Indoor Air Quality Levels of Some Criteria Pollutants in University Hostels in Nigeria

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Abstract— Indoor air quality (IAQ) has been a matter of public concern especially in residential buildings in Nigeria. Poor IAQ can profoundly impact the health, comfort and productivity of building occupants. This study investigated the IAQ of five hostels in Federal University of Technology, Owerri (FUTO) Nigeria. A list of key criteria pollutants measured was nitrogen dioxide (NO2), sulphur dioxide (SO2), carbon monoxide (CO) and particulate matters (PM). The result of the study indicated that only seven cases of NO2 (e.g., three in hostel A and four in hostel B) were reported to exceed the Indoor Air Quality Guidelines and standards [e.g., National Ambient Air Quality Standard (NAAQS)/USEPA value of 0.05ppm]. Also, none of the readings for SO2, CO and PM exceeded the guideline level of 0.14ppm, 9ppm and 150µg/m3 respectively. The levels of indoor pollutants found in the hostels could result from the indoor use of combustion devices such as use of gas and kerosene stoves, high occupant density and air infiltration from outdoor air.

Key words: Indoor Air Quality, Criteria Pollutants

I. Introduction

The problems associated with the air we breathe indoors have become one of the greatest challenges we face in recent time (Ehsanul et al., 2012). In the time past, the study of indoor air pollution was completely ignored because outdoor air problems such as acid rain, smokestack emissions and smog were much more visible and therefore placed heavy demands on the attention of scientists (Jones, 1999). But currently, the increasing research interests and reports on indoor environmental matters have certainly heightened the awareness of the risks which threaten our indoor environments (Ezzati et al., 2001).

Indoor air could be impaired due to the presence of gaseous pollutants such as, NO2, SO2, CO and PM; and human exposures to these pollutants could affect the health, wellbeing and productivity of building occupants (Ballard et al., 1996). A study on human exposure to indoor pollutants indicates that indoor levels may be 2-5 times, and occasionally more hundred times higher than outdoor levels (Weschler, 2004). These levels of indoor air pollutants may be of particular concern because it has been established that most people spend about 80%-90% of their time in indoors environments (Nigel et al., 2000).

In public residential buildings, air contaminants can originate within the building or can be drawn from the outdoor environment. But most likely, activities of people living within the indoor environment such as, fuel combustion, tobacco smoking, use of kerosene and gas stoves and emissions from garage exhaust fumes are main principal factors responsible for the presence of most indoor air pollutants (Samuel and Abayneh, 2014).

A growing research interest has established that the risk factors associated with exposures to indoor pollutants have contributed immensely to overall burdens of diseases and premature deaths. Poor indoor air quality has been linked with a wide range of effects on respiratory health such as asthma development and exacerbation, respiratory infections and upper respiratory tract symptoms. Emmanuel, 2006, has reported that over 1.6 million lives have been lost with over 38.5 million disabled persons in the year 2000 due to IAQ problems.

Hostels are part of public buildings in Nigeria, and so far, there are few studies that focused on the air quality in this complex environment. Recently, Nigeria Government has recognized the potential risk and problems related to indoor air pollution in public buildings and it's striving to establish IAQ guidelines for different types of indoor environments.

This research study therefore aims at investigating the indoor levels of some criteria pollutants such as, NO2, SO2, CO and Particulate matters (PM) in some hostels at Federal university of Technology, Owerri (FUTO), Nigeria.

II. Materials and Methods

A. The Study Area

The Federal University of Technology, Owerri (FUTO), is a public higher institution established in 1981 by the Federal Government of Nigeria. FUTO is located in a town known as Ihiagwa in Owerri, Nigeria, with a land area of 97,298.34 hectares. The University is bounded by four communities of Eziobodo, Umuchima, Ihiagwa and Obinze (Lulat, 2005). Currently a total of 19,819 students are enrolled in campus programs. The climatic condition of the area is typical of the rain forest eco-zone characterized with its distinct dry (November to March) and rainy (April to October) seasons. The study included five hostels of FUTO, namely, Hostel A, Hostel B, Hostel C, Hostel D and Hostel E.

