International Journal of Environmental Monitoring and Analysis
2018; 6(6): 144-151
http://www.sciencepublishinggroup.com/j/ijema
doi: 10.11648/j.ijema.20180606.11
ISSN: 2328-7659 (Print); ISSN: 2328-7667 (Online)

Assessment of Selective Air Quality Parameters in an Industrial Layout and a Residential Settlement within Ibadan, Nigeria

Damir Olusanya Ogunlesi[1], Mumuni Adejumo[2, *], Mynepalli Kameswara Chandra Sridhar[2], Akinwale Oladotun Coker[1]

[1]Department of Civil Engineering, Faculty of Technology, University of Ibadan, Ibadan, Nigeria

[2]Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria

Email address:

ogunlesidamir@yahoo.com (D. O. Ogunlesi), adejumo_mumuni@yahoo.com (M. Adejumo), mkcsridhar@gmail.com (M. K. C. Sridhar), cokerwale@yahoo.com (A. O. Coker)

[*]Corresponding author

To cite this article:

Damir Olusanya Ogunlesi, Mumuni Adejumo, Mynepalli Kameswara Chandra Sridhar, Akinwale Oladotun Coker. Assessment of Selective Air Quality Parameters in an Industrial Layout and a Residential Settlement within Ibadan, Nigeria. *International Journal of Environmental Monitoring and Analysis*. Vol. 6, No. 6, 2018, pp. 144-151. doi: 10.11648/j.ijema.20180606.11

Received: October 24, 2018; **Accepted**: November 22, 2018; **Published**: December 24, 2018

Abstract: Emission of CO_2 into the atmosphere poses both morbidity and mortality health effect on human life. Studies have evaluated CO_2 emissions from different sources in Nigeria, but levels of CO_2 from residential area located within industrial layout have not been investigated. This was the gap which the study set out to bridge. The study was carried out at Oluyole Industrial Estate, Ibadan and a residential settlement within the layout. Levels of CO_2, relative humidity and temperature were measured at 3 hourly intervals from 0600 to 2100 for a period of 7 consecutive days, at nine different points which included 5 industrial areas and 4 residential areas. These measurements were carried out with the aid of a calibrated portable CO_2 Meter. The CO_2 concentration of all the industrial and residential areas exceeded IPCC limit of 350ppm. Percentage spatial increases in CO_2 emission in Res 1, 2, 3 and 4 compared to IPCC standard were 30.1%, 36.3%, 37.6% and 41.4% respectively. Res 4 had the highest on Monday among the residential areas. Res 4 had the highest CO_2 level and differed significantly from the other residential areas. All the industrial and residential areas had temperature values higher than the recommended limit. Based on these findings, the study suggested that residential areas should be cited away from the industrial areas; and policies on maintaining environmental quality should be implemented and enforced.

Keywords: Carbon Dioxide, Industrial Area, Residential Areas, Air Quality

1. Introduction

The emission of greenhouse gases into the earth's atmospheric environment has been on the increase at an alarming rate over the years. This has been resulting from the sharp rise in human activities such as industrialization, transportation, the use of fossil fuels for electricity needs, deforestation and landfills or dumpsites [1]. Indeed, emission of CO_2 (one of the major components of global warming) from anthropogenic sources has increased since the beginning of the 20th century [2, 3]. While Carbon dioxide is a naturally occurring gas that is concentrated in the soil, water, and air; it is also a product of fossil fuel combustion. For example, one study reported that chemical, pharmaceutical, and petroleum industries use CO_2 in large quantities as the raw materials in their production process [4]. Also, high concentrations of CO_2 are emitted by automobiles and transport vehicles especially in urban areas [5]. Unfortunately, twenty-five pounds (11.3kg) of carbon dioxide are produced along with carbon monoxides, sulfur dioxide, nitrogen dioxide, and particulate matter for every vehicular combustion of gasoline [6]. These gases have been reported to cause an average worldwide temperature increase and dramatically increase annual incidences of deadly heat waves [7, 8, 9].

