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Indoor Air Quality and Microclimatic conditions in selected Restaurants and Kitchens at a Tertiary Institution in Benin City, Nigeria

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ABSTRACT: This study investigated the levels of selected indoor air pollutant concentrations and microclimatic conditions in restaurants and kitchens at a tertiary institution in Benin City using standard procedures. Ten (10) restaurants and kitchens were randomly selected within the University environment. Indoor particulates ($PM_{1.0}$, $PM_{2.5}$ and PM_{10}), Carbon monoxide (CO), Relative humidity (RH), Temperature (Temp) and Wind speed (WS) were measured using Handheld Portable Air Samplers. The results showed that the indoor meteorological and air quality parameters ranged between 34.8 - 35.8°C and 34.5 - 35.9°C (Temp); 42.8 -70.2% and 39.7 - 66.9 (RH); 1.1 - 2.0 m/s and 1.2 - 1.8 m/s (WS); 0.0 - 25.4 and 0.0 - 28.7 mg/m^3 (CO); 28.9 - 42.4 µg/m^3 and 24.4 µg/m^3 - 30.6 ($PM_{1.0}$); 47.0 - 75. µg/m^3 and 37.4 - 50.3 µg/m^3 ($PM_{2.5}$); 62.3 - 91.0 µg/m^3 and 53.6 - 56.8 µg/m^3 (PM_{10}) within the restaurants and kitchens respectively. The mean concentrations of the CO and particulates were above the recommended regulatory limits of the WHO in all sampling sites. There were generally weak significant associations between the observed meteorological parameters and the indoor air pollutants (R= -0.352, - 0.419 p<0.001), except for CO and indoor temperature in the kitchens (R=0.649, R^2 = 0.429 p<0.001). The Air Quality Index (AQI) status of the sampled sites varied from moderate to unhealthy. This study underscores the need for adequate ventilation in the sampled restaurants and kitchens and the creation of awareness of the health risks associated with indoor air pollutants in the study area.

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One of the most serious environmental health problems faced by the developed and middle-and low-income countries of the world is air pollution. Household air pollution (HAP) accounts for 3.7 million deaths yearly (Gordon *et al*., 2014). Exposure to pollutants in the indoor environment is a major indicator of health risk in Low and Medium Income Countries (LMICs) countries (Li *et al*., 2016). Globally, fuels used in homes are solid fuel (wood, coal, charcoals, dung, agricultural wastes), biogas, liquefied petroleum gas (LPG), electricity, and natural gas (Gordon *et al*., 2014., Kual *et al*., 2017). A cafeteria located within the learning environment is usually built with a kitchen attached to it, which constitutes a major source of air pollution in restaurants. Commercial kitchens within the school environment are associated with air pollution prominently from cooking sources (Gobo *et al*., 2009).

