# Determination of AER, Ventilation Rate and Indoor Air Quality Index for a Community Kitchen

**Naragam Bhanu Sree, Aditya Kumar Patra, Penchala Abhishek, and Nazneen**

**Abstract** In recent year's indoor air quality has gained much attention throughout the globe. It was ranked as the top five risks to public health. People spend most of their time indoors, it might be their home, workplace or while commuting. They are exposed to different micro environments without knowing that they are inhaling substantially high concentrations of different indoor air pollutants (IAPs). In developing countries, IAP concentrations are generally found high due to poor ventilation and numerous indoor sources. Poor IAQ can severely damage the mental, physical and social ability of a person, which can affect the working efficiency and result in loss in overall productivity. The present study focused on the determination of air exchange rate (AER), ventilation rate (VR) Q, and indoor air quality index (IAQI) for the community kitchen. The study was conducted for 3 days from 18-10-2022 to 20-10-2022. In this study, different pollutants like PM10, PM2.5, PM1, TVOCS, $CO_2$, CO, $O_3$, $NO_2$ were studied. Comfort parameters temperature and relative humidity were also monitored. The levels of all the pollutants, comfort parameters were shown higher on 20-10-22 when cooking activities like frying potato, frying fish took place have crossed the WHO guidelines 2009. The AER value varied from 0.9915 to 0.9906 $h^{-1}$. Lowest value was observed on the highly polluted day i.e. 20-10-2022. Similarly, the VR varied from 0.8262 to 0.8254 lit/s/$m^2$. This VR has shown that buildings have fallen to category III i.e. high polluting buildings according to ventilation rate for non-residential buildings (European Standard, EN 15,251). The indoor air quality index (IAQI) is calculated based on 5 criteria pollutants PM10, PM2.5, CO, $O_3$, $NO_2$ showed that the health condition of the workers falls into the very severe to poor category (NAQI 2014). Further the study suggests the measures to enhance IAQ that can be practiced in the community kitchen which were observed during the study.

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# 1 Introduction

People spend 75–90% of their time in different microenvironments such as residential homes, schools, offices, recreational places, restaurants and saloons. The time spent indoors has increased greatly during the pandemic situation with toddlers spending almost all their time at home. It is going to remain at a higher level even after the pandemic is over because of continuance of online mode for many activities such as business and teaching. It's often believed that outdoor air is more polluted and indoor air is cleaner, which is not the case in the real world. Indoor air is highly polluted; sometimes pollutant levels indoors can exceed 100 times those outdoors. The pollutants that enter from outdoors often don't get flushed out from indoors due to restricted ventilation indoors. According to EPA 1986, the levels of pollutants can be 2–5 times higher indoors than outdoors (Include reference). Indoor environments act as reaction vessels for many secondary pollutants, leading to many health impacts of the persons exposed to it. Poor IAQ can severely damage the mental, physical and social ability of a person, which can affect the working efficiency and result in loss in overall productivity. The present study focussed on the determination of air exchange rate (AER), ventilation rate (VR) Q, and indoor air quality index for the community kitchen.

# 2 Methodology

## *2.1 Site Description*

The microenvironment considered in this study a large community mess, consisting of a kitchen and dining hall, was considered to study the indoor air quality. The community mess located in RP hall, IIT Kharagpur. The mess is surrounded by greenery giving a good ambience. Everyday cooking was prepared for 1000 students consisting of 19 workers constantly working in morning and night shifts. Kitchen has a natural ventilation system but the exhaust fans provided were not working. The kitchen is divided into a number of partitions and the instruments are placed at the section where major activities take place.

**Table 1** Instrument used in this study

| Instruments | Parameters examined for | Instrument description |
|---|---|---|
| OPC (Optical Particle Counter) | Particle mass concentration | PC 11D and OPC 1.108, GRIMM Aerosol Technik GmbH & Co. KG, Germany |
| Graywolf IAQ monitor | TVOCS, CO,$CO_2$, $O_3$, $NO_2$, T, RH | Graywolf sensing solutions, Shelton USA |

## *2.2 Instrumentation*

Real time air samples were collected for four days with different variations. The details of the instruments were shown in Table 1. To understand the concentrations of PM and gasses a setup Grimm 11D and gray wolf were placed in the kitchen for four days from 6.30 a.m. to 12 p.m., located at the major section of a partitioned room.