Carbon dioxide is necessary for most plants to produce food through photosynthesis naturally. CO_2 by itself does not pose any direct negative health effect on human respiration except that its effect could lead to air pollution [10]. For instance, a study revealed a positive correlation between increase in temperature, water vapor, and ozone with increase in CO_2 [11]. This suggests that CO_2 domes have great impacts from temperatures where the CO_2 was emitted. Jacobson's study further suggests that reduction in local CO_2 levels may prevent 300 to 1000 deaths from air pollution sources per year. Increased temperature and CO_2 due to climate change are likely result of increased production of pollen and fungal spores that could exacerbate symptoms of allergic diseases [12].

Regrettably, population growth has been one of the major driving forces behind increasing carbon dioxide emissions worldwide over the last two decades [13]. However, there are evidences which suggest existence of urban CO_2 domes over many large cities [14, 15] and that they are site and time dependent [16]. Also, there is an assumption that all emissions from industry, power stations, and transport come mostly from cities [17]. This evidently shows that the concentration of CO_2 in some of the cities is high. Despite this assumption and possibly local and global environmental and health effects of CO_2, poor urban planning has forced many industries and factories sharing boundaries with residential zones. These practices are especially common in some cities in Nigeria. These industries, during operations, emit large quantities of CO_2 into the atmosphere due to poor machinery and lack of emission reduction provisions, which poses a threat to not only the immediate environment but also the health of the residents in the vicinity. Studies have evaluated CO_2 emissions from different sources in Nigeria, but proximity of CO_2 emission from industries to close-by residential areas or settlements has not been adequately investigated. This study therefore assessed Carbon (IV) Oxide ($CO_{2)}$ emission, humidity and temperature from industrial area and proximity to residential area in Oluyole Industrial Estate in Ibadan, where industrial growth is on increase.

2. Methods

2.1. Study Area

This study was carried out in Oluyole Industrial Estate, Ibadan. The city which is the most populous in West Africa has coordinates of 7°23′0″N and 3°56′0″E. It is located near the forest grassland boundary of Southwest area of Nigeria. Ibadan city has 11 local government administrative areas (LGAs), five within the metropolis and six peripherals with a mix of urban, semi-urban and rural communities. Ibadan city has an estimated population of about 2,550,593 as of 2006 [18]. With an annual growth rate of 4.14%, the estimated population of Ibadan for 2015 is *3,160,200.* The climate is characterized by a rainy season from March through October, while the dry season stretches from November to February. In addition, about 36.25sqkm (34.9% of the land area) is devoted to land use (such as residential area, public buildings and facilities, markets, industrial and commercial areas as well as educational institutions), social amenities and open spaces. The remaining 63.75sqkm is devoted to non-urban uses such as forest reserves, farm lands and aquatic environment [19]. However, the study area, Oluyole Industrial Estate, has a network of roads that is similar to a tree design. A major road from Mobil Filling Station feeds the industrial estate and branches out at different points to other minor roads. Adjacent to the industrial layout, within one km radius, the residential settlements exist. These residents own the houses, live there and are mostly medium income group.

