NITROGEN DIOXIDE AND SULPHUR DIOXIDE POLLUTANTS FROM CEMENT FACTORIES AND URBAN ENVIRONMENT IN OGUN STATE

BY

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DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY

FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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AN UNDERGRADUATE PROJECT SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA; IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.Sc) DEGREE IN ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY.

NOVEMBER, 2022

CERTIFICATION

This is to certify that this research titled “Comparing NO_2 and SO_2 Pollutants from cement factories and Urban Environment in Ogun state” was carried out by “OMOFOMWAN OSAMUDIAMEN VICTORY" and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc.) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science in Environmental Management and Toxicology.

………………………………… ………………………..

PROF. A. A. ENUNEKU **Date**

Project Supervisor

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PROF. A.A. ENUNEKU **Date**

Head of Department

DECLARATION

I “OMOFOMWAN OSAMUDIAMEN VICTORY” declare that “Comparing Nitrogen dioxide NO_2 and Sulphur dioxide SO_2 Pollutants from cement factories and Urban Environment in Ogun State" is my own work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

OMOFOMWAN OSAMUDIAMEN VICTORY

…………………………………….

Date …………………………………………….

DEDICATION

This work is dedicated to God Almighty for His mercy and grace during the period of carrying out this research and to my loving parents Mr. & Mrs. Omofomwan.

ACKNOWLEDGEMENTS

I am indebted to Almighty God for His faithfulness, mercy, protection, favour, guidance, and blessing over my life from the beginning of this programme to the end. I give God all the praise.

My gratitude goes to my able and dynamic supervisor, Prof. Alex Enuneku Your fatherly roles, patience, constructive criticism, guidance, patience and advice have led to the success of this research project. God bless you and your family. My profound appreciation also goes to the Head of Department (HOD) Prof Alex Enuneku and all the lecturers in the department of Environmental Management and Toxicology for their contributions and encouragement throughout the course and success of this research project. I also acknowledged Geographical Information system tutor Dr. Ehinlaiye Ayamezimi who despite his busy schedule contributed greatly.

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I also express my deep appreciation to my friend Eng. Vincent, Mr. Justice, Eng. Moses, and friends in the department especially Obasohan Aisosa, Okoli Jennifer, Ijeoma, Shanney, Justina, Paul, Glory, Collins, and Marizu Blessing. God bless you all. I equally acknowledge my course mates and many others whose names were not mentioned because of space. God bless you all richly. (Amen).

TABLE OF CONTENT

LIST OF FIGURES

ABSTRACT

Major contributions to the pollution in the atmosphere are Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) from cement factories as well as other industrial activities in Urban and Rural areas. The study area covers Ibese, Paplanto, Abeokuta, Ewekoro and other rural areas as they play host to either cement factories or congested urban. This research compared the amount of NO_2 and SO_2 released into the atmosphere at Ibese, Papalanto and Abeokuta. Sentinel 5P data for the study area was used to monitor these pollutants. Google earth engine editor was used to extract the pollutants over the study area. The duration considered was a 4-month interval within year 2019 to 2021 which was used to present 3 spatial maps per year resulting in a total of 9 maps for both pollutants. SO_2 concentration ranged between -0.000161 to 0.0000782; -0.000206 to 0.000162; 0.000194 to 0.000228, for 2019, 2020 and 2021 respectively. NO_2 concentration ranged between 0.0000459 to 0.0000846, 0.0000491 to 0.0000947, 0.0000565 to 0.000122 mol/m^2 for 2019, 2020 and 2021 respectively. The spatial distribution for both pollutants were regrouped into 4 classes namely low, moderate, high and very high. Ibese fell once within the low class, seven times within the moderate class, five times each within the high and very high class respectively considering both the NO_2 and SO_2 maps. Papalanto fell twice within the low class, once within the moderate class, six times within the high class and eight times within the very high class. Abeokuta fell six times within the moderate class and twelve times within the high class. The most dominant zone is the moderate zone followed by the high zone for SO_2 and NO_2 between 2019 and 2021. The frequency of occurrence of Papalanto and Ibese within the peak zone of SO_2 and NO_2 was very high when compared to the frequency of occurrence of Abeokuta which never fell beyond the high zone of either pollutant. This was attributed to the cement factory working nonstop located within Papalanto and Ibese.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Air pollution is the contamination of air via a physical, biological, or chemical alteration to the air in the atmosphere which is deleterious to human health. It is grouped into two categories which are outdoor air pollution and indoor air pollution (NIEHS, Air pollution,). Outdoor air pollution occurs outside of the indoor environment and include fine particles from fossil fuel combustion, noxious gases, ground-level ozone, and tobacco smoke (NIEHS, Air Pollution,). Indoor air pollution refers to exposures that take place within houses and buildings to particulates carbon-oxides, and other pollutants via indoor air and dust; which include gases, household products, building materials, outdoor indoor allergens, tobacco smoke, mold, and pollen (Block and Calderon-Garciduenas, 2009).

Outdoor air pollution is an important environmental health issue in the 21st century and results to approximately 3.7 million deaths globally (Rai *et al*., 2017; WHO, 2013). Exposure to outdoor air pollution can cause adverse effects on humans, other living organisms, and the natural environment (Kim *et al.,* 2015). Also, it has been associated with global climate change, acid rain, ozone depletion, and damage to crops (Garbisu, and Alkorta, 2001). Air pollutants are categorized as primary and secondary pollutants. Primary pollutant are obtained from natural and anthropogenic processes, such as ash from a volcanic eruption or dust from the production of cement; while secondary pollutants are produced in the air by the interaction of primary pollutants (Alvarez-Vazquez *et al*., 2017). Air pollutants include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, volatile organic compounds (VOCs), and particulate matter (PM) (Mustafic *et al*., 2012)

Air pollution can occur through emissions from stationary and mobile sources. A stationary source is a fixed location such as factories, refineries, boilers, and power plants, which releases different types of air pollutants (US EPA, 2015). Stationary sources are divided into point and area sources. Point sources are linked to manufacturing and industrial processes, while; area sources refer to small and *widely* distributed emission sources which may possess substantial cumulative emissions such as residential water heaters, wood burning fireplaces (TCEQ, 2018, NJDEP, 2022). Pollutants may be released from smokestacks, storage tanks, equipment leaks, process vents, and loading and unloading operations (Stationary sources, 2022). While, mobile sources refer to non-stationary sources which are divided into on road vehicles (automobiles, buses, trucks, motorcycles) and non-road vehicles and engines (e.g., ships, trains, heavy equipment, locomotives, and aircraft) (US EPA, 2016). Industrialization plays a vital role in economic growth and social development; however, it can result in environmental degradation, ecological threats, and adverse human health effects.

Unfortunately, studies have shown that small and mid-sized industries do not make use of pollution control measures, which increases the release of air pollutants, especially in populated areas (Afroz *et al*., 2003). Apart from topography, meteorology, traffic emissions and population crowding in urban zones, the presence and proximity of industrial sources can increase the risk of air pollution (Arias-Ortiz *et al.*, 2017).

The lithosphere and hydrosphere are natural resources that enhance agriculture and the development of human race but are frequently subjected to great exploitation and degradation by natural and human factors (Mohammad *et al.,* 2008). McGrath *et al.* (2001) proposed two kinds of pollution sources are responsible for this degradation of land and water which include pollution from industrialization, agricultural activities, and motorization usage while each of the sources affects plants and animals alike as well as posing great danger to human health. Most heavy metals are not easily degradable and thus find their way into water bodies and soils, where they are bio-accumulated in the food chain. Humans are exposed to certain carcinogenic metals (As, Cd, Ni, Pb, Cr, and Co) through ingestion of contaminated foods (Garbisu & Alkorta, 2001). These metals thereby, pose a great threat to human existence and the environment at large.

Exposure to environmental pollutants in the cities is of severe environmental and health concern today in the world (Bickerstaff & Walker, 2001). Studies have documented linkages between health effects and atmospheric pollution (Lee, *et al.,*

2006) leading to adverse health effects ranging from respiratory-related diseases to chronic diseases that could lead to high death rate (WHO, 2013). Bell *et al.* (2005) suggested that poor hygiene and health care delivery are related to low-income populations who are exposed to atmospheric pollution, because they live in a blighted environment, industrial areas and roadsides to gain access to workplace. They thereby exposed themselves to all sorts of environmental hazards; and in many cases denied access to health care delivery leading to death (Bell, 2005). This is particularly high among women and young children, who spend the most time near the domestic health. The World Health Organization is providing technical support to countries in their own evaluations and scale up of promoting safer stove technologies, as well as air quality guidelines with the aim of reducing the health impacts of air pollution (WHO, 2015).

NO_2, SO_2 and CO are categorized under short-lived climate forcers because of the radiative forcing they induce in the atmosphere through the formation of other chemical species. NO_2 and SO_2 are precursors for nitrate and sulphate aerosols, respectively, both of which induce a net cooling effect. CO is a precursor for tropospheric ozone, which bring about a net warming effect. These species also have short atmospheric lifetimes, realistically, days to a few months. SO_2 resides in the atmosphere for 2 days while for NO_2 that time is longer at 1 to 10 days and CO has the longest residence time of 30 to 90 days. This lifetime can change depending on the species height in the atmosphere (Myhre*, et al.,* 2013; Seinfeld and Pandis, 2016). This is why these gases are increasingly becoming regular topics in climate discussions (Stohl, *et al*., 2015; Aamass *et al*., 2017).

Over 3,000 different air pollutants have been identified globally with only a fraction of those investigated for health effects and even fewer monitored in urban areas (Fenger, 2002). The Clean Air Acts of 1970 and 1977 include 6 air pollutants in a category called “Criteria Air Pollutants,” which are monitored and regulated nationally, and most times occur at high concentrations (Fenger, 2002; Miranda *et al.*, 2011). This category includes the pollutant we focus on for this study—nitrogen dioxide (NO_2) & sulfur dioxide (SO_2) as well as carbon monoxide (CO), ozone (O_3), particulate matter and lead.

Sentinel's NO_2 and SO_2 product – 5P (Precursor) is part of the Copernicus global monitoring program dedicated to atmospheric monitoring (ESA, 2020). The mission consists of a satellite with the instrument Tropospheric Monitoring Instrument (TROPOMI), whose main aim is to perform atmospheric measurements with a high spatiotemporal resolution for air quality, ozone, and ultraviolet radiation studies, along with climate monitoring and forecasting. The satellite was launched in October 2017 in Russia and has reported a resolution of 0.01 degrees (ESA, 2020).

Equipped with this information, this research tried to verify air pollutants level within some of the industrial areas and urban areas of Ogun state which are considered as potential sources of pollutant emissions making use of satellite observations to study the long-term trends of NO_2 and SO_2 over the study area.

1.2 AIM AND OBJECTIVES

The aim of the study was to compare NO_2 and SO_2 pollutants around the industrial areas of Papalanto and Ibese and the urban area of Abeokuta.

The objectives were to determine

1. NO_2 variation within the study area
2. SO_2 variation within the study area
3. Changes observed around the areas of interest
4. Descriptive statistics on extracted data

1.3 JUSTIFICATION OF RESEARCH

Industrialization and traffic emissions are sources of NO_2, SO_2, and CO among others into the atmosphere. The concentration of this pollutant may be significant thereby influencing human health, vegetation, and ecosystems. There is a need for these pollutants to be investigated for proper documentation and their links the human health. Therefore, this study seeks to connect the dots between high-air-polluting industries and air quality.

