

Cement Industry and Climate Change in Nigeria: A Case Study of Dangote Obajana Cement Plant

Olanrewaju Clement Alaba^{1,*}, Micheal Babatope Ayodele²

¹Department of Mining Engineering, Federal University of Technology, Nigeria

²Department of Geography and Environmental Management, Bamidele Olumilua University of Education Science and Technology, Ikere-Ekiti, Ekiti State, Nigeria

Received May 19, 2022; Revised August 9, 2022; Accepted August 23, 2022

Cite This Paper in the Following Citation Styles

(a): [1] Olanrewaju Clement Alaba, Micheal Babatope Ayodele, "Cement Industry and Climate Change in Nigeria: A Case Study of Dangote Obajana Cement Plant," *Universal Journal of Geoscience*, Vol. 9, No. 2, pp. 21 - 29, 2022. DOI: 10.13189/ujg.2022.090201.

(b): Olanrewaju Clement Alaba, Micheal Babatope Ayodele (2022). *Cement Industry and Climate Change in Nigeria: A Case Study of Dangote Obajana Cement Plant*. *Universal Journal of Geoscience*, 9(2), 21 - 29. DOI: 10.13189/ujg.2022.090201.

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Abstract Climate change has emerged as a global issue and one of the world's most pressing environmental challenges. Despite the contribution of the cement industry to the releases of carbon dioxide (the most significant contributor to GHG emissions) in Nigeria, only a few research writing focused on its influence on climate change. This paper, therefore, studied the variation in concentration of carbon dioxide (CO₂) within the environment of the Dangote Obajana Cement Plant. The CO₂ data used for the study were collected from the European Space Agency website. The satellite image data were downloaded from Google Earth and digitized to extract the study area using the WGS1984 geographic coordinate system while ArcMap packages were used for the data processing. The annual descriptive statistics for CO₂ variation for the years 2003, 2008, and 2018, showed that the minimum mean concentration was 373.451.07, 382.92054, and 0.950.17 while the maximum mean concentration was 374.931.0, 384.780.69, and 0.970.17. Bartlett's test for equal variances, with chi-squares statistics of 103.44 and 12.33, and a probability (Prob>chi²) value of 0.001 established that the minimum and maximum CO₂ emissions variances within the years are significantly different. The Bonferroni test revealed that all the years had CO₂ emissions that were significantly different from one another as their p-value was less than 0.05 with the minimum emission occurring in 2018 and the maximum in 2008. The study concluded that the influence of the Dangote Obajana Cement Plant's operation on the release of CO₂ concentrations across the

study areas was insignificant since there was no uniformity in their concentrations.

Keywords Cement Industry, Climate Change, Greenhouse Gases, Carbon Dioxide Gas Emissions

1. Introduction

As a result of significant changes in carbon emissions and greenhouse gas levels, the global climate has been warming at an alarming rate in recent years. Carbon dioxide (CO₂) and other greenhouse gases trap heat in the atmosphere, generating temperature rises that cause dramatic changes in the global climate environment [1]. The worrying rise in global temperature has prompted many scientists and environmentalists to focus their research efforts on mitigating climate change's effects around the world [2,3]. The record of CO₂, CH₄, and N₂O emissions accounts for around 98% of the global greenhouse gas (GHG) [4,5] with CO₂, the most significant contributor to GHG emissions), accounting for over 74% of global emissions. Methane (CH₄), nitrous oxide (N₂O), and fluorinated gases (F-gases) each contributed 17.3%, 6.2%, and 2.1%, respectively [6,7]. Mengpinet et al. [8] estimated that 36,700 MtCO₂ was emitted in 2016. In 2018, GCA [3] estimated that 34,807 MtCO₂ was emitted globally from fossil fuel burning, cement production, and

gas flaring, while Olivier and Peters [9] estimated that 37,300 MtCO₂. Crippa et al. [10] reported 37,900 MtCO₂ emitted in the same year, but the IPCC [11] estimated 57,000 MtCO₂ emitted in 2019. The IEA [12] reported total of 34,200 MtCO₂ emissions in 2020 and 36,100 MtCO₂ in 2021. Between 1990 and 2020, total worldwide GHG emissions of 9,312 MtCO₂eq and 12,619 MtCO₂eq were estimated [7,13]. Meanwhile, global GHG emissions by economic factors were estimated to be 509 MtCO₂eq and 1,494 MtCO₂eq for the industrial sector, 2,684 MtCO₂eq and 3,496 MtCO₂eq for energy sector, 1,364 MtCO₂eq and 1,653 MtCO₂eq for wastes generation sector, and 4,755 MtCO₂eq and 5,976 MtCO₂eq for agricultural sector between 1990 and 2020 [7,13,14].

