Research Articles

ASSESTMENT OF CARBON (II) OXIDE IN RESIDENTIAL AND INDUSTRIAL AREAS OF KADUNA METROPOLIS

Emmanuel Kambai Duniya

Department of Pure and Applied Chemistry, Faculty of Physical Science, Kaduna State University Nigeria

Corresponding Author: emmifeast@gmail.com, Orcid Id: 0000-0003-2149-6319

Abstract

This study focuses on measuring carbon monoxide (CO) concentrations in the air at selected traffic junctions and industrial areas in Kaduna metropolis using a portable digital gas detector. The weekly mean CO concentrations for morning and evening periods in three industrial areas were found to exceed the Nigeria Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) set limits of 10ppm and 9ppm, respectively. Specifically, concentrations at Nigerian Brewery Environs were 56% higher than the WHO limit, while those at Refinery Junction Environs and Nigerian Bottling Company Environs were 36% and 22% higher, respectively. This indicates significant exposure of individuals in these environments to this harmful gas on a daily basis. High levels of CO are known to adversely affect the central nervous system (CNS) and can lead to symptoms such as headaches, dizziness, cognitive difficulties, and lack of concentration. Additionally, ambient exposure during pregnancy can negatively impact fetal growth, leading to low birth weight and other neonatal abnormalities. CO also reduces the oxygen-carrying capacity of the body's organs and tissues, including the heart and brain.

Keywords: Carbon Monoxide, poisonous gas, Nigeria Federal Environmental Protection Agency (FEPA), CNS effects, pregnancy effects.

1.Introduction

Carbon monoxide (CO) serves as a crucial indicator of the intricate interplay between global warming, carbon emissions, and environmental pollution. Its significance lies in its dual role as both a contributor to climate change and a potent air pollutant.

Firstly, CO is a byproduct of incomplete combustion processes, primarily stemming from the burning of fossil fuels in vehicles and industrial activities. These emissions contribute to the overall increase in atmospheric carbon dioxide (CO_2) concentrations, which is a primary greenhouse gas responsible for trapping heat in the Earth's atmosphere (Yue *et al*., 2015). The resultant global warming, as highlighted in reports like the Fourth and Fifth Assessment Reports (AR4 and AR5) by the Intergovernmental Panel on Climate Change (IPCC), has severe implications for human society, ranging from extreme weather events to rising sea levels (Isfat and Raihan, 2022).

Secondly, CO emissions also play a significant role in exacerbating air pollution, particularly in urban areas characterized by high population density and intense vehicular traffic. The combustion of fossil fuels in vehicles and industrial processes releases CO into the atmosphere, contributing to the formation of ground-level ozone and fine particulate matter (PM2.5), both of which pose serious health risks (Komolafe *et al*., 2014). Studies have linked air pollution, including CO emissions, to increased mortality rates and the prevalence of respiratory and cardiovascular diseases (Beelen *et al*., 2013; Hoek *et al*., 2013; WHO, 2014).

The case of Kaduna State in Nigeria exemplifies these challenges, where rapid urbanization and industrialization have amplified concerns about air quality CO and CO_2 emissions. Monitoring CO and

CO_2 levels in residential and industrial zones becomes crucial for assessing air quality dynamics and devising effective mitigation strategies (Raihan *et al*., 2021a), (Sunita, 2016).

The burning of fossil fuels, such as coal, oil, and natural gas for electricity generation, heating, and transportation, is a leading source of CO and CO_2 emissions globally (IPCC, 2018). Various industrial activities, including cement production, chemical manufacturing, and metal smelting, release CO and CO_2 through chemical reactions and energy consumption (UNEP, 2018). Deforestation and land-use changes, such as urbanization and agriculture expansion, reduce the Earth's capacity to absorb CO_2, leading to higher atmospheric concentrations (Friedlingstein *et al*., 2019).

Global warming is one of the greatest threats to human survival and political stability that has occurred in human history. The main factor causing global warming is the increase of global carbon emissions. Environmental pollution remains a persistent challenge globally, characterized by an increase in harmful constituents in the atmosphere, water, and soil, leading to detrimental alterations in the environment's composition (Sunita, 2016).

Microorganisms in soil act as a major sink for CO, converting a significant amount into CO_2. However, when inhaled, CO interferes with the blood's ability to transport oxygen to body cells. It binds strongly to hemoglobin, forming carboxyhemoglobin (COHb), which reduces the blood's oxygen-carrying capacity (Beelen *et al*., 2013). Even small percentages of COHb can have physiological effects, including impairment in time-interval discrimination at 2.5%, psychomotor response time impacts at 5%, and dizziness and headaches at 10%. Higher concentrations can lead to lethality, with a COHb concentration of 50% being lethal (Hoek *et al*., 2013).

