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ASSESSING CARBON DIOXIDE EMISSIONS FROM KEY SOURCES AND THEIR RELATIONSHIP WITH ATMOSPHERIC CONDITIONS

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Abstract: *Estimation of carbon dioxide concentration levels from three selected sources (dump sites, traffic junctions, gasoline generating sets) and its correlation with some atmospheric parameters (temperature, relative humidity, and wind speed) were carried out within Port Harcourt city and Obio/Akpor Local Government Area of Rivers State with the help of a carbon dioxide gas sensor, digital thermometer, hygrometer, and anemometer for a period of two weeks. The geographical coordinates of the locations of the selected sources were determined using a global positioning system (GPS). Analyses of the concentration levels of carbon dioxide and atmospheric parameters data obtained from the selected sources for the period under study showed that Obiri-Ikwerre dump site had the highest mean* CO_2 *concentration of 649.79 ppm, while the lowest levels were observed at IAUE Business Centre with a mean value of 477.57 ppm.*

Keywords: *Carbon dioxide, Emission levels, Sources, Effects, Atmospheric parameters*

Introduction

Combustion, fermentation, respiration and decomposition of materials of organic origin are sources of carbon dioxide (CO_2) in our environment. Carbon dioxide constitutes about 0.04 % of the Earth's atmosphere, and plays important roles in photosynthesis and the keeping of the Earth warm for human comfort. But its level has increased significantly since the beginning of the industrial revolution. Before the significant rise caused by human activities, the CO_2 content was generally constant, at around ± 10 ppm of 275, for more than a thousand years (Kabiret al., 2023). Transportation, electricity generation from fossils, commercial and residential sectors, and agriculture have been identified as some of the sources of CO_2 emissions and other greenhouse gases by the United States Environmental Protection Agency (USEPA), 2022). Landfills, also, contribute to emissions of CO_2 and other gases such as methane (Vasarhelyi, 2021). Anthropogenic and natural processes both contribute to the 25% rise in atmospheric carbon dioxide content during the last 125 years (Thurman et al., 2001),

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resulting in an increase in the Earth's surface temperature due to its heat trapping ability. This heat trapping ability of CO_2 and other greenhouse gases is responsible for the imbalance between incoming and outgoing radiation, commonly referred to as radiative forcing. Equation (1) is the equation describing the balance between incoming and outgoing radiation.

$$(1 - \alpha)S\pi R^2 = \alpha T^4 4\pi R^2 \quad 1$$

Incoming radiation = Outgoing radiation

Where S denotes solar constant (i.e. the total energy per unit area received from the Sun at the top of a planet's atmosphere), α is the albedo (representing the fraction of solar radiation reflected by the planet back into space), $1-\alpha$ is the absorbed fraction, R is the radius of the planet, πR^2 is the cross-sectional area of the planet, which determines the levels solar radiation it intercepts, T is the temperature of the planet.

$4\pi R^2$ is the surface area of the planet--assuming to be a sphere over which the planet radiates energy back into space, and T^4 describes the relationship between the temperature of a body and its radiated energy (Stefan-Boltzmann law).

According to the Intergovernmental Panel on Climate Change (IPCC, 2013), the Earth's climate is being threatened by the continued increase in average temperatures, which is caused by the increase in emissions of greenhouse gases. Worldwide, 33.2 billion metric tons of carbon dioxide were emitted in 2011 due to the combustion of fossil fuels (Le Quere et al., 2012). The US National Oceanic and Atmospheric Administration (USNOAA) reported that atmospheric carbon dioxide concentrations exceeded 400 ppm in certain places throughout the world in 2013 (Ravina, 2022). Coal, oil, and natural gas combustion have been reported as being responsible for 43%, 36%, and 20% of CO_2 emissions respectively (International Energy Agency (IEA), 2012).

1.1 Effects of CO_2

Apart from its contribution to climate change, studies have shown that animals and humans can experience a variety of symptoms such as dyspnea, altered respiration, acidosis, headaches, visual impairment, pulmonary damage, elevated blood pressure, bone deterioration, decreased fertility, changes in urine and blood chemistry, and erratic behaviour after short-term exposures to between 1 and 5% of CO_2 (Bierwirth, 2019). A number of studies have linked CO_2 to respiratory problems and symptoms such as asthma, rhinitis, wheezing, sneezing, and rales (Ferreira & Cardoso, 2014). MacNaughton et al. (2016) posited that a 2.3 ppm increase in heart rate was associated with a 1,000 ppm increase in CO_2 from baseline values. Researchers have shown that at ambient indoor concentrations, CO_2 has a negative effect on people's ability to learn and think critically. This was also in agreement with findings of a study conducted by Kajtar & Herczeg (2012) that CO_2 has negative effects on human cognitive processes during

140 minutes of exposure, with increased fatigue at 3000 ppm CO_2 concentrations compared to 600 ppm. Studies have also shown that exposure to CO_2 induces oxidative stress in humans due to reactive oxygen species (ROS) (Ezraty et al... 2011; Kiray et al., 2014).