The cement industry is primarily concerned with the manufacture of cement, which is used to bond other materials together for construction purposes. Concrete is made out of cement, sand, gravel, and water, and is one of the most widely used construction materials on the planet. Portland cement is the common term for the cement business, which was called after a popular construction stone in England during the early 1800s [15]. As a result of increased global urbanization, economic development, and demand for buildings and infrastructure, cement has become the most utilized material in the world today [15-17]. Global cement production rose from 594 Mt in 1970 to 2,550 Mt in 2006, with industrialized countries producing 1,886 Mt (74%), and developing countries producing 529 Mt (21%) [18]. In 2021, over 4,400 Mt of cement was produced worldwide, with China accounting for 2,500 Mt (55%) of global output [17,19]. The cement industry contributes significantly to greenhouse gas emissions both directly (heating of limestone) and indirectly (burning of fossil fuels), making it one of the most energy-intensive businesses that emit the biggest share of industrial GHG [20]. Cement, iron, and steel, as well as chemical industries, contribute to around 20% of worldwide CO₂ emissions [21]. According to Lehne and Preston [22], the cement sector emitted around 2,800 MtCO₂ in 2015, accounting for 8% of world CO₂ emissions. The decomposition of limestone accounts for 50%, fossil fuels used to heat kilns for 40%, and fuels required to mine and transport raw materials account for 10%. GCA [3] reported that the calcination process released 1,500 MtCO₂, accounting for 4.1% of total emissions in 2016. However, according to Olivier and Peters [9], the calcination process emitted 4% CO₂ in 2018, while Oreane et al. [23] estimated that the overall cement sector emitted 6% CO₂ emissions globally. In addition, Mengpin et al. [8] estimated that the calcination process emitted 3% of total CO₂ emissions, whereas the IEA [24] reported that the cement industry emitted 2,400 Mt of CO₂, accounting for 7% of total emissions in 2020. The CO₂ emissions during cement production vary by region, with age and size being significant considerations as a result of different fuel mixtures, cement varieties, and kiln

processes [25].

In 2015, Nigeria was the world's 17th largest producer of greenhouse gases and Africa's second-highest after South Africa. The principal greenhouse gas (GHG) emissions (CO₂, CH₄, and N₂O) account for roughly 98% of global GHG emissions [26]. According to the World Bank [27], total GHG emissions were estimated to be 75 MtCO₂eq and 311 MtCO₂eq between 1970 and 2018, respectively, while Ritchie and Roser [7] estimated 358 MtCO₂eq in 2018. However, overall economic GHG emissions are estimated to be 196 MtCO₂eq in 2020, with waste generation accounting for 15 MtCO₂eq, energy accounting for 76 MtCO₂eq, industry accounting for 18 MtCO₂eq, and agricultural accounting for 87 MtCO₂eq [13]. Nigeria's cement output has increased fast from 2 million metric tonnes per annum (MMtpa) in 2002 to 17 MMtpa in 2011 [28], and the country now has the largest cement industry in West Africa, with 12 integrated cement plants producing 58.9 MMtpa [29]. This has classed the cement sector as one of Nigeria's most energy-intensive industries, emitting enormous volumes of CO₂ and other greenhouse gases [30]. Despite this, the influence of CO₂ emissions from the cement sector on climate change has received little attention. As a result, using Dangote Obajana Cement Plant as a case study, this study estimated the volume of CO₂ emitted by the cement industry and its influence on climate change.

2. Materials and Methods

2.1. Description of the Study Area

The study area lies between longitude 6°10'E and 6°30' East of the Greenwich meridian and Latitude 7°40'N and 8°00'N north of the equator as shown in Figure 1. The Dangote Obajana Cement Plant in Nigeria's Kogi State is the largest cement plant in Sub-Saharan Africa and one of the world's largest cement plants [31]. The factory is located in Nigeria's Kogi state, in the Oworo region of the Lokoja local government area. The Oworo district is a mountainous region bordered on the north by IgbiraIgu (Egbura), on the northwest by Kakanda, on the west by the Abinu, and on the south by Ebira land. Dangote Obajana Cement Plant was incorporated by Kogi State Government in 1992 and acquired by Dangote Industries Limited in 2004. The factory began full production in 2006, with two Smidth-designed cement production lines capable of generating 5.0 MMtpa. The third and fourth lines were commissioned in 2011 and 2012, bringing total production to 13.25 MMtpa [29]. Gas, coal, and LPFO are used to power the plant, which is backed up by a fleet of 2,370 vehicles. Obajana contains 647 Mt of limestone reserves that are estimated to last 45 years, with both the limestone and additives coming from the Obajana mines [31]. The people that live in the area speak Yoruba are known as the Okun Nation. They are one of Kogi State's

three major tribal groupings, the others being the Igala and the Igbirra. They make up around 20% of the population of Kogi State, with an estimated population of 804,945. Farmers and traders make up the majority of the population, which has a long history of engagement with nearby tribes like the Igbomina, Nupe, Gbagyi, and Igala. Kabba and Obajana, which are home to the Dangote Obajana Cement Plant and the most well-known town in the study area, along with Mopa, Okedayo, Odo Ere, Lyara, Isanlu, AyetoroGbede, and Egbe.

2.2. Methodology

The secondary data used for the study was collected from government organizations, agencies, research institutions, and previous studies. These include data obtained by satellite observation, instrument monitoring, and international organizations. The study used a three-year time series containing two months (March/April and September/October) in each three-year cycle. March/April marks the start of the rainy season, while September/October marks the start of the second peak of the rainy season. CO₂ data for the years 2003, 2008, and 2018 was collected in netCDF format from the European Space Agency (ESA) open climate data

webpage, with 2003 used as the base year. The CO₂ data was measured in parts per million (ppm) while Table 1 lists the requirements for satellite-based CO₂ data collection. The research area was extracted using satellite image data collected from high-resolution Google Earth and digitized. The geo-referenced Google earth images were downloaded using the WGS1984 global coordinate system. The ArcMap environment was used for geo-referencing, conversions of image map to vector map using Table 2 classifications, study area border and fish-net generation, base map, and database generation, and data processing.