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The processes involved in cooking result in the release of toxic gaseous and particulate pollutants emanating from cooking fuel combustion and food materials being cooked. Pollutants commonly associated with cooking include Carbon monoxide (CO_2), CO, Nitrogen oxides (NO_X), Sulphur (iv) oxide (SO_2), Volatile Organic compounds (VOC), Polyaromatic hydrocarbons(PAH), Particulate matter ($PM_{2.5}$ and PM_{10}) which are emitted into the kitchen area and restaurants (Lam *et al*., 2012; Wang *et al*., 2017). Apart from the cooking activities within the kitchen, indoor air quality problems are also influenced by poor ventilation systems, indoor biological contaminants and meteorological conditions (temperature and relative humidity) (Muindi *et al*., 2016). Women and girls are the most vulnerable groups to household air pollution exposure caused by incomplete combustion of solid fuels and cooking-related emissions in Sub-Sahara Africa (WHO, 2021). Prolonged exposures to these cooking-generated emissions via inhalation have been linked to health outcomes such as ischaemic heart diseases, stroke, lower respiratory diseases, chronic obstructive pulmonary diseases (COPD), lung cancer, premature mortality and deaths (Wong et al., 2016; Li *et al*., 2016; Xie et al., 2016; WHO, 2021, Eghomwanre et al., 2022). In Nigeria, there are a lot of studies on air emissions from cooking-related activities (Gobo *et al*., 2009; Lam *et al*., 2012; Bindu et al., 2016; Omole et al., 2020). However, there is scarce literature on the monitoring of air pollutants released from commercial kitchens and the eateries environment in higher institutions of learning in urban areas (Lam *et al*., 2012; Muindi *et al*., 2016). A large percentage of students spend their time in eateries where they eat, and may be exposed to varying concentrations of pollutants released into the restaurants which are directly attached to the kitchens. Currently, information on air pollutant concentrations especially particulate matter fractions in restaurants within the environment of higher institutions of learning in Nigeria is rare. Studies related to air pollutant emissions in eateries located in this environment are required to formulate a baseline for exposure limits for exposed individuals who patronize university restaurants. This study was conducted to investigate the levels of selected pollutants (CO, $PM_{1.0}$, $PM_{2.5}$ and PM_{10}) and the microclimatic conditions in a tertiary institution in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area: The study was conducted at the University of Benin in Benin City, Edo State, Nigeria. The geographic location of the university is 6º20′1.32″ N and 5º36′0.53″ E, within Ovia North East Local Government Area. The study area is within a humid tropical environment and its seasons, i.e. rainy and dry seasons, are determined by rainfall. The university's food court popularly referred to as bukas are designed with kitchens attached. The restaurants have single windows and doors with ceiling fans as a means of mechanical ventilation. The eateries accommodate about 20 to 30 customers who are mainly students and staff of the university at a time. There is an average of seven staff including the cooking personnel in each buka. The kitchen behind the eatery is not entirely enclosed as it has large spaces for ventilation. An on-site assessment showed that the predominant source of energy for cooking across the bukas is natural gas and firewood. The influx of vehicles bringing supplies and customers to the eateries and the use of generators as the power source may contribute to an outdoor source of air pollution in the eateries. Fig 1 presents the map of the study area.

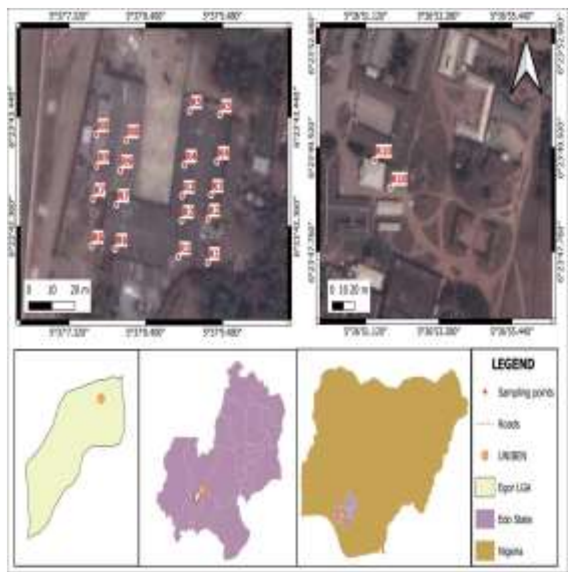

Fig. 1 Map of Benin City showing the sampling sites in the study area

Sample collection and analysis: The sampling areas considered for the study were the food court (buka) was randomly selected for air quality sampling. A total of ten restaurants with attached kitchen or cooking areas were sampled during this study. Indoor air quality measurement was carried out every week in February 2022 from morning hours during cooking till about noon when customers start buying and eating food. Sampling was done in the kitchens and eating areas of restaurants. The concentrations of carbon monoxide in the windward direction at the eateries and cooking areas. The sampler has field-replaceable infrared and gamma radiation with photoionization detectors (PID) sensors. The indoor PM sizes ($PM_{1.0}$, $PM_{2.5}$, PM_{10}) were measured using a BR- SMART-128S portable device. This device is a real-time air quality monitor which uses a high-precision sensor

chip and can convert atmospheric particulate matter levels into visual data. It measures pollutants using a light scattering measurement technique with a recording range of 0-999µg/m^3 and a resolution of 1.0µg/m^3. The equipment was calibrated according to the manufacturer's recommendations.
The indoor air monitoring was conducted in both the eateries and the kitchen areas across the selected locations in triplicates and at a height of 2 m above ground level (the level at which humans are most likely to be exposed). The air pollutants measurements during this study were conducted in line with Eghomwanre and Oguntoke (2022). The data obtained were screened and cleaned for the accuracy of air pollutant data obtained. The results obtained were compared with the baseline 24-hour mean concentrations according to WHO (2018). Meteorological data including temperature, relative humidity and wind speed were recorded at each sampling site consecutively with the measurements of air pollutants in triplicates. An anemometer (BTMETER BT-100 model) was used to determine wind speed and temperature, while the Smart Sensor Model AS8700A was also used in measuring humidity.