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1.2 Carbon Dioxide Mitigation Strategies

A reduction of high levels of CO_2 in the atmosphere is an important step in stemming the effects of climate change on the environment. A number of strategies have been proposed, but not all have been fully implemented.The global carbon cycle involves the continuous sequestration of carbon by atmosphere, land, and ocean (Jayakrishnan, 2022)

Tree planting (afforestation) is one of the most important and simple strategies for CO_2 reduction. As noted by Satish et al. (2012), people in civilized countries often plant trees in their yards and in public locations. Green plants have **sequestered** large amount of **carbon photosynthesis** and essentially removed from the cycle, being buried as fossil deposits of coal (Murphy, 2024). Satish et al. (2012) revealed that the ocean and vegetation are the main global carbon sinks. The oceans are natural steady sinks for carbon dioxide, which later on changes into carbonate rocks on the ocean bed. An estimated 40% of CO_2 from human activity introduced into the atmosphere since the advent of industrial revolution has been absorbed by the Oceans (Cho, 2023). Oceans and phytoplankton absorb half of the CO_2 released (Prentice et al., 2000). Martin and Gordon (1988) reported that supplementing the ocean with iron, can increase the growth of phytoplankton. Geologic storage of carbon dioxide, direct air capture and mineralization of carbon have been identified as critical for reduction of carbon footprint (National Academies Press, 2019).

1.3 Effect of Atmospheric Parameters on CO_2

Liu et al.(2017) studied how humidity and temperature affect CO_2 concentration readings and observed that the accuracy of gas concentration measurements decreases with decreasing temperature. In a study conducted by Chainikov et al. (2016) on the effect of environmental temperature on carbon dioxide emissions from gasoline vehicle exhaust, the finding of the study revealed a link between lower temperatures and corresponding increase in the concentrations of carbon dioxide in the exhaust gasses. A simulated study on the effect of temperature, pressure and humidity on carbon dioxide concentration by Singh and Malarvili (2020), the result showed that the concentration of CO_2 is strongly affected by temperature, relative humidity, and pressure.

2 Materials and Method

2.1 Area of the study

The locations of the selected sources of carbon dioxide were within Port-Harcourt city and Obio/Akpor Local Government Area of Rivers State in the Niger Delta region of Nigeria. The geographical coordinates of Port Harcourt city and Obio/Akpor Local Government Area are 4°46' 43.0" N, 7°1' 20" E, and 4°49' 53.0" N, 6°59' 20.6" E, and elevation of 16 meters and, 24 meters above sea level respectively. Port-Harcourt and Obio/Akpor, each covered an area of 368 km^2 and 260 km^2 respectively. Port Harcourt and Obio/Akpor are hosts to some multinational oil and gas companies, industrial establishments and government institutions. The 2006 national population census put Port Harcourt population at 1,865,000, and its 2023 projection was 3,480,000, reflecting an annual growth rate of 4.66% since 2006, while 2006 national population census figure of Obio/Akpo was 464,789 and a population projection of 665,000 in 2022. Port Harcourt experiences a warm and overcast rainy season, a hot and predominantly cloudy dry season, and oppressive conditions throughout the year.

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2.2 Materials

Instruments and materials employed in obtaining the data in the field include gas sensor, digital thermometer, digital hygrometer anemometer, global positioning system (GPS), and measuring tape.

2.3 Method

Three sources of CO_2 comprising two dump sites, two traffic junctions, and two generating sets in Port Harcourt city and Obio/Akpor Local Government Area were selected for the study. The

CO_2 levels, temperature, relative humidity, and wind speed of the selected sources locations were determined on a daily basis for a period of two weeks. The geographical coordinates of the locations of the selected sources were determined using a global positioning system (GPS).

3 Results and Discussion

The geographical coordinates of the locations of the CO_2 sources are shown in Table.

Table 1. Geographical Coordinates of the Selected Sampling Points S/N Location Geographical Coordinates

St. John's Junction, Iwofe Road	4° 49' 102'' N, 6° 57' 242'' E
Aker Junction	4° 48' 490'' N, 6° 56' 539'' E
Obiri-Ikwerre Dumpsite	4° 90' 607'' N, 6° 96' 268'' E
Rumukalagbor Dumpsite	4° 48' 473'' N, 6° 04' 694'' E
St. John's Campus Business Center ,Aba Road	4° 48' 463'' N, 7° 04' 990'' E
IAUE Business Center	4° 48' 437'' N, 7° 04' 965'' E

Figure 1 shows the levels CO_2 emitted at the selected sources during the period under study.