# 3 Results and Discussions

## *3.1 Particulate Matter Concentrations in Kitchen*

Higher levels of particulate matter were found on 20-10-2022. The mean levels were 322.96 ± 254.17, 191.77 ± 136.11, 132.19 ± 64.89 μg $m^{-3}$ PM10, PM 2.5 and PM1 respectively. The levels could be due to the frying of different eatables like potato and fish. On 18-10-2022 the mean levels are 183.39 ± 74.77, 116.71 ± 40.01, 96.25 ± 32.21 μg $m^{-3}$. On 19-10-2022 the levels are 179.43 ± 76.86, 112.73 ± 47.12, 90.67 ± 25.0 μg $m^{-3}$. The first two days were shown to be nearly equal when only vegetables were cooked. The coarser PM levels are 40% higher when fish frying and potato frying has happened. The Fig. 1 shows the timeseries of pollutants and the lower graphs is on 18-10-2022, middle graphs on 19-10-2022 and upper graphs on 20-10-2022.

## *3.2 Gaseous Matter Concentrations in Kitchen*

### 3.2.1 TVOCs

The levels of TVOCs ranged from a minimum value of 464–4039 μg $m^{-3}$. The minimum value was observed on 18-10-22 when vegetables were cooked. The maximum values were observed on fish frying day. This might also be due to the use of a high amount of detergents to clean vessels and floors. The mean TVOCs of

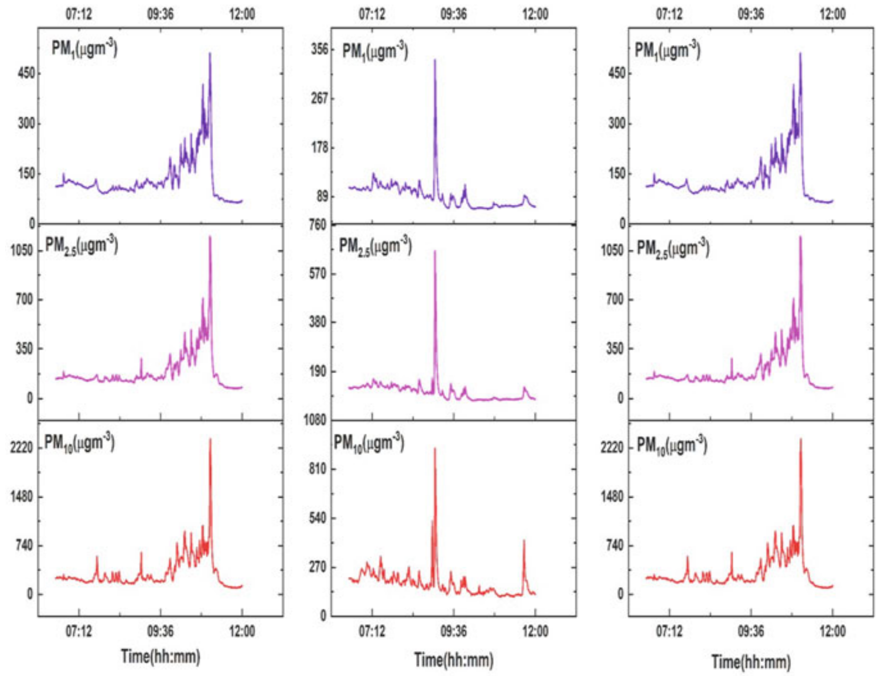


**Fig. 1** Time series for PM from 18-10-2022 to 20-10-2022

1913 ± 910.84 μg $m^{-3}$ were observed on 20-10-22. WHO guidelines 2010 suggest that 400 μg $m^{-3}$ is the tolerable range of TVOCs.

### 3.2.2 Carbon Monoxide

The levels of the CO varied from a minimum of 4.5–90 mg $m^{-3}$. The mean levels on a peak day were 40.93 ± 19.45 mg $m^{-3}$. This shows the staff working there has minimum exposure to CO of 7 mg $m^{-3}$ throughout their working hours as per WHO. Long term exposure of the limit can cause cardiac health.

### 3.2.3 Ozone

The levels of the $O_3$ varied from a minimum of 19.67 μg $m^{-3}$ to maximum 365.48 μg $m^{-3}$. The mean levels on a peak day were 131.82 ± 85.42 μg $m^{-3}$ which was above WHO guidelines 2010. The staff even reported sick building syndrome symptoms like eye irritation, burning.