Determination of Air Quality Index: The AQI values were calculated for all the sampled sites using the 24-hourly mean values of obtained air pollutants. Each air quality index for a given pollutant concentration (Cs) depending on the linear segmented principle was calculated as follows:

$$APQ = \frac{I_{high} - I_{low}}{BP_{high} - BP_{low}} x\left(C_p - BP_{hih}\right) + I_{low} \quad (1)$$

Where: AQI = Index of the pollutant; Cp = mean concentration of pollutant p; BP_{high} = the breakpoint ≥ Cp; BP_{low} = the breakpoint ≤ Cp; I_{high} = the AQI » BP_{high}; I_{low} = the AQI » BP_{low}.

Data Analysis: Data obtained from the monitoring was subjected to descriptive (mean and standard deviation) and inferential (Analysis of Variance, ANOVA, Duncan Multiple Range Test, DMRT, student t-test, correlation and regression analysis) statistics using SPSS for Windows Version 22.0.

RESULTS AND DISCUSSION

Microclimatic conditions in the Restaurants and Kitchens: The mean values of the indoor temperature, relative humidity and wind speed measured during the sampling regime are presented in Table 1. The indoor temperature of the restaurants ranged from 34.8 to 35.8°C while the temperature recorded in the kitchens varied between 34.5 and 35.9°C. The highest temperature was measured at SL1 while the lowest was observed at SL7 in the restaurants. In the kitchens, the highest indoor temperature occurred at SL4 (35.2°C) but the lowest was recorded at SL10 (34.0°C). The mean separation analysis revealed that the temperature varied across the restaurants and kitchens but the difference was only significant in the restaurants ($p<0.05$) at SL10.

The observed mean temperature across the restaurants and kitchens was above the recommended comfort level (23°C - 26°C) in the indoor microenvironment (ASHRAE, 2013). The increase in temperature of the sampled locations could be attributed to various factors which include heat generated during cooking activities in the kitchen area which is likely to also infiltrate the restaurant areas. This is also compounded by the lack of adequate ventilation occasioned by limited windows in the monitored restaurants and the outdoor temperature prevalent during the period of sampling. Indoor temperature above the threshold limit could impact the health of occupants negatively (Akanmu *et al*., 2020).

The relative humidity recorded in the restaurants varied from 42.8 to 70.2% and 39.7 to 66.9 in the selected kitchens. The highest RH was recorded at SL7 (70.2%) and SL6 (66.9%) respectively, while the lowest RH was observed at SL2 (42.8%) and SL4 (38.7%). The indoor relative humidity within the range of 30 – 60% does not influence thermal comfort. This study revealed that relative humidity above 60% was observed in about 60% of the sampling locations. The high RH could be due to moisture released from the cooking areas and it prevents the evaporation of sweat thereby resulting in workers' and customers' discomfort (Zhao, 2019). The relative humidity also varied across the sampling locations but the variation was only significant in the restaurants at SL7.

These findings could be ascribed to the differences in ventilation rates due to the variations of window and door types in restaurants and kitchens. This study is in line with Eghomwanre et al. (2022). The wind speed measured across the study locations ranged between 1.1 to 2.0m/s and 1.2 to 1.8m/s in the restaurants and kitchens respectively. The highest wind speed was observed at SL2 (2.0m/s) at the restaurants. The variations in wind speed were only significant in the restaurant at location SL7. The low wind speed recorded during this study could be related to still air movement resulting from the high temperature observed during the sampling. This study is in tandem with the report of Ukpebor et al, (2010).

Table 1: Mean meteorological parameters across sampled locations in Benin City.