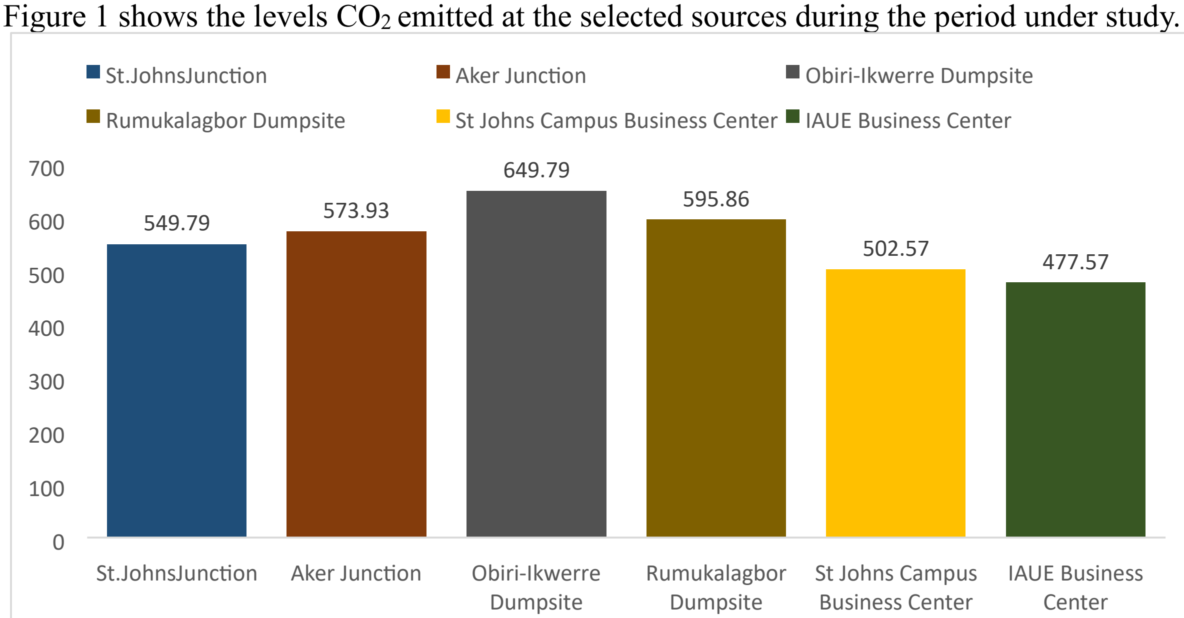

Figure 1: Levels of carbon dioxide emission from the selected sources

In figure 1, Obiri-Ikwerre dumpsite has the highest CO_2 concentration mean of 649.79 ppm, followed by Rumukalagbor dumpsite with a mean value of 595.86 ppm, indicating a substantial emission

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attributable to trash breakdown and related activities like the burning of refuse. The third and fourth CO2 emission levels as shown in figure 1 are Aker and St. John's traffic junctions with average values of 573.93 ppm and 549.79 ppm respectively. These CO_2 emissions were largely from auto-mobile traffic and urban activities.The third source of CO_2 was investigated at St. John's Campus Business Centre and Ignatius Ajuru University of Education (IAUE) Business Centre with mean values of 502.57 ppm and 477.57ppm respectively, and indicating relatively lower emission source, likely attributable to low business activity and prevailing atmospheric conditions during the period under study.