Table 1. Satellite-based CO₂ data acquisition

2	Panchromatic	Multispectral
Spatial Resolution	0.61 meter GSD at Nadir	2.4 meter GSD at Nadir
Spectral Range	445-900 nm	450-520 nm (blue) 520-600nm (green) 630-690nm (red) 760-900nm Near IR)
Swath Width	16.4kmat nadir	

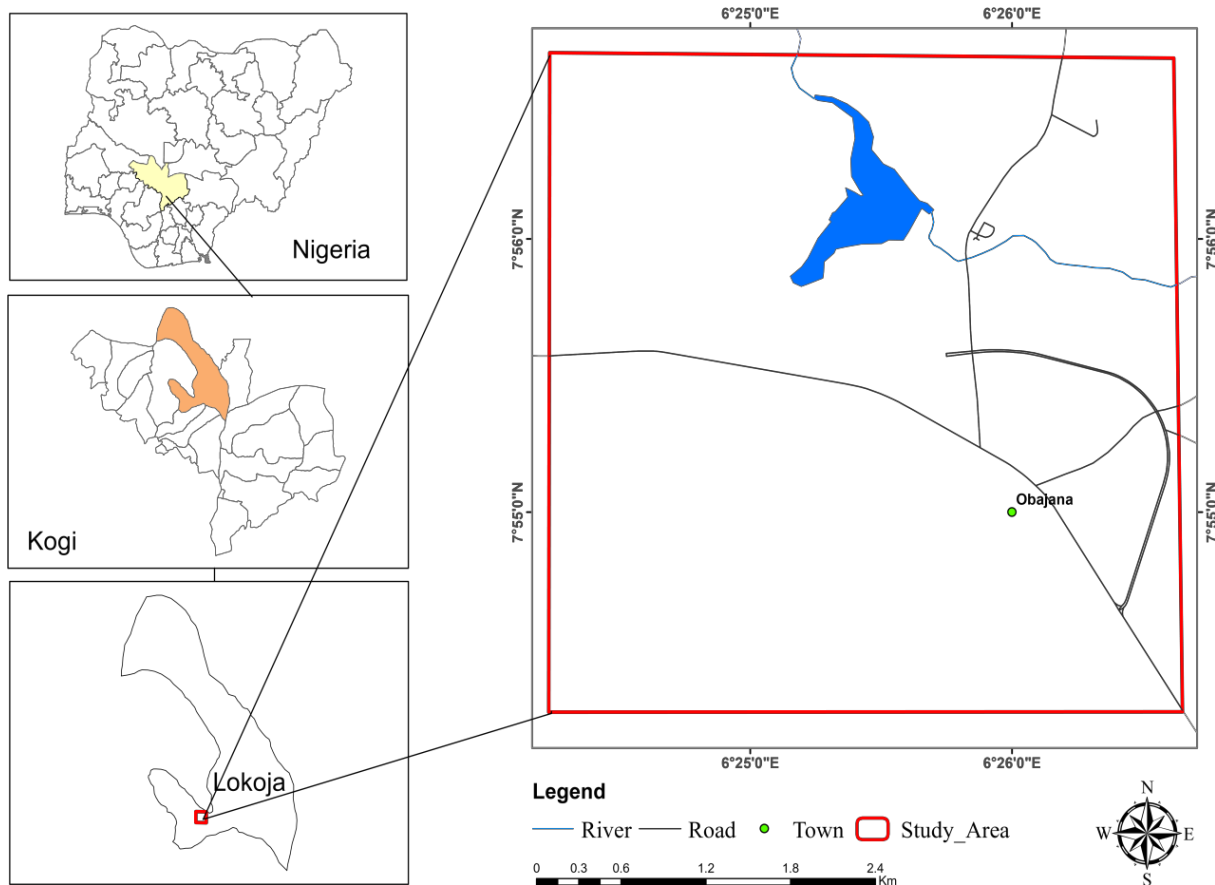


Figure 1. Map showing the Study Area

Table 2. Classification of vector data

Vector data type	Features	Comment
Points data	Isolated and singular features	
Line data	Linear features such as roads, pipelines, and railways.	1. The Ilorin-Kabba-Lokoja Road 2. The Lokoka-Ikare Road 3. The Kabba-Ikare Road
Polygon data	Features with defined area extent.	1. Kabba township 2. Obajana area 3. Other smaller villages in the study area e.g Ode Ape, Aiyetoro Gbede.