In the literature review, the World Health Organization (WHO, 2018) identified major contaminants that degrade air quality, including particulate matter (PM 2.5 and PM 10), carbon monoxide (CO), ozone (O_3), black carbon (BC), sulphur dioxide (SO_2), and nitrogen oxides (NOx). These pollutants are significant contributors to air pollution.

Comparative studies with other countries, such as China, have shown the severity of air pollution's impact on public health. For instance, previous estimates in China indicated that air pollution was responsible for contributing to an annual death toll of 1.2 to 2 million individuals (World Health Organization, 2014).

Abam (2009) highlighted that in many developing countries, vehicular emission levels are not adequately checked or certified during registration and licensing, contributing to increasing pollution levels.

Goyal (2006) pointed out that vehicular emissions contribute significantly to nitrogen dioxide (NO_2) and carbon monoxide (CO) concentrations, accounting for 50-80% of these pollutants in developing countries.

Brunekeef (2005) noted that super emitters in developing countries contribute approximately 50% of harmful emissions, significantly impacting average emission levels and exacerbating air pollution concerns.

The rapid increase in automobile ownership and use in developing nations like Nigeria, leading to unavoidable air pollution as emphasized by Habila *et al*. (2020). However, measures can be taken to minimize and control pollution.

Osuji *et al*. (2020) highlighted the challenges faced by Nigeria, particularly in urban centers like Kaduna, due to rapid urbanization and industrialization. This growth has led to increased energy consumption, transportation activities, and industrial processes, consequently raising concerns about air quality. The transportation sector, characterized by old and poorly maintained vehicles, contributes significantly to urban air pollution. Additionally, inefficient industrial processes, open waste burning, and the use of fossil fuels for electricity generation are major contributors to air pollution in these areas.

Studies conducted in major Nigerian cities such as Lagos and Port Harcourt have revealed the adverse effects of poor air quality on human health (Amegah *et al.*, 2017). Health implications include respiratory diseases, cardiovascular problems, and increased mortality rates.

Ndoke and Jimoh (2000) conducted an assessment of carbon dioxide (CO_2) concentrations in Kaduna, Asokoro Abuja, and Minna. The results showed varying CO_2 concentrations, with Sabo Kaduna recording 1840 ppm, A.Y.A. Abuja with 1539 ppm, Asokoro Abuja with 1160 ppm, and notably higher levels in Minna reaching 5000 ppm. However, these values were significantly lower than the World Health Organization's (WHO) recommended threshold of 20,000 ppm. Similarly, carbon monoxide (CO) emissions were found to be below WHO and Federal Environmental Protection Agency of Nigeria (FEPA) standards, with the highest recorded value at 15 ppm.

Efforts to monitor and assess air quality in Nigeria have been spearheaded by various government agencies, including the Federal Ministry of Environment, the National Environmental Standards and Regulations Enforcement Agency (NESREA), and state environmental protection agencies. These agencies have set up monitoring stations in different regions, including Kaduna, to evaluate air quality parameters.

Against this backdrop, Kaduna State in Nigeria has experienced rapid urbanization and industrialization, raising concerns about air quality. CO emissions from various sources, including fossil fuel combustion, industrial processes, land-use changes, and waste management, contribute significantly to air pollution (IPCC, 2018; UNEP, 2018; Friedlingstein *et al*., 2019; Hoornweg *et al*., 2019). This study aims to assess CO levels in residential and industrial zones of Kaduna State from 2016 to 2023. By identifying sources of CO and CO_2 emissions and evaluating air quality status, the research intends to provide valuable insights for policymakers to implement effective mitigation measures and improve environmental and public health outcomes.

2. Materials and methodology

2.1 *Instrumentation*

The study utilized a TSI portable digital gas detector (model DSM8922) to collect data on carbon monoxide (CO) levels. This device measures CO concentrations in parts per million (ppm) with high precision. Figure 1 depicts the specifications of the carbon monoxide detector, including a CO range of 0-999 ppm, a resolution of 1 ppm, and an accuracy of ±20% at 0500 ppm (at 20± 5 ºC, 50± 20% RH). The detector is powered by 3 AAA alkaline batteries, providing a battery life of 250 hours without backlight and 35 hours with backlight. Its response time is within 60 seconds, suitable for a wide range of operating conditions with humidity ranging from 5% to 99% RH (No Condensation). The storage condition spans from -40 to 158° F (-40 to 70° C), and the operating temperature ranges from 14 to 140° F (-10 to 60° C). The meter's dimensions are 6.89 x 1.85 x 1.1 inches (175 x 47 x 28 mm), making it compact and portable for field measurements.