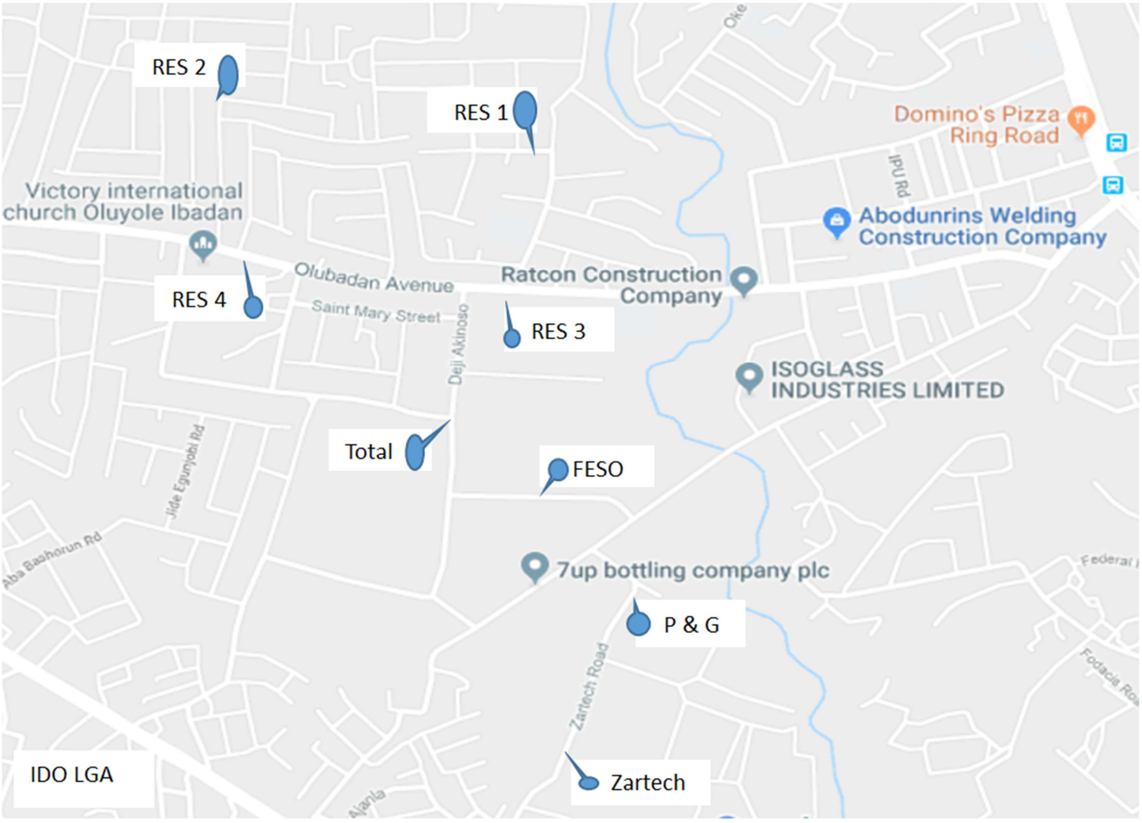
2.2. Sampling Points

The decision of choosing sampling points within the location was based purely on reason (Figure 1). Sampling was carried out at nine different points (see Table 1 for details) which included 5 industrial sites and 4 residential sites from the purposively selected study location. Two of the sampling points (P&G and Sumal-7up) are located on this main road and were chosen as points of primary interest, while the other 3 points (Zartech, Feso and Total Filling Station) are located on the minor roads. In addition, Oluyole Residential Estate (labelled as Res 1, 2, 3, and 4) has a road network similar to a grid design. One major road feeds the residential estate from Mobil and it branches out to minor roads which intertwine to form a grid-like structure. Two sampling points (Res 3 and Res 4) were chosen on the major road while two other points (Res 1 and Res 2) were chosen deep into the grid. The industries are Foods and Beverage, Cosmetics/pharmaceuticals, and petroleum-based and most of them operate 3 shifts a day with Sunday maintenance operations. The Total Filling Station closes after 9 pm till dawn.

Table 1. *Sampling points and Relative Distances between them.*

	P&G	Sumal-7up	Zartech	Feso	Total	Res1	Res2	Res3	Res4
P&G									
Sumal-7up	0.339								
Zartech	0.329	0.315							
Feso	0.340	0.327	0.561						
Total	0.869	0.812	1.092	0.540					
Res1	1.281	1.314	1.560	1.003	0.541				
Res2	1.423	1.372	1.657	1.102	0.564	0.348			
Res3	0.907	0.918	1.170	0.611	0.190	0.397	0.531		
Res4	1.077	0.978	1.275	0.741	0.224	0.529	0.413	0.337	

Source: Author's Field Work (2013). All figures are in kilometres



Source: (Google map, 2018)

Figure 1. *Map Showing the Sample Points.*

2.3. Data Collection

Levels of CO_2 at each of the sample locations were measured at 3 hourly intervals from 0600 to 2100 for a period of 7 consecutive days. A portable CO_2 meter (Model AZ7755) was used and three parameters - carbon dioxide level, air temperature and humidity - were measured using the same equipment. The portable CO_2 meter uses non-dispersive infrared technology to ensure the reliability and long term stability. The meter was calibrated at standard 400ppm CO_2 concentration in factory following the manufacturer's instruction. This calibration was done by placing the meter in the fresh outdoor air and turning it on. The 'CAL Esc' and 'MODE' buttons were held simultaneously until '400 ppm' started flashing on the display. It was then left for about 5 minutes until the blinking stopped. The meter started measurement when power was on and updated readings every second. The equipment gave minimum, maximum and time weighted averages of the 3 variables. Readings were recorded, though, its accuracy was not exact. The measures of deviation are stated below.

