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Assessment of the Indoor Air Quality in Selected Housing Designs within Uvwie Local Government Area of Delta State

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Abstract: This study assessed the indoor air quality in selected housing designs within Uvwie Local Government Area of Delta State. This was done using Aerocet 531S (for particulate matter ($PM_{2.5}$, PM_{10})), Aeroqual series-500 (for carbondioxide, humidity and temperature) and Fluke meter (for carbon monoxide). The indoor air quality was measured in the morning and evening and the results were compared with the WHO (2000) air quality standard. The humidity recorded within the housing units fell below the WHO acceptable limit between 200000ppm to 500000ppm standards. The observed results for carbon monoxide showed 0ppm as minimum for all the housing units and a maximum value of 1.13pm recorded in a single room in the evening. Particulate matter was observed to be highest (1.73ppm) in a single room and lowest (0µg/m³) in 2 bedroom in the morning. Results for temperature did not follow any trend which showed that the temperature values vary for the different days but observed to be as high as 36.7 ^{0}C in evening in a 3 bedroom. The findings showed that all the parameters investigated fell within the WHO acceptable limits for indoor air quality except for humidity. ANOVA statistical analysis showed that there is no significant difference in the indoor air quality between the housing units at P>0.05 significant level. The level of air pollutants in the study housing units can be concluded to be of good concentration levels except for humidity which may aid the growth of microbes and result in the harmful effects to inhabitants. This study recommended improved ventilation systems which will help in improving ventilation in housing designs.

Keywords: *Air Pollution, Indoor Air Quality, Humidity, Carbon Monoxide, Carbon Dioxide, Particulate Matter, Temperature Housing Design.*

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I. INTRODUCTION

Air pollution is as old as civilization itself, starting from man's first attempt at heat generation. Air pollution is believed to kill more people worldwide than AIDS, malaria, breast cancer, or tuberculosis (World Health Organization (WHO), 2014). According to Ojo and Awokola (2012), the quality of air is very essential to sustenance of life on earth. Deteriorated air quality threatens human health and contributes to environmental damage such as climate change, acid rain thereby leading to immense economic loss (Akpoghelie, Irerhievwie, Agbaire, and Orisaremi, 2016). Human and natural activities can lead to the pollution of air by the release of varying concentrations of gaseous pollutants and particulate matter that could either be static, mobile or both and could both affect indoor and outdoor air quality. Akpoghelie et al (2016) reported the detrimental effect of air pollution affects nearly all phases of human lives. Aside from compromising the quality of air, these pollutants may trigger long and short-term effects. Examples of short-term effects of indoor air pollutants include irritation in the eyes, nose and throat, and cause upper respiratory infections such as bronchitis, and pneumonia (Giri, Krishna, Smith, 2006). Long-term effects of poor indoor air quality include chronic respiratory disease, lung cancer, heart disease and even damage to the brain, sensory nerves, liver or kidneys (Das, 2004).

The use of domestic fuels for cooking and heating purposes also generates pollutants thus affecting indoor air quality (Akpofure, 2015). Domestic indoor practices which are mainly influenced by financial constraints often release suspended particulates, carbon monoxide, hydrocarbons, nitrogen oxides, sulphur oxides, and particulate matter, most of which are mutagenic compounds. As dangerous as polluted outdoor air can be to human health, indoor air pollution also poses a greater health risk on a global level because of associated indoor human activities, housing designs and subsequent transport of air pollutants (Oguntoke, Opeolu and Babatunde, 2010). By far the greatest threat of indoor air pollution occurs in the developing countries of the world, where some 3 billion people, mostly in rural areas continue