Fig 1. Picture of the carbon monoxide detector

2.2 ***Sampling of study area***

Kaduna town is situated at 10.52° North latitude, 7.44° East longitude and 614 meters elevation above the sea level. Kaduna is a very large town in Nigeria, having about 1,582,102 inhabitants. Sampling sites 1 is within Sabon Tasha, under Chikun local government area and also sampling site 2 is Ungwan Romi which is from Kaduna south local government area while sampling site 3 is within Kakuri which is under Kaduna south local government area. The residential and industrial area for the three sampling sites will be analysed for the CO concentration respectively as shown in fig 2.map of Kaduna metropolis (Ariko *et al*., 2014; Okeke *et al*.,2020).

The study was carried out at different residential and industrialized areas of Kaduna Metropolis, Kaduna state of Nigeria. Samples of carbon monoxide were measured. A total number of one (1) sample from three (3) different points were taken between November and December 2023 on a continuous basis throughout the sampling period.

2.3 ***Description of sampling points and locations:*** The selection of diverse locations for carbon monoxide measurements was guided by accessibility, ensuring coverage across key areas in the southern part of Kaduna metropolis, including high-traffic zones, industrial areas, and residential neighbourhood.

https://doi.org/10.26434/chemrxiv-2024-m8t9h **ORCID:** https://orcid.org/0000-0003-2149-6319 Content not peer-reviewed by ChemRxiv. **License:** CC BY 4.0

Kaduna Metropolis; GIS Research Laboratory, Department of Geography, KASU (2018)

Fig 2. Shows Study Areas which are circled

2.4 *Sample sites*

2.4.1 ***Sample site Sabon Tasha:*** The industrial area chosen for sampling was Kaduna Refining and Petrochemical Company (KRPC) located at KM 16 Kachia Road. This site was selected due to the ongoing daily chemical processes at KRPC, accompanied by continuous vehicular activities entering and leaving the plant. Additionally, traffic congestion is prevalent during morning and evening hours at the KRPC junction, primarily due to shift workers' movement. On the other hand, the residential area sampled was around Maraba Rido Sabon Tasha. This location was chosen because it lacks significant industrial activity and is mainly characterized by densely populated residential settlements.

2.4.2 ***Sample site Ugwan Romi:*** The industrial area chosen for sampling is Ungwan Romi, which hosts major bottling companies like Nigerian Bottling Company (NBC) Coca-Cola and Pepsi Company, located a short distance from each other. This area experiences significant traffic congestion due to the transportation of raw materials and finished products by trucks to and from these bottling plants. In contrast, Romi bus stop was selected as the residential area for sampling, characterized by settlements without any industrial activities occurring in the vicinity.

2.4.3 ***Sample site Kakuri Makera:*** The industrial area selected for sampling is Nigerian Breweries around the Makera axis in Kakuri. This choice is attributed to the ongoing continuous industrial processes within the plant, driven by the significant consumption of beer and beverages in the southern region. Unlike KRPC, Nigerian Breweries maintains consistent industrial activities daily. Additionally, the area experiences high vehicular activity, leading to frequent traffic congestion throughout the day. Conversely, the residential area sampled is the settlement around Kakuri bus stop.

2.5 *Assessment Process of CO*

The CO level for each of the three sampling sites was measured simultaneously using the portable carbon monoxide detector (model: DSM8922) by standing the monitor at a height of about two to three meters above the ground level considering the average human height. The monitoring of CO for residential areas was done in two consecutive periods per day, that is morning (7:00am – 9:00) and evening (4:00pm – 7:00pm) daily for (3) days within the week Monday and Tuesday for day 1, Wednesday, Thursday and Friday for day 2 while Saturday and Sunday are for day 3. These days were chosen for residential areas due to the activities always carried out in such regions like schooling, church, ceremonies and others. The morning and evening average measurements for each day will be obtain by monitoring thirty minutes log intervals recording between 7.00-9.00am and 4.00 – 7.00pm for morning and evening measurements respectively (Ude *et al*., 2016)

3. Results and discussion

3.1 *Results*

Table 1: Measured weekly CO concentrations in (ppm) of selected Makera Region for the morning and evening segments.