CO_2: ±50ppm ±5% rdg

Temperature: ±0.6^{o}C

Humidity: ±3% (10-90%); ±5% (others)

2.4. Data Quality Assurance

The equipment (Portable CO_2 Meter-Model AZ7755) was not held in hand but placed at a distance on an elevated platform during the taking of readings. This was to eliminate CO_2 contributions from operator's respiration. Moreover, whenever a vehicle was used for personal transportation, the engine was turned off to eliminate CO_2 contributions from vehicular emissions. These were done during data collection in order to ensure collection of quality data.

2.5. Data Analysis

Data were analysed using the SPSS (20) statistical package. The mean and the corresponding standard deviation were used to summarize the level of CO_2 in all the sampling points. Analysis of Variance (ANOVA) was used to determine if there were significant variations in CO_2 concentration, relative humidity and temperature at the industrial and residential areas. Duncan's Multiple Range Test (DMRT) was used to analyse the detection of significance differences in the mean values of CO_2 concentration among industrial area and residential locations. The level of significance was set at 5%.

3. Results

3.1. Daily CO_2 Concentration, Relative Humidity and Temperature

Table 2 presents the daily CO_2 concentration, relative humidity and temperature at industrial and residential area. It was revealed that daily CO_2 (PPM) concentrations were

697.3±126.5, 865.8±160.3, 594.4±113.6, 598.7±108.6 and 567.7±162.3 at P&G, Zartech, Sumal-7up, Feso and Total Filling Station respectively. Likewise, the CO_2 (PPM) concentration was found to be higher in Res 4 (597.3±116.0 PPM) compared to Res 1 (500.8±60.4), Res 2 (549.2±135.5) and Res 3 (560.5±84.5) respectively. All these concentrations exceeded IPCC CO_2 concentration limit of 350ppm. Industrial areas CO_2 emission exceeded the IPCC standards by 49.8% (P&G), 59.6% (Zartech), 41.1% (Sumal-7up), 41.5% (Feso) and 38.3% (Total). Similarly, the percentages increase in CO_2 emission in Res 1, 2, 3 and 4 compared to IPCC standard were 30.1%, 36.3%, 37.6% and 41.4% respectively. Relative humidity and temperature were 66.5±14.4 and 33.8±6.7 (P&G); 74.2±17.4 and 34.1±5.4 (Zartech); 67.9±23.2 and 35.2±5.8 (Sumal-7up); 68.8±21.1 and 33.8±6.5 (Feso); and 64.8±14.2 and 34.8±4.9 (Total) respectively. Moreover, Res 1 (71.1±21.6), Res 2 (71.3±24.1) and Res 3 (72.1±21.8) had similar relative humidity (%) compared to Res 4 (63.1±17.6) whereas temperature (°C) in Res 1, Res 2, Res 3 and Res 4 were 33.6±6.5, 33.6±7.4, 33.5±5.7 and 36.7±6.2 respectively. High temperature was observed at Res 4 compared to the three other residential areas.

The temporal distribution of CO_2 at the industrial location is shown in Figure 2. It was found that the CO_2 concentration in all the industrial area followed similar trend. High CO_2 values were recorded at 0600hr for P&G, Zartech and Sumal-7up respectively except Feso and Total industrial area which had the highest CO_2 concentration at 1500hr. However, only Res 2 had high CO_2 at 0600hr while Res 1, Res 3 and Res 4 had higher CO_2 concentration at 1200hr, 1500hr and 1800hr respectively (Figure 3).