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to rely on traditional fuel like wood and charcoal for cooking and heating (Oguntoke *et al.,* 2010). These activities of cooking and heating resulting in the indoors burning of biomass fuel leads to major sources of large amounts of smoke and other pollutants in the confined space of the home. The human relies so much on an good clean healthy indoor environment which is essential for a healthy life and comfort. According to Torres-Dosal et al (2007) most people have health problems because they spend so much time indoors, where the air seems more likely to be polluted. The World Health Organization stated that women and children, who are the most exposed and vulnerable to the indoor pollutants, are two to six times at risk of contracting serious respiratory infections (Oguntoke *et al.,* 2010). Bindu & Tejwant (2023) noted that it's only natural that as the global population and economy expand, so does the need for a better quality of life. Indoor air quality necessitates the addition of new features to the built environment. In addition, there is a shift over time in the types of buildings, which influences indoor air quality and, by extension, human health. Due to the poorly designed housing unit often without adequate or poor-quality ventilation, it has been noted that some housing types'/ design are without cooking rooms (kitchens) and hence, people tend to engage in indoor cooking within the living room and bedroom areas. Abulede, Fagbayide, Akinnusotu, Makinde and Elisha (2018) there are persistent pollutants in various categorized housing types/ designs. This study provides some useful information on the state of indoor air quality by investigating the indoor air quality in some of the most popular types of housing unit designs in Uvwie Local Government Area in Delta State Nigeria.

II. MATERIALS AND METHODOLOGY

In assessing air quality in the various housing designs, air quality monitoring devices Aerocet 531S (for particulate matter), Aeroqual series-500 (for carbon dioxide, humidity and temperature) and Fluke meter (for carbon monoxide) were used to obtain concentrations of the parameters under investigation in the indoor air. The types of housing designs used for the sampling of indoor air quality were.

- Single room (comprising of a room without toilet and kitchen within)
- One-bedroom (comprising of a bedroom, toilet and kitchen)
- Two-bedroom (comprising of a sitting room, bedroom, toilet and kitchen)
- Three room (comprising of a sitting room and three bedrooms, toilets and a kitchen)

The air quality measurements were carried out thrice per location in each of the rooms within each of the housing design and the average values obtained as concentration levels of air pollutants for the housing design. The measurement was conducted in the morning between the hours 7:00 – 8:00am and evening hours 6:00 – 7:00pm when inhabitants are available and carrying out household activities like cooking and cleaning. All measuring devices are held at 1.5m above the floor surface representing the average breathing height of humans.

III. RESULTS AND DISCUSSION

➢ *Results*

The number and average window size in the various housing units under consideration within Effurun are presented below in table 1.

Table 1 Average Window Size Measurements and Number

Housing Unit	Window Size	Number of Windows
Single Room	4 × 6	1
One-Bedroom	4 × 6	3
Two-Bedroom	5 × 6	6
Three-Bedroom	5 × 6	8

The result of the indoor air quality parameters measured in the various types of housing units under consideration during the morning and evening period are presented below in tables 2 – 5.

Table 2 Average Results of Measured Parameters for Single Room

Parameters	Time	Day 1	Day 2	Day 3	Day 4	Average	SD
Humidity(ppm)	**Morning**	82.07	93.17	114.7**	78.9	92.2	16.2
	Evening	77.73	76.97*	97.43	77.73	82.5	9.98
Carbon Monoxide (ppm)	**Morning**	0*	0.13	0.34	1.13**	0.4	0.51
	Evening	0	0	0.63	0	0.16	0.32
Carbon Dioxide (µg/m^3)	**Morning**	667.7	517.3*	720	602.3	627	87.5
	Evening	695.3	612	740.7**	695.3	686	53.7
Particulate Matter (ppm)	**Morning**	0.4*	0.9	0.4	1.73**	0.86	0.63
	Evening	0.5	0.84	0.31	0.5	0.54	0.22
Temperature (^{O}C)	**Morning**	31.23	33.43	30.1*	36.1**	32.7	2.65
	Evening	33.93	34.17	34.5	33.9	34.1	0.28

* Represent Lowest Value and ** Represent Higher Value.