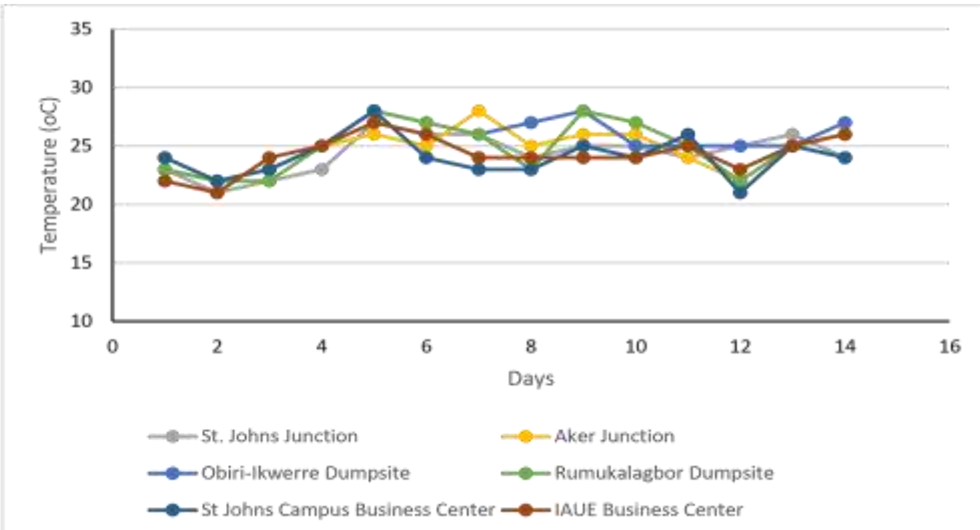

Figure2: Temperature (°C) curve for the various locations

The temperature fluctuated between 21°C and 28°C, with the peak average temperature recorded at Obiri-Ikwerre dump site (25.43°C). Temperature is essential in the dynamics of CO_2 emissions and atmospheric distribution. The temperatures in the examined places varied from 21°C to 28°C, with the highest average temperature recorded at Obiri-Ikwerre dump site (25.43°C). Elevated temperatures can accelerate organic decomposition, resulting in increased CO_2 emissions, as demonstrated by the high CO_2 concentrations at landfills. A study on the relationship between "Atmospheric Carbon Dioxide Concentration and Global Temperature for the Last 425 Million Years" by Davis (2017) showed that changes in atmospheric CO_2 concentration did not cause temperature change in the ancient climate. According to Afifa et al. (2024) "climate change in the form of higher temperatures due to increased CO2 in the atmosphere can, in turn, release ground-level ozone into already polluted air while utilizing nitrogen oxides and volatile organic compounds". And as rightly pointed out by Ofremu et al.(2024) that "understanding the intricate interplay between emission sources, meteorology, and pollutant dispersal is vital for implementing effective strategies to mitigate air pollution worldwide and safeguarding environmental sustainability and public health"

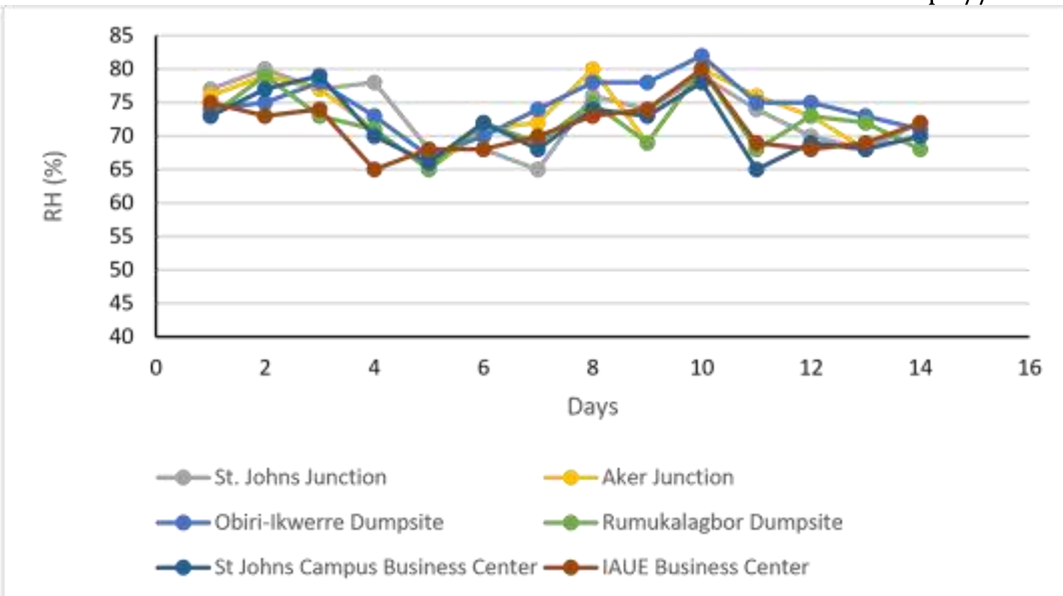

Figure 3: Relative humidity (%) Curve for the various locations

Relative humidity (RH) is a significant meteorological component that influences the emission and dispersion of CO_2. The relative humidity (RH) values in the studied locations varied from 65% to 82%, with the greatest average RH observed at Obiri-Ikwerre dumpsite, measuring 74.50%. Elevated relative humidity can affect CO_2 concentrations in multiple ways. High humidity levels can augment microbial activity in organic waste, resulting in elevated CO_2 emissions in dump sites. Furthermore, relative humidity can impact the density and buoyancy of air, thereby affecting the dispersion of contaminants.

