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Assessment and Characterization of Indoor and Outdoor Air Quality of Selected Facilities in a University Environment Using Different Fuel Sources

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Abstract:
This study aims to assess and characterize indoor and outdoor air quality of selected facilities in Federal University of Technology Owerri (FUTO) environs using different fuel sources. Six points in the study areas were sampled; Senate building, SOES, Old SEET Head, Female Hostel C, Market Square and Old registry designated as P1, P2, P3, P4, P5 and P6 respectively. The concentrations of PM2.5, PM10, CO, SO2, VOC, O3 and NO2 were measured using a hand-held gas analyzer. A handheld Germin-300 GPS device was used to get the coordinates of the sampling points which aided the data processing. Results showed high concentrations of CO at P5 for indoor environment, Indoor NO2 results in the P5 (0.064ppm) and P6 (0.072ppm) where Charcoal and Firewood respectively are used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Indoor H2S at P1 and P4 with fuel sources of Diesel and Kerosene respectively had values of 0.2ppm and 0.1ppm which is above the maximum limit of 0.01ppm set by the Federal Ministry of Environment and Department of Petroleum Resources. Although, the average mean of both indoor and outdoor air quality differs, there were no statistically significant variations between the sample means of indoor and outdoor air quality parameters. The independent variables (meteorological parameters) perfectly predicted the combined indoor-outdoor air quality parameters at an adjusted R square value of 70.3% from the model summary and a statistical significance of 0.043 from the ANOVA table. Results showed that the meteorological parameters accounted for 70.3% of the air quality parameters sampled from six different facilities in FUTO utilizing varying fuel sources. Apart from the wet temperature that contributed uniquely in predicting the air qualities, the remaining meteorological parameters (dry temperature, relative humidity and wind speed) combined in predicting the air quality of FUTO environment.

Keywords: Assessment, Characterization, Indoor-Outdoor Air Quality, Fuel Sources, University Environment.

INTRODUCTION

Exposure to air pollution is globally a serious environmental issue leading to a risk factor to many diseases (Pope *et al.*, 2009; Shah *et al.*, 2013; Beelen *et al.*, 2014; Lelieveld *et al.*, 2014; Smith *et al.*, 2014; Chen *et al.*, 2017; Emeka and Chukwunyere, 2017), attracting worldwide attention (Ni *et al.*, 2018). The World Health Organization (WHO) estimates that approximately 3.7 million premature deaths worldwide result from exposure to ambient air pollution each year (WHO, 2009). Similarly, the increased burden on the use of solid fuel for cooking has resulted globally in over 4 million premature deaths from exposure to household air pollution (Shindell *et al.*, 2010: Anenberg *et al.*, 2012), with the most recent estimates from WHO reporting 4.3 million deaths for 2012 (Wilkinson *et al.*, 2009). It has been projected under socioeconomic scenarios that air

pollution will be the topmost environmental cause of premature mortality (OECD, 2012), contributing to worldwide premature mortality by 2050 (Lelieveld *et al*., 2014).

The impacts of air pollution are not limited to the public health of humans alone; Ole (2009) studies showed that air pollution has a variety of negative effects on climate and nature. Climatic effect results from the releases of particles and trace gases capable of changing a radiation balance in the atmosphere. Adverse health effects in the population are dependent on exposure level to air pollution while the effect on nature is caused by atmospheric deposition of acid gases and aerosols capable of leading to acidification of lakes and terrestrial ecosystems. Therefore, it is against this backdrop, that it becomes imperative to assess and characterize indoor and outdoor air quality of selected facilities at the Federal University of Technology Owerri environment using different fuel sources.

MATERIALS AND METHODS

Study Area

The Federal University of Technology, Owerri (F.U.T.O), prided as a premier Federal University of Technology in the South East and South West parts of Nigeria, was established in 1980. The University which operates a mono-campus structure is located in Owerri West Local Government Area, Southeast Nigeria and is bordered by Ihiagwa and Nekede communities on the North, Okolochi, Obibiezena, and Emeabiam on the East, Eziobodo community on the South and Umuoma, Avu and Obinze on the West. The campus occupies an area of about 4,048 hectares, housing eight (10) schools with over forty (40) departments, and a students' population of over 22,000. The popular Otamiri River traverses the campus from North to South adoring the site with its accompanying lush vegetation.

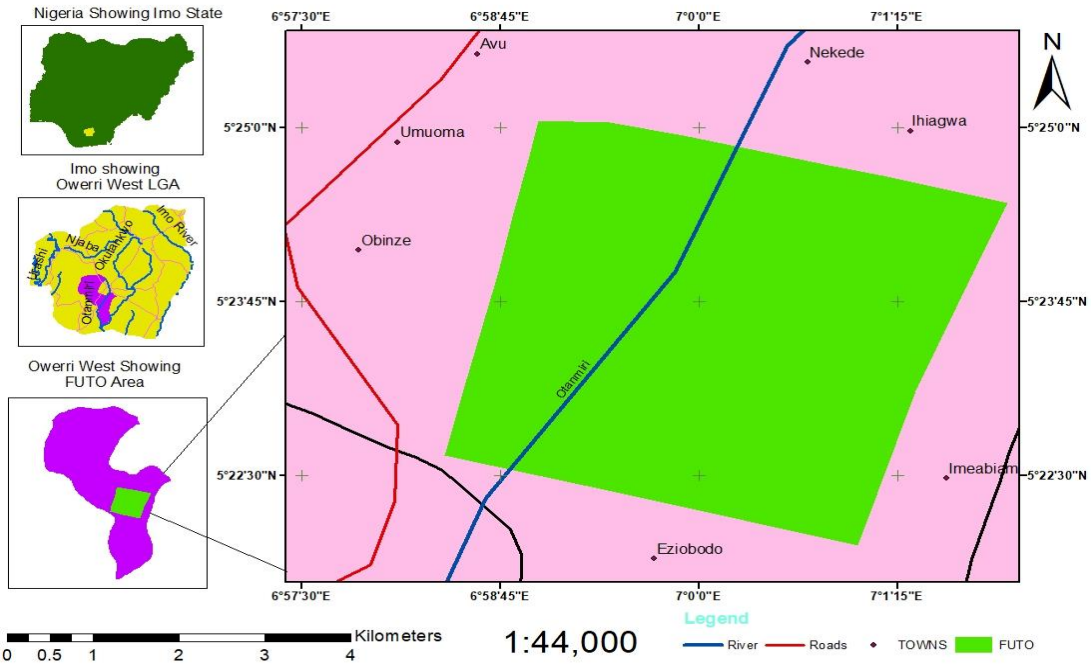


Fig. 1: Study Area

Measurement of Air Quality Parameters

A pilot study was carried out to determine the number of sites from where measurements of air quality parameters of interest were done during a regular working day and at peak hours. Gaseous

pollutants (Sulphur (IV) oxide (SO_2), Carbon Monoxide (CO), Nitrogen (IV) oxide (NO_2), Volatile Organic compounds (VOCs), particulate matter of different sizes ($PM_{2.5}$ and PM_{10}) and Ozone (O_3) and meteorological parameters (Temperature, Relative humidity, and Wind speed) were monitored for both indoor and outdoor in the study location (P1 to P6). Six (6) different fuel sources (charcoal, diesel, petrol, firewood, kerosene and gas) were identified for sampling to assess the variation in the concentration of gaseous pollutants emitted in both indoor and outdoor environments. The locations were randomly selected to spatially represent the university environment. Where each fuel source of interest is limited, selection is based on its availability irrespective of the proximity to another fuel source of interest.

Table 1: Sampled facilities from varying fuel sources

S/N	Name	Fuel Source Type	Longitude	Latitude
1	Female Hostel C	kerosene	6.99713	5.37874
2	Old Seat Head	Gas	6.99609	5.3835
3	Senate	Diesel	6.9933	5.38499
4	Behind Old Registry	firewood	6.99623	5.37924
5	SOES	Petrol	6.99955	5.38924
6	Market Square behind Catholic church	Charcoal	7.00015	5.39005

In-situ measurement was deployed to collect data of indoor-outdoor air quality parameters within the study area. This method involves air quality monitoring using a hand-held Gas analyzer (Aeroqual gas monitor). HT9600 Detector was used for Temperature, Relative humidity, $PM_{2.5}$, PM_{10}. Wind speed was measured using a Digital Handheld Anemometer. The remaining gaseous pollutants were measured using an Aeroqual 500 model instrument. A portable Samsung Android phone was used to take snapshots of the facility while Etrax GPS was used to record the coordinates of the sampling points in each facility. The portable air quality meter was raised to varying heights of 1.5 to 3 meters in the direction of the prevailing wind at each sampling location to avoid obstructions.