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Table 3 Average Results of Measured Parameters for One-Bedroom

Parameters	Time	Day 1	Day 2	Day 3	Day 4	Average	SD
Humidity (ppm)	Morning	83.57	76.23	119.5**	59*	84.6	25.5
	Evening	79.07	82.03	95	81.47	84.4	7.19
Carbon Monoxide (ppm)	Morning	0*	0.03	0.017	0.697	0.19	0.34
	Evening	0	0.163	0.5	0.757**	0.36	0.34
Carbon Dioxide (µg/m^3)	Morning	676	445.3*	684.3	611	604	111
	Evening	704.7	775.7**	659.3	643.3	696	59.3
Particulate Matter (ppm)	Morning	0.01*	0.08	0.093	0.787**	0.24	0.36
	Evening	0.03	0.22	0.263	0.287	0.2	0.12
Temperature (^{O}C)	Morning	31.03	28.57*	29.73	36.1	31.4	3.32
	Evening	34.2	36.77**	35.1	35.6	35.4	1.07

* Represent Lowest Value and ** Represent Higher Value.

Table 4 Average Results of Measured Parameters for Two Bedroom

Parameters	Time	Day 1	Day 2	Day 3	Day 4	Average	SD
Humidity (ppm)	Morning	85.83	84.07	106.2**	87.3	90.9	10.3
	Evening	79.57	83.67*	98	91.53	88.2	8.21
Carbon Monoxide (ppm)	Morning	0*	0.1	0.197	0	0.07	0.09
	Evening	0	0	0.203**	0.05	0.06	0.1
Carbon Dioxide (µg/m^3)	Morning	843**	830.7	718.3	748.7	785	61.2
	Evening	797.7	854	821	713*	796	60.2
Particulate Matter (ppm)	Morning	0.133	0.14	0.263	0.287**	0.21	0.08
	Evening	0.267	0*	0.123	0.033	0.11	0.12
Temperature (^{O}C)	Morning	29.83	32.83	33.17	30.03	31.5	1.78
	Evening	34.1	35.5**	29.67*	34.07	33.3	2.53

* Represent Lowest Value and ** Represent Higher Value.

Table 5 Average Results of Parameters for Three Bedroom

Parameters	Time	Day 1	Day 2	Day 3	Day 4	Average	SD
Humidity (ppm)	Morning	84.87	83.47	100	85.63	88.5	7.72
	Evening	78.07*	78.83	124.7**	84.63	91.6	22.3
Carbon Monoxide (ppm)	Morning	0*	0.123	0*	0.067	0.05	0.06
	Evening	0*	0.057	0.167**	0.047	0.07	0.07
Carbon Dioxide (µg/m^3)	Morning	598.3*	809.7**	804.3	656.3	715	110
	Evening	604.7	740.3	792.3	646.3	696	85.7
Particulate Matter (ppm)	Morning	0.31**	0.1	0.033*	0.157	0.15	0.12
	Evening	0.17	0.2	0.183	0.167	0.18	0.02
Temperature (^{O}C)	Morning	29.1	33.73	27.2	28.07	29.5	2.91
	Evening	30.1	29.53	25.77*	32.07**	29.4	2.63

* Represent Lowest Value and ** Represent Higher Value.

