sampling 1	27.5ºC	60%
Sampling 2	28ºC	58%
Sampling 3	29.5ºC	53.5%
Sampling 4	27.5ºC	55%

As stated in table no 1, school 2 is located in commercial zone the pollutant concentration is higher than school 1. The school is located near railway station and many retail shops are near the vicinity. As there is high traffic density in the area as the Manipal – Udupi highway passes nearby. Due to this entire factor, the air pollution is more in the area. Due to heavy traffic the concentration of NO_2 and PM is high in indoor air. This indicates the vehicular emissions are the major contributors to the rise in concentrations indoors. The CO_2 concentrations indoors exceed the standard limit provided by ASHRAE and WHO. The higher level of CO_2 is mainly because of maximum occupancy in small size of classroom.

4.1.4. Outdoor Air Quality Results

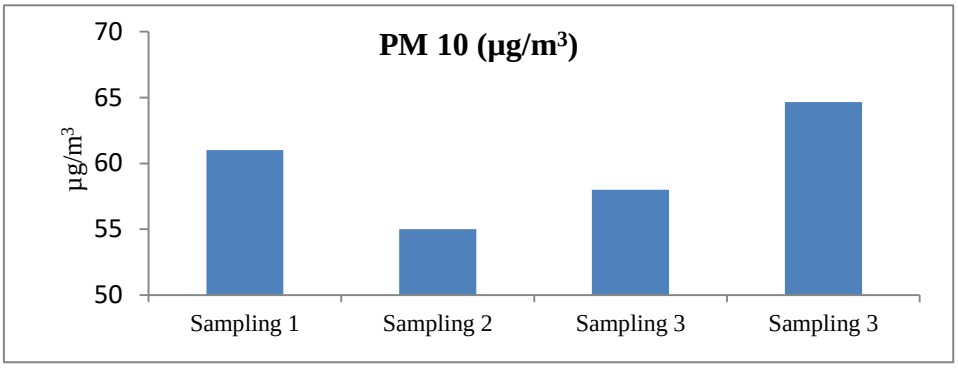

Figure 13 School 2 outdoor winter PM10 concentration

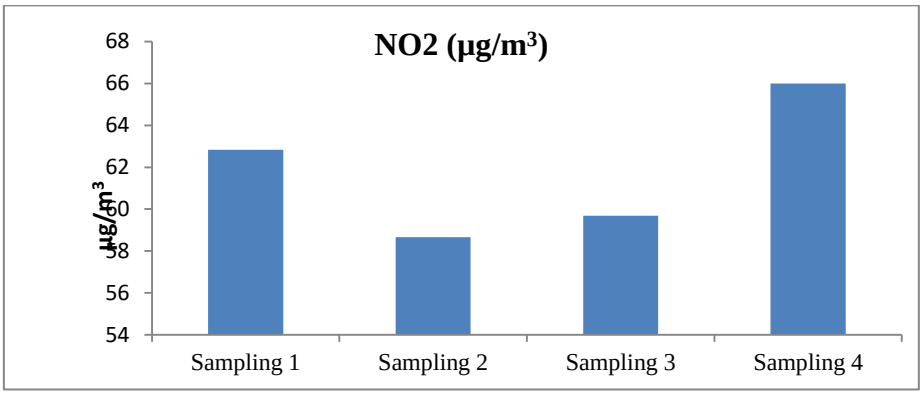

Figure 14 School 2 outdoor winter NO_2 concentration

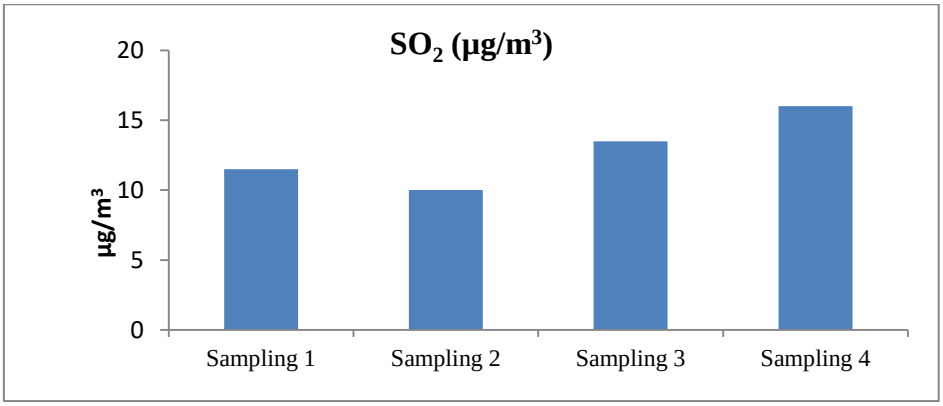

Figure 15 School 2 outdoor winter SO_2 concentration

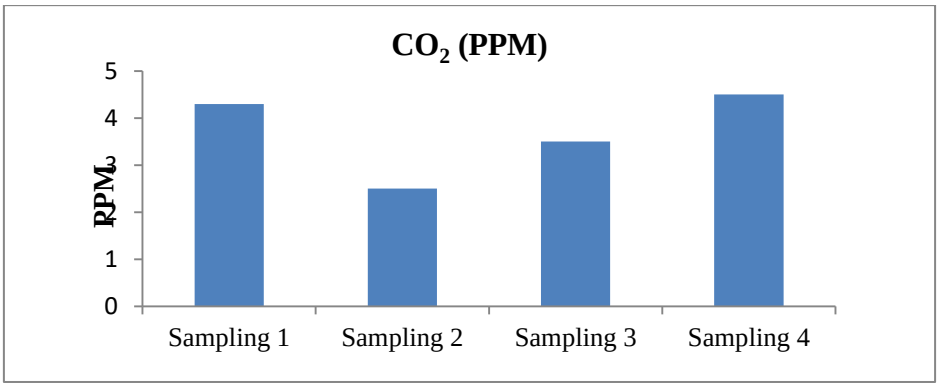

Figure 16 School 2 outdoor winter CO_2 concentration

Table 7 School 2 outdoor winter temperature and humidity results

Sample no	Temperature	Relative Humidity
Sampling 1	27.5ºC	50%
Sampling 2	28.5ºC	47%
Sampling 3	28ºC	48%
Sampling 4	27ºC	54%

Similar results have been obtained for the school 2. From the graphs it is seen that the outdoor air pollution concentration is more than indoor. Also more concentration of outdoor pollutant was found in school 2 as compared to school 1. Indoor air pollutant level is mainly

affected by outdoor source i.e., Outdoor vehicular emissions, dust coming indoor due to movement of children's or re-suspension of particles.

5. MITIGAUTION MEASURES

As observed in the results the pollutant concentration except CO_2 are below the standard limit but PM10 and NO_2 level was about alarming position and CO_2, Temperature and Relative Humidity are crossing the standard limit by ASHRAE standards, which is harmful for the students as well as teachers in the school building. So for better air quality and comfort for the students and teachers some mitigation measures are suggested.

5.1. Indoor Plants

Results show that during winter and summer season in both school CO_2 level was crossing the standard limit of 1000 PPM in classroom, so there is need to reduce the CO_2 level. Planting indoor plants inside classrooms which are help to reduce indoor CO_2. In last few decades researchers work on that and they found that indoor plants have abilities to reduce indoor air pollution. Generally in photosynthesis process plant, CO_2, light, and temperature is involved. According to NASA research common indoor plants may provide a natural way of helping for better air quality. English Iry, Philodendrons, Spider plant, Golden Pathos, Boston Ferm, Dracaena and Spathiphyllum these are some plants listed by NASA which having positive impact on total air quality for removing indoor CO_2. Also in some studies mentioned that Anthurium, Dumbcane, Golden Pathos, Kadapa Ferm, Prayer Plant, Spider Plant and Syngonium these are some effective plants for CO_2 reduction [14]. Generally, these plants are selected based on their availability. Most of these plants are easily available in study area and these are cost effective plants. . So there is no disturbance and harm due to planting these plants inside classrooms. So this is one of important mitigation measure for indoor CO_2 reduction.