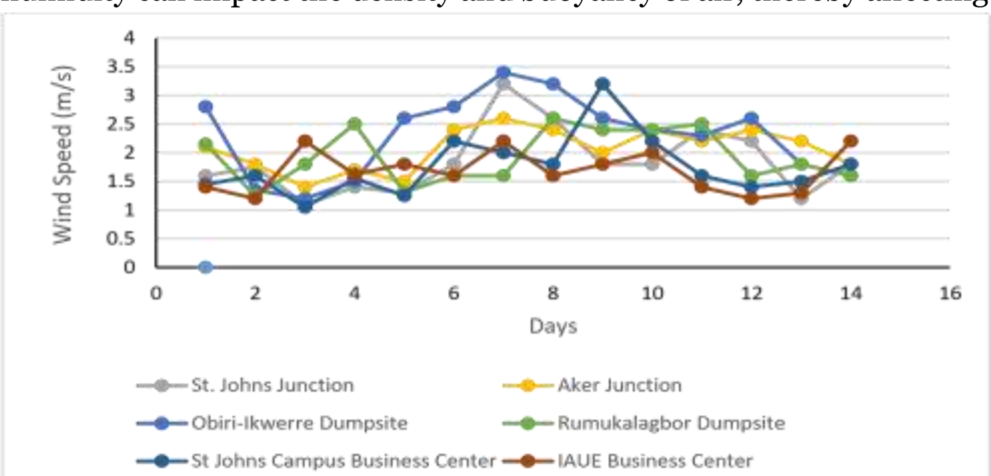

Figure 4: Wind Speed (m/s) Curve for the various locations

Wind speeds varied from 1.10 m/s to 3.40 m/s among the locations, with the highest average recorded at Obiri-Ikwerre dumpsite (2.30 m/s). Relative humidity fluctuated between 65% and 82%, with the highest mean relative humidity documented at Obiri-Ikwerre dump site (74.50%). Wind speed is a vital atmospheric parameter that profoundly affects the distribution and concentration of air pollutants, such as carbon dioxide (CO_2). In the examined sites, wind speeds fluctuate, with the maximum average wind speed recorded at Obiri-Ikwerre Dump site (2.30 m/s) and the minimum at IAUE Business Centre

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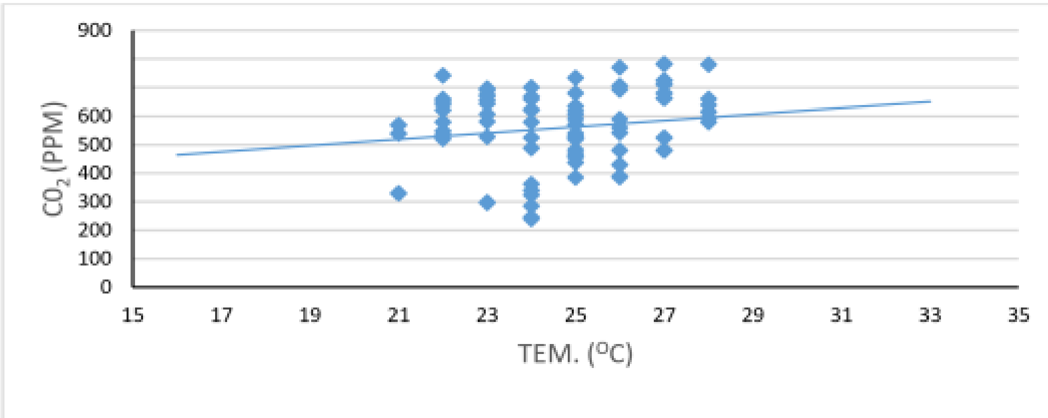
(1.68 m/s). Increased wind velocities can facilitate the dispersion of CO_2, hence diminishing its concentration in a localised area by distributing it across a broader geographic expanse. The dispersion effect is crucial in metropolitan regions and landfills where emissions are elevated due to motor traffic and the decomposition of organic waste, respectively. A study showed that efficient wind circulation can alleviate local air pollution, therefore enhancing air quality.

CO_2 Emission Level and its Correlation with Atmospheric Parameters

A correlation analysis of atmospheric factors and CO_2 concentrations demonstrates multiple significant correlations, as illustrated in the scatter plots.



Figures 5, 6, and 7 are scatter plots showing the relationship between CO2 concentrations with temperature (T), relative humidity (RH) and wind speed (WS) respectively.

800
700

Figure 5**:** A scatter plot showing the correlation between CO_2 concentration and Temperature (°C)

Higher temperatures at Obiri-Ikwerre dump site correlate with increased CO_2 concentrations, consistent with a study by (USEPA, 2024) that high temperature and humidity levels can also increase concentrations of some pollutants. "Warming is expected to accelerate carbon release into the atmosphere" (Cavicchioli et al. 2019). The link between temperature and CO_2 concentration suggests that warmer regions, particularly those with significant organic waste, are prone to higher CO_2 emissions. Moreover, elevated temperatures can generate thermal updrafts that promote the upward distribution of CO_2, momentarily decreasing surface concentrations while potentially exacerbating overall air pollution.