RESULT AND DISCUSSIONS

Table 1: Outdoor air quality result

Parameter	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	FMEnv STD/DPR Limit
	N: 5.3932^0	N: $5{\cdot}3851^0$	N: 5.38357084^0	N: 5.3876782^0	N: 5.39007217^0	N:5.37875216^0	
	E:6.9860^0	E: 6.9931^0	E: 6.99606351^0	E: 6.999397^0	E: 6.999709^0	E: 6.99701288^0	
	TIME: 10:05 AM	TIME: 12:17 PM	TIME: 1:49 PM	TIME: 3:09 PM	TIME: 4:35 PM	TIME: 5:54 PM	
	ELEVATION: 54.5 m	ELEVATION: 57.9 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 60 m	
CO, ppm	1.1	ND	ND	2.7	3.6	5.8	10.00 – 20.00
CO2, ppm	478	470	490	516	488	495	NS
O_3, ppm	ND	ND	ND	ND	ND	ND	0.15
NO2, ppm	0.039	0.055	0.034	0.049	0.058	0.064	0.075 - 0.11– 1 hour
CH_4, ppm	21	4	4	4	7	1	NS
H_2S, ppm	ND	ND	ND	ND	ND	ND	0.042
VOC, ppm	1	ND	ND	ND	ND	ND	NS
SO_2, ppm	ND	ND	ND	ND	ND	ND	0.026 – 24 hrs.;

							0.26– 1 hr.;
PM_{10}, ppm	0.016	0.009	0.011	0.018	0.1	0.025	0.15 - 24 hours;
$PM_{2.5}$, ppm	0.005	0.004	0.005	0.006	0.04	0.021	0.23 - 1 hours;
AIR TEMP. ^{0}C	30.1	31.9	33.7	33.5	30.3	29.6	NS
WIND SPEED, m/s	0.6	1.6	0.9	0.7	0.8	0.5	NS
Relative Humidity, %	72.2	64.3	64.7	75.8	74.6	72.8	NS
Wet Bulb Temperature, ^{0} C	27	27.6	28.5	28.9	39	25.6	NS

POINT 1	**DIESEL**	**Senate Building**
POINT2	**FUEL**	**School of Environmental Sciences (SOES)**
POINT3	**GAS**	**Old SEET Head**
POINT4	**KEROSEENE**	**Female Hostel C**
POINT5	**CHARCOAL**	**Market Square**
POINT6	**FIREWOOD**	**Commercial Building behind Old Registry**

Table 2: Indoor air quality result

PARAMETER	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	FMEnv STD/DPR Limit
	N: 5.3927^0	N: 5·3819^0	N: 5.38367782^0	N: 5.3877084^0	N: 5.38976121^0	N:5.37863721SS^0	
	E:6.9859^0	E: 6.9951^0	E: 6.99593321^0	E: 6.99925983^0	E: 7.00008279^0	E: 6.9969437^0	
	TIME: 10:46 AM	TIME: 11:38 AM	TIME: 1:11 PM	TIME: 2:34 PM	TIME: 3:58 PM	TIME: 5:19 PM ELEVATION: 60 m	
	ELEVATION: 54.1m	ELEVATION : 59.2 m	ELEVATION: 59 m	ELEVATION: 59 m	ELEVATION: 59 m		
CO, ppm	8.3	4.4	5.3	8.2	8.2	9.1	10.00 – 20.00
CO_2, ppm	513	523	708	541	450	498	NS
O_3, ppm	ND	ND	ND	ND	ND	0.02	0.08
NO_2, ppm	0.057	0.053	0.056	0.05	0.064	0.072	0.04 - 0.06– 1 hour
CH_4, ppm	6	4	4	4	1	7	NS
H_2S, ppm	0.2	ND	ND	0.1	ND	ND	0.01
VOC, ppm	ND	ND	ND	ND	ND	ND	0.0001
SO_2, ppm	ND	ND	ND	ND	ND	ND	0.01 – 24 hours; 0.1– 1 hour;
PM_{10}, ppm	0.012	0.01	0.012	0.011	0.013	0.008	0.37- 24 hours;
$PM_{2.5}$, ppm	0.004	0.004	0.005	0.006	0.005	0.003	0.34 - 24 hours;
AIR TEMP. ^{0}C	35.7	31.7	34.2	35.5	30.2	30	NS
WIND SPEED, m/s	0.6	0.7	0.25	0.5	1.3	0.3	NS
Relative Humidity, %	62.4	72.6	69.9	63.9	66.9	74.2	NS
Wet Bulb Temperature, ^{0} C	28.3	27.6	29.4	30.1	24.7	25.8	NS

POINT 1	DISEL	Senate Building
POINT2	FUEL	School of Environmental sciences (SOES)
POINT3	GAS	Old SEET Head
POINT4	KEROSEENE	Female Hostel C
POINT5	CHARCOAL	Market Square
POINT6	FIREWOOD	Commercial Building behind Old Registry

Meteorological Parameters

Dry-Bulb Temperature:

Mean dry bulb temperature of the fuel sources ranged from 29.6 to 35.7°C (Fig. 2). The highest dry bulb temperature was found at indoor measurement (35.7°C) in P1 utilizing diesel as fuel source while the least indoor temperature value was gotten at P5 utilizing firewood at 30°C. Similarly, the highest outdoor dry-bulb temperature was gotten at P3 using gas as fuel source while the least was at P5 utilizing firewood. Mean indoor dry bulb temperature ranged from 30 to 35.7°C with an average of 32.9°C while that of outdoor ranged from 29.6 to 33.7 with an average of 31.5°C

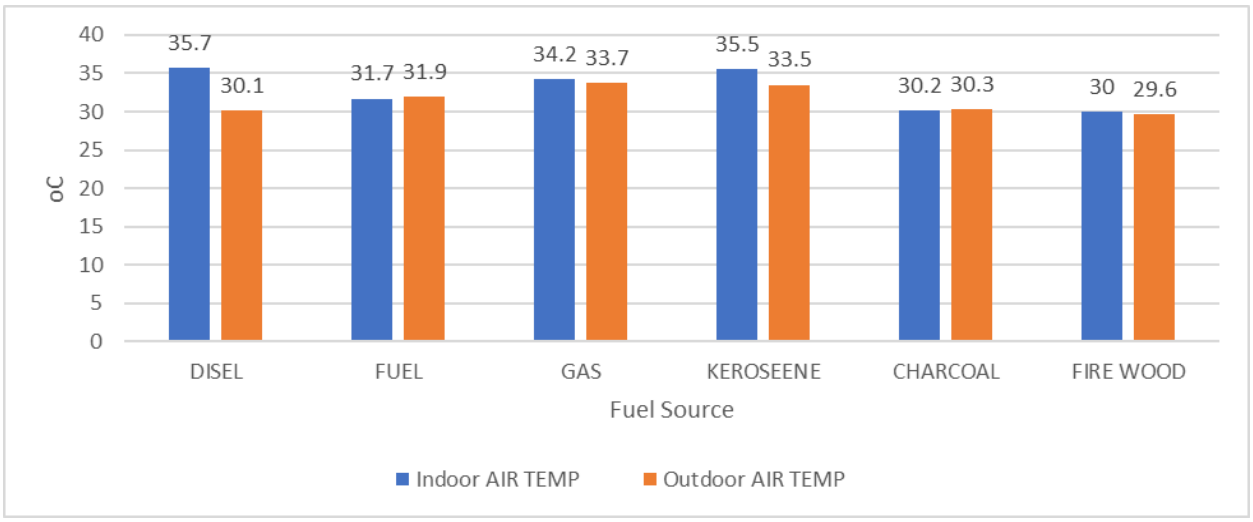


Fig. 2: mean dry bulb temperature for indoor and outdoor fuel sources

Wet Bulb Temperature:

Mean wet bulb temperature of the fuel sources ranged from 24.7 to 39°C (Fig. 3). The highest and lowest mean wet bulb temperature was found at outdoor measurement (39°C) and (24.7°C) respectively in P5 utilizing Charcoal as fuel source for both outdoor and indoor. Mean outdoor wet-bulb temperature ranged from 25.6°C to 39°C with an average of 29.4°C while that of indoor ranged from 24.7 to 30.1°C with an average of 27.7°C.