Sampling Locations	Temp (°C)	R/H (%)	WS (m/s)	Temp (°C)	R/H (%)	WS (m/s)
	Kitchen			Restaurant		
SL1	**35.8±0.2**^{d}	61.3±8.3^{ab}	1.9±0.3^{b}	35.4±0.1^{a}	38.8±4.7^{a}	1.0±0.2^{a}
SL2	35.3±0.2^{bcd}	42.8±5.5^{a}	**2.0±0.4**^{b}	35.3±0.1^{ab}	66.8±7.2^{c}	1.2±0.2^{a}
SL3	35.6±0.1^{cd}	62.8±8.1^{ab}	1.9±0.3^{b}	35.9±0.2^{b}	63.6±7.4^{bc}	1.2±0.2^{a}
SL4	35.2±0.1^{bcd}	63.2±7.8^{ab}	1.4±0.1^{ab}	**35.9±0.1**^{b}	38.7±4.6^{a}	**1.8±0.2**^{a}
SL5	35.6±0.1^{cd}	66.4±7.1^{ab}	1.4±0.1^{ab}	34.4±0.1^{ab}	64.0±8.0^{bc}	1.9±0.5^{a}
SL6	35.1±0.1^{bc}	44.0±5.6^{a}	2.0±0.2^{b}	35.4±0.1^{ab}	**66.9±7.6**^{c}	1.6±0.3^{a}
SL7	34.8±0.1^{b}	**70.2±5.8**^{c}	1.5±0.2^{ab}	35.2±0.1^{ab}	45.0±6.2^{a}	1.6±0.1^{a}
SL8	34.8±0.1^{b}	64.6±7.5^{ab}	1.7±0.2^{ab}	35.1±0.1^{ab}	67.3±7.2^{c}	1.3±0.1^{a}
SL9	35.5±0.1^{cd}	63.0±8.0^{ab}	1.1±0.1^{a}	34.9±0.1^{ab}	67.0±7.1^{c}	1.4±0.3^{a}
SL10	**34.0±0.6**^{a}	44.1±7.7^{a}	3.6±0.2^{c}	34.5±0.3^{a}	43.1±7.0^{ab}	1.8±0.4^{a}

Values are means ± standard error of nine replicates. Different superscripts in the same column indicate significant differences at p < 0.05 according to Duncan Multiple Range Test (DMRT). Temp: Temperature; R/H: Relative Humidity; WS; Wind speed

Table 2: Correlation between meteorological and air quality parameters

	COr	$PM_{1.0}$r	$PM_{2.5}$r	PM_{10}r	COk	$PM_{1.0}$k	$PM_{2.5}$k	PM_{10}k
TEMPr	-0.056	-0.023	-0.088	-0.017	0.222*	0.012	-0.012	0.023
R/Hr	0.141	-0.262*	-0.276**	-0.222*	-0.295**	-0.016	-0.079	-0.024
WSr	0.058	-0.026	0.055	-0.054	0.056	-0.261*	-0.236*	-0.233*
TEMPk	-0.090	0.072	0.026	0.074	0.649**	0.258*	0.269*	-0.182
R/Hk	0.043	-0.368**	-0.434**	-0.364**	-0.352**	-0.075	0.033	-0.067
WSk	0.118	-0.267*	-0.314**	-0.230*	0.419**	0.018	-0.114	-0.099

***Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed); r= restaurants, k= kitchen*

Table 3: Explanatory factors of air pollutants concentrations

Air pollutant (Y)	Regression Model	R	R^2	Standard error
COk	24.01 - 0.250RHk*	0.325	0.124	15.24
COk	479.05 -13.35 Tempk*	0.649	0.429	12.39
COk	-4.00 + 7.283 WSk*	0.419	0.175	14.79
PM2.5k	257.40- 5.78Tempk*	0.269	0.072	16.41
PM10k	154.75 – 3.44 Tempk	0.258	0.067	10.19

*RH= Relative humidity, Temp= Temperature, WS= Wind speed, R= Coefficient of determination *Significant at p < 0.05*