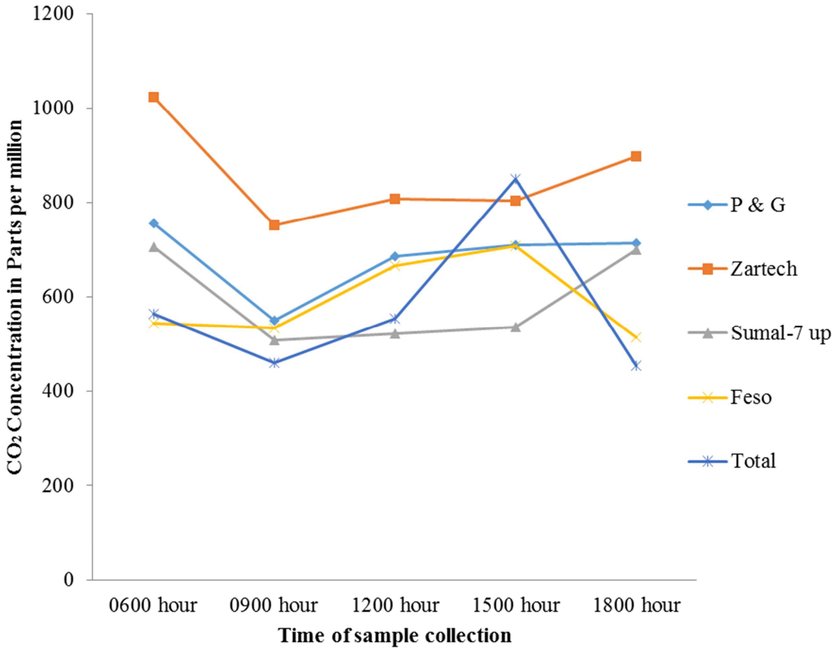


Figure 2. *Hourly concentration of CO_2 at various industrial sites sampled.*

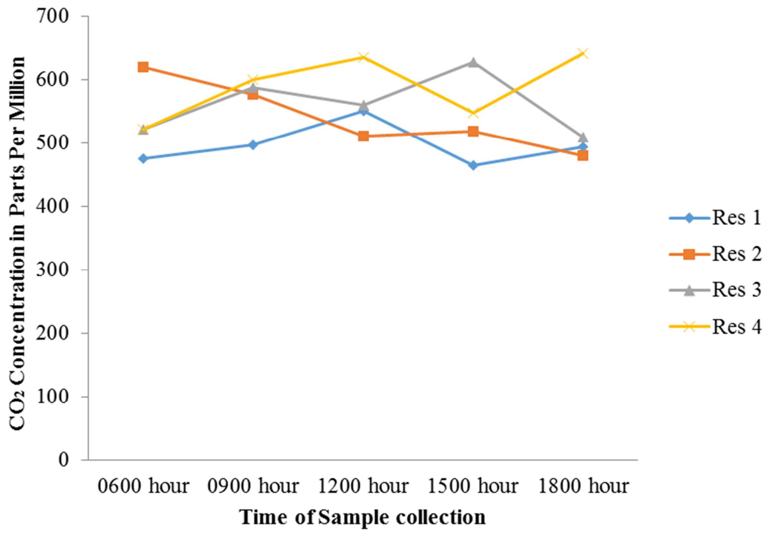


Figure 3. *Hourly concentration of CO_2 at residential sites sampled.*

Table 2. *Daily CO_2 levels and temperature.*

Sampling points	CO_2 Concentration (PPM)	(%) exceeding IPCC standard	Temp. (°C)	(%) exceeding IPCC standard	Relative humidity (%)
Industrial area					
P&G	697.3±126.5	49.8	33.8±6.7	24.6	66.5±14.4
Zartech	865.8±160.3	59.6	34.1±5.4	25.2	74.2±17.4
Sumal-7up	594.4±113.6	41.1	35.2±5.8	27.6	67.9±23.2
Feso	598.7±108.6	41.5	33.8±6.5	24.6	68.8±21.1
Total	567.7±162.3	38.3	34.8±4.9	26.7	64.8±14.2
Residential area					
Res 1	500.8±60.4	30.1	33.6±6.5	24.1	71.1±21.6
Res 2	549.2±135.5	36.3	33.6±7.4	24.1	71.3±24.1
Res 3	560.5±84.5	37.6	33.5±5.7	23.9	72.1±21.8
Res 4	597.3±116.0	41.4	36.7±6.2	30.5	63.1±17.6
*IPCC	350		23.5-25.5		30.0-50.0