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➢ *Discussions*

- *Humidity*

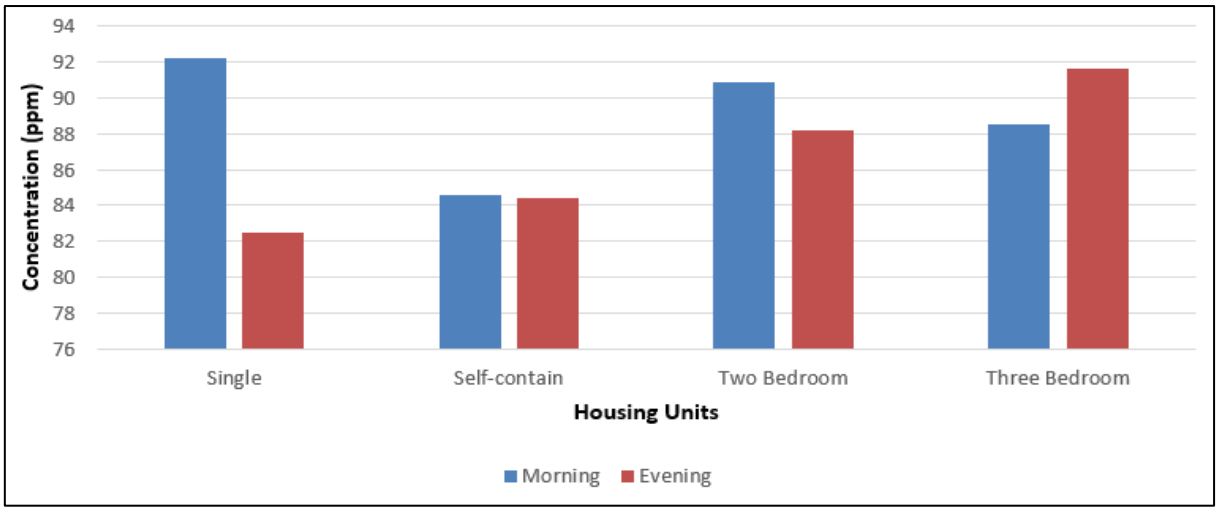


Fig 1 Average Concentration of Humidity for the Different Housing Unit

Fig. 1 shows the average concentration of humidity in the different housing units. The average concentration of humidity recorded in the housing units were three-bedrooms 88.5ppm and 91.6ppm, two-bedrooms 90.9ppm and 88.2ppm, single room 92.2ppm and 82.5ppm and one-bedroom 84.6ppm and 84.4ppm for morning and evening period respectively. The highest humidity level of 124.7ppm was recorded in the three bedroom during the evening period, while the lowest was 59.0 ppm recorded in the one-bedroom during the morning period. The more water evaporated in a given area, the more humidity in the air, and the higher the humidity of that area. According to Lennox (2021), one of the hazards of high humidity is that it encourages the growth of fungus, mold and dust mites, which can create breathing difficulties for people with asthma and allergies. All concentrations of humidity obtained at various housing units fell below the WHO acceptable limit between 200ppm to 500ppm. This result shows that the concentration of humidity in various housing units will not likely cause an adverse effect on the occupants. This indicates that there is more moist air in three-bedrooms apartment than in others. The one-bedroom units have the least humidity level and this can be attributed to structure position and possibly hot temperature compared to the other housing units. These values recorded corresponds to the average humidity values of 83.94ppm recorded by Abulude *et al.*, (2018) in air quality assessment of residents in Akure.