Concentrations of Carbon monoxide and Particulate matter: Figure 2a-d presents the concentrations of air pollutants obtained across the sampled restaurants and kitchens within the university. The carbon monoxide concentrations ranged between 0.0 - 25.47mg/m^3 and 0.0 to 28.7mg/m^3 in the sampled restaurants and kitchens respectively with the highest concentration at monitoring site SL8 and the lowest at SL1 (Figure 2). The mean level of CO obtained in one-fifth of the kitchens investigated was above the maximum of 12.3mg/m^3 put up by WHO on exposure to CO for 24 hours (WHO, 2010). This was however lower than the levels obtained by Giwa et al. (2019) who measured the pollutants in kitchens for a 1-hour interval. The increase in the concentration of CO is attributed due to the utilisation of dirty fuels for cooking in the sampling locations. Prolonged exposure to cooking-generated emissions has been related to the inflammation of the respiratory airways, impairment of the immune response and decrease in the ability of the blood to transport oxygen (Li et al., 2016; WHO, 2021). The CO levels were significantly higher inside the kitchen than in the restaurants. The concentrations of CO were significantly higher (t= 4.55 p<0.05) in the kitchen compared to the concentrations of the respective pollutants in the monitored restaurants. This is obviously due to the cooking activities in the kitchen areas.

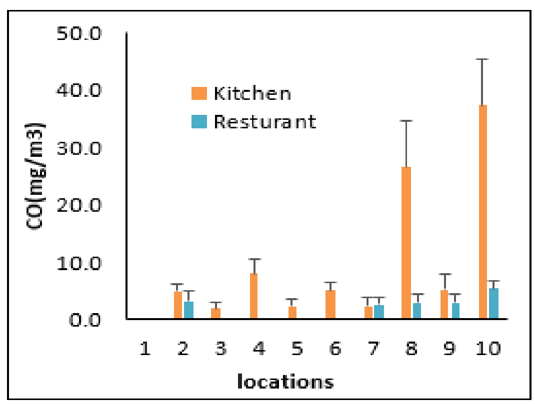

Fig 2a: Levels of CO in the kitchens and restaurants

The $PM_{1.0}$ in the kitchens varied from 28.9 to 42.4µg/m^3 and 24.4 to 30.6µg/m^3 in the restaurants across the sampling sites. The highest $PM_{1.0}$ concentrations were observed at monitoring sites SL8 and SL2 in the kitchen and restaurants respectively, the lowest values were recorded at SL4 and SL3 (Fig 2a-d). The concentrations of $PM_{2.5}$ ranged between

47.0 to 75.3µg/m^3 and 37.4 to 50.3µg/m^3 in the kitchen and restaurants respectively. The highest $PM_{2.5}$ was monitored at SL8 and SL5 while the lowest was observed at SL4 and SL3 (Figure 2). PM_{10} values varied from 62.3 to 91.0µg/m^3 in the kitchen and 53.6 to 56.8µg/m^3 in the restaurant kitchen. The highest level of PM_{10} was monitored at SL8 while the lowest was recorded at SL3 (Figure 2a-d). The concentrations of PM were significantly higher ($t = 5.34, 4.83, 4.15$; $p<0.05$) in the kitchen compared to the concentrations of the respective pollutants in the monitored restaurants.