CHAPTER TWO

LITERATURE REVIEW

2.1 CEMENT INDUSTRY

According to Hossain *et al.*, 2016, the cement industry is one of the top polluting industries listed by the Central Pollution Board, with noise and dust being its major pollutants. At every stage of the manufacturing process the pollutants are being emitted, including extraction of the raw materials, crushing, production, etc.

Cement dust changes the elemental concentration of soil and its physicochemical properties (Zerrouqi *et al.*, 2008). It is also the major source of particulate matter such as SO_2, NO_2, and CO_2 emissions. The dust contains heavy metals like chromium, nickel, cobalt, lead, and mercury, which are hazardous to the environment and affect human and animal health. Cement dust may also cause carcinogenesis, decreased antioxidant capacity, acute respiratory symptoms, and acute ventilatory effects in man and animals (Baby *et al.*, 2008).

2.1.1 CEMENT MANUFACTURING

A mixture of calcareous and argillaceous minerals is heated to a temperature of around 1,450 ^{o}C to create cement. The process results in partial fusing and the formation of clinker nodules. The cooled clinker is combined with trace amounts of gypsum and occasionally additional additives before being processed into a raw meal. Figure 2.1 depicts a basic overview of the cement manufacturing process (Duda, 1985; Labalm and Kohlhaas, 1983; Peray and Waddell, 1972)

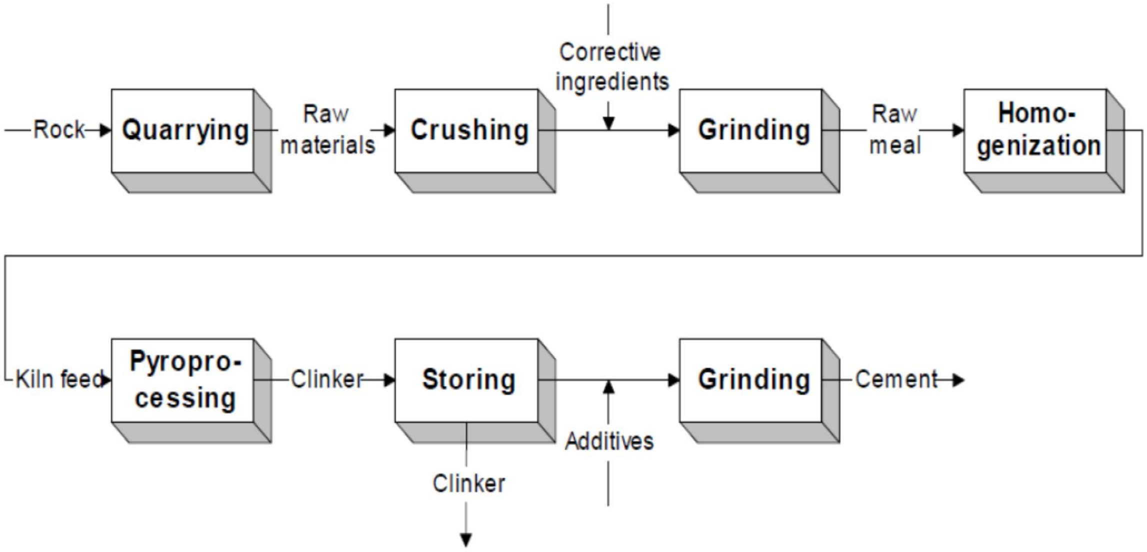

Figure 2. 1: Principle drawing of the cement manufacturing process (Tokheim, 1999)

2.1.2 MODELLING PROCESS

Aspen Plus v10.2 is used to model and determine the mass balance of the molecules involved in chemical processes. A kiln system's incoming and outgoing compound flows need to be studied in order to better control any chemical processes and pertinent modifications (Kaantee, *et al.,* 2001, 2002). The goal of modeling is to determine how effectively a particular type of reactor or separator can accurately depict a specific function in a process and the behavior of a kiln process. Important data on chemical alterations caused by heat transfer in a kiln and other variables affecting the clinker-burning process are included in the modeling process. For a modeling process, chemical tests of the fuel and kiln feed are crucial because these reveal the chemical makeup of emission gases.

The two main processes that cause NOx emissions to be produced during fuel combustion are the oxidation of chemically bonded nitrogen in the fuel and the thermal fixation of nitrogen in the combustion air. As flame temperature rises, more thermally generated NOx is produced. Sulfur compounds in the raw materials and, to a lesser extent, sulfur in the fuel is the sources of SO_2 emissions (Interim White Paper-Midwest, 2006)

2.1.3 GAS POLLUTANTS IN CEMENT ROTARY KILN

The creation of NO from nitrogen and oxygen only occurs at high temperatures therefore the level of NO serves as a gauge for its combined feed and flame temperature. Calcium sulfate in clinker thermally decomposes to produce sulfur dioxide (SO_2), which indicates the temperature of the clinker (Saidu, *et al*., 2011). Anhydrite contains SO_3, which is easily broken down into SO_2 and O_2 (HFW, 1997)

The combustion flame of a rotary kiln produces the nitrogen oxides NO, NO_2, and N_2O, which are released into the environment along with the exhaust gases and undergo a variety of atmospheric processes (Duda, 1985)

2.1.3.1 NITROGEN DIOXIDE (NO2)

Nitrogen oxide (NOx) in the environment is emitted by various air pollution sources. Obvious sources include motor vehicles, boilers, kilns, industrial processes, stoves and many other combustion chambers that burn coal. The dominant source of NOx is the burning of Fossil fuel. NOx emissions from incineration include 95% NO and 5% NO_2. A study in China by Zhao *et al.* (2017), applying the structural equation model, suggested that industrial-scale, urban-scale, and resident activities had a significant impact on NOx emission. Among these factors, industrial-scale activities contributed the most to NOx pollution (Dan *et al*., 2014; Kasulis *et al.,* 2019). NO_2 formed by the photochemical oxidation of ambient NO is a secondary pollutant. However, it has been shown that for mobile NOx sources, the share of NO_2 primary emission may be variable (Yoo *et al.,* 2016). In addition, it depends on vehicle types and operating conditions (Carslaw and Beevers, 2004). A previous study by Ban-Weiss *et al.* (2008) estimated that the major NO_2 emissions came from gasoline, diesel vehicles, and diesel trucks. The results indicated that the NO_2/NOx mixing ratios for gasoline vehicles, diesel vehicles, and diesel trucks were < 0.2 vol.%, 5.9 vol.%, and

11.0 vol.%, respectively. However, NO is not only generated in the combustion of fossil fuels and biomass, but also in the production of adipic acid and nitric acid in nylon 6.6 (Heeb *et al.*, 2006). Additionally, the existing data in the literature show that the NOx emissions from fossil fuel combustion is similar to that in soil, and soil emissions are greatest in areas where a large amount of nitrogen fertilizer is applied (Oenema *et al.*, 2004).

Nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O), which breaks down into NO and NO_2, are all considered important pollutants in the lower atmosphere. Nitric oxide is a colorless gas with a pungent odor, and varies in color from orange-yellow to reddish-brown, it is a powerful oxidizing agent that converts in the air to nitric acid (HNO_3). Sources of NOx are either natural such as volcanoes or industries such as electric power stations, automobile engines, industrial boilers, burners, and factories producing nitrogenous compounds such as nitric acid.

Nitrogen oxides emitted from industrial sources such as fixed industrial furnaces contribute about 30% of nitrogen oxides emissions, and 70% are attributed to power plants (PPAH, 1998; Cooper and Alley, 1994).

2.1.3.2 SULPHUR DIOXIDE (SO_2)

Sulphur dioxide (SO_2) is generated both naturally and anthropogenically via eruptive activity of volcanoes and industrial emissions (fossil fuel combustion included).

In regard to outdoor sources of SO_2, the combustion of fossil fuels is responsible for the vast majority of annual SO_2 emissions, according to the Tropospheric Emission Monitoring Internet Service (TEMIS) (Constantin *et al.,* 2020). Additional smaller amounts of SO_2 are released from natural sources; industrial processes; and vehicles and heavy equipment that burn fuel with a high sulphur content (Hosseiniebalam *et al.*, 2015; Banerjee *et al.*, 2019). There are several studies comparing indoor and outdoor SO_2 levels, with most showing that SO_2 concentrations in indoor environments were lower than those of outdoors (Hisham *et al.*,1991; Yannopoulos *et al.*, 2007). In South African research by Sanyal and Maduna (2000), SO_2 concentrations in the atmosphere were linked with lower socio-economic status.

Fuels containing sulfur release sulfur oxides in the form of SO_2 and SO_3 into the atmosphere. Sulphate of sulfur dissolves in atmospheric water vapor, producing sulfide acid H_2SO_3. Sulfur trioxide is either released directly from the source or produced from the transformation of sulfur dioxide in the air. The Presence of Sulphur dioxide is more common than other sulfur compounds in the lower atmosphere. Sulfur dioxide has a foul odour, it is colourless and its presence in the surrounding air can be sensed by smelling at concentrations within 1,000 to 3,000 µg/m3 (PPAH, 1998).

Papalanto is one of the villages along the Sango-Ifo- Abeokuta expressway of Ogun State of Nigeria. However, the establishment of West African Portland Cement Company (WAPCO) now referred to as Lafarge-Cement WAPCO changed the economic sphere of this once sleepy and serene town (Aribigbola *et al*., 2012). The activities of this industry in Ewekoro area of Papalanto constitute a source of environmental pollution, thus subjecting the inhabitants to hardship from dust-laden and polluted air, cracking of walls of structures, and soil and water pollution by dust.

Ibese is also a village located along Elekuro-Ilaro road of Ogun State, Nigeria. The establishment of Dangote cement also changed the economic sphere of this serene town. There is considerable contribution from the cement industry to the immediate environment and beyond of the town. It is therefore necessary to determine the concentrations of the air pollutants around the cement industry since no such report has been made in recent times.

Abeokuta is the capital of Ogun State and it is a sprawling urban town whose traffic could contribute significantly to air pollution.