- *Carbon Monoxide (CO)*

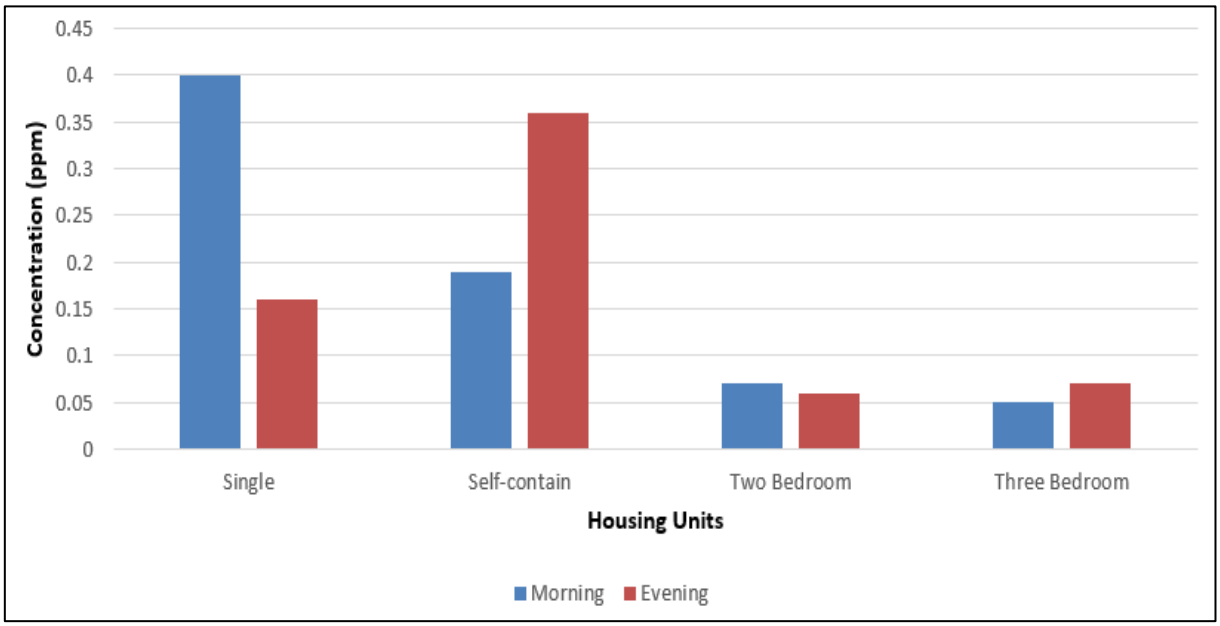


Fig 2 Average Concentration of Carbon Monoxide for Different Housing Unit

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Fig 2 shows the average concentration of carbon monoxide (CO) in the different housing units. The average concentration of carbon monoxide recorded in the housing units were single room 0.4ppm and 0.16ppm, one-bedroom 0.19ppm and 0.36ppm, two-bedrooms 0.07ppm and 0.06ppm and three-bedroom 0.05ppm and 0.07ppm for morning and evening period respectively. The highest carbon monoxide concentration level of 1.13ppm was recorded in the single room unit during the morning period, while the lowest was 0.0 ppm recorded in all the sampled housing units at different days and periods. The recorded values were observed to be less than WHO acceptable limit of 6ppm and also less than the results reported by Akpofure (2015) for indoor air quality. Akpofure (2015) recorded the assessment of indoor air quality in selected households living in squatter settlements at Warri and reported that carbon monoxide concentrations in selected homes vary significantly and reaches mean levels of 28.7ppm. The low concentration carbon monoxide can be attributed to the provision of adequate ventilation or the use of cleaner energy sources.