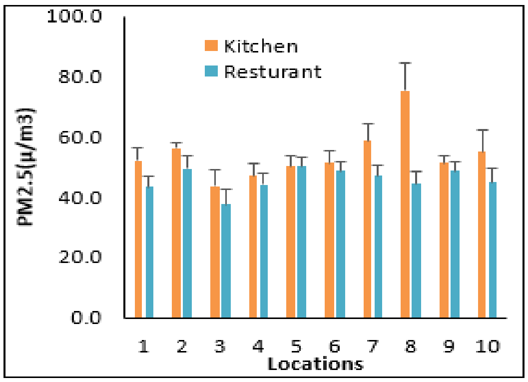

Fig 2c: Levels of $PM_{2.5}$ in the kitchens and restaurants

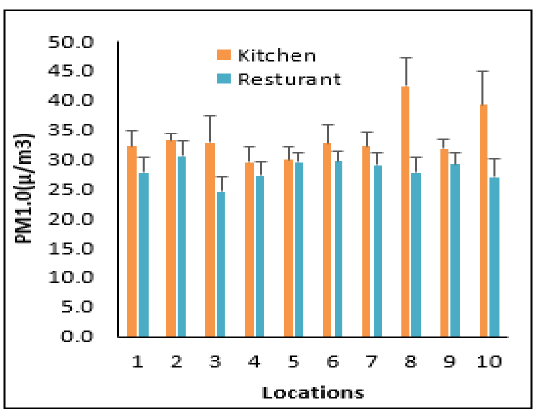

Fig 2b: Levels of $PM_{1.0}$ in the kitchens and restaurants

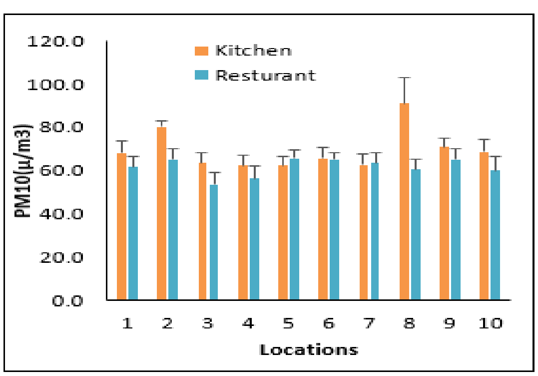

Fig 2d: Levels of PM_{10} in the kitchens and restaurants

Association between microclimatic parameters on air pollutant concentrations: The correlations between the meteorological and air quality parameters in kitchens and restaurants are presented in table 2. The in situ temperature did not correlate with the air pollutants significantly and the correlation coefficient was negative and very weak (R=-0.056, -0.023, -0.088 and -0.017). The lack of a significant correlation between the measured wind speed and air pollutants in the restaurants could be due to the relatively low values of wind speed recorded during the monitoring regime. This finding is in tandem with Rogula-Kopiec *et al* (2022). The relative humidity in the restaurants exhibited a significantly weak and negative relationship with the monitored air pollutants (R=-0.262. -0.276, -0.222; p>0.001). The temperature of the kitchen correlated positively strongly and significantly with the CO (R=0.649; p<0.001). This implies that the indoor CO increases with a corresponding increase in the kitchen temperature. This finding is consistent with the report of Eghomwanre and Oguntoke (2022). It is further supported by Jacobson (2005) who ascertain that the increased temperatures lead to the downward movement of pollutants and consequently increased ground-level concentrations. The relationship was weak and positive with $PM_{1.0}$, and $PM_{2.5}$ (R= 0.259, 0.269; P<0.001. The relative humidity and wind speed observed in the kitchen only correlated with the CO. However, the association was negatively weak (R= -0.352, 0.419; p<0.001) respectively. The weak association between the meteorological parameters and the observed air pollutants could mean that other factors could have influenced the air pollutant concentrations in the study area. The effect of the in situ meteorological parameters on the indoor air pollutant concentrations was only significant in the sampled kitchens across the locations (Table 3). The indoor CO was mostly influenced by the microclimatic parameters across the selected kitchens. Temperature, relative humidity and wind speed contributed 42.9, 12.4 and 17.5% of the observed indoor CO. There were minimal contributions of temperature to the levels of $PM_{2.5}$ and PM_{10} across the kitchens. Indoor temperature only contributed 7.2 and 6.7% of the monitored particulate matter respectively.

Air Quality Index (AQI) of the air Pollutants: The Air Quality Index values were obtained for the various pollutants in the sampling locations to establish the level of health risks associated with the exposed individuals. The results are presented in Fig 3. The AQI ranges from 0 to 432 in the kitchens and 0 to 56 in the restaurant. The AQI for $PM_{2.5}$ varied from 108 to 157 in the kitchen and 83 to 118 in the restaurants. The AQI values for PM_{10} ranged between 55 70 69 and

50 to 57 in the kitchen and restaurants respectively (Fig 3). The air quality status of the sampling locations was moderate or unhealthy for sensitive individuals. At location SL8 in the kitchen, the AQI status was unhealthy.