5.2. Mechanical Ventilation Design

CFM (Cubic Feet Per Minute of Air Supply) = (Volume of room × ACPH) ÷ 60

ACPH stands for Air Changes per Hour

ACPH = 10 for classroom according to ISHRAE 1981 (Indian Society of Heating, Refrigeration and Air conditioning Engineers) standards [10].

By Thum Rule Tonnage calculator (T.R) = CFM÷400

According to above calculation mechanical ventilation system is design for both the schools. Also size of class, occupancy rate, temperature and humidity these factors should be considered.

For School 1--2000 CFM capacity ventilation supply and exhaust fan needs to be placed in classroom for proper air supply (for actual designing factor of safety should be considered as 1.5). It's Cost about 1.5Lakh Rs. In this system temperature will not decrease but due to ventilation supply which is provided will extract little amount of heat from class, which gives comfort felling to the occupants in room. To maintain the temperature below 25 to 26 ºC, AC of 3.5 – 5.5 T.R or AHU of 2000 CFM capacity DX coil will be required. So windows and doors shall be fully closed. It will help to improve air quality.

For School 2 - 1500 CFM capacity ventilation supply and exhaust fan required to fit in classroom. Its cost is around 1.5 lakh. In this system temperature will not decrease but gives comfort to occupants inside classroom. For further maintaining temperature below 25 to 26ºC

and relative humidity below 60% required docutable AC of 3.5 TR or AHU of 2000 CFM capacity DX coil will required to place. Doors and windows shall be fully closed.

There are some other steps which could taken from school management for improvement of air quality are listed below

- Schools required to setup formal Indoor Air quality management program
- The main goals of this program are to fix existing problems related IAQ, creates awareness among school staff.
- Main priorities for IAQ management programs mostly includes heating, ventilation and AC systems, moisture and mold cleaning and maintenance, material selection and source control.

6. CONCLUSIONS

From the results and discussion, we have come to following conclusion.

- The indoor air quality parameters (PM10, NO_2) are found significant in winter seasons.
- It is observed that PM concentrations were found significant in classrooms. They were higher when the classrooms were occupied.
- Outdoor pollutant concentrations found more than indoor pollutant concentration.
- As there is no significant indoor source, so outdoor pollution seems to be important factor to influence indoor concentration.
- The indoor CO_2 level at all monitoring stations during all sampling time exceeds the standard of 1000 PPM given by ASHRAE. This is mainly due to overcrowded classroom. Proper ventilation will help to reduce its concentrations.
- Also plantation of indoor plant CO_2 will also help to reduce its concentrations.
- By providing proper air flow the pollutant concentration can be reduced as it gets diluted.
- Cross ventilation will help us in achieving this.
- As providing proper mechanical ventilation system will also help to improve indoor air quality.

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