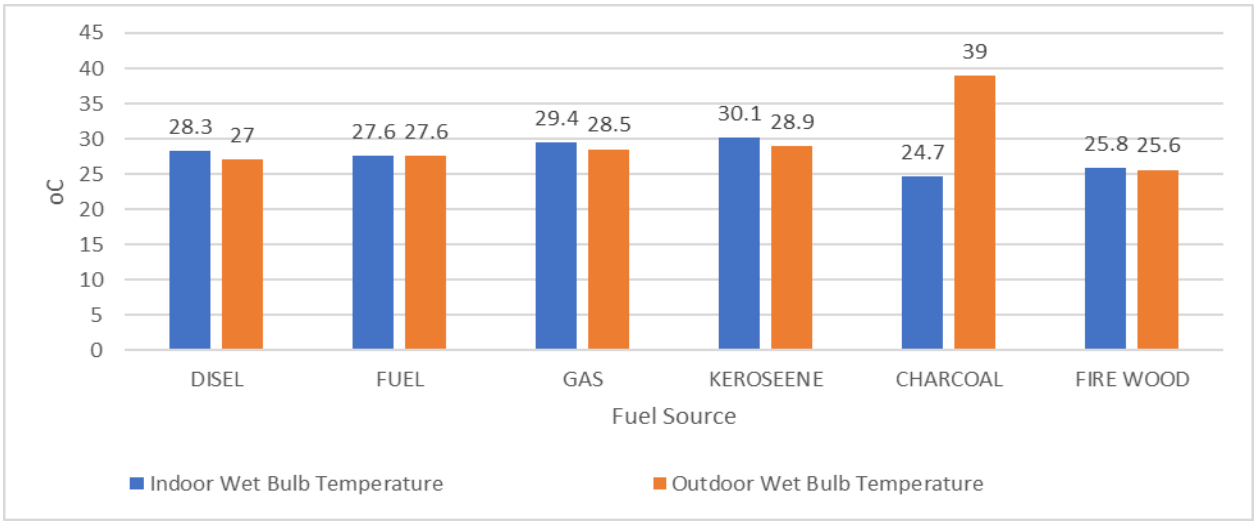


Fig. 3: mean wet bulb temperature for indoor and outdoor fuel sources

Relative Humidity:

Relative humidity readings were higher in outdoor fuel sources with an average of 70.7% compared to that of the indoor at an average of 68.3% (Fig. 4). The highest relative humidity wasfound at outdoor P_4 utilizing Kerosene as fuel source at 75.8% while the least relative humidity was found at indoor P_3 utilizing Diesel as fuel source.

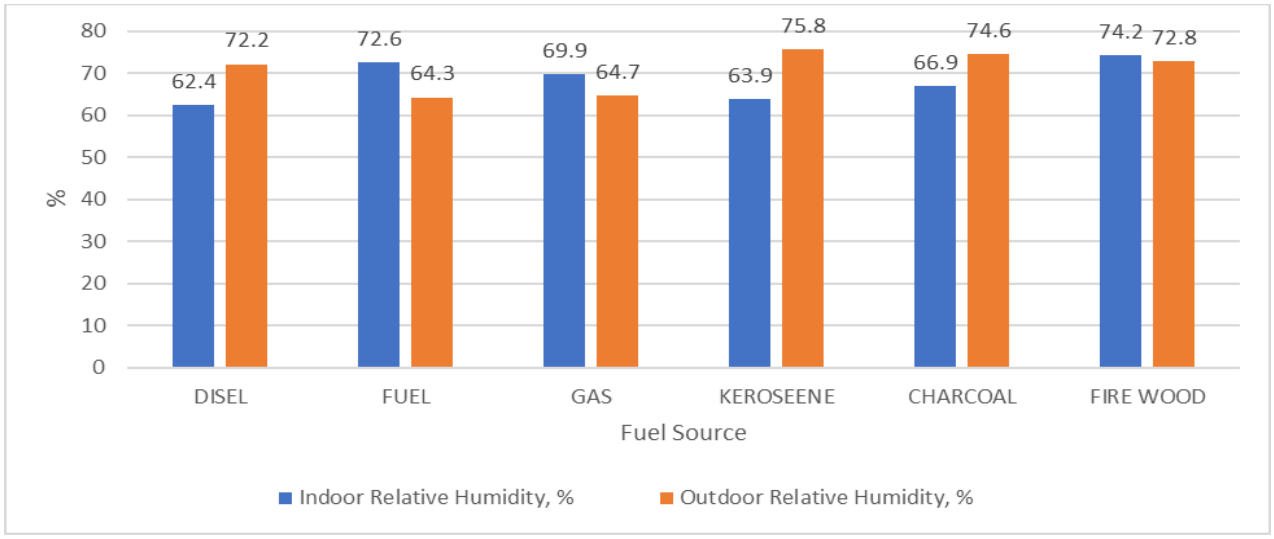
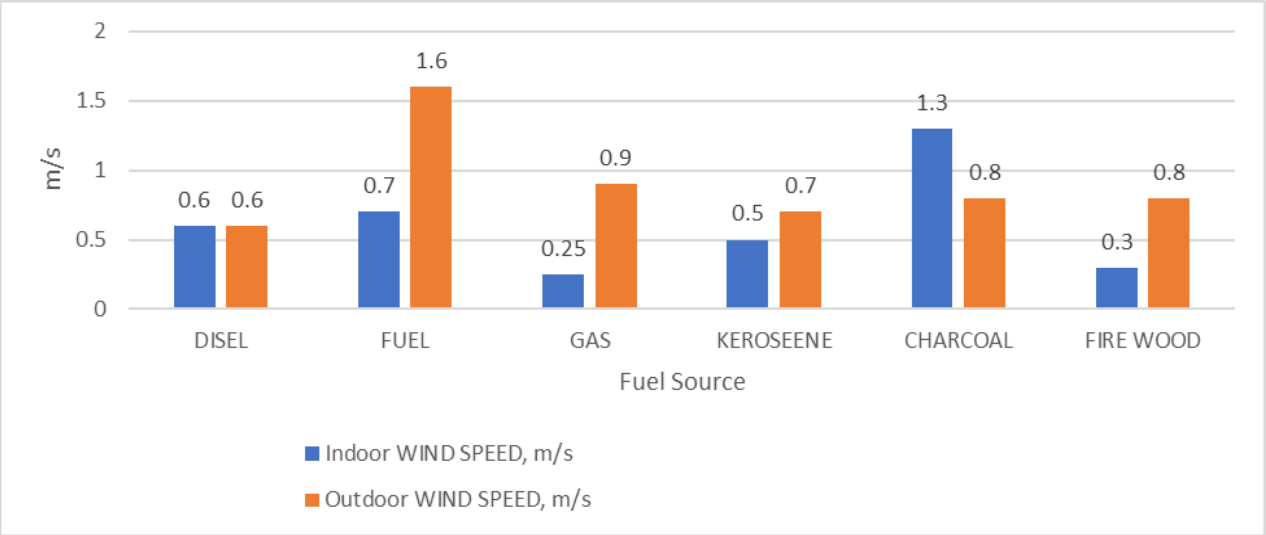


Fig 4: mean dry Relative humidity for indoor and outdoor fuel sources

Wind Speed:

Figure 5 presents the mean wind speed for both outdoor and indoor fuel sources. Outdoor fuel source had the highest and lowest wind speed at P_2 (1.6m/s) and P_1 (0.6m/s) respectively with an average of 0.9m/s. Indoor fuel source had the highest and lowest at P_5 (1.3m/s) and P_3 (0.25m/s) respectively with an average of 0.6m/s



Figs 5: mean wind speed for indoor and outdoor fuel sources

Physiochemical Parameters

Carbon Monoxide (CO):

There are observable variations between indoor and outdoor CO across six sampled building (Fig 6). Mean indoor CO concentration varies from 4.4 to 9.1ppm with an average of 7.3ppm whereas; mean outdoor CO varies between 0.000 to 5.8ppm with an average of 2.3ppm. Mean Indoor concentration at P6 where firewood is used for cooking was observed to be 9.1ppm. This result is above limit set for 8 hours indoor concentrations of less than 8.7ppm. WHO (2010) has identified cooking, heating, and smoking as common indoor sources of CO. Observed high concentrations of CO at P5 for indoor environment have been associated with burning of anthropogenic activities that include the firewood that emit CO and other gases as by-products in the university environments, there were no CO concentrations observed at location P2 and P3 where Petrol and Gas were fuel type utilized.