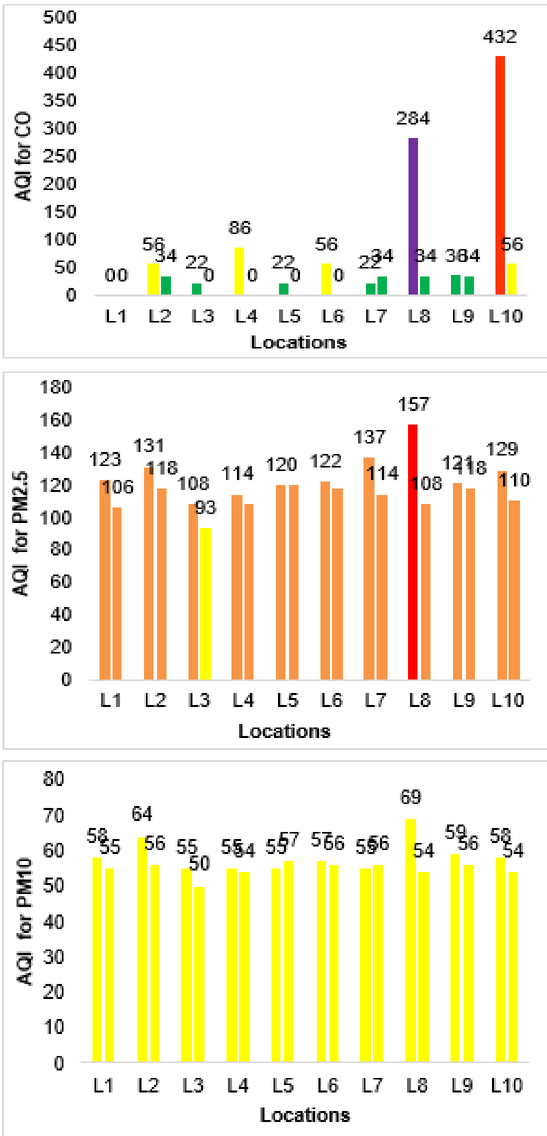

Fig 3: AQI for CO, $PM_{2.5}$ and PM_{10} and corresponding AQI colour code

Conclusion: This study revealed that the concentrations of CO, particulate matter and the observed meteorological parameters of the investigated restaurants and kitchens at the institution were above the allowable limits. This demonstrates possible health risks to exposed individuals within the study area. Therefore, the need for proper ventilation of the restaurants and kitchens as well as urgent education and sensitization of the restaurant owners, workers and students on preventive measures to mitigate the possible health risks is highly recommended.

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REFERENCES

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (2013). Standard 62.1-2013, Ventilation for Acceptable Indoor Air Quality, ASHRAE, Atlanta, GA, USA.

Bindu, SH; Reddy, MV. (2016). Indoor Air Quality in Commercial Kitchens. International *J. Sci. Res*, **5**(10): 1337 – 1340.

Buonanno, G., Morawska, L; Stabile, L. (2009). Particle emission factors during cooking activities, *Atmos. Environ*. 43: 3235–3242.

Cheng, JC; Cui, T; He, WQ; Nie, L; Wang, JL; Pan, T (2015). Pollution characteristics of aldehydes and ketones compound in the exhaust of Beijing typical restaurants, *Environ. Sci*. 8: 2743–2749.

Eghomwanre, AF; Oguntoke, O (2022). Concentrations of indoor gaseous air pollutants and risk factors associated with childhood asthma in Benin City, Nigeria. *Environ. Monit. Assess*. 194(5):391

Eghomwanre, AF; Oguntoke, O; Taiwo, AM. (2022). Levels of indoor particulate matter and association with asthma in children in Benin City, Nigeria, *Environ. Monit. Assess,* 194(6):467

Eghomwanre, AF; Oguntoke, O; Taiwo, AM., Ukpebor, EE. (2022) Air pollutant concentrations and health risk assessment around residential areas in Benin City, Nigeria, *J. Mater. Environ. Sci*. 13(9):1081-1100

Giwa, SO; Nwaokochaa,CN; Odufuwab, BO. (2019). Air pollutants characterization of kitchen microenvironments in southwest Nigeria, *Build. Environ.* 153:138–147.

Gobo, A; Ubong, I., Ede, P; Inyang, I. (2009). Indoor and outdoor air quality in selected restaurants and canteens in Port Harcourt Metropolis, Nigeria. *Afr. J. Environ, Poll. Healt.* **7**(1): 1-6.