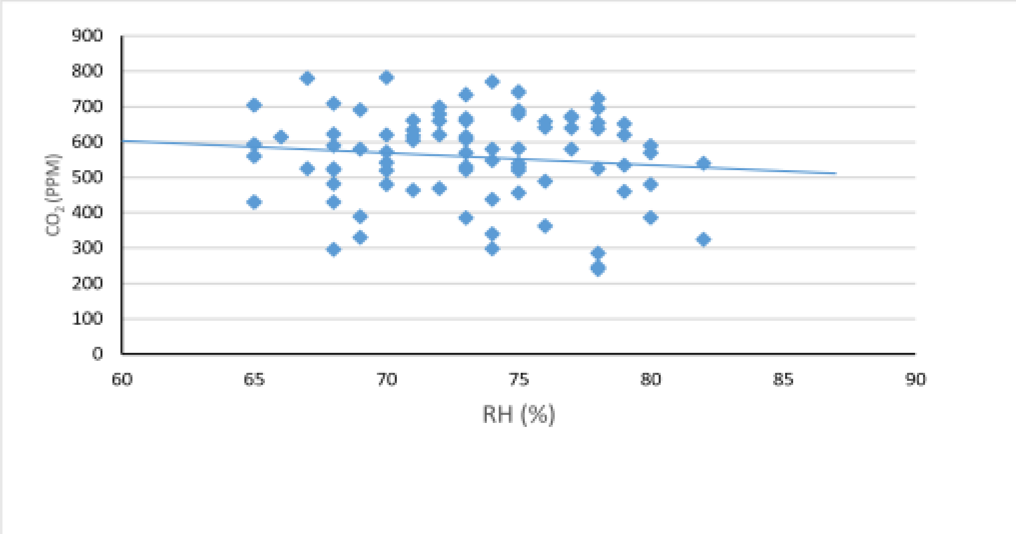


Figure 6: A scatter plot showing the correlation between CO_2 concentration and Relative Humidity (%)

Relative humidity and temperature exhibit a mixed association with CO_2 concentration. In contrast, elevated relative humidity at Obiri-Ikwerre Dumpsite is associated with increased CO_2 concentration, likely attributable to moist circumstances facilitating decomposition processes that emit CO_2. Elevated relative humidity levels can augment microbial activity in organic waste, resulting in heightened CO_2 emissions, as evidenced in dumpsites such as ObiriIkwerre, which has a high average relative humidity of 74.50%. Conversely, areas with reduced relative humidity, such as St. Johns Junction (73.29%), may exhibit distinct emission behaviours. Elevated humidity can affect air density, enhancing the retention of pollutants at the surface and thereby elevating local CO_2 levels.

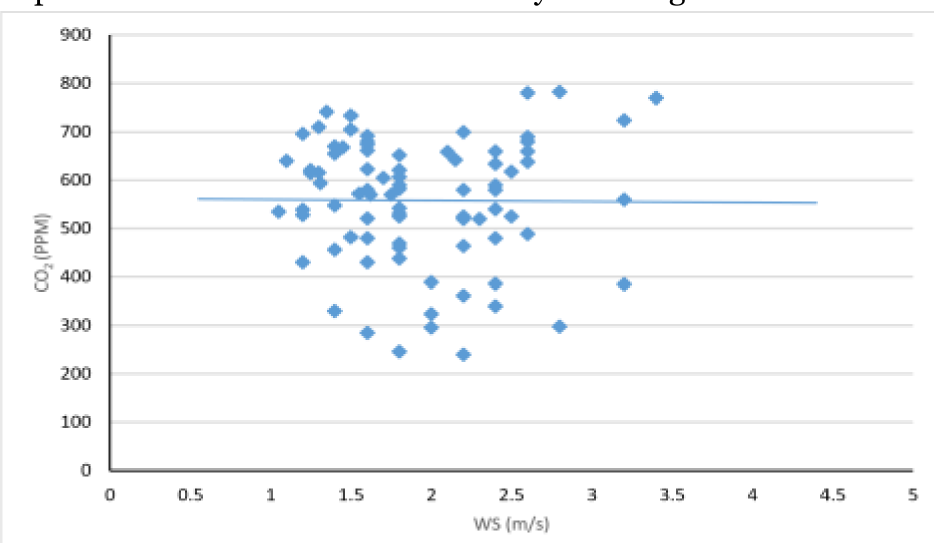


Figure 7: A scatter plot showing the correlation between CO_2 concentration and Wind Speed (m/s)

Typically, elevated wind velocities correlate with diminished CO_2 concentrations, indicating that enhanced wind promotes the dispersion of CO_2, thus lowering its local concentration. At Obiri-Ikwerre dumpsite, with an average wind speed of 2.30 m/s, significant variations in CO_2 levels are observed,

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demonstrating the wind's influence in dispersing emissions from the site. In contrast, regions characterised by reduced wind velocities, shown by the IAUE Business Centre with an average wind speed of 1.68 m/s, typically exhibit elevated and more stable CO_2 concentrations. This inverse correlation underscores the significance of wind velocity in alleviating air pollution.