CHAPTER THREE

METHODOLOGY

3.1 RESEARCH DESIGN

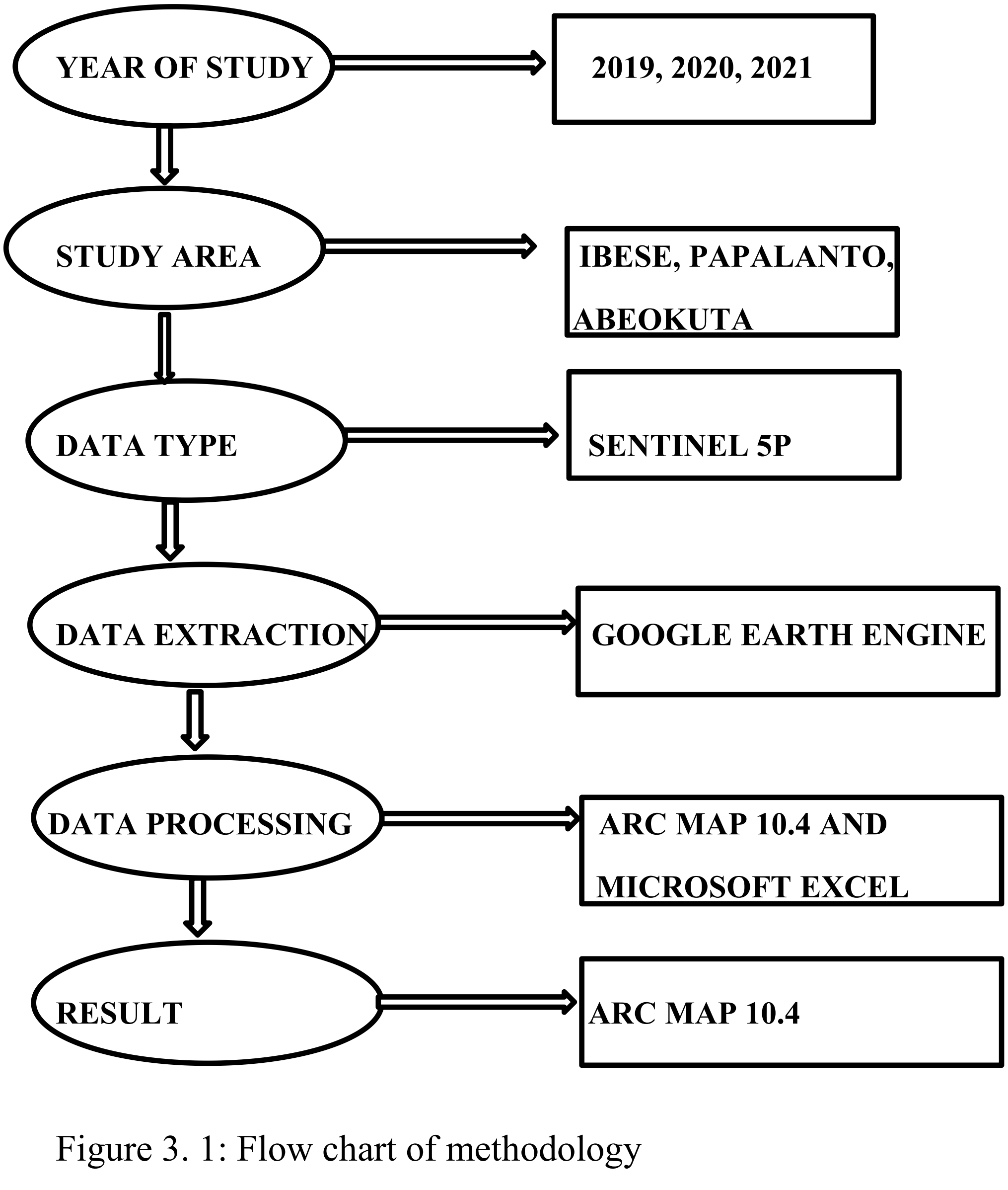

Figure 3. 1: Flow chart of methodology

3.2 REMOTE SENSING DATA

The main tool that will be used in this research is Google Earth Engine (GEE). Google Earth GEE is a platform cloud-based spatial data computing developed by Google, which offers a worldwide analysis of environmental data. GEE is used to analyze satellite data to produce the distribution of pollutant concentrations. GIS software (ArcGIS 10.4) is used to process spatial data and map layout.

The processed data is Tropospheric Monitoring Instrument (TROPOMI) data brought by the Copernicus Sentinel-5 Precursor satellite. The instrument, the single payload of the Sentinel-5P spacecraft, uses passive remote sensing techniques to achieve its goal by measuring, at the Top of Atmosphere (TOA), the solar radiation reflected and emitted from the earth. The instrument operates in a push sweep (non-scan) configuration, with a sweep width of ~2600 km at the earth's surface. The primary aim of the Copernicus Sentinel-5P mission is to carry out atmospheric measurements with high spatio-temporal resolution, which will be used for air quality, ozone, UV radiation, and climate monitoring & forecasting. The satellite was successfully launched on October 13, 2017, from the Plesetsk cosmodrome in Russia. The TROPOMI instrument combines the power of SCIAMACHY, OMI, and advanced technology to provide observations with performances that today's instruments cannot meet in space. The performance of current orbital instruments is surpassed in terms of sensitivity, spectral resolution, spatial resolution, and temporal resolution (European Space Agency, 2014).

The Nitrogen Dioxide (NO_2) data was released on 10 July 2018 while the Sulphur dioxide (SO_2) data was released on 17th October, 2018 and is accessible on the GEE platform. NO_2 and SO_2 in GEE has a spatial resolution of 0.01°or 1.11 km per pixel. In this study, Sentinel-5P satellite data was used to monitor changes in NO_2 and SO_2 pollutants within industrial areas and urban areas. The variables of this research is the level of NO_2 and SO_2 extracted from the Sentinel 5-P Satellite Remote Sensing Data by cloud computing through the GEE platform. Utilization of Sentinel 5-P satellite data for air quality monitoring has been carried out by (Zheng *et al,* 2019; Lorente et al, 2019; Mahato *et al,* 2020; Otmani *et al*, 2020; Shikwambana *et al,* 2020; Goldberg *et al*, 2020; Sanningrahi *et al*, 2021) in several countries, including China, India, Paris, and Africa.

3.3 DATA ANALYSIS

Sentinel 5P TROPOMI satellite data is available in high temporal resolution (daily). Therefore, it is necessary to filter by data acquisition date. The date range chosen for 2019, 2020 and 2021 are January to April; May to August and September to December. The time range was chosen to determine changes in SO_2 and NO_2 gas concentration before around the industrialized and urban area of the study area. The result of this filtering process is a four-month temporal composite image for each pollutant gas SO_2 and NO_2. The data is then imported into the ArcGIS environment using the ArcGIS 10.4. Within the ArcGIS environment, the Clip tool is used to extract the study area. The clipped raster is then projected to the UTM Zone 31 of the WGS 84 datum using the Project Raster tool. The reclassify tool was used to reclass the data into low, moderate, high and very high zones within the study area.

The percentage coverage of the different zones were achieved using the following procedure.

- The reclassed raster was converted to polygon
- The polygon data was dissolved using the grid code field
- Area and percentage fields were added to the attribute table of the dissolved polygon
- The Calculate Geometry function was used to add the area in hectares of the different zones.
- The summarize tool was used to determine the total area coverage of the study area
- The calculate field was used to calculate the percentage coverage using the formula ([Area/Sum total of area]*100)

Furthermore, the results of data extraction for each period both spatially and temporally from January 2019 to December 2021 was used to determine the trend of changes in SO_2 and NO_2 levels around Ibese, Papalanto and Abeokuta.

3.4 LOCATION OF STUDY AREA

The study area presented in figure 1 is located within Odeda, Abeokuta South, Abeokuta North, Egbado North, Egbado South, Ifo, Ewekoro and Obafemi Owode local government area, and lies geographically between latitude N6^{o}52’10” to N7^{o}13’11” and longitude 3^{o}1’16.3E to 3^{o}26’5.5”E. Major towns within the study area include Ibese, Papalanto, Ilaro, Wasinmi, Ewekoro, Abeokuta, Obada and Oke.

3.5.1 ACCESSIBILITY, CLIMATE, AND VEGETATION

The study area is networked by several roads such as Papalanto-Shagamu road, Lagos Abeokuta Road, Logbara-Magbon road classified as expressway as well as Awba road, Owode-Abeokuta road, Ajura-Ogere-Iperu road among others, classified as major roads.

The climate is a humid tropical type and is characterized by wet and dry seasons. The dry season starts around November to March while the wet season starts around April to October. Temperature ranges between 23^{o}C to 33^{o}C with a mean temperature of 28^{o}C while mean annual rainfall is 1300mm.

The vegetation of the study area falls within the transitional zone between the derived savanna and dry lowland forest featuring mainly mixed association of secondary bush re-growth and scattered economic trees which are equally punctuated by a mixture of arable crops and comprised of the degraded rainforest. Some of the common forest trees found within the study area are *Elais guinensis, Bambusa vulgaris, Anogeisus leocarpus* and *Daniella olliveri.*

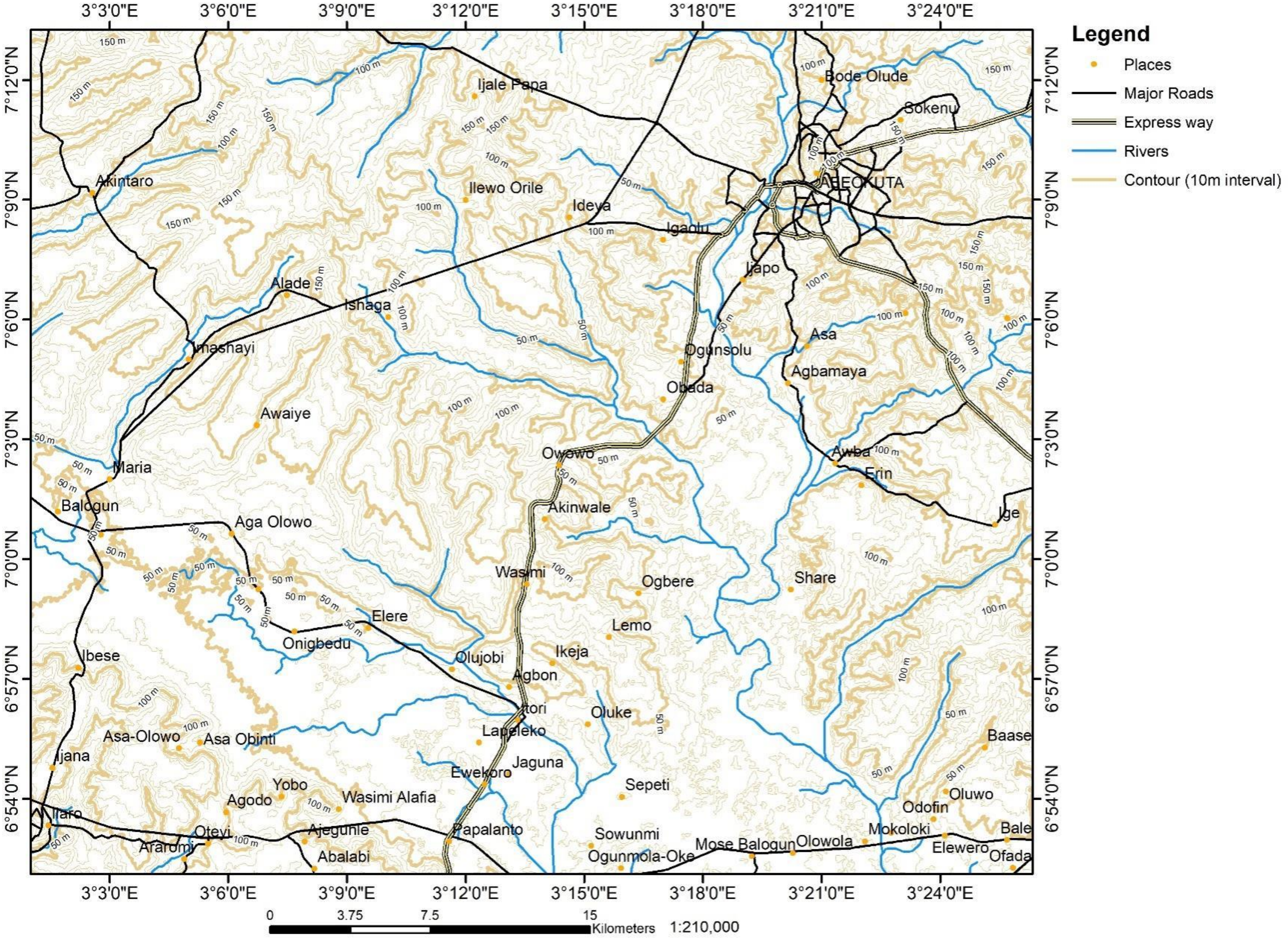

Figure 1. 1: The location map of the study area.