- *Carbon Dioxide (CO_2)*

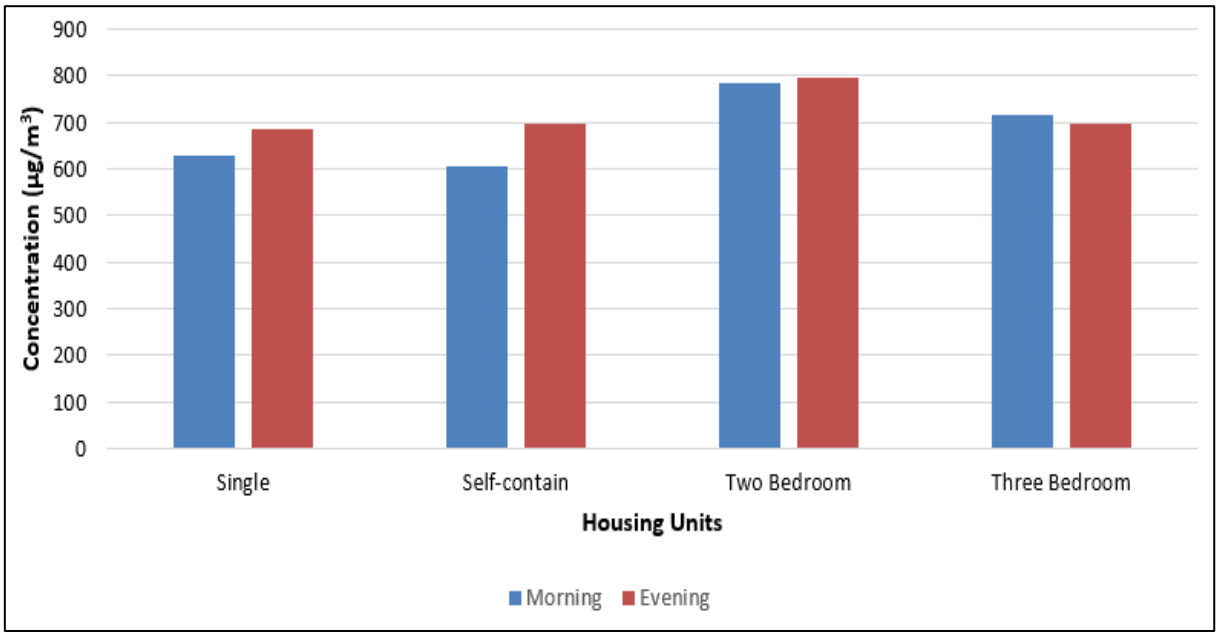


Fig 3 Average Concentration of Carbon Dioxide for Different Housing Unit

Fig 3 shows the average concentration of carbon dioxide (CO_2) in the different housing units. The average concentration of carbon dioxide recorded in the housing units during the morning period were single room 627 µg/m^3, one-bedroom 604 µg/m^3 two-bedrooms 785 µg/m^3 and three-bedroom 715 µg/m^3. Similarly, the evening average concentration of CO_2 recorded were single room 668 µg/m^3, one-bedroom 696 µg/m^3, two-bedroom 796 µg/m^3 and three-bedrooms 696 µg/m^3. The highest carbon dioxide concentration level of 843µg/m^3 was recorded in the two-bedroom unit during the morning period, while the lowest concentration level 445.3 µg/m^3 recorded in the one-bedroom housing unit. The average concentration of carbon dioxide obtained at the various housing units all fell below the WHO acceptable limits of less than 1000µg/m^3. This shows that the concentration of CO_2 in various housing units will not cause any adverse effects on the occupants. A review by Abaje, Bello and Ahmad (2020) highlighted that a significant percentage of air pollutant particularly CO_2 and CO are emitted from traffic congestion within the major cities in Nigeria. According to Asubiojo (2016) there are two types of emissions (exhaust and non-exhaust emissions) which are produced from fuel combustion and gives rise to the presence of pollutants like CO_2. These emissions can be linked to be contributors to carbon dioxide levels in some housing units and results in rise in levels of carbon dioxides during the morning and evening rush hours. The low concentration carbon monoxide can be attributed to the provision of adequate ventilation or the use of cleaner energy sources.