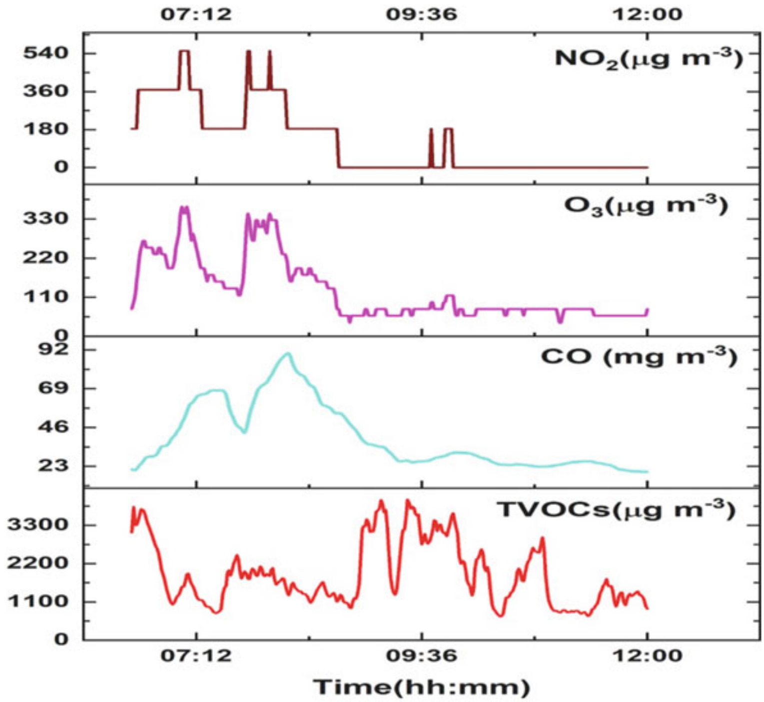


**Fig. 2** Shows the time series of gaseous pollutants on peakday 20-10-2022

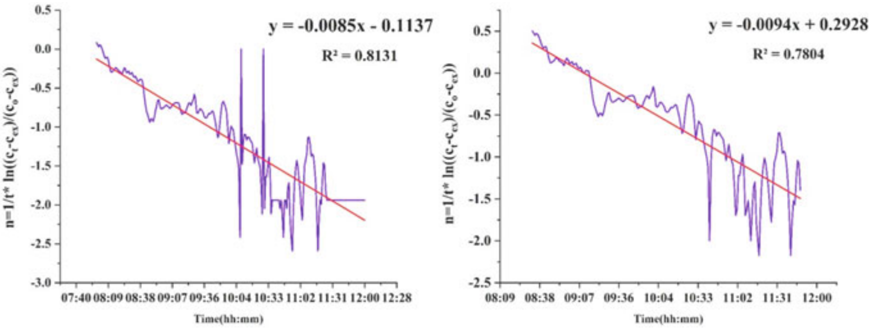


**Fig. 3** Shows the decay curve on 18-10-2022 and 20-10-2022

### 3.2.4 Nitrogen Dioxide

The levels of the $NO_2$ varied from a minimum of 0 to 553.16 $\mu g\ m^{-3}$. The mean levels on a peak day were $125.66 \pm 160.32\ \mu g\ m^{-3}$. The $NO_2$ mean values exceeded thrice the annual average as per WHO which should be 40 $\mu g\ m^{-3}$. The $NO_2$ readings were not continuous; sometimes they are 0 and this could be because the instrument cannot detect diffusion principle. This happened when ozone readings have come down. The below figure shows the variation of the typical variation of gaseous pollutants with time on a peak day 20-10- 2022.

## 3.3 Carbon Dioxide

The rate of change in the concentration of $CO_2$ depends on the concentration of $CO_2$ in the in-flowing air, the concentration of $CO_2$ in the out-flowing air, and the internal generation rate. The $CO_2$ concentrations during the entire study ranged from a minimum value of 310 ppm to a maximum of 1258 ppm, sometimes exceeding the ASHRAE standards 900 ppm.