CHAPTER FOUR

RESULTS

4.1 RESULT PRESENTATION

Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) concentration were collected between 2019 and 2021. A 4-month average of January to April, May to August and September to December were used for comparison within the year. The results are presented below.

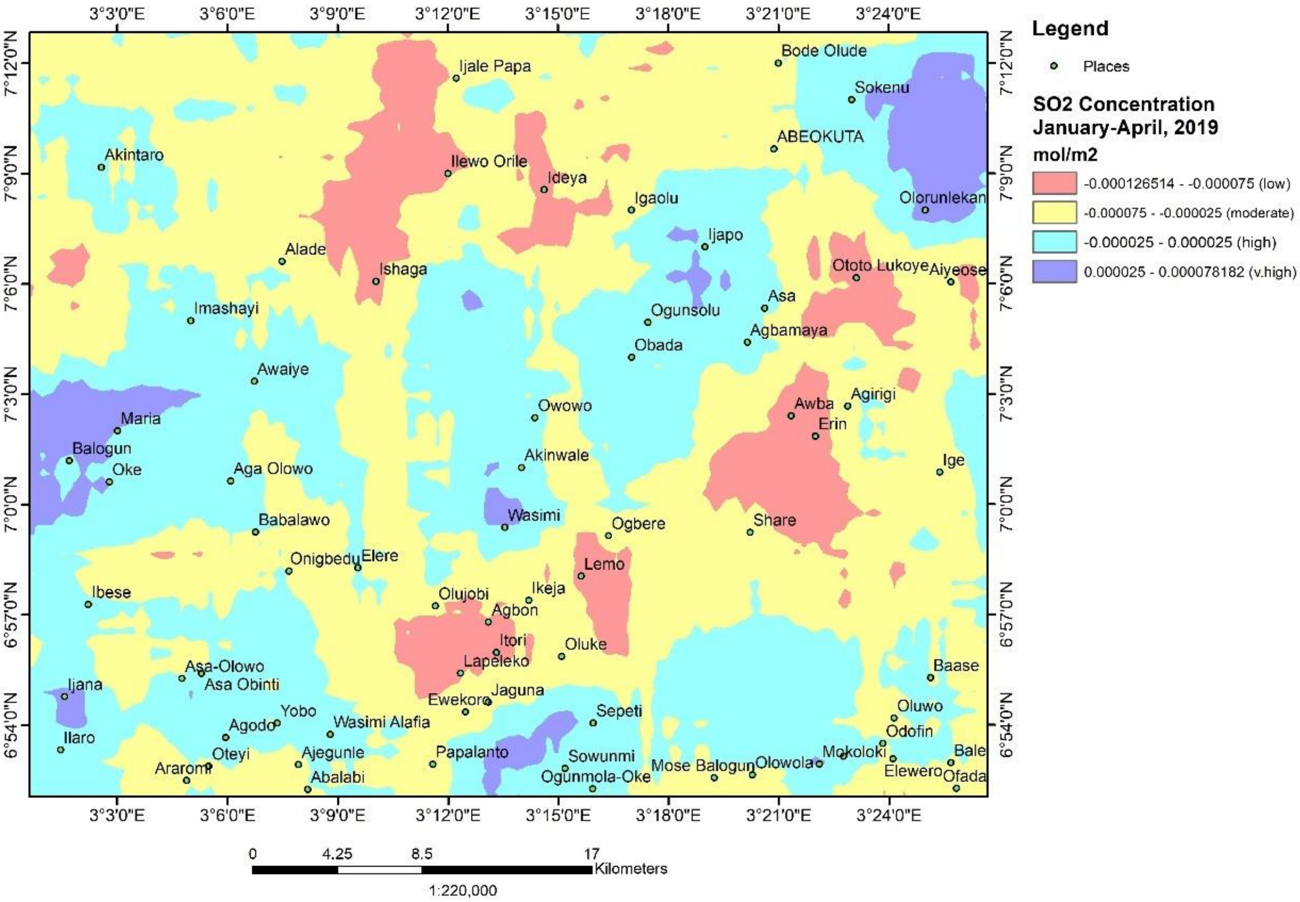

Figure 4. 1: Spatial distribution of average SO_2 between January and April 2019

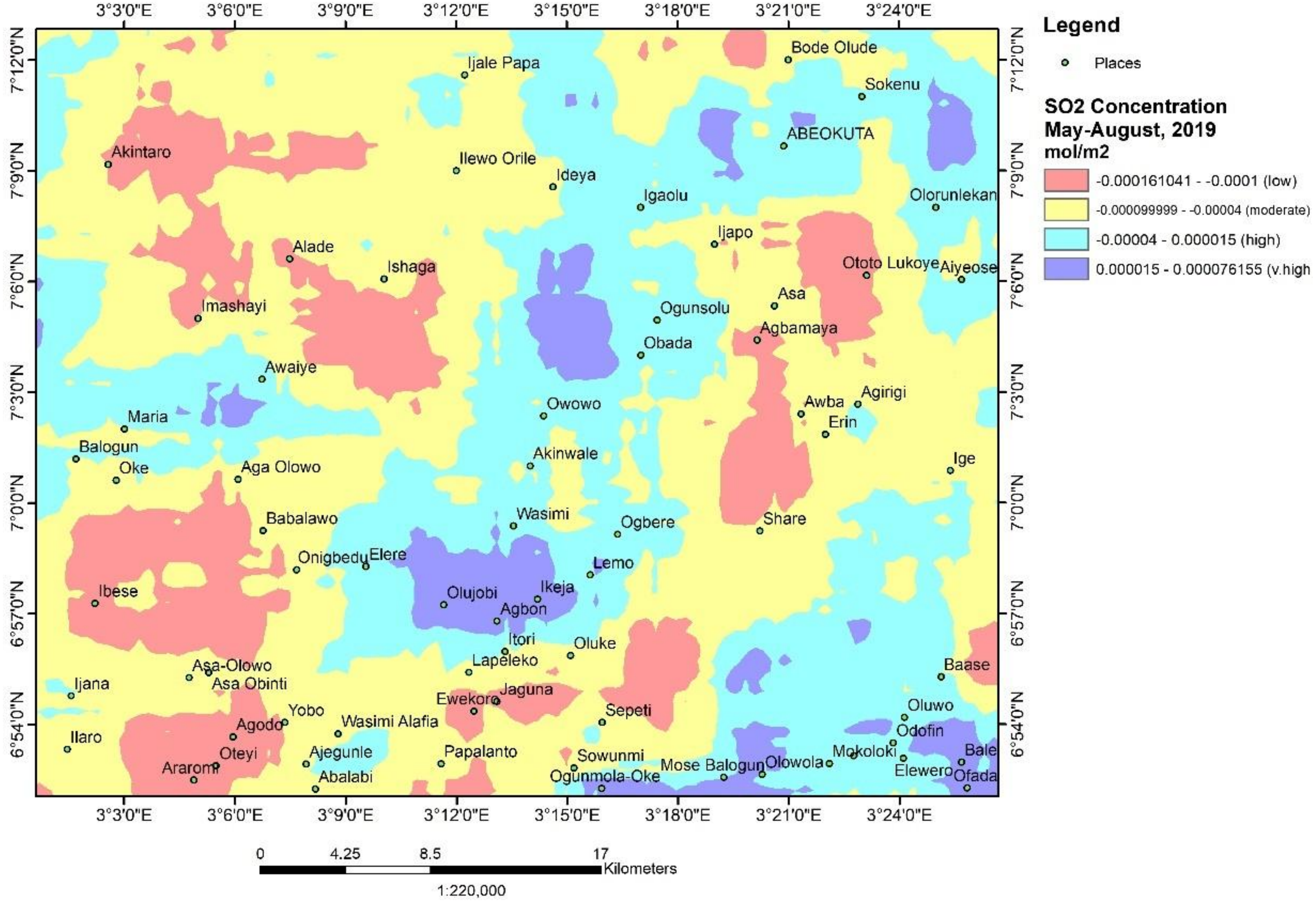

Figure 4. 2: Spatial distribution of average SO_2 between May and August 2019

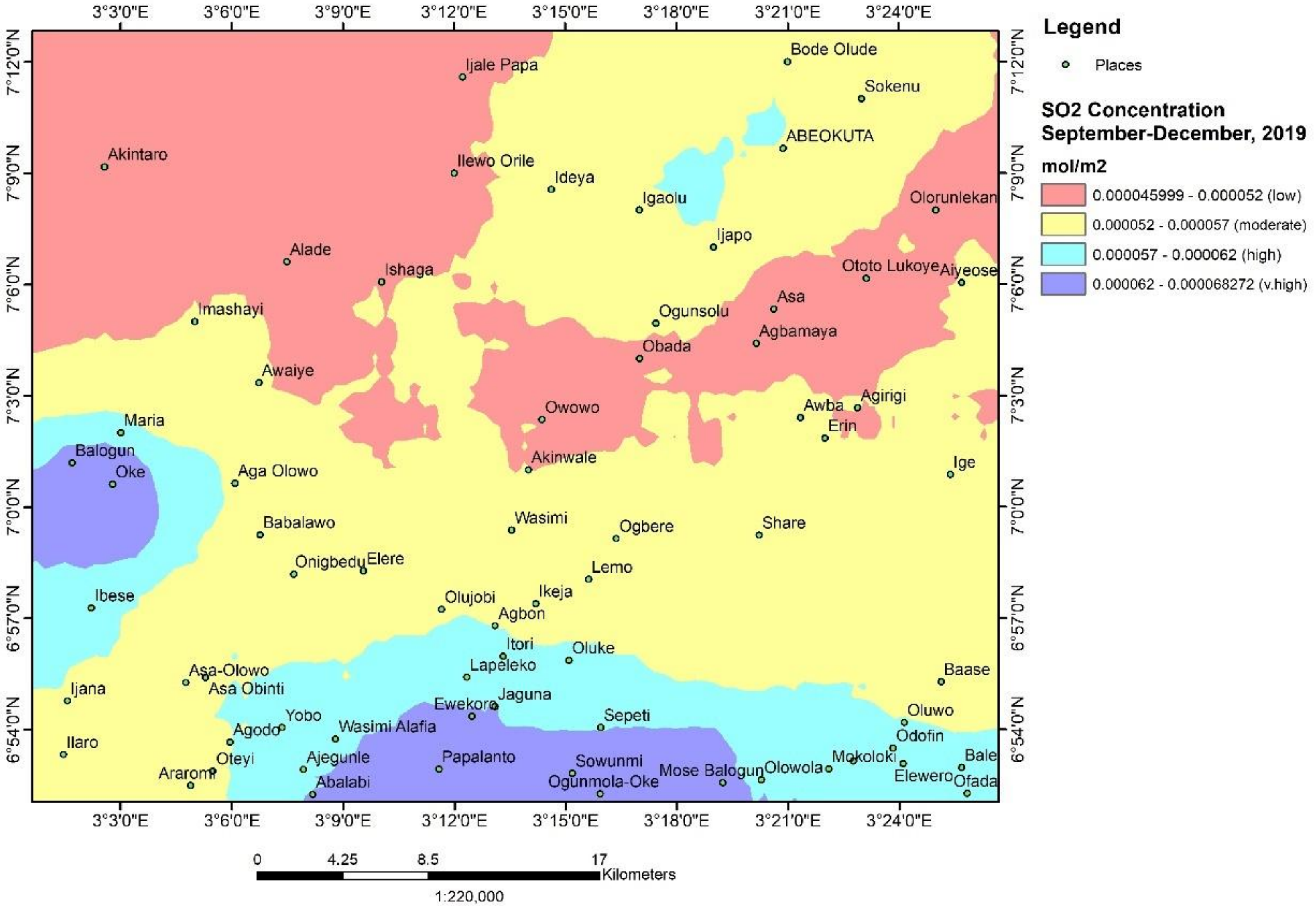

Figure 4. 3: Spatial distribution of average SO_2 between September and December 2019