*IPCC, 2007 - Intergovernmental Panel on Climate Change

3.2. Variations in CO_2 Level

Variations in CO_2 levels for two days (Sunday and Monday) were recorded for seven of the sampling points as depicted in Figure 4. It was revealed that CO_2 rose from Sunday to Monday for virtually all the industrial and the residential area except in Res 2. Also, the highest CO_2 level was observed at Zartech industrial area on both the Sunday and Monday. For the 3 industrial points, there was a rise from Sunday to Monday. After Sunday mandatory holiday, the industries pick up operations on Monday morning. Although, CO_2 level in residential areas were lower compared to industrial area on both Sunday and Monday, Res 2 had higher CO_2 level on Sunday than on Monday while Res 4 had the highest on Monday among the residential areas.

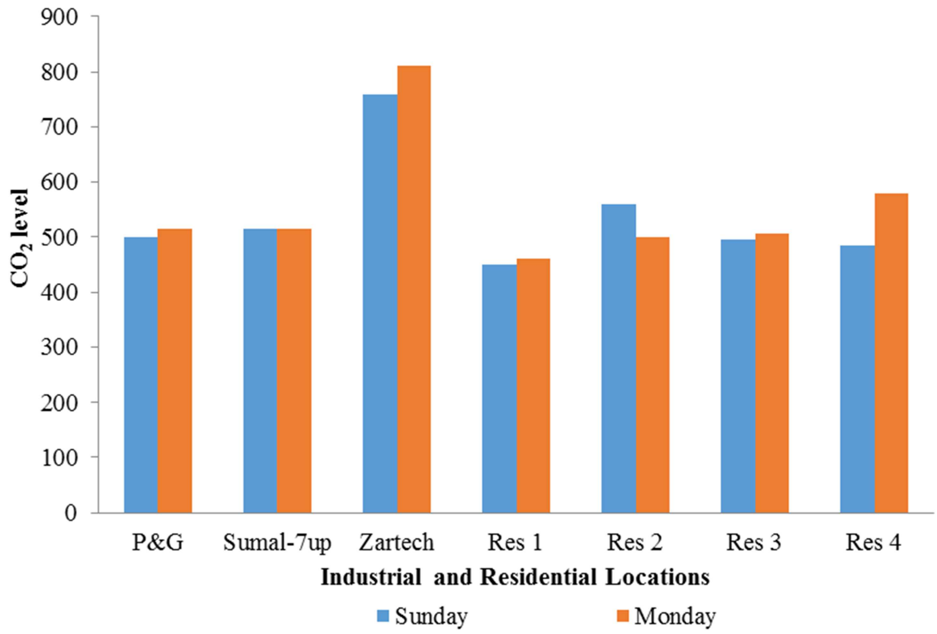


Figure 4. *CO_2 variations between Sunday and Monday at industrial and residential sites.*

3.3. Comparison of CO_2, Humidity and Temperature at Industrial and Residential Sites

The mean CO_2, relative humidity and temperature at industrial and residential sites were compared (Table 3, Table 4). Zartech had higher CO_2 level (865.8±160.3 PPM) compared to P&G (697.3±126.5 PPM), Sumal-7up (594.4±113.6 PPM), Feso (598.7±108.6 PPM) and Total (567.7±162.3 PPM) respectively. The difference was statistically significant. However, no significant difference existed between relative humidity and temperature values in all the industrial area. In residential area, CO_2 level was significantly higher at Res 4 (597.3±116.0 PPM) compared to Res 1 (500.8±60.4 PPM), Re2 (549.2±135.5 PPM) and Res 3 (560.5±84.5 PPM) respectively. There was no significant difference between relative humidity and temperature values in all the residential areas.