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- *Particulate Matter*

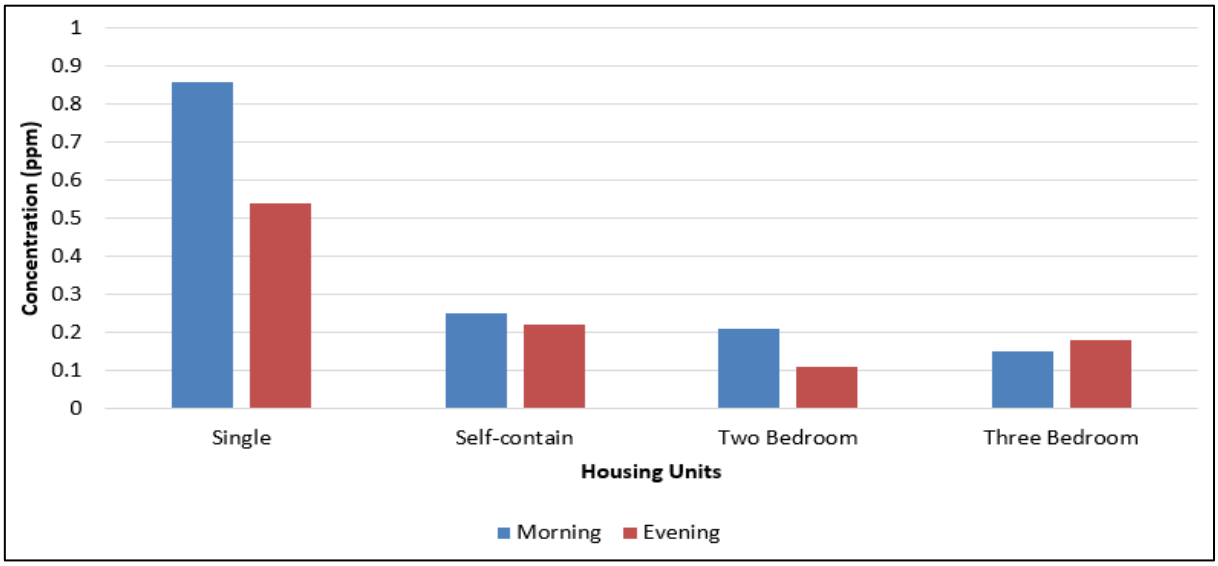


Fig 4 Average Result of Particulate Matter for Different Housing Unit

Fig 4 shows the average concentrations of particulate matter in the housing units, three-bedrooms 0.15ppm, two-bedroom 0.21ppm, one-bedroom 0.2450ppm and single room 0.86ppm recorded during the morning period and similarly two-bedrooms 0.1150ppm, three-bedroom 0.18ppm, one-bedroom 0.24ppm and single room 0.54ppm. The highest concentration of particulate matter of 1.73ppm was recorded in the single bedroom unit during the morning period. This concentration though very low may be attributed to routine house cleaning activities in the morning hours which gave rise to the suspension of particles. The average results recorded for particulate matter were observed to be below WHO accepted limit of 50ppm. This shows that the concentration of particulate matter in the various housing units will not cause any adverse effects on the occupants. The recorded concentration level of particulate matter observed were considerably low with maximum values obtained at 0.86µg/m^3 and similar to previous results by Abulude *et al.*, (2018) and Akpofure (2025) and this can be attributed to the reduced household like swweping and dusting activities which gives rise to the propulsion and suspension the particulate matters.