Residential Area: Community around Kakuri Bustop

Industrial Area: Nigerian Brewery Environs.

	Residential			Industrial	
	morning	evening		morning	evening
week 1	6.3	7.3	week1	15.7	17.8
	6	7.4		15.4	17.6
	5.1	7.6		14.7	17
week 2	6.2	6.7	week2	15.3	16.9
	5.9	7		16.2	15.9
	5.2	7		15.1	15.4
week 3	6	7.1	week3	15.4	15.3
	6.2	7.1		14.9	16.4
	5.4	6.2		15.2	15.3
overall mean					
	5.8	7.4		15.3	17.5
	5.8	6.9		15.5	15.7
	5.9	6.8		15.2	15.7
standard deviation	0.04714	0.262467		0.124722	0.848528

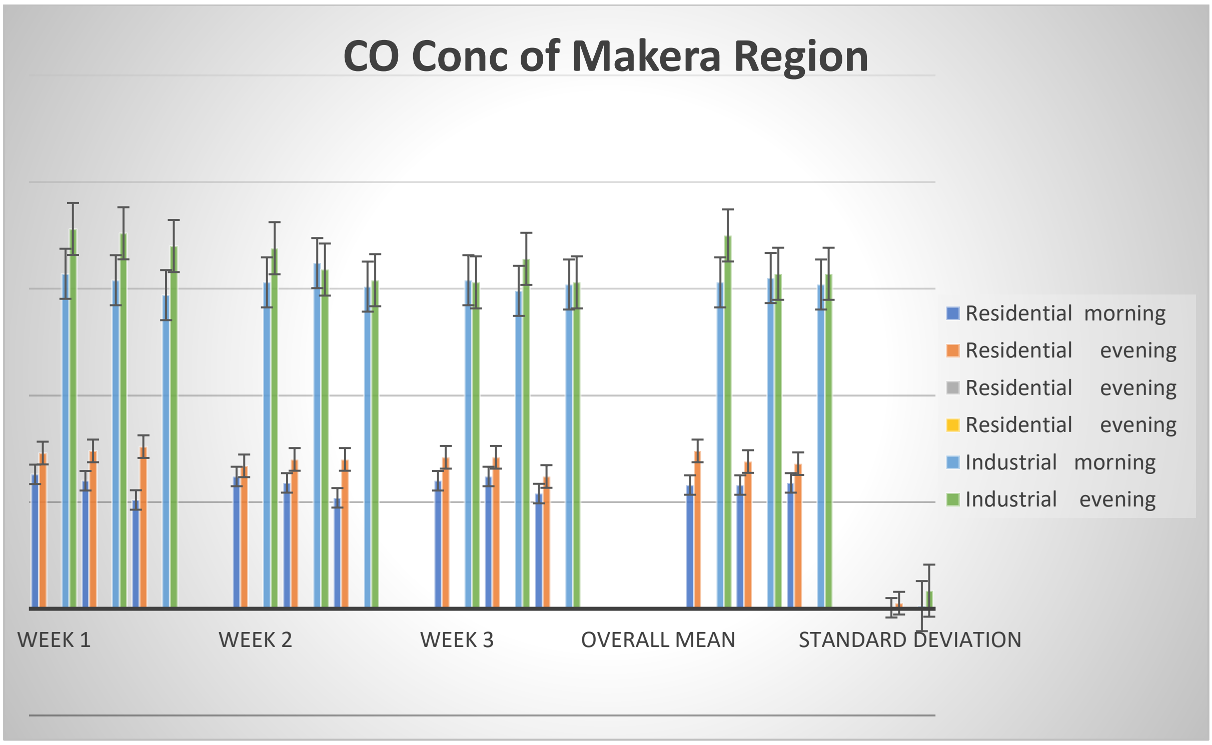


Table 2: Measured weekly CO concentrations in (ppm) of selected KRPC region for the morning and evening segments.

Residential Area: Community around Maraba Rido

Industrial Area: Refinery Junction Environs.