Gordon, B; Bruce, N; Grigg, J; Hibberd, P; Kurmi, O; Lam, K. (2014). Respiratory risks from household air pollution in low and middle-income countries, *Lancet Respir. Med***.** 2: 823 - 860.

Jacobson, MZ. (2005). Fundamentals of atmospheric modelling, 2nd edition, Cambridge University Press, New York; pp120-12

Kaul, N; Gupta, A; Khandelwal, S; Singh, G; Singh, V. (2017). Impact of exposure to cooking-generated air pollution on human respiratory health: a case study of different microenvironments of India, *Hum. Ecol. Risk Assess*. 23:1989 – 2001.

Lam, N. L; Smith, KR; Alison, GA. Bates, M. N. (2012). Kerosene: a review of household uses and their hazards in low- and middle-income countries, *J. Toxicol. Environ. Health*. 15: 396–432.

Lee, SC; Li, WM. Chan, LY. (2014). Indoor air quality at restaurants with different styles of cooking in metropolitan Hong Kong. *Sci. Total Enviro.*, 279: 181 – 193.

Li, TS; Cao, D; Fan, Y; Zhang, B; Wang, X; Zhao, BP; Leaderer, G; Shen, Y; Zhang, X; (2016). Household concentrations and personal exposure of $PM_{2.5}$ among urban residents using different cooking fuels, *Sci. Total Environ.*548:549 6–12.

Muindi, K; Kimani-Murage, E; Egondi, TJ; Rocklov, J. (2016). Household air pollution: sources and exposure levels to fine particulate matter in Nairobi slums, *Toxics* 4(3):12

Muindi, K; Kimani-Murage, E; Egondi, T; Rocklov, J; Ng, N. (2016). Household air pollution: sources and exposure levels to fine particulate matter in Nairobi slums, *Toxins,* 4(3): 12 - 17.

Omole, AO; Mbamali, I; Abdulsalam, D. (2020). Comparison of indoor air quality in eateries within Zaria Metropolis, *Int. J. Atmos. Oce. Sci*, 4(1): 1 - 6.

Rogula-Kozłowska, W; Majewski, G. (2022) Particulate Matter Concentration in Selected Facilities as an Indicator of Exposure to Their Service Activities. *Int. J. Environ. Res. Public Health***,** 19:10289.

Sidhu, MK; Ravindra, K; Mor, S; John, S, (2017). Household air pollution from various types of rural kitchens and its exposure assessment, *Sci. Total Environ*. 586:419–429.

Ukpebor, EE; Ukpebor, JE; Eromomene, F; Odiase, JI; Okoro, D. (2010). Spatial and diurnal variations of Carbon Monoxide (CO) pollution from Motor Vehicles in urban space’. *Pol. J. Environ. Stud.* 19(4): 817-823.

Wang, Z; Xiang, S; Stevanovic, Z; Ristovski, F; Salimi, J; Gao, H; Wang, L; Li, H. (2017). Role of Chinese cooking emissions on ambient air quality and human health, *Sci. Total Environ.* 589 173 – 181.

WHO (World Health Organisation) (2021). Household air pollution and health. Available online at www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. Accessed March 21st, 2022.

Wong, TZ; Wong, AH; Lee, FS; Qiu, H. (2016). Respiratory health and lung function in Chinese restaurant kitchen workers, *Occup. Environ. Med*., 68: 746 - 752.

World Health Organisation, (2018), Guidelines for Indoor Air Quality: Selected Pollutants, The Regional Office for Europe, 978-92-890-0213-4, 2010.

World Health Organization, (2014). Guidelines for Indoor Air Quality, Household Fuel Combustion, 2014

Xie, Y; Jiang, Y; Jin, S. Li, Y. (2016). Association between cooking oil fume exposure and lung cancer among Chinese non-smoking women: A meta-analysis, *Onco Targets Ther, 9:* 2987–2992.

Zhao, Y; Liu, L; Tao, P; Zhang, B; Huan, C; Zhang, X. Wang, M. (2019). Review of Effluents and Health Effects of Cooking and the Performance of Kitchen Ventilation. *Aerosol Air Qual. Res*, 19: 1937–1959.