B. Sampling Procedure and Analysis

The indoor air quality (IAQ) monitoring was conducted from February 2012 to March, 2012. All the hostels were visited once only in a weekday when there was high occupant density. The air measurements were also taken twice in that same day (i.e., morning and evening). The monitoring times were during the peak periods, in the hours of 8:30 a.m. and 4:00 pm when indoor activities were high. The air pollutants investigated were four criteria pollutants which included, NO_2, SO_2, CO, Particulate matters (PM).

Every floor level in each hostel was selected for this study as they reflected the total indoor activities of the students. The areas of air measurement included major activity areas such as kitchens, toilets and bathrooms, common rooms, entertainment facilities, stores and selected rooms. The air intakes of the air monitoring equipment were positioned at a height of approximately 1.5m above the ground and also kept away from any source of targeted air pollutant. The pollutants were measured at about the sitting and breathing zone. During sampling, various indoor parameters including numbers of floors and ventilation type were recorded.

Portable digital gas monitors or analyzers were used to monitor the gaseous pollutants (NO_2, SO_2 and CO). The gas monitors used are products of Crowcon Gas Detection Instruments with Model (AR 8806A, EZ48 and MS6310) used for measuring NO_2, SO_2 and CO respectively. These monitors were able to detect the gases based on the mechanism of metal-oxide gas sensing principle. The metal-oxide used is a SnO_2 semiconductor with a very low conductivity. At each strategic point within the Hostel, a sample of air was drawn onto the sensor through a small outer orifice. On adsorption of the gas, oxidation-reduction reactions occurs which releases electrons within the semiconductor layer, and hence drop its resistance. This fall in resistance is registered via a sensor signal output (Barsan & Weimar, 2003). The units of the different concentrations are expressed in parts per million (ppm).

Split2 Particulate monitor was used to measure PM concentrations. The monitor measures particulate matters based on the method of light scattering of airborne particles which was collected and measured. The sample of air was normally drawn into the light scattering sensor (nephelometer) with a flow controlled rotary vane pump. The monitor measures PM at 1-min interval at a flow rate of 1.86/min. The output signals from the detector are empirically proportional to the number and size of particles. The concentrations are expressed in micrograms per cubic meter (µg/m^3).

III. RESULTS AND DISCUSSION

The indoor air qualities of five hostels of FUTO were determined by taking a total of 160 samples of four criteria pollutants (NO_2, CO, SO_2, and PM). The description of the sampling sites was shown in table 1, while the results of the concentrations of all the pollutants, NO_2, CO, SO_2, and PM in all the hostels are presented in Tables 2, 3, 4, 5. Table 6 shows the statistical summary of all the monitored indoor pollutants.

Site/Hostel	Hostel type	Hostel age (year)	No of Room in all the Floors	No of Occupants	Cooker Type	Ventilation Condition	Frequency of Household Cleaning During Sampling
A	Public rental	20	86	806	Gas/kerosene stove	Natural Ventilation all the time	Infrequent cleaning
B	Public rental	20	86	896	Gas/kerosene stove	Natural Ventilation all the time	Daily cleaning
C	Public rental	18	78	746	Gas/kerosene stove	Natural Ventilation all the time	Daily cleaning
D	Public rental	18	80	801	Gas/kerosene stove	Natural Ventilation all the time	Infrequent cleaning
E	Public rental	17	50	580	Gas/kerosene stove	Natural Ventilation all the time	Weekly cleaning

Table 1: General Description of Sampling Location & Indoor Activities in the Five Hostels

WEEK	sampling Time	Sampling sites				
		Hostel A	Hostel B	Hostel C	Hostel D	Hostel E
WK 1	8:30am	0.045	0.030	0.005	0.052	0.022
	4.00pm	0.052	0.008	0.006	0.008	0.037
Wk 2	8:30am	0.030	0.010	0.008	0.050	0.015
	4:00pm	0.040	0.025	0.010	0.040	0.025
WK3	8:30am	0.060	0.035	0.004	0.053	0.005
	4:00pm	0.045	0.012	0.005	0.045	0.010
WK 4	8:30am	0.048	0.030	0.006	0.006	0.020
	4:00pm	0.055	0.020	0.008	0.051	0.035
Mean		**0.049**	**0.021**	**0.007**	**0.051**	**0.021**