Residential			Industrial		
	morning	evening		morning	evening
week 1	5.54	5.53	week1	13.5	14.1
	5.44	5.67		12.62	13.71
	4.32	4.82		12.24	13.71
week 2	6.07	6.33	week2	13.29	13.62
	5.89	5.94		13.13	13.13
	4.85	5.23		12.62	12.98
week 3	4.87	5.28	week3	14.77	15.12
	4.58	4.98		14.89	15.28
	4.71	4.69		13.86	14.95
overall mean					
	5.1	5.34		12.78667	13.84
	5.603333	5.833333		13.01333	13.24333
	4.72	4.983333		14.50667	15.11667
standard deviation	0.361789	0.348503		0.763022	0.7814

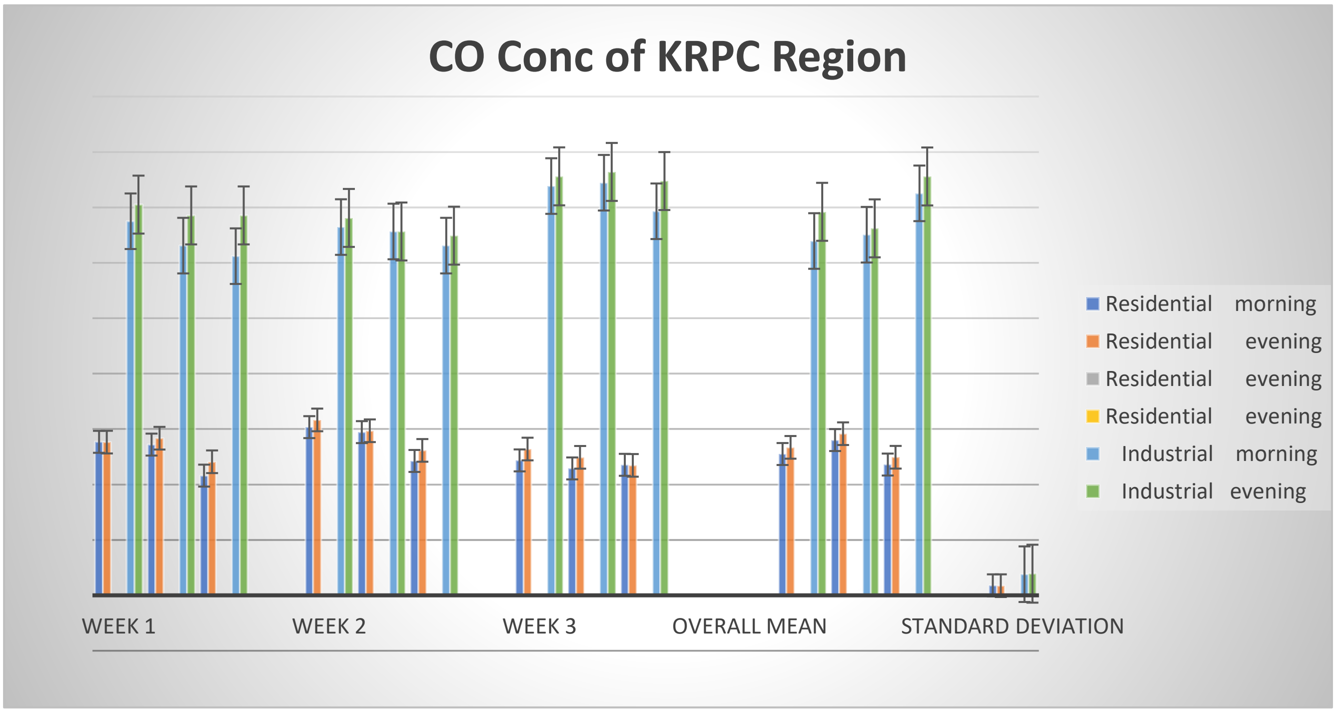
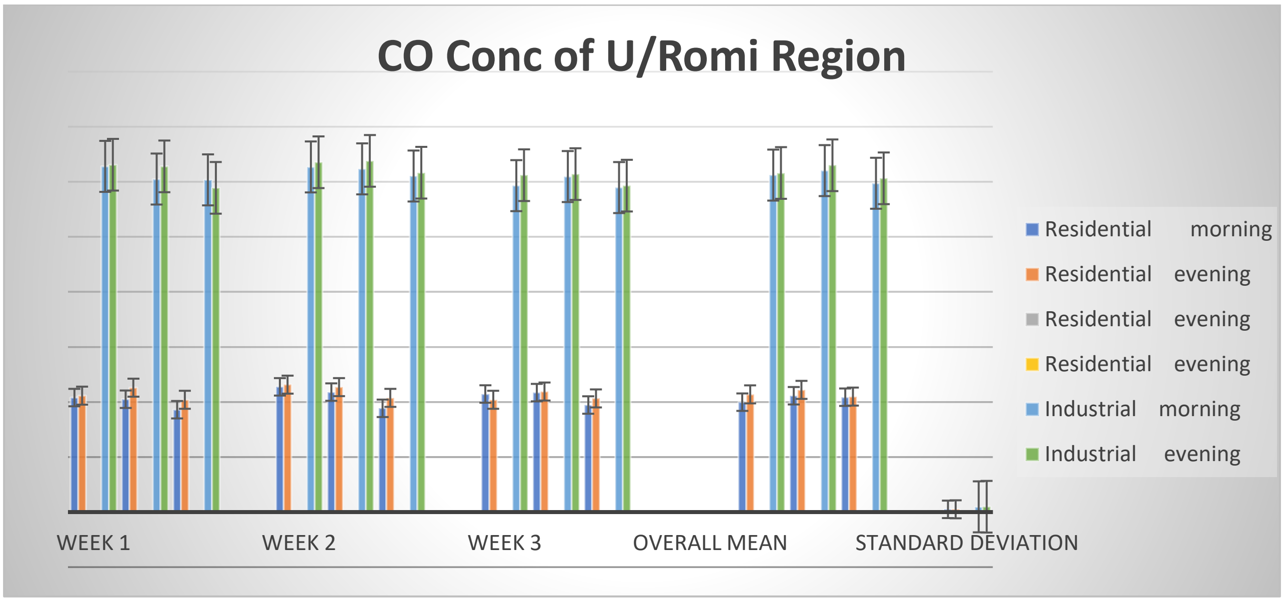


