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Determining the Outdoor Air Ventilation with Carbon Dioxide (CO_2) as a Tracer Gas

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Insufficient ventilation can lead to occupant complaints of discomfort and reduced productivity as human and building generated pollutants build up. Some combinations of these elevated pollutants may have short or long-term detrimental health effects.

Carbon Dioxide (CO_2) is very rarely a pollutant of direct health concern itself. Rather a tracer gas, because building occupants exhale CO_2 and is used as a tracer gas that is an excellent indicator of adequate (or inadequate) ventilation.

Keeping in view this fact we measured CO_2 as a marker, or tracer gas, to determine the outdoor air ventilation (dilution air) rate in an occupied space.

Low CO_2 concentration, when measured during periods of average and higher occupancy, implies that human generated pollutants are being properly diluted. And in the absence of a specific pollutant source, it is a rough estimator that the thousands of potential building generated pollutants are being dispersed. This makes it a key indoor air quality indicator.

US Occupational Safety and Health Administration (OSHA)

OSHA states that 1,000 ppm CO_2 should be used as an upper limit for indoor levels, as a guideline for occupant comfort. >1000 ppm indicates inadequate ventilation; complaints such as headaches, fatigue, and eye and throat irritation will be more widespread.

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American Society of Testing and Materials (ASTM International)

Studies have concluded that about 7.5 L/s of outdoor air ventilation per person will control human body odour such that roughly 80% of visitors will find the odour at an acceptable level. These studies also showed that the same level of body odour acceptability was found to occur at a CO_2 concentration that is about 650 ppm (v) above the outdoor concentration.

US Environmental Protection Agency (USEPA)

EPA Testing for Indoor Air Quality, Baseline IAQ, and Materials, 2009 states that "Acceptance of respective portions of buildings by the Owner is subject to compliance within specified limits of IAQ contaminant.
Levels and CO_2 not to exceed 800 ppm"

Observations/Readings:

Reading start time: 20-Oct-15 11:31:23 AM
Reading End Time: 03-Nov-15 08:13:43 AM
Average: 547

A study was carried out with IAQ Meter acquired from USA (GrayWolf IAQ Meter) that has capability to measure CO_2 along with other pollutants in air. In this paper we would focus only on CO_2 values as a tracer gas.

Data comprises more or less for 11 days. Out of these days comparisons are made for Carbon dioxide at a particular time and date with respect to the occupancy of the space (lab).

The max/min of the CO_2 concentration is summarised as follow:
Carbon Dioxide ppm :

Min = 373 at 02-Nov-15 05:43:43 AM
Max = 1489 at 20-Oct-15 05:31:23 PM
Average = 546.6

The highest value of 1489 was attained on 20 Oct 2015 Tuesday. If we analyze the lab time table we notice in that time the lab was occupied by students which lead to the highest level of carbon dioxide as it's exhaled by humans.

Rise in carbon dioxide value is evident with the number of occupants in the lab. Carbon dioxide value increases with increasing number of people inside the lab. It starts to rise by 3.30 PM (Lab started) and reaches maximum value of 1489 ppm by 5.31 PM.

It gradually decreases as occupants leave by the end of the lab time.
Average = 546.6 is still within American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) guidelines i.e. 700 ppm

ASHRAE Standard 62.1-2013 suggests maintaining a steady-state CO_2 concentration in a space no greater than about 700 ppm above outdoor air levels will result in a substantial majority of visitors being satisfied in respect to human bio effluents (body odor).

Carbon Dioxide (21st Oct Wednesday to 28th Oct Wednesday)

Same lab was occupied on Wednesday 21 October 2015 and 28th October 2015.

If we analyse the trends for CO_2 for 21st Oct and 28th Oct (Wednesday) we found that it's quite similar. This is obvious. As per lab time table lab starts by 2.00 PM and ends by 4.45 PM.

We can clearly see the values on the graph for CO_2 a start increasing once it's occupied by the students at 2.30 PM and continue to rise until it reaches 900 ppm. The values gradually decrease by 4.45 PM indicating that students started vacating the lab at its end time.

The typical CO_2 concentration indoors will increase above outdoor levels depending on the balance between occupancy (as occupants are all exhaling CO_2), and the natural and forced ventilation. While levels of 600 ppm to 1000 ppm are typical in office buildings, many factors may result in higher levels (e.g. inadequate ventilation, elevated outdoor levels), or in lower values (e.g. low occupancy at the time of measurement, over-ventilation).

CO_2 proved to be a tracer gas as its concentration was affected by number of occupants. This gives a clear picture for the ventilation. If the CO_2 concentration increases this means ventilation isn't adequate and if its below the documented value i.e 700 ppm that means the space is well ventilated.