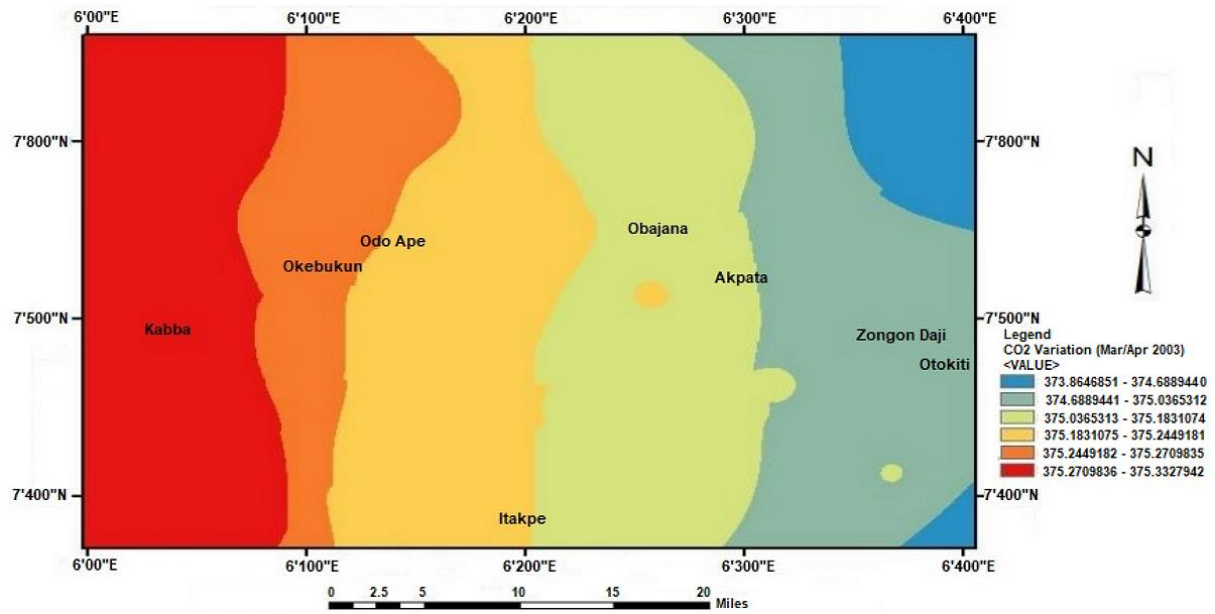


Figure 2a. Variation of CO₂ concentration in March/April 2003

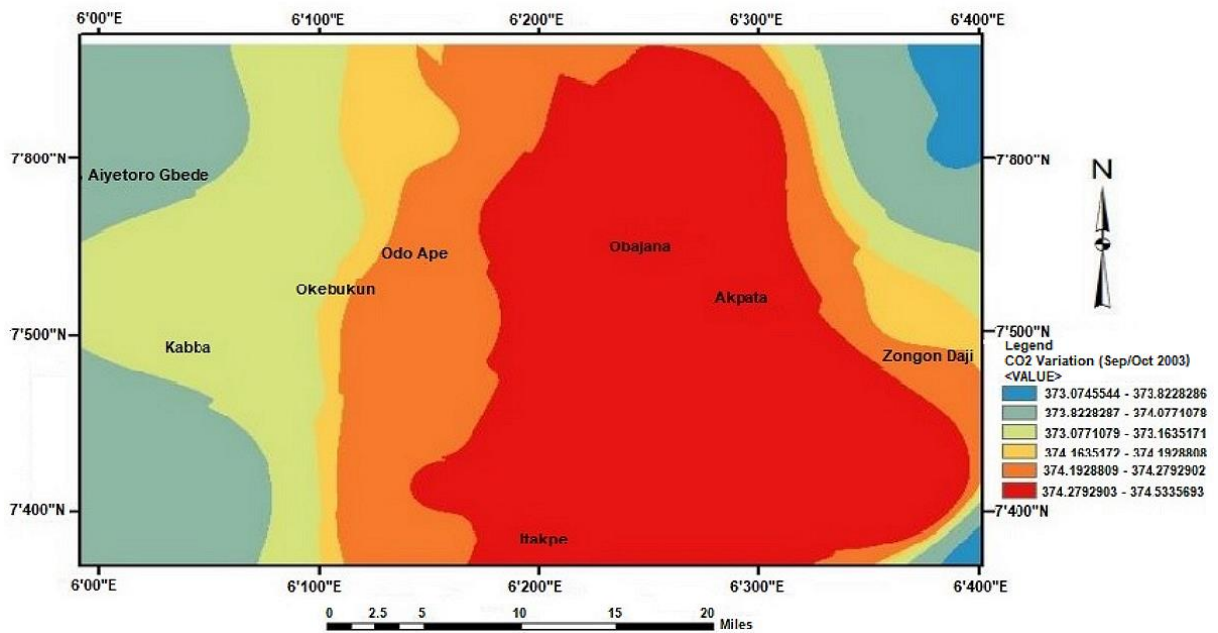


Figure 2b. Variation of CO₂ concentration in September/October 2003

3. Results and Discussion

3.1. Concentration of CO₂ Variation

The study area consists of nine (9) significant communities located around the Dangote Obajana Cement Plant in Kogi State, Nigeria. On the east, where Kabba village was located, and in the center, where Dangote Obajana Cement Plant was built to the east of Zongon Daji and Otikiti Township, are the major concentrations of human activity. Apart from that, these towns were discovered in Guinean savannas and derived from forests that had been turned into farmland. CO₂ should be more concentrated in built-up areas and less concentrated in forest/agricultural areas, according to the research area's geography. The Dangote Obajana Cement Plant commenced pre-production of cement in 2004, with 2003 as the base year to ascertain the natural state of CO₂ concentrations variation across the study area before the commencement of the company's operations. The base year information in March/April (2003) showed that CO₂ emissions varied from higher to lower concentrations as shown in Figure 2a. The areas of higher concentrations are Kabba, Okebukun, Ode-Ape and Aiyetoro Gbede

while the lower concentrations areas are Obajana, Akapta, Zongon Daji, and Itakpe.

In September/October 2003, the concentrations of CO₂ variation were scattered and not uniformly distributed like that of March/April (2003) as displayed in Figure 2b. The areas with higher concentrations are Obajana, Akpata, Zongon Daji, Ode-Ape, and some parts of Okebukun while those with lower concentrations are Kabba, Aiyetoro Gbede, and some parts of Okebukun.

In March/April 2008 and 2018, the concentrations of CO₂ variation followed the same trend as in 2003, varying from higher to lower concentrations as depicted in Figures 3(a&b). The areas of higher concentrations are Kabbi, Okebukun, Ode- Ape and Aiyetoro Gbede while areas of lower concentrations are Obajana, Akapta, ZongonDaji, and Itakpe.