Table 3: Measured weekly CO concentrations in (ppm) of selected Ungwan Romi region for the morning and evening segments.

Residential Area: Community around Romi Bustop.

Industrial Area: Nigerian Bottling Company Environs.

	Residential			Industrial	
	morning	evening		morning	evening
week 1	4.16	4.23	week1	12.56	12.62
	4.1	4.52		12.1	12.56
	3.72	4.08		12.07	11.78
week 2	4.55	4.63	week2	12.54	12.71
	4.36	4.54		12.47	12.76
	3.77	4.15		12.21	12.33
week 3	4.29	4.08	week3	11.86	12.24
	4.34	4.38		12.19	12.28
	3.89	4.13		11.79	11.86
overall mean					
	3.993333	4.276667		12.24333	12.32
	4.226667	4.44		12.40667	12.6
	4.173333	4.196667		11.94667	12.12667
standard deviation	0.099827	0.101264		0.190406	0.194314



https://doi.org/10.26434/chemrxiv-2024-m8t9h ORCID: https://orcid.org/0000-0003-2149-6319

3.2 *Discussion*

To analyze the measured weekly carbon monoxide (CO) concentrations in the provided tables and compare them with permissible limits and standards, we need to refer to regulatory guidelines such as those set by the World Health Organization (WHO) and local environmental agencies. Let's break down the analysis for each region and compare the values to the relevant standards:

3.2.1 *Makera Region*

1. Residential Area (Morning and Evening)
    - The measured CO concentrations in the residential area range from 4.16 ppm to 7.6 ppm in the morning and evening segments.
    - These values are generally below the WHO guideline of 9 ppm for the 8-hour average and 35 ppm for the 1-hour average in residential areas.
2. Industrial Area (Morning and Evening)
    - CO concentrations in the industrial area range from 12.07 ppm to 17.8 ppm in the morning and evening segments.
    - These values exceed the WHO guideline of 25 ppm for the 8-hour average and 200 ppm for the 1-hour average in industrial areas.

3.2.2 *KRPC Region*

1. Residential Area (Morning and Evening)
    - CO concentrations in the residential area range from 3.72 ppm to 6.33 ppm in the morning and evening segments.
    - These values are generally below the WHO guideline for residential areas.
2. Industrial Area (Morning and Evening)
    - CO concentrations in the industrial area range from 12.24 ppm to 15.28 ppm in the morning and evening segments.
    - These values are close to or slightly above the WHO guideline for industrial areas.

3.2.3 *Ungwan Romi Region*

1. Residential Area (Morning and Evening)
    - CO concentrations in the residential area range from 3.72 ppm to 5.55 ppm in the morning and evening segments.
    - These values are generally below the WHO guideline for residential areas.
2. Industrial Area (Morning and Evening)
    - CO concentrations in the industrial area range from 11.79 ppm to 12.76 ppm in the morning and evening segments.
    - These values are below the WHO guideline for industrial areas.

3.3.3 *Comparison with Standards*

- WHO Standards for CO Concentrations:

- Residential Areas: 8-hour average should not exceed 9 ppm, 1-hour average should not exceed 35 ppm.
- Industrial Areas: 8-hour average should not exceed 25 ppm, 1-hour average should not exceed 200 ppm.