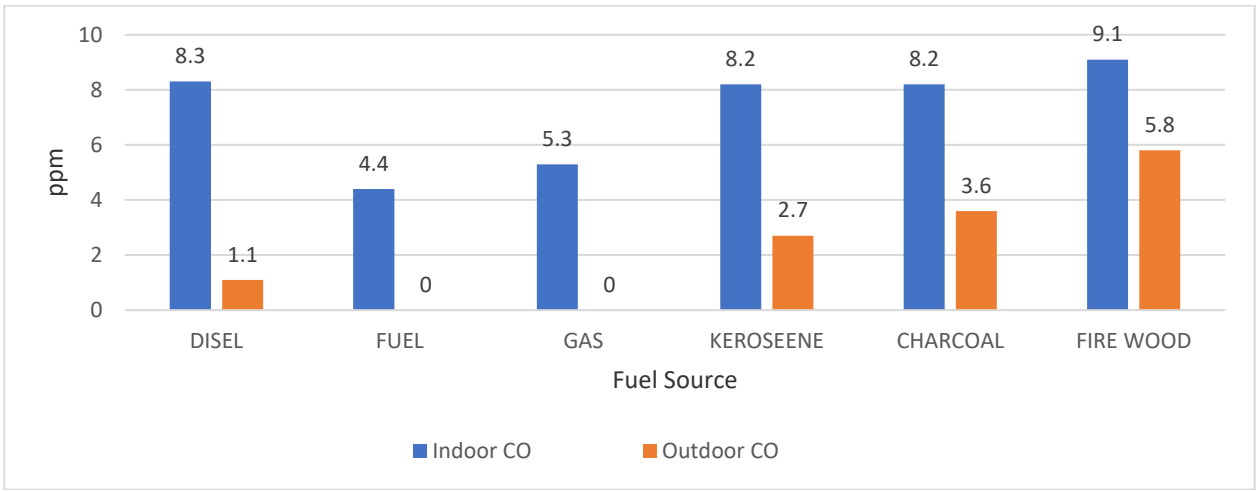


Fig 6: Mean CO concentration for indoor and outdoor fuel sources

Carbon Dioxide (CO_2):

Figure 7 presents CO_2 concentrations of different fuel sources from indoor and outdoor ranging from 450 to 708ppm. The mean values for outdoor concentrations ranged from 470 to 495ppm with an average of 489.5ppm while the indoor with the least and highest observed CO_2 concentration maintained an average of 538.8ppm. High indoor value was observed at P3 at

708ppm utilizing gas as fuel source. Meanwhile the highest outdoor value was observed at P6 where charcoal was used as fuel source. Indoor CO_2 concentrations were observed to be higher than outdoor cocentrations in four of the six sampled buildings in FUTO environment. Observed higher indoor CO_2 concentrations in comparison to the outdoor CO_2 concentrations found in this study can be attributed to the high occupant densities within the buildings which might have contributed to the high CO_2 concentrations through breathing.

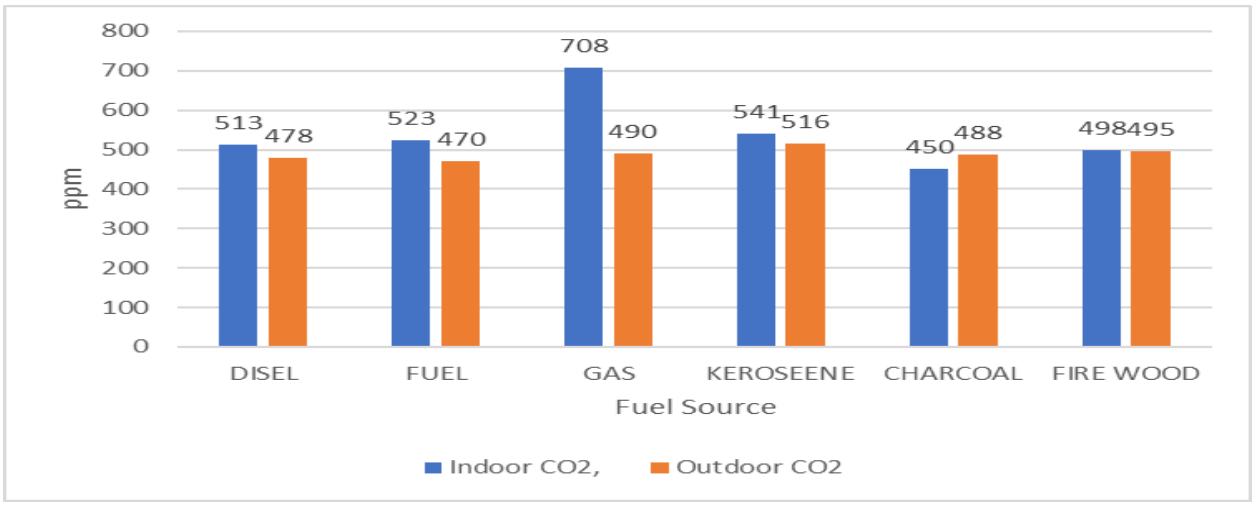


Fig 7: Mean CO concentration for indoor and outdoor fuel sources

Nitrogen Dioxide (NO_2):

Higher values of NO_2 were observed in indoor fuel source building compared to outdoor buildings (Fig .8). The mean values for indoor concentrations ranged from 0.05 to 0.072ppm with an average of 0.059ppm while the outdoor value ranged from 0.034 to 0.064ppm with an average of 0.049ppm. Highest indoor and outdoor values were observed at P6 at 0.072 and 0.064ppm respectively utilizing firewood as fuel source. These results are above the limit of 0.05ppm set by Federal Ministry of Environment for NO_2. Indoor NO_2 results at P_5 location (0.064ppm) and P6 (0.072ppm) where Charcoal and Firewood respectively are used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Outdoor NO_2 concentration for the six buildings were within the limit of 0.075-0.11ppm set by the Federal Ministry of Environment. The lowest values for outdoor and indoor NO_2 concentration were at P_3 (0.034ppm) and P_4 (0.05ppm) representing Gas and Kerosene fuel sources respectively.

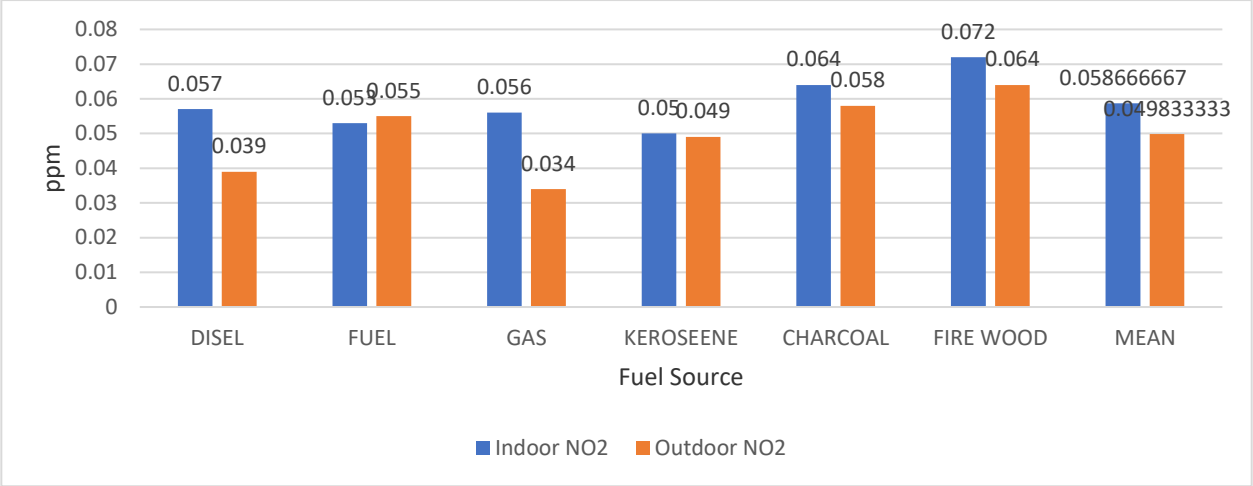


Fig 8: Mean NO_2 concentration for indoor and outdoor fuel sources

Methane (CH_4):

Indoor and Outdoor CH_4 maintained the same values at 3 fuel sources (Fuel, Gas and Kerosene) representing P2, P3 and P4 respectively (Fig. 9). Higher values of CH_4 were observed in outdoor fuel source of P1 (21ppm against 6) and P5 at (7ppm against 1). Mean values for indoor concentrations ranged from 1 to 7ppm with an average of 4.3ppm compared to outdoor value ranged from 1 to 21ppm with an average of 6.8ppm.