However, the CO₂ variation concentrations in September/October 2008 and 2018 followed the same trend as in 2003, where the CO₂ variation concentrations were dispersed and not uniformly distributed like in March/April as shown in Figures 4(a&b). The areas with higher concentrations of CO₂ are Obajana, Akpata, Itakpe, and some parts of Ode-Ape while those with lower concentrations are Zongon Daji, Kabba, Aiyetoro Gbede, Okebukun, and some parts of Ode-Ape.

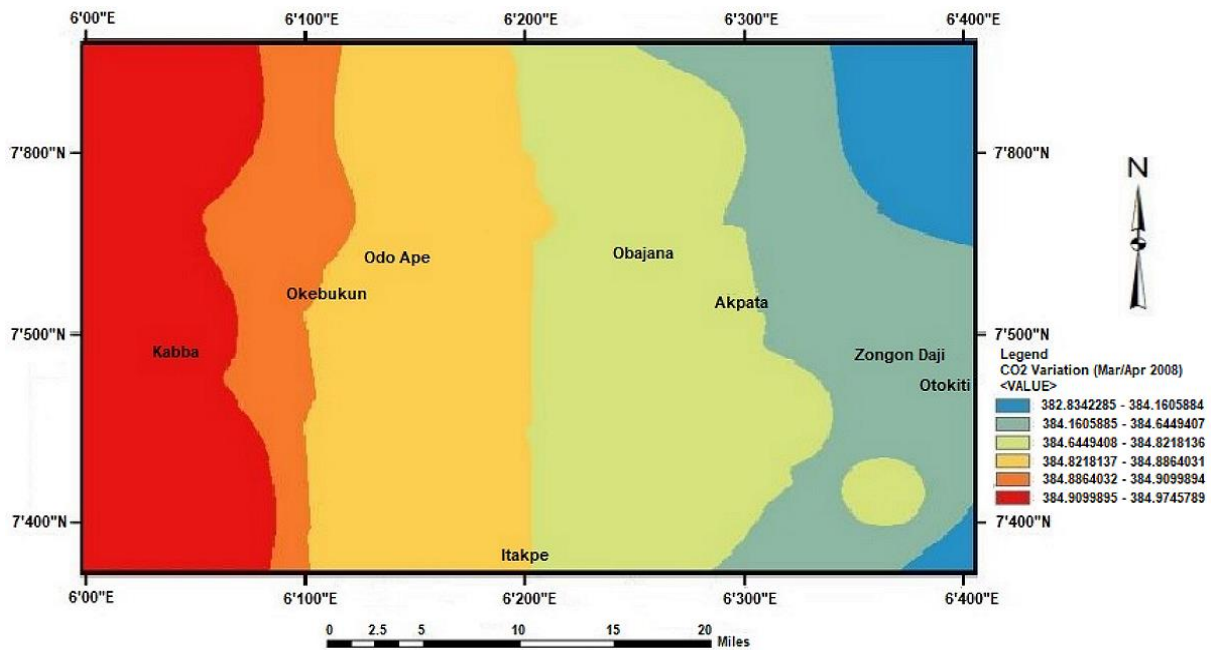


Figure 3a. Variation of CO₂ concentration in March/April 2008

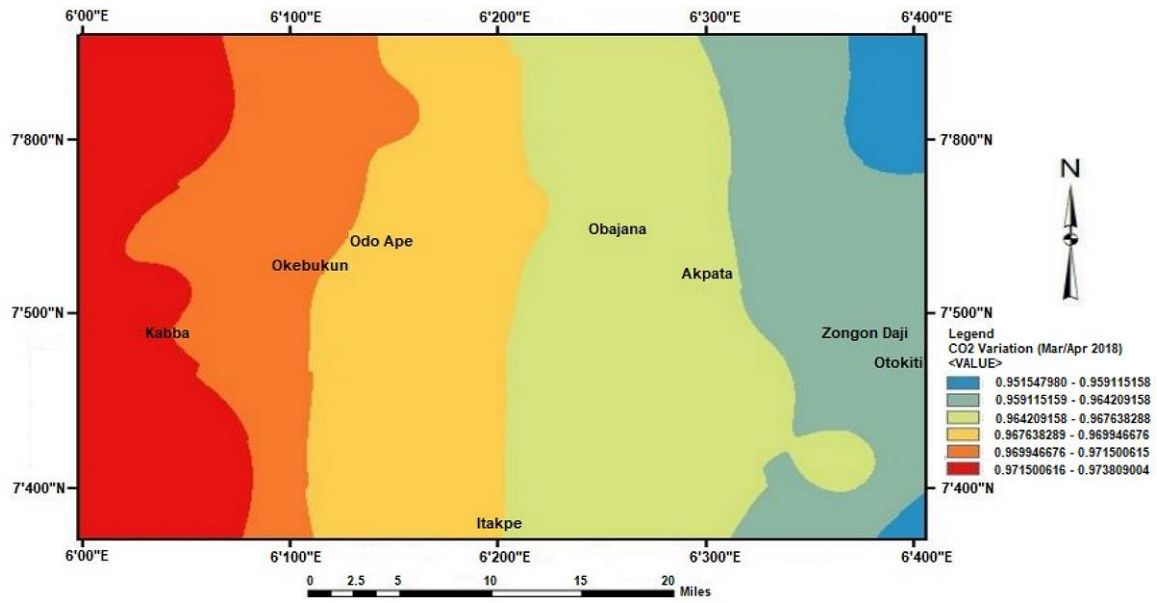


Figure 3b. Variation of CO₂ concentration in March/April 2018

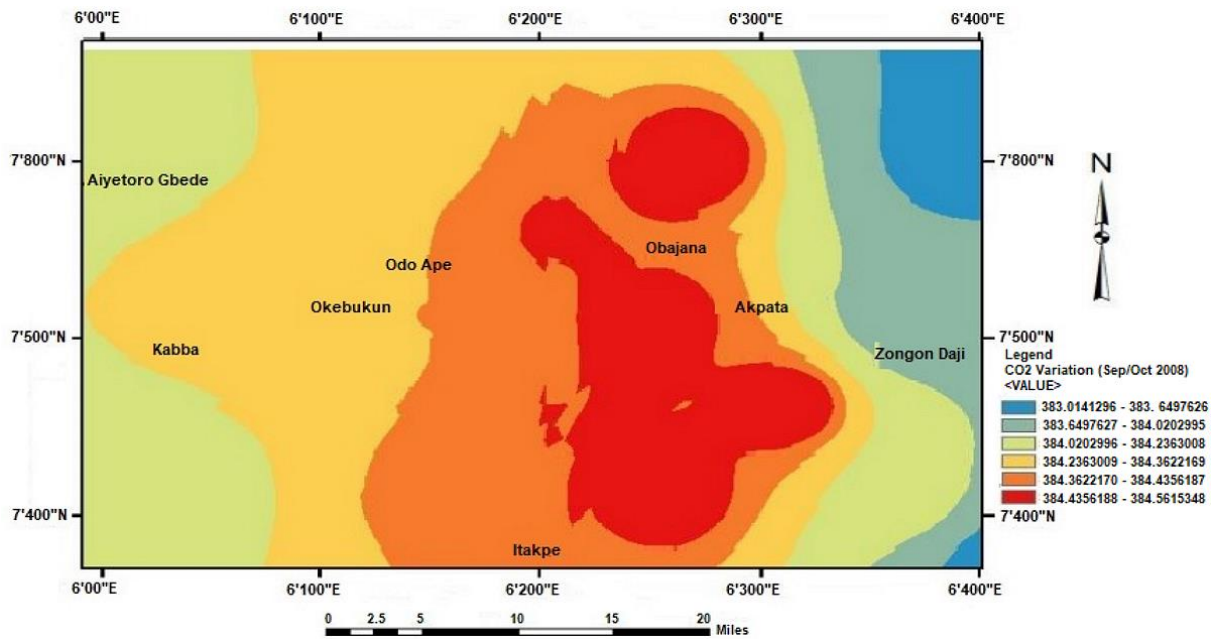


Figure 4a. Variation of CO₂ concentration in September/October 2008

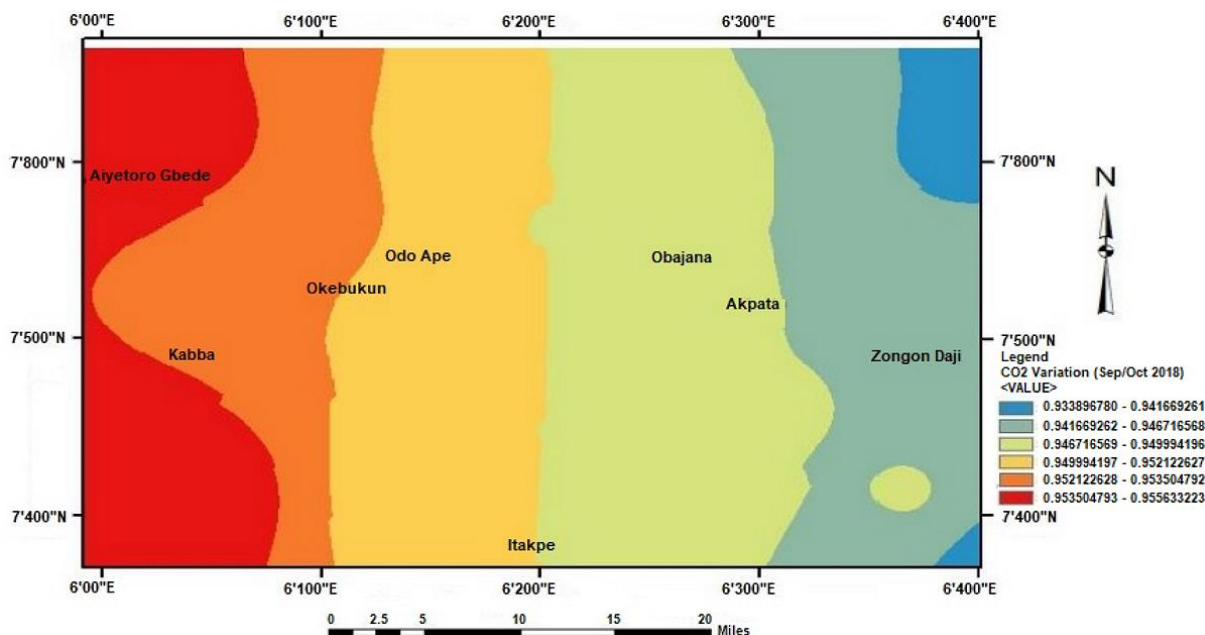


Figure 4b. Variation of CO₂ concentration in September/October 2018

By comparing the concentrations of CO₂ variations in the study areas before and after the commencement of Dangote Obajana Cement Plant operations in March/April and September/October of each year, it was discovered that there were no significant differences between the concentrations of CO₂ variations of the study areas before and after the commencement of the company operations. On the other hand, there were disparities in CO₂ concentrations in March/April and September/October of each year, since the variations in concentrations were scattered and not uniformly distributed in September/October, but they were consistently distributed in March/April. Because there were no significant differences in CO₂ concentrations throughout the sample areas, the data demonstrated that the Dangote Obajana Cement Plant's operation is contributing little to CO₂ variation across the study areas.