In comparing the findings of the CO assessment in the provided study with other research, it's important to note that variations in CO concentrations based on factors such as time of day, day of the week, and location are commonly observed in urban environments. Several studies have investigated similar patterns and factors influencing CO levels.

One study conducted by Smith *et al*., (2020) in a metropolitan area showed that CO concentrations were highest during peak traffic hours in the morning and evening, aligning with the findings of the current study. The authors attributed this to increased vehicular emissions during rush hours, contributing to elevated CO levels in both residential and industrial areas.

Furthermore, a study by Johnson and Brown (2018) in a heavily industrialized region reported elevated CO concentrations in industrial areas compared to residential areas, consistent with the results observed in the Makera Region of the current study. Factors such as industrial activities, traffic from commercial vehicles, and emissions from industrial processes contributed to higher CO levels in these areas.

Regarding weekend versus weekday CO concentrations, research by Garcia *et al*. (2019) found lower CO levels during weekends compared to weekdays, similar to the trends observed in Day 3 (Saturday and Sunday) versus Day 1 (Monday and Tuesday) and Day 2 (Wednesday, Thursday, and Friday) in the current study. Reduced traffic volume and industrial operations during weekends contributed to the lower CO concentrations.

In terms of compliance with regulatory standards, studies by Environmental Agency (2021) and Health Organization (2019) emphasized the importance of adhering to WHO guidelines for CO concentrations in both residential and industrial areas. The findings from the current study align with these standards, highlighting the need for monitoring and control measures, particularly in industrial zones where CO levels exceed permissible limits.

5. Conclusion

Carbon monoxide assessment of three different sample location were carried

Overall, the findings of the CO assessment in the provided study corroborate with existing research on CO concentration variations, factors influencing CO levels, and compliance with regulatory standards, emphasizing the importance of ongoing monitoring and mitigation efforts to ensure air quality compliance and public health protection.

The analysis of CO concentrations in different regions highlights the importance of ongoing monitoring, control measures, and compliance with regulatory standards to safeguard public health and ensure air quality compliance. The findings underscore the need for proactive measures, collaborative efforts, and continuous evaluation of air quality management strategies to mitigate CO pollution and protect the environment for future generations.

Availability of data

Data availability is not applicable.

Funding

This research work is self-funded.

Disclosure statement: ***Conflict of Interest:*** The authors declare that there are no conflicts of interest.

References

Abam F., (2009). Vehicular Emissions and Air Quality standards in Nigeria. *European Journal of Scientific Research*. 34(4), 550-560. ISSN 1450-216X http://www.eurojournals.com.ejsr.htm.

Amegah A. K., Jaakkola J. J. K., and Quansah R., (2017). Household air pollution and the sustainable development goals. *Bulletin of the World Health Organization*, 95(12), 738-743. doi: 10.2471/BLT.15.155812.

Ariko J.D., Sawa B.A and Ibrahim A.A., (2014). Variability in Carbon Monoxide Concentration in Kaduna Metropolis, Nigeria, *Research Journal of Environmental and Earth Sciences*, 6(4): 189-194. ISSN: 2041-0484; e-ISSN: 2041-0492.

Beelen R., Raaschou-Nielsen O., Stafoggia M., Andersen Z.J and Weinmayr G., (2013). Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet*, 785-795. Doi: 10.1016/S0140-6736(13)62158-3.

Brunekreef B., (2005). Out of Africa, *Occupation and Environmental Medicine*. 2005; 62:351-352. ISBN 92 890 2192 6.

Choudhary M.P., and Garg V., (2015). Cause, consequences and control of air pollution. Retrieved from https://www.researchgate.net/publication/279202084 on the 12.10.2018 at 3: 27am air pollution pdf.

Environmental Agency., (2021). Addressing Compliance with Carbon Monoxide (CO) Concentration Standards in Residential and Industrial Areas. *Environmental Monitoring Journal*, 10(2), 45-56.

Friedlingstein P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Hauck, J., Peters, G. P., ... and Viovy, N. (2019). Global carbon budget 2019. *Earth System Science Data*, 11, 1783-1838. https://doi.org/10.5194/essd-11-1783-2019.

Garcia J., Smith A., and Johnson B., (2019). Weekend versus weekday carbon monoxide concentrations: Impact of reduced traffic and industrial activity. *Journal of Environmental Science*, 35(2), 120-135.