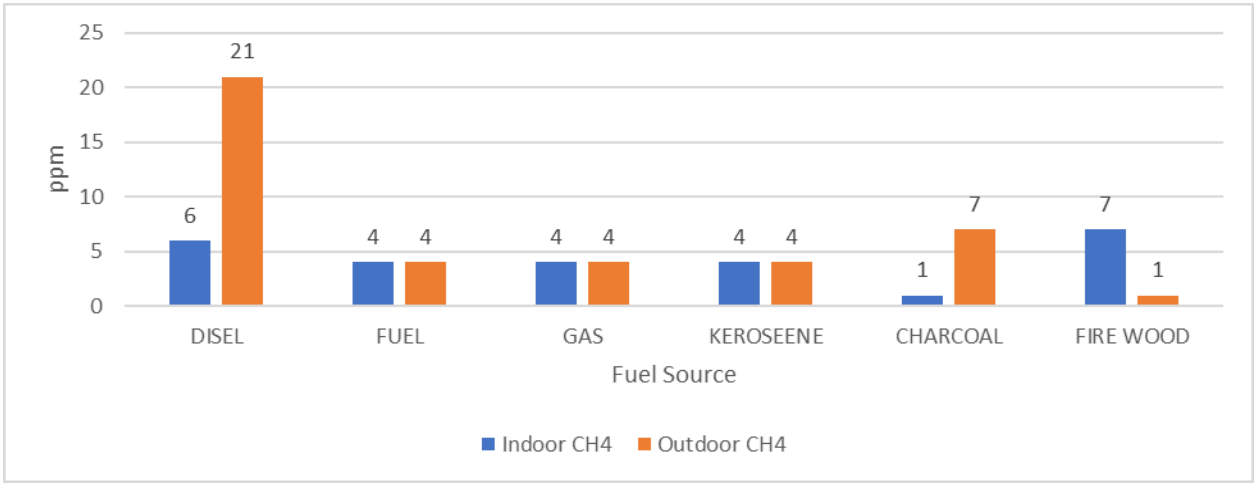


Fig. 9: Mean CH_4 concentration for indoor and outdoor fuel sources

Hydrogen Sulphide (H_2S):

There were no outdoor observations for hydrogen sulphide across the six fuel sources sampled (Fig. 10). P1 and P4 with fuel sources of Diesel and Kerosene respectively have 0.2ppm and 0.1ppm values for hydrogen sulphide out of the six sampled indoor air quality. The observed results for the two buildings were above the limit set by both Federal Ministry of Environment and Department of Petroleum Resources.

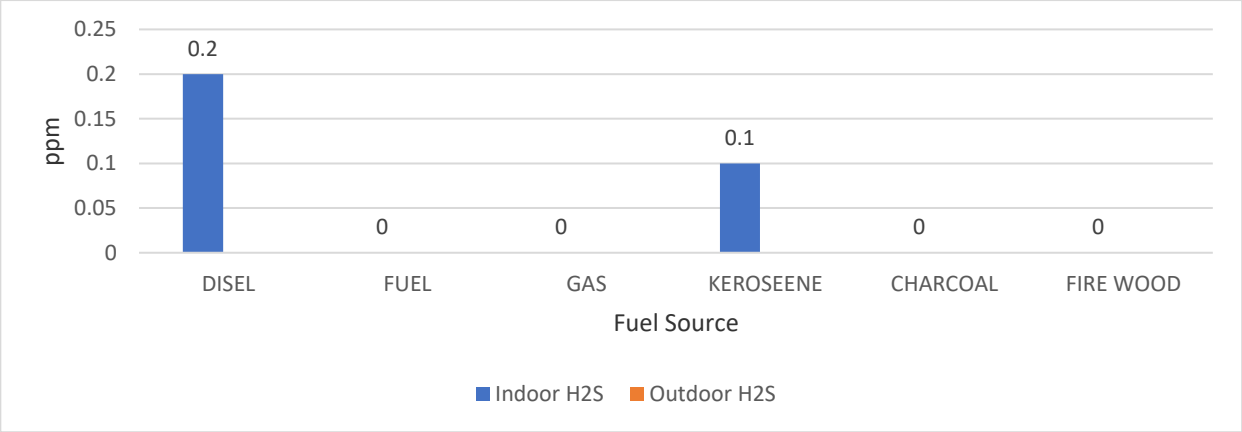


Fig. 10: Mean H_2S concentration for indoor and outdoor fuel sources

Volatile Organic Compound (VOC):

Out of the six sampled fuel sources for both indoor and outdoor air quality parameters (Fig. 11), outdoor location for P1 utilizing diesel was the only fuel source observed to have emitted VOC at 1ppm.

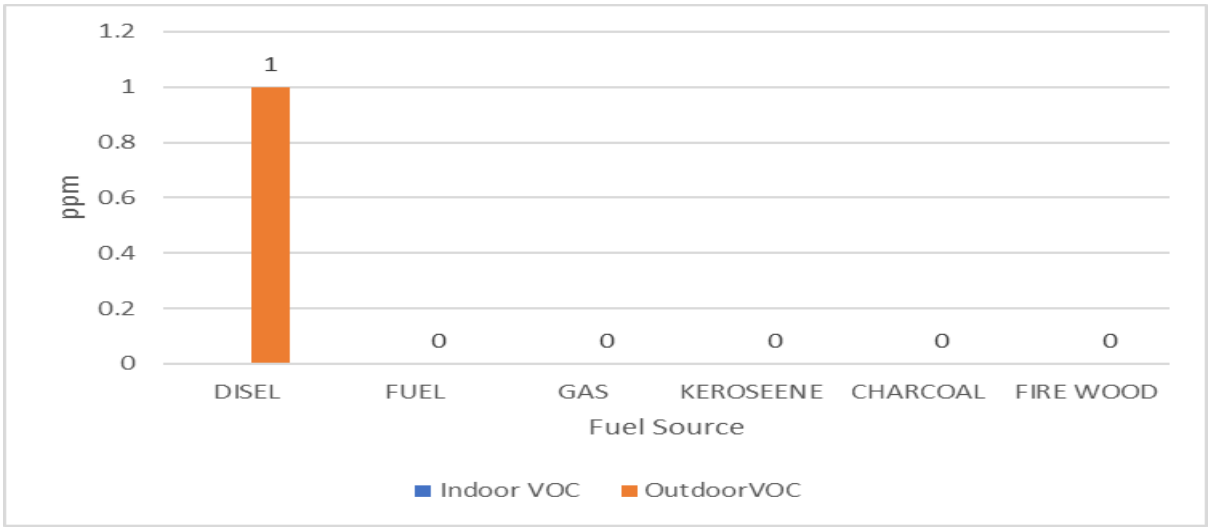


Fig 11: Mean VOC concentration for indoor and outdoor fuel sources

Particulate Matter PM_{10}:

Figure 12 presents the mean outdoor and indoor concentration of PM_{10} across six fuel sources in FUTO environs. The mean value of outdoor PM_{10} ranges from 0.008 to 0.13ppm compared to the outdoor concentration that ranged from 0.09 to 0.1ppm. The highest values of PM_{10} for both indoor and outdoor were observed at 0.13 and 0.1ppm respectively location P5 where charcoal was used as fuel source.