Table 2: The Concentration of Indoor NO_2 (ppm) at Different Sampling Times of Day and Week

WEEK	sampling Time	Sampling sites				
		Hostel A	Hostel B	Hostel C	Hostel D	Hostel E
WK 1	8:30am	5.35	3.00	2.15	4.89	1.89
	4.00pm	6.26	2.56	1.55	6.55	3.16
Wk 2	8:30am	4.86	2.84	2.35	7.56	0.95
	4:00pm	5.26	3.22	0.98	4.52	1.33
WK3	8:30am	6.52	2.86	1.85	6.05	2.15
	4:00pm	7.63	4.36	2.05	4.81	1.65
WK 4	8:30am	4.86	2.35	2.25	6.33	2.52
	4:00pm	5.32	4.26	1.85	7.05	1.50
Mean		**5.77**	**3.18**	**1.88**	**5.97**	**1.89**

Table 3.The Concentration of Indoor CO (Ppm) at Different Sampling Times of Day and Week

WEEK	sampling Time	Sampling sites				
		Hostel A	Hostel B	Hostel C	Hostel D	Hostel E
WK 1	8:30am	0.046	0.022	0.008	0.050	0.010
	4.00pm	0.040	0.010	0.015	0.042	0.008
Wk 2	8:30am	0.042	0.025	0.010	0.042	0.018
	4:00pm	0.038	0.032	0.005	0.033	0.004
WK3	8:30am	0.035	0.016	0.007	0.038	0.018
	4:00pm	0.038	0.009	0.005	0.042	0.020
WK 4	8:30am	0.025	0.011	0.004	0.037	0.006
	4:00pm	0.017	0.008	0.001	0.028	0.015
	Mean	0.035	0.017	0.007	0.039	0.012

Table 4: The Concentration of Indoor SO_2(Ppm) at Different Sampling Times of Day and Week

WEEK	sampling Time	Sampling sites				
		Hostel A	Hostel B	Hostel C	Hostel D	Hostel E
WK 1	8:30am	35.32	30.55	10.56	41.65	40.56
	4.00pm	38.50	25.22	15.55	30.56	50.26
Wk 2	8:30am	29.60	28.00	9.36	35.00	35.36
	4:00pm	32.50	25.35	11.55	28.56	45.20
WK3	8:30am	25.80	20.50	8.36	30.44	30.26
	4:00pm	28.06	19.35	4.50	28.55	20.26
WK 4	8:30am	25.26	15.80	5.60	25.36	30.05
	4:00pm	30.35	21.35	7.55	18.55	41.22
Mean		30.67	23.27	9.13	29.83	36.65

Table 5: The Concentration of Indoor Particulate Matter ($\mu g/m^3$) at Different Sampling Times of Day and Week

Pollutant	N	Minimum	Maximum	Range	Overall Mean	Std. Dev.	IAQG
NO_2	40	0.004	0.052	0.048	0.029	0.019	0.050
SO_2	40	0.001	0.046	0.045	0.022	0.015	0.14
CO	40	0.95	7.63	6.68	3.74	1.99	9.0
PM	40	4.50	50.26	45.76	26.19	11.45	150

Table 6: The Statistical Summary of Indoor Pollutants Measured During the Study Period (February 2012 to March 2012)
IAQG: Indoor Air Quality Guideline

IV. DISCUSSION

The results of the study indicated that the maximum value of NO_2 was recorded at 8:30am in Hostel A, which is 0.060ppm, while the minimum value of 0.006ppm was recorded at 4:00 pm in Hostel C (Table 3). The monthly average of NO_2 levels at the monitored hostels ranged from 0.021 to 0.051ppm (Table 3). The concentrations of NO_2 in the hostels could be directly attributed to some specific activities such as fuel combustion for heating and cooking, and some other identified sources such as tobacco smoking and use of water heaters. The highest weekly average of 0.051ppm was observed in Hostel D which was above the recommended indoor air quality Guideline (IAQG). This elevated concentration in Hostel D could be due to indoor combustion sources within the hostel environment, in addition to its closeness to FUTO market where fossil fuel combustion from the activities of settlers was on the increase. Among 7 out of 40 measurements (e.g., three in Hostel A and four in Hostel B), NO_2 levels were recorded above the guidelines for indoor air quality (Table 7). The maximum value observed in Hostel A could be due the number of occupants. Previous studies have shown that indoor air depends on several factors including the number of people present, their standard of hygiene, the quality of the Hostel environment and the mechanical movement within the enclosed space (Tang *et al.*, 2009., Godish, 1997., Hines *et al.*, 1993). Another reason for the concentration could be due to the close proximity of FUTO car park to the hostel. This could cause direct transfer of vehicular emissions from the parking area into the hostel environment. (Fromme *et al.*, 2007).