3.1 Comparison of Measured CO_2 Concentration with Set Standards

Evaluating the measured CO_2 concentrations against International Standards is essential for determining air quality. Carbon dioxide levels below 400 ppm are regarded as appropriate for human safety (Occupational Safety and Health Administration (OSHA), 2012).

The World Health Organisation (WHO) recommended CO_2 levels of less than 1,000 ppm to maintain optimal indoor air quality (WHO, 2023). All assessed locations are much below this criterion, demonstrating adherence to WHO criteria. The elevated concentrations in dump sites and urban intersections highlight the necessity for ongoing monitoring and mitigation initiatives. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommended indoor CO_2 levels of not more than 700 ppm (Abu-rahmah, 2021) , The heightened levels at all locations, especially near the dump sites, underscore the influence of human activities on local air quality and stress the necessity of efficient waste management and traffic regulation measures.

4. Conclusion

The heightened concentrations of carbon dioxide (CO_2) emissions from the chosen sources have considerable environmental and health repercussions. Elevated levels of CO_2, especially at places such as Obiri-Ikwerre and Rumukalagbor dumpsites, would intensify the greenhouse effect, thereby aggravating climate change, and resulting in detrimental weather patterns and other climate change consequences, as well as health hazards to humans if the trend is not abated.

References

Abu-rahmah, A..Ahmad, R., Haboub, A.. Yasmin Abu-Rahmah, Y. (2021).Towards healthy levels of carbon dioxide in schools of the national oil company of Abu Dhabi. Advances in Meteorology. 2021 (1), 6680476. https://doi.org/10.1155/2021/6680476

Afifa, K. A., Nazim, H., Muhammad H. A., Muhammad, Z .S. (2024). Air pollution and climate change as grand challenges to sustainability, Science of The Total Environment, 928(2024), 172370 https://doi.org/10.1016/j.scitotenv.2024.172370.

Bierwirth, P. N. (2019). Carbon dioxide toxicity and climate change: a major unapprehended risk for human health. Emeritus Faculty, Australian National University.

Cavicchioli, R., Ripple, W.J., Timmis, K.N., Azam, F., Bakken, R. L., Baylis, M., Behrenfeld,

J. M.., Boetius, A., Boyd, W. P., Classen, T. A., Crother, W. T.,

Danovaro, T., Foreman., M. C., Huisman, J., Hutchins, A. D., Jansson, K. J., Karl, M. D., Koskella, B… & Welch,M. B.D …& Webster, S. N. (2019). Scientists' warning to humanity: microorganisms and climate change. Nat Rev Microbiol, 17, 569–586 (2019). https://doi.org/10.1038/s41579-019-0222-5

Chainikov, D., Chikishev, E., Anisimov, I., & Gavaev, A. (2016). Influence of ambient temperature on the CO_2 emitted with exhaust gases of gasoline vehicles. In IOP Conference Series: Materials Science and Engineering, 142(1), 012109.

Cho. R. (2023, August 23). Plankton are central to life on Earth. How is climate change affecting them?. News from the Columbia Climate School.

https://news.climate.columbia.edu/2023/08/23/plankton-are-central-to-life-on-earthhow-is-climate-change-affecting-them/

Davis, J. W. (2017).The Relationship between atmospheric carbon dioxide concentration and global temperature for the last 425 million years, Climate, 5(4), 76. Doi: 10.3390/cli5040076

Ezraty, B., Chabalier, M., Ducret, A., Maisonneuve, E., & Dukan, S. (2011). CO2 exacerbates oxygen toxicity. EMBO Reports, 12(4), 321–326. https://doi.org/10.1038/embor.2011.21

Ferreira, A M. & Cardoso, M. (2014). Indoor air quality and health in schools. J Bras Pneumol, 40(3), 259 - 68.

IPCC. (2013). Climate change 2013: The physical science basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

International Energy Agency. (2012). CO_2 emissions from fuel combustion. Paris: Organization for Economic Co-operation and Development.

Jayakrishnan, U.K., & Govindasamy, B., Cao, L., & Caldeira, K. (2022). Contrasting climate and carbon-cycle consequences of fossil-fuel use versus deforestation disturbance. Environmental Research Letters. 17. 10.1088/1748-9326/ac69fd.