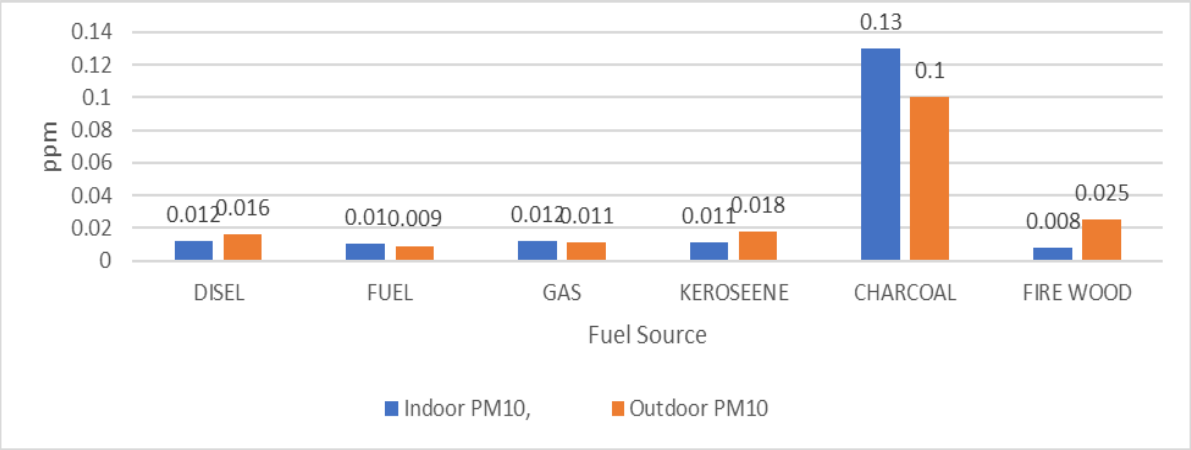


Fig 12: Mean PM_{10} concentration for indoor and outdoor fuel sources

Particulate Matter ($PM_{2.5}$):

Unlike PM_{10} Observation, outdoor air quality had more $PM_{2.5}$ than indoor air quality (Fig. 13). More significant variation was observed at P5 at 0.04ppm against 0.005ppm and at P6 (0.021ppm) against 0.003ppm. Mean range of indoor air quality ranged from 0.003 to 0.005ppm with an average of 0.0045 while the outdoor air quality ranged from 0.004 to 0.04ppm with an average of 0.012ppm.

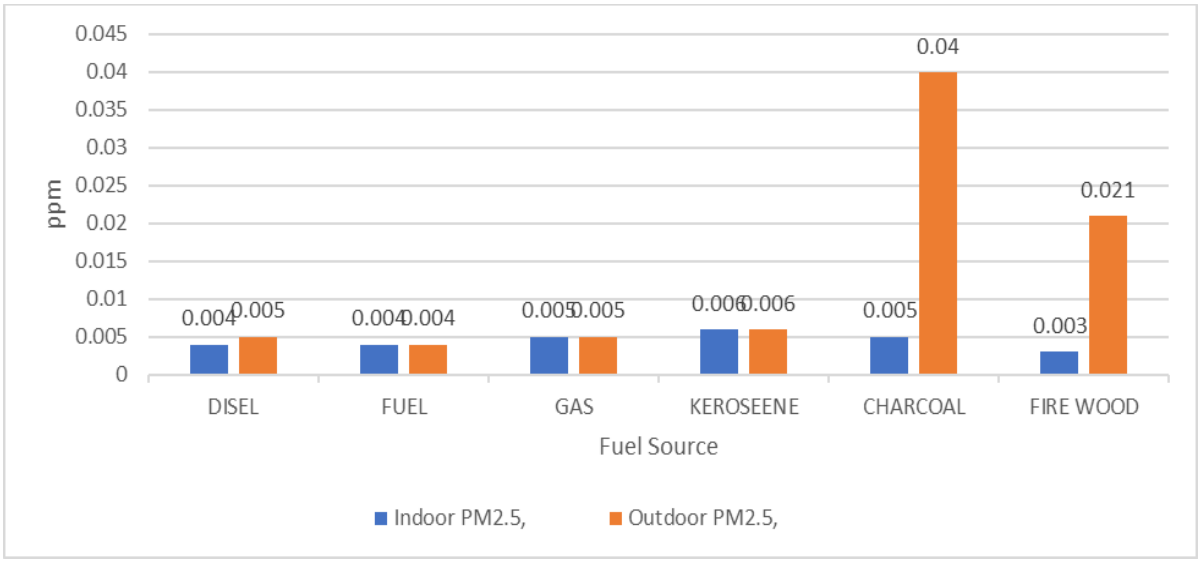


Fig 13: Mean $PM_{2.5}$ concentration for indoor and outdoor fuel sources

Ozone (O_3):

Ozone was only observed at indoor air quality sample at P6 where firewood is utilized as fuel source at 0.02ppm (Fig. 14). It remains the only observations made on both indoor and outdoor air quality sampling for ozone concentrations across the six fuel sources in the study.

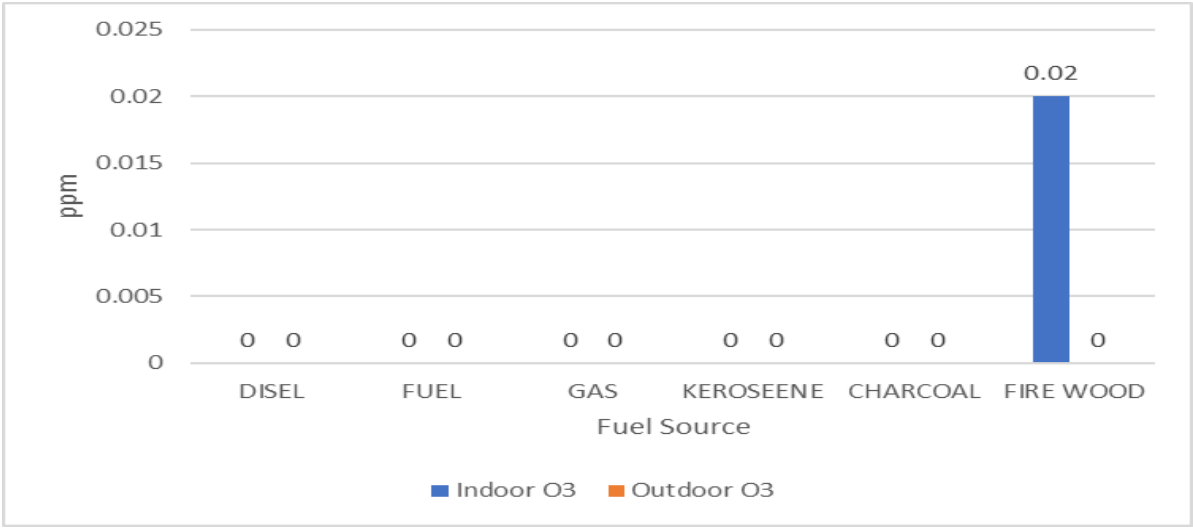


Fig 14: Mean O3 concentration for indoor and outdoor fuel sources

Table 3: Correlation of indoor-outdoor meteorological parameters

		Indoor TEMP	Outdoor TEMP	Indoor WIND SPEED	Outdoor WIND SPEED	Indoor Relative Humidity	Outdoor Relative Humidity	Indoor Wet Temp	Outdoor Wet Temp
Indoor TEMP	Pearson Correlation	1	.537	-.377	-.355	-.725	.011	.887*	-.351
	Sig. (2-tailed)		.272	.461	.490	.103	.983	.018	.495
	N	6	6	6	6	6	6	6	6
Outdoor TEMP	Pearson Correlation	.537	1	-.353	.191	-.114	-.365	.800	-.107
	Sig. (2-tailed)	.272		.492	.718	.830	.476	.056	.839
	N	6	6	6	6	6	6	6	6
Indoor WIND SPEED	Pearson Correlation	-.377	-.353	1	.074	-.271	.321	-.601	.876*
	Sig. (2-tailed)	.461	.492		.890	.603	.535	.207	.022
	N	6	6	6	6	6	6	6	6
Outdoor WIND SPEED	Pearson Correlation	-.355	.191	.074	1	.615	-.733	-.065	-.118
	Sig. (2-tailed)	.490	.718	.890		.193	.098	.903	.824
	N	6	6	6	6	6	6	6	6
Indoor Relative Humidity	Pearson Correlation	-.725	-.114	-.271	.615	1	-.520	-.382	-.251
	Sig. (2-tailed)	.103	.830	.603	.193		.290	.454	.631
	N	6	6	6	6	6	6	6	6
Outdoor Relative Humidity, %	Pearson Correlation	.011	-.365	.321	-.733	-.520	1	-.233	.333
	Sig. (2-tailed)	.983	.476	.535	.098	.290		.657	.519
	N	6	6	6	6	6	6	6	6
Indoor Wet Temp	Pearson Correlation	.887*	.800	-.601	-.065	-.382	-.233	1	-.509
	Sig. (2-tailed)	.018	.056	.207	.903	.454	.657		.302
	N	6	6	6	6	6	6	6	6
Outdoor Wet Temp	Pearson Correlation	-.351	-.107	.876*	-.118	-.251	.333	-.509	1

	Sig. (2-tailed)	.495	.839	.022	.824	.631	.519	.302	
	N	6	6	6	6	6	6	6	6
*. Correlation is significant at the 0.05 level (2-tailed).									