SO_2 is a major component of IAQ whose concentrations directly or indirectly reflect on human activities. Fossil fuel combustion is the major source of indoor SO_2 (Osuntogun and Koku., 2007). Throughout the study period, the concentrations of SO_2 in the hostels fall in the range between 0.001ppm (Hostel C, 4:00pm) and 0.046ppm (Hostel A, 8:30am). The monthly average of SO_2 levels at the monitored hostels ranged from 0.012 to 0.039ppm. Unlike in the NO_2, the SO_2 results in all the hostels were within the IAQG value of 0.14ppm. Among the five hostels measured, the highest concentration of SO_2 was observed in hostel A. The closing of windows and doors may cause insufficient ventilation of SO_2 under overcrowded hostel conditions. The influence of outdoor environment could also be a contributing factor (Shun *et al.*, 2002). Researchers have linked increased indoor SO_2 with numerous health issues such as, respiratory disorders, deterioration of lung function, irritation of nose and throat (Smith 1997., Samet *et al*. 1987).

Carbon monoxide is a highly recognized combustion indoor pollutant. Indoor sources of CO are from heating devices such as gas and kerosene stoves, water heaters, dryers, automobile exhaust from attached garages, generator and other gasoline powered equipment (Ayodele *et al*., 2007). In this study, the highest concentration of 7.63ppm was recorded at 4:00pm in Hostel A, while the lowest of 0.95ppm was recorded at 8:30 am in Hostel E (Table 4). The monthly average of CO levels at the monitored hostels ranged from 1.89 to 5.97ppm. In Hostel A, the highest concentration might be due to the number of occupants resident in the hostel coupled with the various activities going on within and outside the hostel (Samuel and Abayneh, 2014). In hostel E, the location, good structural design and the low number of occupants per area during the assessment might be responsible for the low level of CO recorded. However, the observed CO concentrations in all cases were much lower than the indoor guideline level of CO. The various health consequences of CO include cardiovascular disease and symptoms such as headaches, nausea, fatigue, rapid breathing and chest tightness (Modic, 2003., Ankita *et al.*, 2014).

The concentration of PM in indoor environment could be attributed to cooking activities in kitchens and nearby restaurants. In this report, the maximum value of $50.26\mu g/m^3$ was recorded at 4:00pm in Hostel E, while the lowest value of $4.50\mu g/m^3$ was recorded at 4:00 pm in Hostel C (Table 5). The monthly average of PM levels at the monitored hostels ranged from 9.129 to $36.64\mu g/m^3$. This value of PM recorded in hostel E could be due to the direct influence of dilution station site of a new lecture hall under construction that was located very close to the hostel (Wallace, 1996., Milhave and Skov, 1992). In addition to this, some housekeeping activities such as sweeping and vacuuming could lead to an increase in large particulate concentration within the hostel. This is because the household cleaning may cause the re-suspension of indoor particulate matters from domestic floors and furniture (Lee, 2000).

V. Conclusion

This study investigated the levels of indoor pollution in hostels of Federal University of Technology, Owerri Nigeria. The measurements of NO_2 in the hostels indicated that only seven cases were reported to exceed the recommended Indoor Air Quality Guideline. None of the readings for SO_2, CO and PM_{10} exceeded the guideline level. In spite of the overcrowded hostel environment, the structural design of the hostel buildings which gave room for improved ventilation system could be responsible for the low distribution of some of the pollutants within the hostels. Thus, the University authority should consider erecting more hostels so as to safeguard the health of students resident in the hostels

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