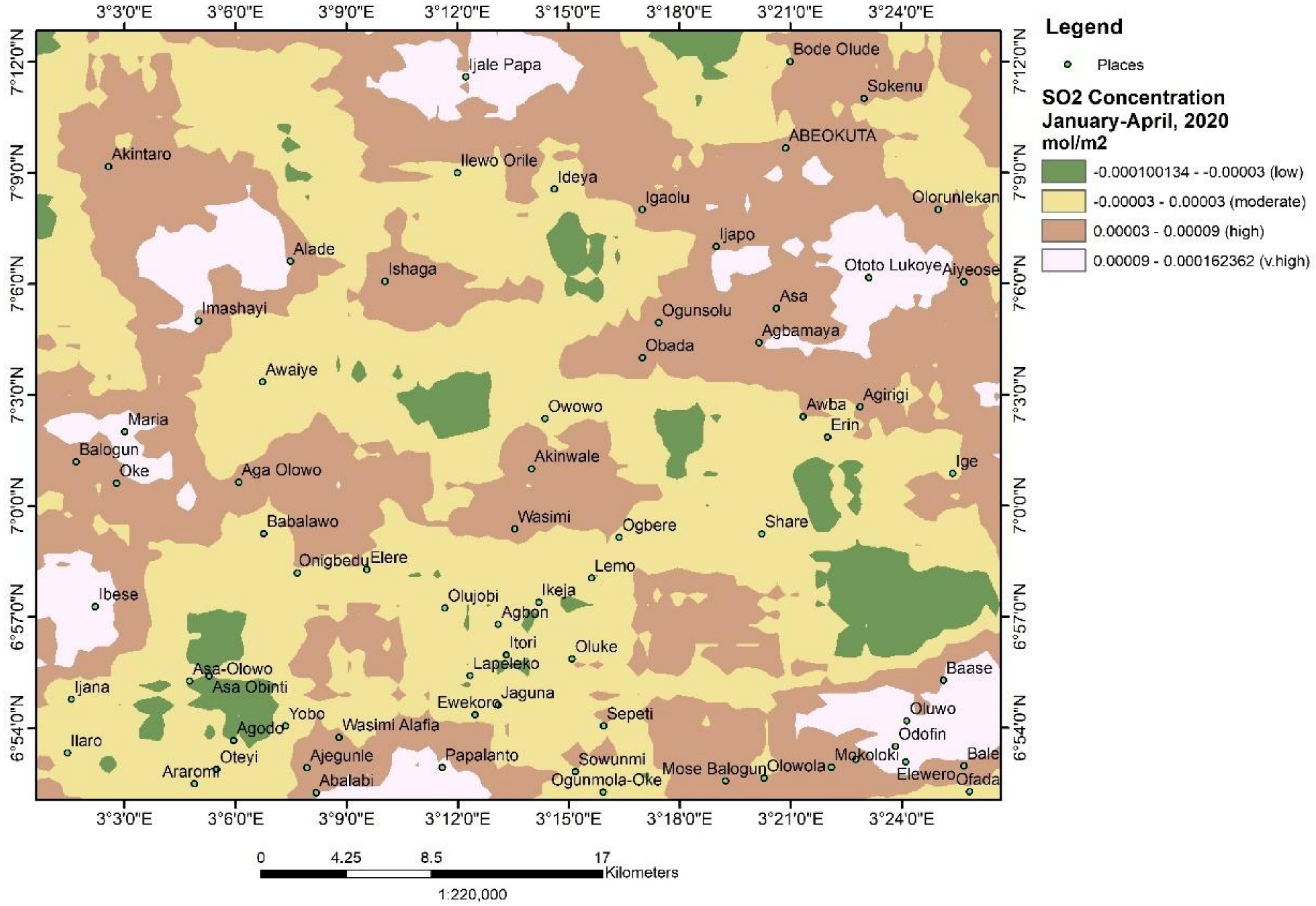

Figure 4. 4: Spatial distribution of average SO_2 between January and April 2020

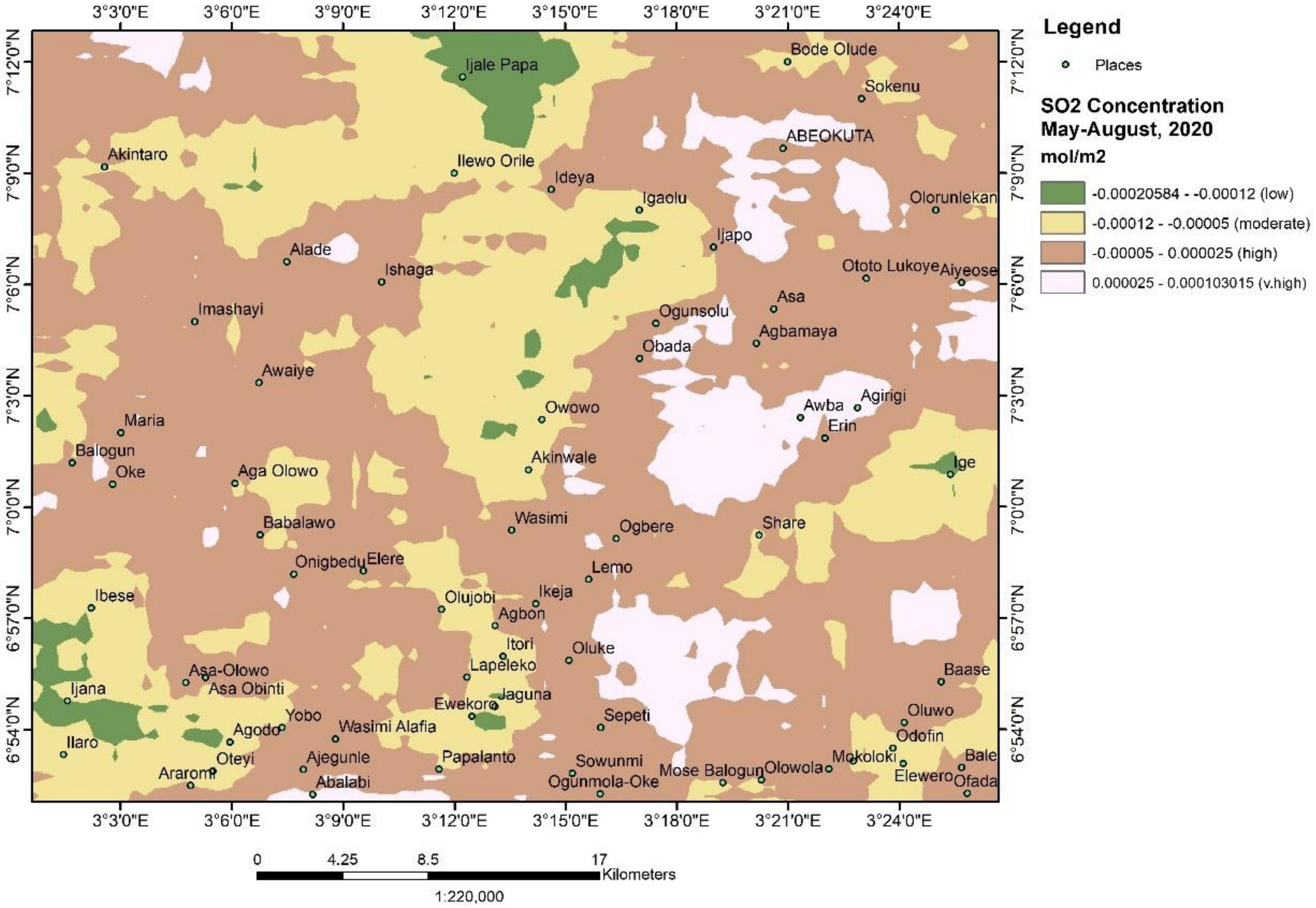

Figure 4. 5: Spatial distribution of average SO_2 between May and August 2020

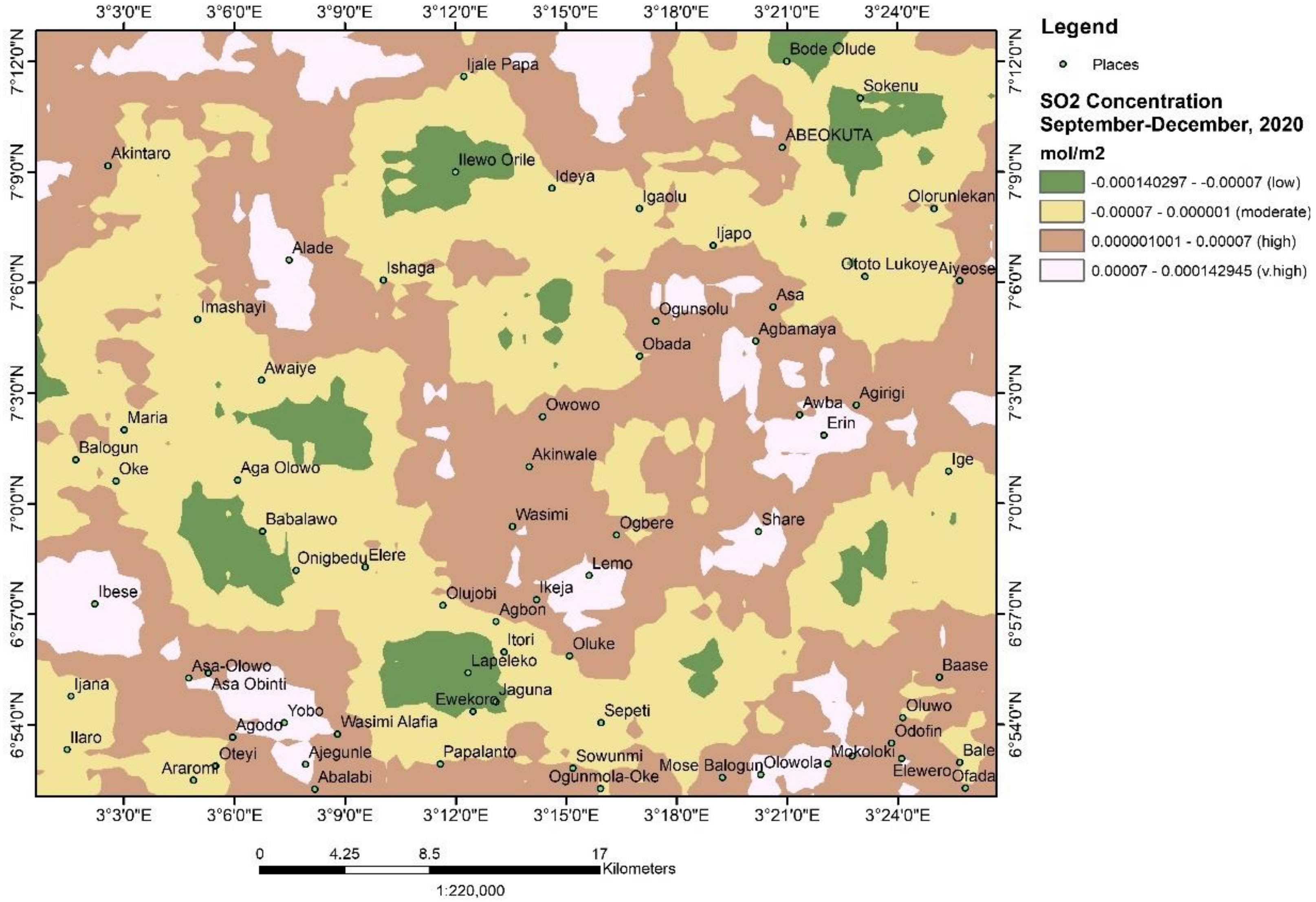

Figure 4. 6: Spatial distribution of average SO_2 between September and December 2020