### 3.3.1 Air Exchange Rate

The AER for the kitchen present just before the auditorium was calculated by the $CO_2$ decay test. The $CO_2$ readings were taken from the starting of the experiment and continued until the values reach the outdoor value or the constant value. The slope of the graph gives the AER value figure. Then the air change rate $n = (Q/V)$, is given by the logarithmic gradient of the tracer gas concentration curve, as follows:

From the above equation the decay rate for the kitchen is calculated. The AER value varied from 0.9944 to 0.9955 $h^{-1}$. The lowest value was observed on the highly polluted day i.e. 20-10-2022. Similarly, the VR varied from 0.8286 to 0.8295 lit/s/$m^2$ (area of the kitchen is 364.98 $m^2$). This VR has shown that buildings have fallen to category III i.e. high polluting buildings according to the ventilation rate for non-residential buildings (European Standard, EN 15251).

## 3.4 Comfort Parameters

The comfort parameters temperature varied from 30 to 32 °C which should be in the range of 20–23.6 °C for winter according to ASHRAE standards. The relative humidity varied from 80 to 83% which was supposed to be 30–65% that was also higher than ASHRAE standards.

## 3.5 Indoor Air Quality Index

The air quality index (AQI) is an index for reporting air quality on a daily basis. The AQI is based on the measurement of PM2.5 and PM10, $O_3$, $NO_2$, $SO_2$, CO, $NH_3$ and Pb emissions. These raw measurements are converted into a separate AQI

**Table 2** Shows the IAQI for various days

| DATE | PM10 | PM2.5 | CO | $O_3$ | $NO_2$ | IAQI | Responsible pollutant | IAQI category |
|---|---|---|---|---|---|---|---|---|
| 18-10-2022 | 155 | 290 | 187 | 98 | 113 | 290 | PM2.5 | Poor |
| 19-10-2022 | 153 | 276 | 175 | 92 | 118 | 276 | PM2.5 | Poor |
| 20-10-2022 | 273 | 355 | 500 | 145 | 146 | 500 | CO | Very severe |

value for each pollutant using standard formulae developed. Sub-index function represents the relationship between the pollutant concentration X*i* and corresponding sub index I*i*. It may take a variety of forms such as linear, non-linear and segmented linear. Usually, segmented linear functions are used. The sub-index (*Ip*) for a given pollutant concentration (*Cp*) is calculated using the following equation (based on 'linear segmented principle'). The same AQI for ambient air is applied to indoors to find IAQI.

$$I_p = \frac{(Ihi - Ilo)}{BPhi - BPlo}(Cp - BPlo) + Ilo$$

*BPhi* Breakpoint concentration greater or equal to given concentration
*BPlo* Breakpoint concentration smaller or equal to given concentration
*Ihi* AQI value corresponding to *BPhi*
*Ilo* AQI value corresponding to *BPlo*

In the present study, the indoor air quality index was calculated on the basis of 5 criteria pollutants: PM10, PM2.5, CO, $O_3$, $NO_2$ shown in the table below. The health condition of the workers falls into the very severe to poor category [5].

## 4 Conclusion

The present study focused on determination of air exchange rate (AER), ventilation rate (VR) Q, and indoor air quality index (IAQI) for the community kitchen. The study was conducted for 3 days from 18-10-2022 to 20-10-2022. In this study, different pollutants like PM10, PM2.5, PM1, TVOCS, $CO_2$, CO, $O_3$, $NO_2$ were studied. Comfort parameters temperature and relative humidity were also monitored. The levels of all the pollutants were shown higher on 20-10-22 when cooking activities like frying potato, frying fish took place. All the values crossed WHO 2009 guidelines [1–3]. The AER value varied from 0.9915 to 0.9906 $h^{-1}$. The lowest value was observed on the highly polluted day i.e. 20-10-2022. Similarly, the VR varied from 0.8262 to 0.8254 lit/s/$m^2$. This VR has shown that buildings have fallen to category III i.e. high polluting buildings according to the ventilation rate for non-residential buildings [4]. The indoor air quality index (IAQI) calculated based on 5 criteria pollutants PM10, PM2.5, CO, $O_3$, $NO_2$ showed that the health condition of the workers falls into the poor to very severe category [5, 6]. Both indexes indicate that the health becomes vulnerable to workers causing respiratory and cardiac issues.

The exhaust fans provided in the kitchen were not working. The working of the fans will definitely reduce the pollutants load. This will not only enhance indoor air quality but also enhances the comfort parameters RH, Temperature. The windows were kept open all the time and there are some table fans which were not on in winters. These table fans might be used during summers to maintain a comfortable temperature. A summer study might be useful to understand the indoor air quality and comfort parameters.

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