Table 3. *Comparison of CO_2, Humidity and Temperature among Industrial Locations.*

Parameters	Location	Mean±SD	F-statistics	p Value
CO_2 (PPM)	P &G	697.3±126.5	24.278	<0.001
	Zartech	865.8±160.3		
	Sumal-7up	594.4±113.6		
	Feso	598.7±108.6		
	Total	567.7±162.3		
Relative Humidity (%)	P &G	66.5±14.4	0.302	0.876
	Zartech	74.2±17.4		
	Sumal-7up	67.9±23.2		
	Feso	68.8±21.1		
	Total	64.8±14.2		
Temperature (°C)	P &G	33.8±6.7	0.888	0.473
	Zartech	34.1±5.4		
	Sumal-7up	35.2±5.8		
	Feso	33.8±6.5		
	Total	34.8±4.9		

Table 4. *Comparison of CO_2, Humidity and Temperature among Residential Locations.*

Parameters	Location	Mean±SD	F-statistics	p Value
CO_2 (PPM)	Res 1	500.8±60.4	4.023	0.010
	Res 2	549.2±135.5		
	Res 3	560.5±84.5		
	Res 4	597.3±116.0		
Relative Humidity (%)	Res 1	71.1±21.6	1.471	0.227
	Res 2	71.3±24.1		
	Res 3	72.1±21.8		
	Res 4	63.1±17.6		
Temperature (°C)	Res 1	33.6±6.5	0.938	0.426
	Res 2	33.6±7.4		
	Res 3	33.5±5.7		
	Res 4	36.7±6.2		

4. Discussion

The study revealed that CO_2 concentrations in all the industrial sites and residential sites were higher compared to internationally acceptable safe limit of 350ppm for atmospheric CO_2 [20]. The concentration is predictably higher in the industrial areas than in residential areas. This is an indication that the level might be as a result of high concentrations coming from industrial operations in the area. This concurs with the findings of [21] that high spatial structures of intense human activity could lead to localized accumulations of CO_2 concentrations. Although, the concentrations might not be high enough to incur adverse health effects such as nausea and headaches, yet increase in unregulated industrial activities may lead to increase in the CO_2 concentration in future [22]. This may contribute to climate change, in the long term, if unmitigated. Data from this study revealed that relative humidity and temperature both at the industrial and residential areas in all sampled locations exceeded the guideline limits. Release of a small amount of CO_2 into the atmosphere could result in increase in ambient temperature and consequent climatic changes [23]. Increasing temperature can cause severe droughts in some parts of the world (including Nigeria), extreme weather conditions, the degradation of ecosystems and potentially hazardous health effects on people living or working in the areas [24]. The increase in the temperature at the study sites should be a concern which requires urgent attention. Similarly, relative humidity values at the residential sites were higher compared to the industrial sites.

Furthermore, this study found that the daily CO_2 concentrations in all the industrial sites were higher compared to those in residential sites. This observation is similar to the findings from [25, 17]. However, the levels of CO_2 showed similar trends among all the residential sites studied. Furthermore, there were variations in CO_2 levels across all the industrial and residential sites as well. This increase suggests more CO_2 emission operations from industries. Mondays seem to be a critical day as the CO_2 emissions peak after the weekend break. This is similar to the findings of studies where CO_2 levels increase in areas with intense human activities and decline where decreased activities exist [26, 21]. This study also recorded significantly higher CO_2 level in one of the industries sampled. This may be due to the nature of the processes involved and the size of the industry. This was also reflected in one of the residential sites. This evidently revealed that the residential area might be very close to the specific industry with the highest CO_2 emission therefore anthropogenic. There was no significant difference of relative humidity and temperature values as they are mostly natural.

Furthermore, the mean temperature in all the industrial and residential sites was higher than the permissible limits allowed by regulatory bodies. Temperature values were similar across the industrial and residential sites. The temperature was high and could cause a detrimental health problem either directly or through increased vector breeding [20]. This could also lead to increasing the risk of flooding particularly in a flood prone Nigeria city like Ibadan where floods occur more regularly in recent years. Also, occurrence of high rate of evaporation due to increase in temperature could lead to the drying up of well [20].

5. Conclusion

The study revealed that the CO_2 concentrations in all the industrial and residential areas within were higher than the guideline limits recommended by IPCC. However, significantly higher CO_2 concentration was observed in one of the industrial sites which has also reflected in a residential site in the vicinity. Similarly, temperature fluctuations showed impact of industrial operations on the residential areas in the vicinity. It is therefore imperative that residential areas should be sited farther away from the industrial areas. Similarly, policies on regular monitoring of environmental quality and sustained maintenance should be implemented and enforced.

Acknowledgements

The authors express their gratitude to the Chief Executive Officers of the selected industries and communities, and the Research Assistants who participated in data collection for their cooperation during the study.

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