Table 4: Paired Samples t Test for meteorological parameters

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Indoor TEMP - Oudoor TEMP	1.3667	2.2187	.9058	-.9617	3.6951	1.509	5	.192
Pair 2	Indoor WIND SPEED - Outdoor WIND SPEED	-.2917	.5024	.2051	-.8189	.2356	-1.422	5	.214
Pair 3	Indoor Relative Humidity - Outdoor Relative Humidity, %	-2.4167	8.4828	3.4631	-11.3188	6.4855	-.698	5	.516
Pair 4	Indoor Wet Temp - Outdoor Wet Temp	-1.7833	6.1545	2.5126	-8.2421	4.6754	-.710	5	.510

Indoor-Outdoor Physiochemical Characteristics

Table 5 shows result of correlation of Indoor-outdoor air quality parameters, strong correlations were observed between Indoor and outdoor CO, NO_2, PM_{10} at 81.9%, 58.5% and 98.3% respectively. CO and PM_{10} maintained strong significant correlation at .045 and .000 respectively. Weak correlations were observed between indoor and outdoor CO_2, CH_4 and $PM_{2.5}$ at 9.4%, 13.9% and 5.9% respectively.

Across parameters, indoor NO_2 maintained strong positive correlation with indoor CO, outdoor CO at 53.5% and 77.7% respectively while outdoor NO_2 had strong correlations with outdoor CO and indoor CO_2 at 74.1% and 74.4% respectively.

The mean correlation between indoor and outdoor air quality physiochemical characteristics were tested for significance using the paired t-Test method to determine if there are significant variations between the sample means of the indoor and outdoor air quality measurements. Result showed only significant value on CO at 0.000. Thus, justifying that there is no major significance variation of the sample mean of the indoor-outdoor air quality parameters.

Table 5: Indoor-outdoor air quality Correlation result

		Indoor CO	Outdoor CO	Indoor CO2,	Outdoor CO2	Indoor NO2	Outdoor NO2	Indoor CH4	Outdoor CH4	Indoor PM10,	Outdoor PM10	Indoor PM2.5,	Outdoor PM2.5,
Indoor CO	Pearson Correlation	1	.819*	-.556	.507	.535	.345	.243	.220	.235	.385	-.095	.482
	Sig. (2-tailed)		.046	.252	.305	.274	.503	.642	.675	.654	.451	.858	.334
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CO	Pearson Correlation	.819*	1	-.574	.474	.777	.741	.187	-.308	.278	.446	-.284	.661
	Sig. (2-tailed)	.046		.234	.343	.069	.092	.723	.553	.594	.375	.585	.153
	N	6	6	6	6	6	6	6	6	6	6	6	6

Indoor CO_2,	Pearson Correlation	-.556	-.574	1	.094	-.381	-.744	.101	-.183	-.477	-.556	.271	-.585
	Sig. (2-tailed)	.252	.234		.859	.456	.090	.849	.728	.339	.252	.604	.223
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CO_2	Pearson Correlation	.507	.474	.094	1	-.057	.065	-.012	-.381	-.048	.040	.561	.071
	Sig. (2-tailed)	.305	.343	.859		.915	.902	.982	.456	.927	.940	.246	.893
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor NO_2	Pearson Correlation	.535	.777	-.381	-.057	1	.585	.249	-.181	.304	.431	-.664	.682
	Sig. (2-tailed)	.274	.069	.456	.915		.223	.634	.732	.558	.394	.150	.136
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor NO_2	Pearson Correlation	.345	.741	-.744	.065	.585	1	-.031	-.488	.320	.426	-.389	.607
	Sig. (2-tailed)	.503	.092	.090	.902	.223		.954	.326	.537	.399	.446	.201
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor CH_4	Pearson Correlation	.243	.187	.101	-.012	.249	-.031	1	.139	-.800	-.702	-.646	-.495
	Sig. (2-tailed)	.642	.723	.849	.982	.634	.954		.793	.056	.120	.166	.319
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor CH_4	Pearson Correlation	.220	-.308	-.183	-.381	-.181	-.488	.139	1	.029	-.008	-.066	-.168
	Sig. (2-tailed)	.675	.553	.728	.456	.732	.326	.793		.956	.988	.901	.751
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor PM_{10},	Pearson Correlation	.235	.278	-.477	-.048	.304	.320	-.800	.029	1	.983**	.252	.884*
	Sig. (2-tailed)	.654	.594	.339	.927	.558	.537	.056	.956		.000	.630	.019
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor PM_{10}	Pearson Correlation	.385	.446	-.556	.040	.431	.426	-.702	-.008	.983**	1	.178	.946**
	Sig. (2-tailed)	.451	.375	.252	.940	.394	.399	.120	.988	.000		.736	.004
	N	6	6	6	6	6	6	6	6	6	6	6	6
Indoor $PM_{2.5}$,	Pearson Correlation	-.095	-.284	.271	.561	-.664	-.389	-.646	-.066	.252	.178	1	-.059
	Sig. (2-tailed)	.858	.585	.604	.246	.150	.446	.166	.901	.630	.736		.911
	N	6	6	6	6	6	6	6	6	6	6	6	6
Outdoor $PM_{2.5}$,	Pearson Correlation	.482	.661	-.585	.071	.682	.607	-.495	-.168	.884*	.946**	-.059	1
	Sig. (2-tailed)	.334	.153	.223	.893	.136	.201	.319	.751	.019	.004	.911	
	N	6	6	6	6	6	6	6	6	6	6	6	6
. *Correlation is significant at the 0.05 level (2-tailed).													

**. Correlation is significant at the 0.01 level (2-tailed).										

DISCUSSION OF RESULTS

Temperature has been documented widely in several studies as a major parameter that affects the chemistry and behaviour of air pollutants (Budiakova, 2017; Anthony, 2020). Mean indoor dry bulb temperature ranged from 30.2 to 35.7°C with an average of 32.9°C compared to that of outdoor which ranged from 29.6 to 33.7 °C with an average of 31.5°C. Studies by Budiakova, 2017; Choo *et al*., 2015; Fadeyi *et al*., 2014, have reported an indoor temperature range of 13.0 to 26.0 °C for school classrooms and university lecture halls in Europe and Asia. This differs from the result obtained from this study and can be explained that most of these studies were carried out in cold regions where temperature values hardly reach the values obtainable in West African Countries. Similarly, outdoor temperature range observed differs from the range of 1 to 28°C recommended by Wangchuk *et al*., 2015 and Mohammadyan *et al*., 2017 in Universities and Home environments. Relative Humidity ranged from 64.3 to 75.8% for outdoor buildings against a range of 62.4 to 74.2% for indoor. Relative humidity results were higher in outdoor compared to indoor. Similar results were obtained from several studies carried out of indoor and outdoor of university buildings (Jovanovic *et al*., 2014; Wangchuk *et al*., 2015; Lu *et al*., 2016; Mohammadyan *et al*., 2017 and Anthony, 2020).

However, on the buildings where Gas, fuel and firewood were utilized, relative humidity was higher at indoor than outdoor, this observation can be justified by the inverse relationship of relative humidity with temperature because warm air tends to hold more moisture than cold air reported by Anthony (2020) in few of the buildings sampled in the University environment. Variances in the results of relative humidity of sampled buildings for indoor and outdoor occur as a result of differences in terms of activities going on in the various buildings which may be contributing to indoor moisture levels as well as the building structure.

Mean values of indoor wind speed ranged from 0.25 to 1.3m/s with an average of 0.6m/s while the outdoor ranged from 0.6 to 1.6m/s with an average of 0.9m/s. The higher values for outdoor wind speed against indoor obtained in this study were consistent with studies by Choo *et al*., 2015; 2016; Budiakova, 2017; Mohammadyan *et al*., 2017; and Anthony 2020 for indoor and outdoor wind speed.