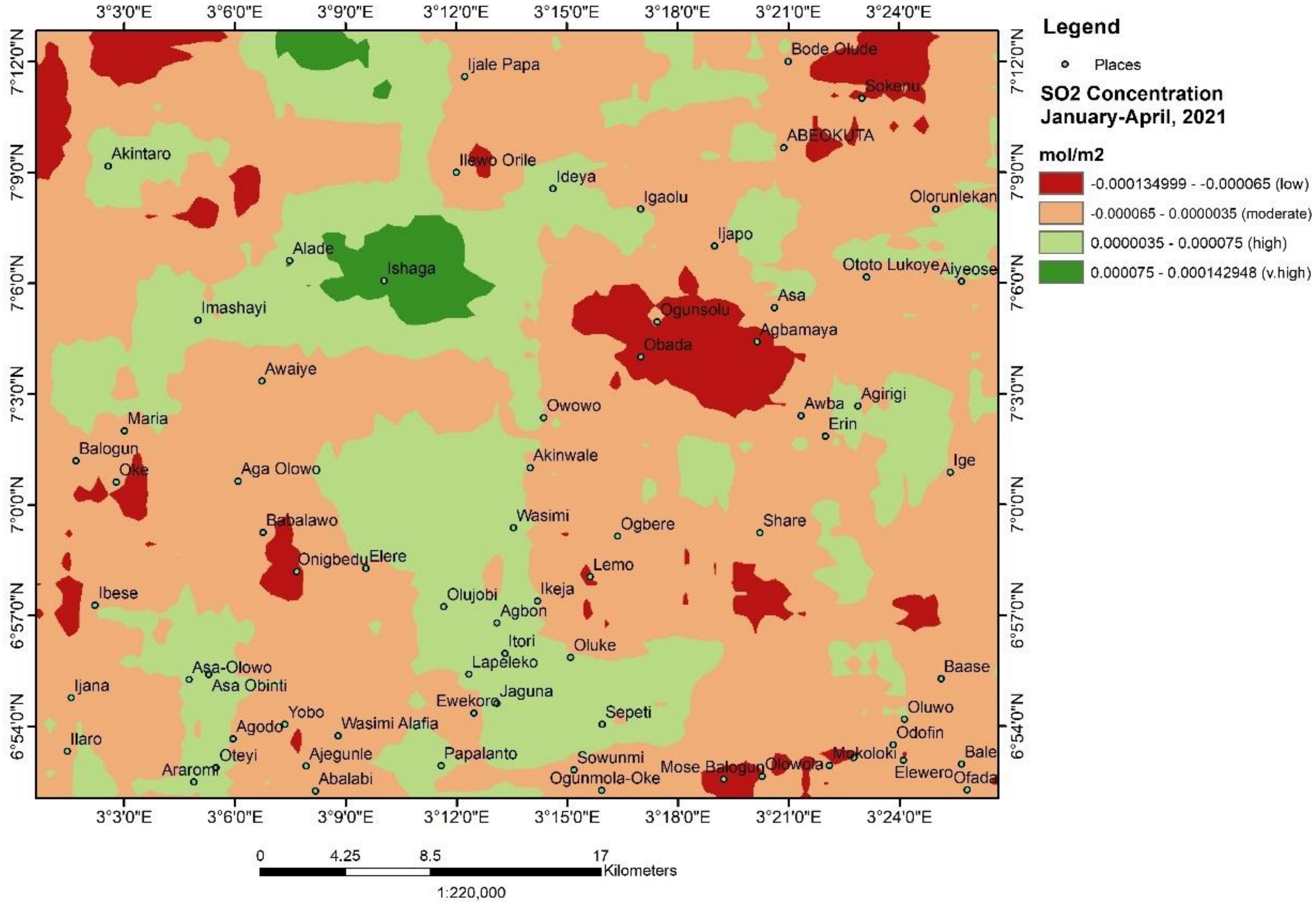

Figure 4. 7: Spatial distribution of average SO_2 between January and April 2021

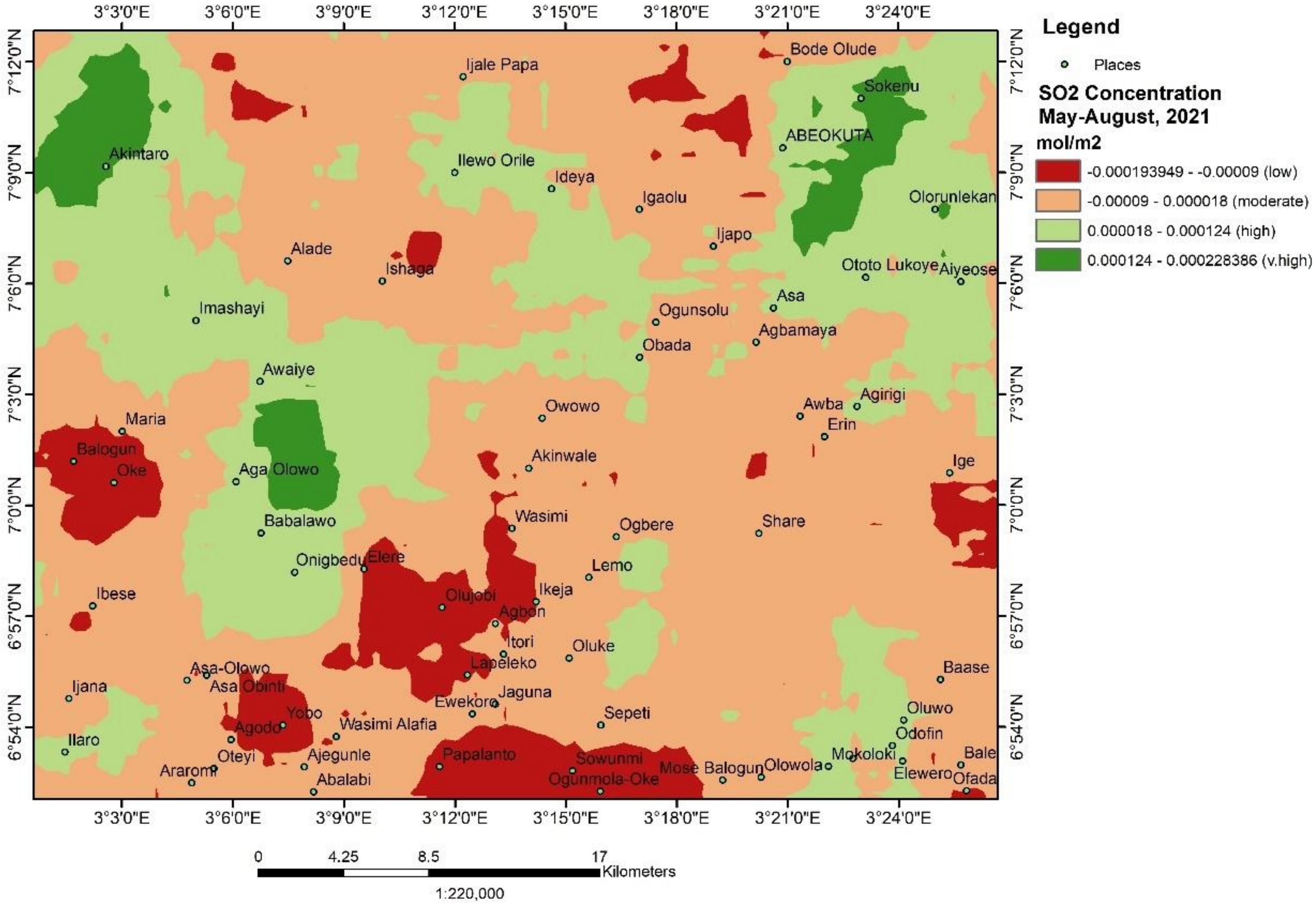

Figure 4. 8: Spatial distribution of average SO_2 between May and August 2021

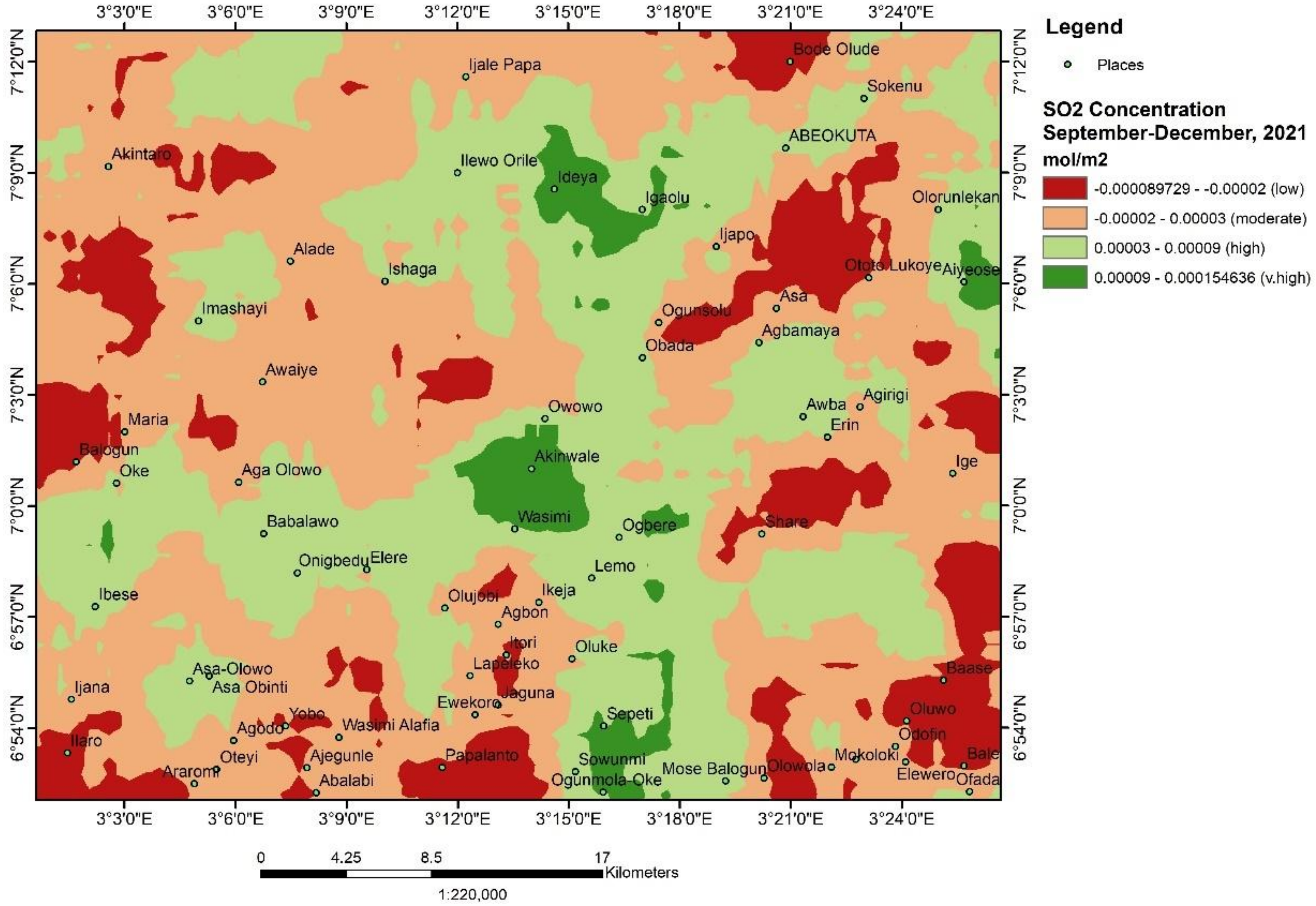

Figure 4. 9: Spatial distribution of average SO_2 between September and December 2021

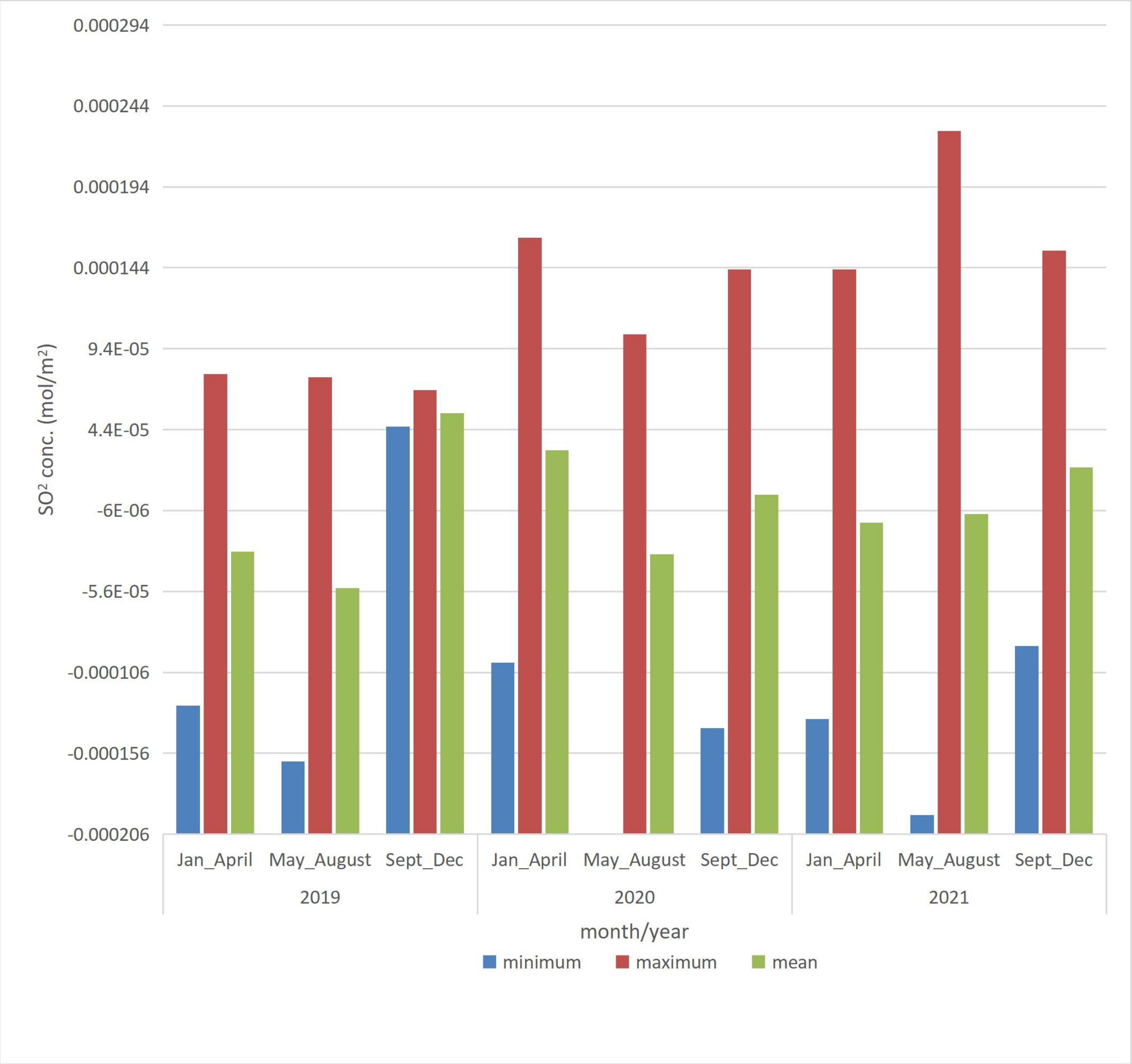

Figure 4. 10: Histogram plot of SO_2 concentration for the 3-year period

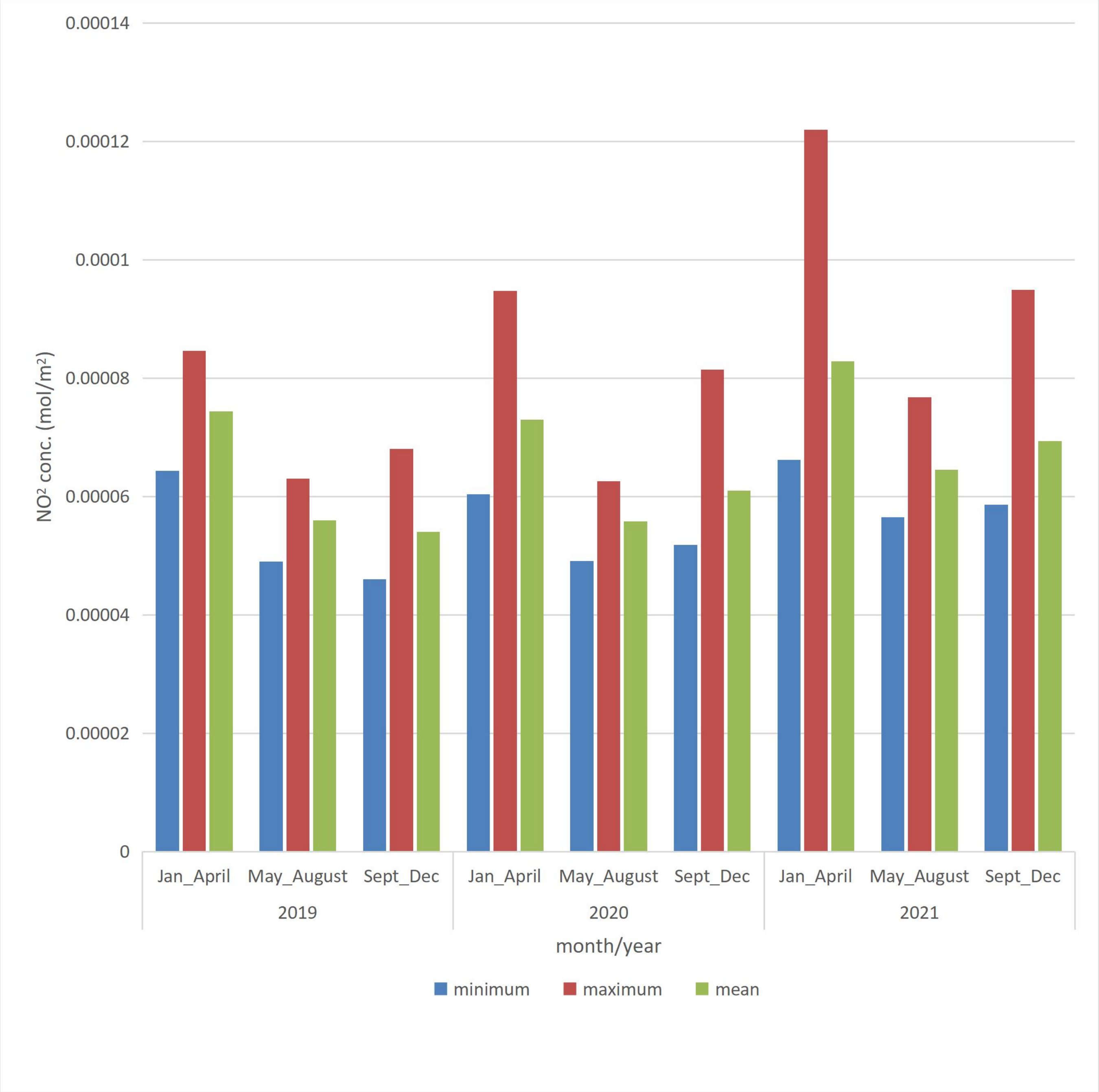

Figure 4. 11: Histogram plot of CO_2 concentration for the 3-year period

CHAPTER FIVE

DISCUSSION

5.1 SULPHUR DIOXIDE (SO2) SPATIAL DISTRIBUTION

SO_2 concentration within the study area ranged between -0.000127 to 0.0000782 mol/m^2 with a mean value of -0.0000314 mol/m^2 between January to April 2019. Average SO_2 concentration observed between May and August 2019 revealed a minimum value of -0.00016, a maximum value of 0.000076 and a mean value of -0.000054 mol/m^2. September to December 2019 also revealed average SO_2 values ranging from 0.000046 to 0.000068 with a mean value of 0.000054 mol/m^2. The average SO_2 concentration recorded between January to April of 2020 showed that minimum value of -0.0001, maximum value of 0.00016 and a mean value of 0.000031 mol/m^2. Average SO_2 concentration in the study area ranged between -0.000206 and 0.000103 with a mean value of -0.000033 mol/m^2 between May and August 2020 while average SO_2 ranged between -0.00014 to 0.00014 with a mean value of 0.0000036 mol/m^2 between September and December. January to April 2021 average SO_2 showed a minimum of -0.00013, maximum of 0.000143 and mean of -0.0000135 mol/m^2 while May to August 2021 average SO_2 showed a minimum of -0.000194, maximum of 0.000228 and mean of -0.0000081 mol/m2. The last four months of 2021, September to December recorded average SO_2 ranging from -0.00009 to 0.000155 with a mean value of 0.0000206 mol/m^2.