Kabir, M., Habiba, E. U., Khan, W., Shah, A., Rahim,S., De los Ríos-Escalante, R. P., Farooqi, Z., Ali, L., Shafiq, M. (2023).Climate change due to increasing concentration of carbon dioxide and its impacts on environment in 21st century; a mini review. Journal of King Saud University - Science, 35(5). 102693.

Kajtar, L., & Herczeg, L. (2012). Influence of carbon dioxide concentration on human wellbeing and intensity of mental work. Quarterly Journal of the Hungarian Meteorological Service, 116, 145-169.

Kiray, M., Sisman, A. R., Camsari, U. M., Evren, A., Baykara, B., Aksu, I., Ates, M., & Uysalet, N. (2014). Effects of carbon dioxide exposure on early brain development in rats. Biotech Histochemistry, 89, 371-383.

Le Quéré, C.; Andres, R. J.; Boden, T.; Conway, T.; Houghton, R. A.; House, J. I.; Marland, G.; Peters, G. P.; van der Werf, G.; Ahlström, A.; Andrew, R. M.; Bopp, L.; Canadell,

J. G.; Ciais, P.; Doney, S. C.; Enright, C.; Friedlingstein, P.; Huntingford, C.; Jain, A. K.; Jourdain, C.; ... (2012). The global carbon budget 1959–2011. Earth System Science Data Discussions, 5(2), 1107-1157. Copernicus 10.5194/essdd-5-1107-2012

Liu, Y., Ni, X., Wu, Y., & Zhang, W. (2017). Study on the effect of temperature and humidity on the CO2 concentration measurement. In IOP Conference Series: Earth and Environmental Science, 81(1) 012083).

Martin, J. H., & Gordon, R. M. (2008). Northeast Pacific iron distributions in relation to phytoplankton productivity. Deep Sea Research, 35, 177-196.

MacNaughton, P., Spengler, J., Santanam, S., Satish, U., & Allen, J. (2016). Environmental perceptions and health before and after relocation to a green building. Building and Environment, 104, 138-144.

Murphy, D. J. (2024). Biological carbon sequestration: From deep History to the present Day. Earth, 5(2), 195-213. https://doi.org/10.3390/earth5020010

National Academies Press. (2019). Negative emissions technologies and reliable sequestration: A Research Agenda (2019). DOI 10.17226/25259

Occupational Safety and Health Administration (OSHA). (2012). sampling and analytical methods: Carbon dioxide in workplace atmospheres. https//:www.osha.gov.

Ofremu, O. G., Raimi,Y. B., Yusuf, O. S. Dziwornu, A. B., Nnabuife, G. S., Eze, M. A., Nnajiofor, A. C. (2024). Exploring the relationship between climate Change, air pollutants and human health: Impacts, adaptation, and mitigation strategies, Green Energy and Resources, 2024, 100074, https://doi.org/10.1016/j.gerr.2024.100074.

Prentice, I. C., Heimann, M., & Sitch, S. (2000). The carbon balance of the terrestrial biosphere: Ecosystem models and atmospheric observations. Ecological Applications, 10, 1553– 1573.

Ravina, A. (2022). On bond returns in a time of climate change. The Energy Journal, 43(1), 139-160.

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DOI:https://doi.org/10.5281/zenodo.15976562

Satish, U., Mendell, M. J., Shekhar, K., Hotchi, T., Sullivan, D., Streufert, S., & Fisk, W. J. (2012). Is CO2 an indoor pollutant? Direct effects of low-to-moderate CO_2 concentrations on human decision-making performance. Environmental Health Perspectives, 120, 1671-1677.

Singh, O. P., & Malarvili, M. B. (2020). Effect of temperature, pressure and humidity on carbon dioxide concentration—simulation study. In IOP Conference Series: Materials Science and Engineering, 884(1), 012007).

Thurman, H. V., & Elizabeth, A. B. (2001). Introductory Oceanography (10th Ed.). Prentice Hall.

USEPA. (2022). Sources of greenhouse gas emissions https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Vasarhelyi, K. (2021). The hidden danger of landfills. Environmental Centre, University of Colorado, USA.

WHO. (2023). WHO Guidelines on indoor air quality and the role of air quality Monitors. https://www.hibouair.com/blog/wp-content/uploads/2023/05/who-air-quality.jpg

USEPA. (2024). the inside story: A guide to indoor air quality. https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air- quality

Zhang, J., Pang, L., Cao, X., Wanyan, X., Wang, X., Liang, J., & Zhang, L. (2020). The effects of elevated carbon dioxide concentration and mental workload on task performance in an enclosed environmental chamber. Building and Environment, 178, 106938. https://www.colorado.edu/ecenter/2021/04/15/hidden-damage-landfills