The result of indoor-outdoor air quality parameters for of six buildings in FUTO where different fuel sources are utilized were within the Federal Ministry of Environment and Department of Petroleum Resources standards, except for indoor CO from P6 where firewood is utilized. An indoor CO concentration of 9.1ppm against indoor air quality value of either 8.7ppm or <10000ug/m3 for an 8-hour average testing period of Indoor Air Quality Management Quality Group. The overall trend was higher indoor CO concentrations compared to outdoor CO concentrations across the six buildings (Figure 6), Observed high value of CO concentration is attributed to the fuel type associated with high smoke as a result of incomplete combustion of firewood (WHO, 2010). A similar observation was made by Anthony, (2020) that high concentrations of CO in the indoor environment have been associated with burning of firewood and other fuels that emit CO gas as by-products.

DEH, (2005) opined that under natural and unpolluted atmospheric conditions, the mean CO concentrations are around 0.20 ppm. Carbon monoxide being a product of incomplete

combustion of carbon-containing material was strongly reported in the works of Choo *et al*, 2015 as a major pollutant released into the environment through sources of vehicular traffic emissions, domestic fuel burning (gas, fuel, firewood, or coal appliances), tobacco smoking or industrial sources. This report agrees with findings from this research as a higher concentration of indoor CO was observed in areas where appliances of the fuel types (Charcoal, Firewood, Gas, Kerosene, Diesel, and fuel) were used at FUTO.

Indoor CO_2 concentration across the six buildings followed the pattern of Gas > Kerosene>Fuel> Diesel > Charcoal > Firewood whereas that of outdoor followed the order of Kerosene > Firewood > Gas > Charcoal > Diesel >Fuel (Fig. 6). In comparison, the average mean of indoor CO_2 concentration across the six buildings is 538.8ppm while that of outdoor CO_2 concentration is 489.5ppm. Several studies (Budiakova, 2017; Peng *et al*., 2017; Choo *et al*., 2015; Fadeyi *et al*., 2014) have reported an indoor CO_2 concentration range of 408 to 2739ppm. However, an upper limit range of 708ppm was reported for Indoor in this research which is lower than observed findings from earlier researchers.

In comparison, higher CO_2 concentrations were observed in indoor environments than outdoor, this observation is similar to the findings from Knížatová *et al*., (2010); Widder and Haselbach, (2017) and Anthony (2020), which was attributed to mainly human respiration and the burning of different types of fossil fuels. In addition to the contributions of the fuel sources in the observed values of Indoor CO_2 concentrations, higher indoor CO_2 concentrations can be explained by the combined operation of different fuel sources serving mostly for commercial purposes coupled with high occupant densities within the buildings which might have contributed to the high CO_2 concentrations through breathing. Budiakova (2017) and OSHA (2011) also found a positive correlation between CO_2 concentrations and occupant density within a given environment.

In a similar pattern, higher values of NO_2 were observed in indoor compared to outdoor results (Fig. 8). Highest values for indoor and outdoor concentrations were observed at P6 at 0.072 and 0.064ppm respectively utilizing firewood as the fuel source. Four out of five of the six facilities had indoor NO2 concentrations above the limit set by the Federal Ministry of Environment compared to outdoor concentrations above the limit of three out of the six facilities. This can be attributed to complex human activities in the university environment involving the burning of biomas fossil fuels (gas, oil, diesel wood burning etc) and vehicular emissions. A similar observation was reported on WHO (2009) guidelines for indoor air quality of selected pollutants and EPA (2011) report on air quality guide for nitrogen. WHO 2009 outlined factors with complex interactions contributing to the variations in indoor-outdoor concentrations of nitrogen to be; the level of buildings, building designs for ventilations classroom distances to the road and sources of NO_2 emissions to the environment.

There were significant variations in the Indoor and Outdoor CH_4 concentration at P1 (Fig. 9) where diesel is the major fuel source at 21ppm against 6. A similar obervation was seen at P5 (7ppm against 1) where charcoal was used as the fuel source. Among other sources of methane emission in the environment, observed variations on the two buildings can be attributed to the fuel sources sampled because methane is a natural gas originating mainly from fossil fuel among other sources with little to rare reactivity apart from combustion, steam reforming to syngas, and halogenation which results to carbon monoxide and H_2O.

Hydrogen sulphide was not found in the outdoor ambient environment across the six facilities sampled. However, H_2S was found at only two buildings (P1 and P4) where diesel and kerosene were used as the fuel source for indoor air quality. Results obtained 0.2ppm for P1 and 0.1ppm for P4 was by far above the limit set by both the Federal Ministry of Environment and the Department of Petroleum Resources (Table 2 and Fig .10). Anthony (2020) observed that only very few studies so far have looked at H_2S concentrations across indoor and outdoor environments. Hence, indoor and outdoor H_2S concentration mean values and ranges are not common in literature.

There was no result for indoor VOCs on the entire six buildings sampled. Similarly, outdoor had 1ppm only at P1 among the six buildings sampled. The observed result at P1 (Fig. 11) can be attributed to diesel combustion and some renovation activities that were ongoing during the entire sampling period. Paints usually comprise alcohols, esters, texanol, cellosolve, and glycols, which are all primary VOCs (Chang *et al*., 2011). Other sources of VOCs especially indoor are floors, ceilings, walls, renovated environments (stripping painting and construction which release formaldehyde. Consumer products such as nail polish and remover, perfumes and detergents, floor wax and polish, solvents (adhesives, welding, inks, chlorinated tap water), other building materials (plastics, coatings, foam insulators, varnish, paint remover, plywood, phenolic resins, furniture polish), moth repellents, cigarette smoke and burning of fossil fuels are inclusive sources of VOC (Anthony, 2020).

Outdoor-indoor particulate matter (PM_{10} and $PM_{2.5}$) were presented in Figs. 12 and 13 respectively. The highest outdoor PM_{10} and $PM_{2.5}$ were recorded in P5 where charcoal is used as the fuel source at 0.1 and 0.04 ppm respectively. The lowest mean concentrations of indoor PM_{10} and $PM_{2.5}$ were obtained at P5 and P4 where Charcoal and Kerosene were used at 0.13ppm and 0.006ppm respectively. Result for both indoor and outdoor PM_{10} and $PM_{2.5}$ were within the provided limit by the Federal Ministry of Environment and The Department of Petroleum Resources. The finding from this research is in agreement with the report from Jelili *et al* (2020) in indoor and outdoor particulate matter having higher values of PM_{10} and $PM_{2.5}$ observed on facilities where Kerosene and Charcoal were used among other fuel types sampled. Jelili *et al*., (2020) justified the result by stating that Kerosene and charcoal were the dominant forms of cooking fuels, used by 92.5% and 66.0% of the population, respectively in Ogbomoso, Nigeria, followed by firewood (20.5%), while the least used was sawdust.

The mean concentration for Ozone (O_3) was only found at P6 at 0.02ppm (Fig. 14). Indoor O_3 concentrations in this study were with the limit provided by Federal Ministry of Environment and the Department of Petroleum Resources. In comparison was within the limit found in literature for university classrooms (Fadeyi *et al*., 2014; Jovanovic *et al*., 2014; Kalimeri *et al*., 2016) and above the result obtained by Anthony (2020) in the University of Limpopo, South Africa.

CONCLUSION

In pursuance of the main and specific objectives of the study, assessment of the indoor-outdoor air quality and meteorological parameters captured most of the air pollutants associated with different fuel sources (Diesel, Kerosene, Fuel, Gas, Charcoal and Firewood) in FUTO buildings (P1-P6). Result showed high concentrations of CO at Market Square for indoor environment, Indoor NO_2 results in the Market Square (0.064ppm) and Commercial building behind Old Registry (0.072ppm) where Charcoal and Firewood respectively is used were above the limit set by the Federal Ministry of Environment and Department of Petroleum Resources at maximum limit of 0.06ppm. Similarly, indoor H_2S at P1 and P4 with fuel sources of Diesel and Kerosene respectively

have 0.2ppm and 0.1ppm values which is above the maximum limit of 0.01ppm set by the Federal Ministry of Environment and Department of Petroleum Resources.

Although, the average means of both indoor and outdoor air quality differ, there are no statistical significant variations between the sample means of indoor and outdoor air quality parameters. The independent variables (meteorological parameters) perfectly predicted the combined indoor and outdoor air quality parameters at an adjusted R square value of 70.3% from the model summary and a statistical significance of 0.043 from the ANOVA table. The result showed that the meteorological parameters were able to account for 70.3% of the air quality parameters sampled from six different buildings in FUTO utilizing varying fuel sources. Apart from the wet temperature that contributed uniquely to predicting the air qualities, the remaining meteorological parameters (dry temperature, relative humidity and wind speed) combined in predicting the air quality of FUTO environment.

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