- *Temperature*

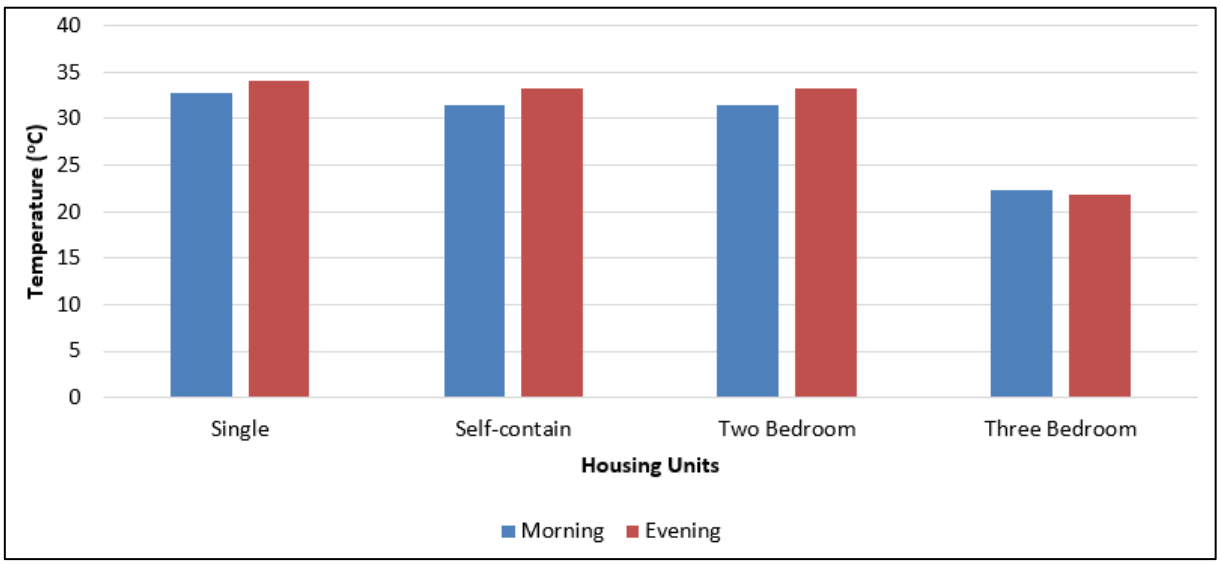


Fig 5 Average Temperature for Different Housing Unit

Fig 5 shows the average temperature in the different housing units. The average temperature recorded during the morning period were single room (32.7^{O}C and 34.1^{O}C), one-bedroom (31.4 ^{O}C and 35.4 ^{O}C), two-bedrooms 31.5 ^{O}C and 33.3 ^{O}C and three-bedroom 29.5 ^{O}C and 29.4^{O}C for morning and evening period respectively. The temperature values obtained are largely influenced by ventilation systems and domestic activities. Temperature readings varied slightly for

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the different housing units. This variation can be attributed to size of ventilation, size of the occupant space and the structural designs. Housing units with smaller windows and reduced number of windows will record higher temperatures than others. This shows that air vents play a vital role in the flow of air which may influence temperature within the different housing units. However, smaller vents may be attributed to reduce air flow in addition to retention of cooking smoke within the housing units and contributing immensely to the rise in temperature. The average results recorded for temperature in all the housing unit except for the three-bedroom were all observed to be greater than the WHO maximum accepted limit of 26 - 28ºC for health and comfort. This shows that there might be some adverse effect or discomfort observed by the occupants within the single room, one-bedroom, two-bedroom and three-bedroom housing units.

Although the temperature recorded in the three-bedroom were within the limits and similar to the findings of Ogunsote and Prucnal-Ogunsote (2023) recorded in contemporary buildings. However, the results in the other housing units that were above the WHO accepted limits were similar to findings of Marcellinus et al (2022) were temperatures of up to 38ºC were recorded in traditional and modern buildings in warm humid climate regions.

➢ *Statistical Analysis (ANOVA)*

The overall results of the findings were subjected to ANOVA statistical analysis and the findings revealed that *F* (0.014872) is less than the *F*-critical (3.490295) at 0.05 level of significance. It can thus be concluded that the hypothesis which states that there is no significant difference in the indoor air quality between the types of housing units investigated in the morning was accepted. Similarly, for the evening period *F* (0.005345) is less than the *F*-critical (3.490295) at 0.05 level of significance. It can thus be concluded that the hypothesis which states that there is no significant difference in the indoor air quality between the types of housing units investigated was accepted.

This finding shows that the indoor air quality between the types of housing units under investigation sampled in the morning and evening were not significantly different. This could be attributed to the fact the most times the windows and doors were locked because of security concerns as observed during the sampling period.

IV. CONCLUSION AND RECOMMENDATIONS

The level of air parameters investigated in the studied housing units can be concluded to be of fairly good concentration levels except for humidity and temperature which were not within the acceptable limits for some housing units. It is, however, important to maintain reduced environmental indoor pollution to minimize the levels of some pollutants which may increase or persist overtime. It is therefore recommended that the following mitigating measure could be adopted to improve the indoor air quality.

- Alternatively, cooking smoke in single rooms which may be the sole cause of rise in humidity level, temperature and particulate matter could be avoided if cooking practice is carried outside the housing units.
- Proper ventilation systems should be adopted for housing units to help in improving ventilation in housing units as well as lowering temperature levels.
- Wet cleaning methods should be adopted in daily routine cleaning of homes to minimize suspension and propulsion of particulate matter levels in housing units.
- Effective and regular indoor air quality monitoring is essential for evaluating the effectiveness of these recommended interventions and ensuring that that they lead to sustainable improvements in the quality of the indoor environment.
- Future studies could expand the scope by examining seasonal variations, meteorological influences.

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