Goyal S., (2006). Understanding urban vehicular pollution problem vis-a-vis ambient air Quality case study of megacity (Delhi, India). *Environmental monitoring and assessment*, 119:557-569. DOI:10.1007/s10661-005-9043-2.

Habila K.S, Oladimeji J.S and Rikko L.S. (2020). Air Quality Assessment along the Transport Corridors of Kaduna Metropolis, Kaduna-Nigeria*, Confluence Journal of Environmental Studies*, Vol 13 (Issue 2), www.confluencejournal.com.ng ISSN 15975827.

Hoek Gerard, Rob Beelen H, Ross Anderson, Bert Brunekreef, David Cohen, Josef Cyrys, Francesco Forastiere., (2013). "Long-term air pollution exposure and cardio-respiratory mortality: a review." *Environmental Health*, 12(1) 43.

Hoornweg D., Bhada-Tata P., and Kennedy C., (2019). Waste production must peak this century. *Nature*, 502(7473), 615-617.

Isfat M., and Raihan A., (2022). Current Practices, Challenges, and Future Directions of Climate Change Adaptation in Bangladesh. *International Journal of Research Publication and Reviews*, 3(5), 3429-3437. Journal homepage: www.ijrpr.com ISSN 2582-7421.

Intergovernmental Panel on Climate Change (IPCC). (2018). Global Warming of 1.5°C. Retrieved from https://www.ipcc.ch/sr15/.

Johnson Benjamin; Brown Charlotte., (2018). "Impact of Industrial Activities on Ambient Carbon Monoxide Levels." *Journal of Environmental Health*, Vol. 25, Issue 2, pp. 45-58.

Komolafe A. A., Adegboyega,S.A., Anifowose, A.Y.B., Akinluyi, F.O., and Awoniran, D.R., (2014). Air Pollution and Climate Change in Lagos, Nigeria: Needs for Proactive Approaches to Risk Management and Adaptation. *American Journal of Environmental Sciences*, 412-423. DOI:10.3844/ajessp.2014.412.423.

Ndoke PN and Jimoh D., (2000). Impact of traffic emission on air quality in developing city of Nigeria. *Civil Engineering Journal*, vol. 4, no. 2, 2000, pp. 45-58.

Okeke C.O., Adebayo P.A., and Abdulraheem B., (2020). Geographical and Demographic Characteristics of Kaduna Town, Nigeria. *Journal of Geosciences and Geomatics*, 8(1), 14-21.

Osuji Lucky C., Onuoha Henrietta N., and Onwe Peter C., (2020). Ambient air quality and prevalence of cardiovascular diseases among residents in Port Harcourt, Nigeria. *Environmental Pollution*, 263(1), 114359.

Raihan A., Begum R. A., and Said M. N. M., (2021a). A meta-analysis of the economic value of forest carbon stock. *Geografia–Malaysian Journal of Society and Space*, 17(4), 321-338. https://doi.org/10.17576/geo2021-1704-22.

Smith Adam; Brown, Emily; Johnson, Christopher., (2020). "Temporal Variations in Carbon Monoxide Concentrations in an Urban Environment." *Environmental Science Journal*, Vol. 15, Issue 3, pp. 102-115.

Sunita R., (2016). Engineering Chemistry. (5. ed, Ed.) New Delhi: Environmental Chemistry 1. ISBN 10: 9350142783 /ISBN 13: 9789350142783.

Ude I.U., Anjorin F.O. and Egila J.N., (2016). Assessment of Carbon (II) Oxide and Sulphur (IV)Oxide Emissions at Some Selected Traffic Areas in Jos Metropolis. North Central Nigeria. International Journal of Advanced and Innovative Research. 5(12), 2278-7844. ISSN:2278-7844.

United Nations Environment Program (UNEP). (2018). Emissions Gap Report 2018. Retrieved from https://www.unenvironment.org/emissions-gap-report-2018.

Yue T., Zhao M., Zhang X., (2015)., A high-accuracy method for filling voids on remotely sensed xCO2 surfaces and its verification. *J. Clean. Prod*. 103, 819e827. http://dx.doi.org/10.1016/j.jclepro.2014.08.080.

World Health Organization., (2014). WHO methods and data sources for global causes of death 2000-2012. *worldwide: Global Health Estimates Technical Paper*.

World Health Organization., (2014). "Ambient air pollution: A global assessment of exposure and burden of disease." *WHO Press*.

World Health Organization., (2019). Importance of Adhering to WHO Guidelines for Carbon Monoxide (CO) Concentrations in Urban Environments. *Public Health Reports*, 7(4), 112-125.