3.2. Statistical Analysis of the Concentration of CO₂ Variation

Table 3 displays the annual descriptive statistics for CO₂ variation at the minimum and maximum levels across the research locations. For the years 2003, 2008, and 2018, the minimum mean variation was 373.451.07, 382.92054, and 0.950.17, respectively, while the maximum mean variation was 374.931.0, 384.780.69, and 0.970.17. It was discovered that the year 2018 had the minimum CO₂ emissions, while the year 2008 had the maximum CO₂ emissions. This replicated the fact that the Dangote Obajana Cement Plant contributed little to CO₂ concentration variations across the study locations as a result of non-uniformity in CO₂ variation. Normally, we

would expect CO₂ variations to rise in 2003 (before the company's existence) and continue to rise steadily through the years 2008 and 2018, however, this was not the case. By getting the minimum concentrations of CO₂ variation in the year 2018 after nearly twelve years of Dangote Obajana Cement Plant operations, it was obvious that the plant had little impact on CO₂ concentrations across the research locations. This can be related to the efficiency of the electrostatic separator-based approach to handling and reducing CO₂ emissions from industrial plants. The change in CO₂ from the research areas may be the result of CO₂ emissions from the transportation sector, forestry, land use, and other factors, while CO₂ variations can be easily changed by a variety of factors such as wind, pressure, and rainfall.

Table 4 illustrates the results of a Bonferroni test used to determine the year that contributed to the difference in CO₂ emissions between the minimum and maximum concentrations. A pairwise comparison reveals that all years had CO₂ emissions that were significantly different from one another as their p-values were less than 0.05. Also, the findings revealed that the minimum emission occurred in 2018 and the maximum occurred in 2008.

Table 3. Descriptive statistics of the minimum and maximum variation of CO₂

Year	Mean (Min)	Mean (Max)	Frequency
2003	373.45±1.07	374.93±1.00	62
2008	382.92±0.54	384.78±0.69	62
2018	0.95±0.17	0.97±0.17	46
Total	277.33±168.14	277.33±168.88	170

Table 4. Analysis of variance of the minimum and maximum CO₂ variations

Minimum CO ₂ Variations					
	SS	Df	MS	F	Prob>F
Between groups	4777755.9	2	2388877.95	4500000	0.01
Within groups	89.3744595	167	0.535176404		
Total	47777845.27	169	28271.2738		
Maximum CO ₂ Variations					
Source	SS	df	MS	F	Prob>F
Between groups	4819722.19	2	2409861.09	4400000	0.01
Within groups	92.0886893	167	0.551429277		
Total	4819814.28	169	28519.6111		

4. Conclusions

The variation in concentration of CO₂ emissions within the environment of the Dangote Obajana Cement Plant in 2003, 2008, and 2018 was studied. The findings revealed that there were no significant differences between the concentrations of CO₂ variation before and after the commencement of the company operations. The annual descriptive statistics for CO₂ variation for the years 2003, 2008, and 2018, showed that the minimum mean concentration was 373.451.07, 382.92054, and 0.950.17, while the maximum mean concentration was 374.931.0, 384.780.69, and 0.970.17. Bartlett's test for equal variances, with chi-squares statistics of 103.44 and 12.33, and a probability value of Prob>chi² = 0.001 established that the minimum and maximum CO₂ emissions variances within the years are significantly different. However, the result of the Bonferroni test to determine the year that contributed to the difference in CO₂ emissions between the minimum and maximum concentrations revealed that all the years had CO₂ emissions that were significantly different from one another as their p-value was less than 0.05. Also, the result revealed that the minimum emission occurred in 2018 and the maximum occurred in 2008. The study concluded that the influence of the Dangote Obajana Cement Plant's operation on the releases of CO₂ concentrations across the study areas was insignificant since there was no uniformity in their concentrations. Moreso, the impact of variation of CO₂ and other greenhouse gases (GHG) generated from Dangote Obajana Cement Plant's operation on the climate change of the study areas should be investigated in the future.

REFERENCES

- [1] Union of Concerned Scientists (UCS), "Each Country's Share of CO₂ Emissions.", Online available from

www.ucsusa.org/globalwarming/science-and-impacts/science/each-countrys-share-of-co2.htm l#.XFhLji2ZOqA.

- [2] Chestney N, "Global Carbon Emissions Hit Record High in 2017." Reuters, Thomson Reuters, 22 Mar. 2018, Online available from <https://www.reuters.com/article/us-energy-carbon-ia/global-carbon-emissions-hit-record-high-in-2017-idUSKBN1GYORB>.
- [3] Global Carbon Atlas (GCA, 2020). Emissions fossils, Online available from <http://www.globalcarbonatlas.org/fr/CO2-emissions>.
- [4] J. C. López, G. Quijano, T. S. O. Souza, J. M. Estrada, R. Lebrero, R. Muñoz. Biotechnologies for greenhouse gases (CH₄, N₂O, and CO₂) abatement: state of the art and challenges. *Applied Microbiology and Biotechnology*, Vol.97, No.6, 2277–2303, 2013
- [5] Climate Watch (CW) and World Resources Institute (WRI). Global Historical Emissions. Data published by CAIT Climate Data Explorer via Climate Watch. Online available from <https://www.climatewatchdata.org/data-explorer/historical-emissions>.
- [6] World Resources Institute (WRI). Online available from https://www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector?utm_source=twitter&utm_medium=ghgprotocol&utm_campaign=socialmedia&utm_term=e03cfd49-08dc-4c1c-851e-c2f12d81f464.
- [7] Ritchie H, Roser M. "CO₂ and Greenhouse Gas Emissions". Online available from <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>.
- [8] G Mengpin, J Friedrich, L Vigna, 4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors. Online available from <https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors>
- [9] Olivier J. G. J, Peters J. A. H. W. Trends in global CO₂ and total GHG emissions. 2018 Report. PBL Netherlands Environmental Assessment Agency, The Hague. Online available from <https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gasemissions-2018-report>.
- [10] Crippa M, Oreggioni G, Guizzardi D, Muntean M, Schaaf E, Lo-Vullo E, Solazzo E, MonfortiFerrario F, Olivier J. G. J,

- Vignati E. Fossil CO₂ emissions of all world countries, 2019. Online available from <https://edgar.jrc.ec.europa.eu/overview.php?v=booklet2019>.
- [11] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2022: Summary for Policy Makers. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Mitigation of Climate Change. Geneva, Switzerland, IPCC AR6 WG III, 63, 2019
- [12] International Energy Agency (IEA), Global CO₂ emissions rebounded to their highest level in history in 2021. Press release 8 March 2022. Online available from <https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2>.
- [13] United State Environmental Protection Agency (US EPA), Non-CO₂ Greenhouse Emission Projections & Mitigation Potential Reports (2019 & 2022). Online available from <https://cfpub.epa.gov/ghgdata/nonco2/>
- [14] T. A. Boden, G. Marland, R. J. Andres. Global, Regional, and National Fossil-Fuel CO₂ Emissions. Carbon Dioxide Information Analysis Center, doi 10.3334/CDIAC/00001_V2017, 2017
- [15] Timperley J, Why cement emissions matter for climate change? Carbon brief. Online available from <https://www.carbonbrief.org/qa-why-cement-emissions-matter-for-climate-change>.
- [16] Ramsden K, Cement and Concrete: The Environmental Impact, PSCI 3, November 2020. Online available from <https://psci.princeton.edu/tips/2020/11/3/cement-and-concrete-the-environmental-impact>
- [17] Garside M, Global cement production 1995-2021. Online available from <https://www.statista.com/statistics/1087115/global-cement-production-volume/>
- [18] E Worrell, L. Bernstein, J. Roy, L. Price, J. Harnisch. Industrial energy efficiency and climate change mitigation. Energy Efficiency, Vol.2, 109-123, 2009.
- [19] Hatfield A. K, Mineral Commodity Summaries. U.S. Geological Survey, Online available from <https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-cement.pdf>.
- [20] Rubenstein M, Emissions from the Cement Industry. State of the Planet, Colombia Climate School, Climate 9 May 2012. Online available from <https://news.climate.columbia.edu/2012/05/09/emissions-from-the-cement-industry/>
- [21] Dworzan M, Reducing industrial carbon emissions. MIT Joint Program on the Science and Policy of Global Change Publication Date: July 21, 2021. Online available from <https://news.mit.edu/2021/reducing-emissions-decarbonizing-industry-0721>
- [22] Lehne J, Preston F, Making Concrete Change: Innovation in Low-carbon Cement and Concrete, Chatham House Report 13 June 2018. Online available from <https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete>
- [23] E. Oreane, D. Vuuren, K. Kermeli, W. Crijns-Graus, B. J. Ruijven, S. Mima, E. Worrell. The scope for better industry representation in long-term energy models: Modeling the cement industry long-term energy models. Applied Energy, Vol.240, 964-985, 2019.
- [24] International Energy Agency (IEA), Energy Technology Perspectives 2020. Online available from <https://www.iea.org/reports/energy-technology-perspective-s-2020>, accessed March 2022.
- [25] M. Tang, S. Wang, C. Dai, Y. Liu. Exploring CO₂ mitigation pathway of local industries using a regional-based system dynamics model. International Journal of Information Management, <https://doi.org/10.1016/j.ijinfomgt.2020.102079>, 2020
- [26] M. O. Dioha, A. Kumar. Exploring greenhouse gas mitigation strategies for agriculture in Africa: The case of Nigeria. Ambio, doi: 10.1007/s13280-019-01293-9, 2019
- [27] World Bank. Nigeria Greenhouse Gas (GHG) Emissions 1970-2022. Online available from <https://www.macrotrends.net/countries/NGA/nigeria/ghg-greenhouse-gas-emissions/net>. Retrieved 2022-04-21
- [28] S. O. Olayinka, R. L. Oluwafemi, A. A. Olatunde, K. O. Moradeyo, B. B. Oluwafemi. Energy and cost analysis of cement production using the wet and dry processes in Nigeria. Energy and Power Engineering, Vol.5, 537-550, 2013
- [29] M. A. Etim, K. Babaremu, J. Lazarus, D. Omole. Health risk and environmental assessment of cement production in Nigeria. Atmosphere, <https://doi.org/10.3390/atmos1209111>, 2021
- [30] M. Schneider, M. Romer, M. Tschudin, H. Bolio. "Sustainable Cement Production-Present and Future," Cement and Concrete Research, Vol.41, No.7, 642-650, 2011
- [31] Ibanga I. Dangote's Obajana Cement Plant, Kogi State Nigeria. Online available from <https://infoguidenigeria.com/obajana-cement-plant/>