SO_2 concentration in the study area was regrouped into 4 classes namely low, moderate, high and very high. The low, moderate, high and very high classes covered about 8.74, 49.59, 37.21 and 4.46 % of the study area respectively for the January to April, 2019 period. The heavy industrialized zones such as Ibese and Papalanto with their immediate environs fall within moderate to very high class of the SO2 concentration for January to April, 2019. Abeokuta and environs which is heavily urban, falls within the moderate to high class. The low areas of SO2 pollution for the month period of January-April, 2019 were Awba, Itori, Ishaga, among others.

SO_2 concentration for May – August period in 2019 show that area coverage of 14.76 % corresponds to low, 47.64% corresponds to moderate, 32.01% corresponds to high while 5.59% corresponds to very high. The heavily industrialized areas of Ibese and Papalanto as well as their immediate environs falls within the low to moderate in both areas while Abeokuta falls within the high to very high zone. Ibese and Papalanto corresponding to the low areas could be as a result of the migration of the polluted air whereas over the urban areas the high and very high zones were observed which could be as a result of traffic pollution.

Average SO_2 concentration of September to December period in 2019 revealed that the low zone has a 28.74% coverage, the moderate zone has a 52.17 % coverage, the high zone has a 12.97% coverage, and the very high zone has a 6.12% coverage.

Ibese and Papalanto together with their environ fall within the high to very high zone. The urban area falls within the moderate to high zones. The area within the low zone were Akintaro, Alade, Agbamaya, Owowo, among others.

Similarly, January to April of 2020 showed that 5.51% fall within the low zone, 44.99% were within the moderate zone, 40.46% were within the high zone and 9.04% were within the very high zone. Ibese and Papalanto were within the high and very high zones while Abeokuta fall within the moderate to very high zone. Other places within the moderate zone are Share, Awaiye, Owowo, among others.

SO_2 concentration for May to August of 2020 revealed that the low class has a coverage of 3.14%, the moderate class has a coverage of 28.56%, the high class has a coverage of 59.61% and the very high class has a coverage of 8.69%. Ibese and Papalanto including their environs fall within the moderate to very high class. Abeokuta, Awba and Agirigi fall within the high to very high class while Ijale Papa, Ijana among other fall within the low to moderate class.

Average concentration for September to December of 2020 also revealed that Ibese, Yobo, Alade among other fall within the very high SO_2 class while Papalanto, Ishaga, among other fall within the very high to moderate SO2 zones. 6.22% is covered by the low zones, 42.64 % is covered by moderate zone, 41.68% is covered by high zone while 9.46% is covered by the very high SO2 zone.

In 2021, average SO_2 observed between January to April shows that the low SO_2 zone covers 6.66%, the moderate zone covers 64.18 %, the high zone covers 27.15% and the very high zone covers 2.01%. Papalanto, Ibese, Ajegunle, Wasimi, Igaolu, and environs falls within moderate to high SO2 zone. Ishaga was will within a very high SO_2 zone while Obada and some parts of Abeokuta was within the low SO_2 zone.

May to August of 2021 also show that average SO_2 coverage of the low zone was 8.59%, coverage of the moderate zone was 58.38%, coverage of the high zone was 28.8% and coverage of very high was 4.13%. Papalanto and Ibese together with their environs fall within the low to moderate zone. Abeokuta, Ilewo Orile, Ilaro among others fall within the moderate to very high zone.

September to December 2021 show that average SO_2 coverage for the low zone was 12.61%, coverage for moderate zone was 48.72%, coverage for the high zone was 35.04% and coverage for the very high zone was 3.63%. The most dominant zone was the moderate zone. Ibese, Lemo among other fall within the high to moderate zone while Papalanto, Bode Olude among others fall within the low to moderate zone.

5.2 NITROGEN DIOXIDE (NO_2) SPATIAL DISTRIBUTION

NO_2 concentration within the study area collected from google earth engine ranged between 0.000064 and 0.000085 mol/m^2 (64 & 85 mol/km^2) with a mean value of 0.0000744 mol/m^2 for the 4-month average of January to April 2019. This is similar to the research carried out by Tripathi *et al*, 2022 which revealed that NO_2 concentration within China ranged between 45mol/km^2 to 155mol/km^2 between December 18, 2018, to April 19, 2019. May to August 2019 average concentration of NO_2 range between 0.000049 and 0.000063 with an average mean of 0.000055 mol/m^2 while September to December 2019 average concentration of NO_2 ranged between 0.000046 and 0.000068 with a mean of 0.000054 mol/m^2. For the year 2019, average NO_2 concentration within the study are ranged between 0.000046 to 0.000085 mol/m^2 (46 – 85 mol/km^2). This is similar to the research carried out by Tripathi *et al* which revealed NO_2 concentration for Wuhan, China 2019 ranged between 20 to 900 mol/km^2. January to April 2020 recorded minimum, maximum and mean of average NO_2 as 0.0000604, 0.0000947 and 0.000073 mol/m^2 respectively. Concentration of average NO_2 between May and August 2020 revealed a minimum value of 0.000049, a maximum value of 0.0000626 and a mean value of 0.0000558 while average values of NO_2 between September and December showed minimum value of 0.0000518, maximum value of 0.0000814 and mean value of 0.000061 mol/m^2. NO_2 concentration within the whole of 2020 for the study area ranged between 0.000049 to 0.0000947 µmol/m^2 which is higher than the range observed from the research carried out by Galodha *et al*. (2022) for the state of Himachal, Pradesh, India which revealed a range of 11 – 30 µmol/m^2 in 2020. This could be attributed to the strict adherence to the lockdown mandate imposed by the Indian government during the peak of COVID 19.

The third year of 2021 showed that between January and April, average NO_2 values ranged between 0.000066 to 0.000122 with an average value of 0.0000828 mol/m^2 while average NO_2 ranged between 0.0000565 to 0.000077 with an average of 0.0000645 mol/m^2 for the same year. The average NO_2 of the last 4 months of 2021, September to December showed a minimum value of 0.0000586 and a maximum value of 0.0000949 with an average of 0.0000694 mol/m^2. NO^2 for the year 2021 ranged between 0.0000565 to 0.000122 mol/m^2 (56.5 to 122 µmol/m^2)

NO_2 concentration in the study area was reclassed into 4 classes namely low, moderate, high, and very high. The low, moderate, high, and very high classes covered about 19.79, 46.4, 26.42 and 8.39 % of the study area respectively for the January to April 2019 period. The heavily industrialized zones such as Ibese, Ajegunle, and Abeokuta among others fall within moderate to high NO_2 zones such as Papalanto, Oke, and Ewekoro among others fall within the high to very high zone of NO_2 concentration for January to April, 2019.

NO_2 concentration for May-August period in 2019 shows that area coverage of 15.38 % corresponds to low, 43.37% corresponds to moderate, 26.09% corresponds to high and 15.16% corresponds to very high. Ibese, Abeokuta, Ilaro, and Ishaga among others fall within the moderate NO_2 zone while Papalanto, Ewekoro, and Sapeti, among others fall within the very high NO_2 zone.

The average NO_2 concentration of September to December period in 2019 revealed that the low zone has a 28.75 % coverage, the moderate zone has a 52.17 % coverage, the high zone has a 12.97 % coverage, and the very high zone has a 6.11 % coverage. Ibese, Yobo, Lapeleko among others fall within high NO_2 zone while Papalanto, Oka, Sowunmi, among others fall within the high NO_2 zone. Areas such as Akintaro, Asa, Alade, among other fall within the low NO_2 zone.

Similarly, January to April of 2020 showed that 22.82% fall within the low zone, 49.30 % were within the moderate zone, 20.29 % were within the high zone and 7.59% were within the very high zone. Ibese, Papalanto, Oke, Balogun among others fall within the very high NO_2 zone while Akintaro, Alade, Ishaga and other fall within the low NO_2 zone. The low NO_2 zones were restricted to the northwestern part of the study area. Abeokuta, Ijapo, Ige, among others fall within the moderate to high NO_2 zone.

NO_2 concentration for May to August of 2020 revealed that the low class has a coverage of 15.38 %, the moderate class has a coverage of 43.37 %, the high class has a coverage of 26.09 % and the very high class has a coverage of 15.15%. Ibese, Ishaga, Abeokuta, and other fall within the moderate zone while Papalanto, Sapeti, Oluwo and other fall within the very high potential zone. Akintaro, Ijale Papa and others fall within the low NO_2 zone. The most dominant zone is the moderate zone covering the most part of the study area.

Average concentration for September to December of 2020 also revealed that Ibese, Balongun, Mose Balogun and their environs fall within the very high NO_2 zones while Papalanto, Ofada, Sepeti among others fall within the high NO_2 zone. Ijana, Abeokuta, Basse, and other fall within the moderate zone while Akintaro, Alade, Owowo, Araromi, and other fall within the low NO2 zones. 47.03% is covered by the low zones, 40.25 % is covered by moderate zone, 9.47% is covered by high zone while 3.25% is covered by the very high NO_2 zone. It was observed that the dominant zone was the low zone occurring towards the end of 2020.

In 2021, average NO_2 observed between January to April shows that the low NO_2 zone covers 10.79%, the moderate zone covers 59.01 %, the high zone covers 24.17% and the very high zone covers 6.03%. Ibese, Papalanto, Abeokuta, Sepeti, Baase, and other fall within the high NO_2 zone while Oke, Balogun, among others fall within the very high NO_2 zone. Akintaro and Ijale Papa fall within the low NO2 zone.

May to August of 2021 also show that average NO_2 coverage of the low zone was 8.77%, coverage of the moderate zone was 62.43%, coverage of the high zone was 27.36% and coverage of very high was 1.44%. Ibese, Ishaga, Obada, and numerous other places fall within the moderate NO_2 zone while Papalanto, Abeokuta, Maria and other fall within the high NO2 zone. Akintaro fall within the low NO2 while Ofada and Elewero fall within the very high NO2 zone. The most dominant zone is the moderate zone.

September to December 2021 show that average NO_2 coverage for the low zone was 24.4%, coverage for moderate zone was 48.03%, coverage for the high zone was 17.25s% and coverage for the very high zone was 10.32%. The most dominant zone was the moderate zone. Ibese, Papalanto, Balogun, Oke, Sowunmi and other fall within the very high NO_2 zone while Akintaro, Alade, Ishaga and other fall within the low NO_2 zone. Abeokuta, Oluke, Oluwo, among others fall within the high NO_2 zone. The most dominant zone is the Moderate zone followed by the low zone.

The industrial areas of Ibese and Papalanto mostly fall within the high and very high class in all the three years of NO_2 and SO_2 analysed while Abeokuta fall within the high class frequently.

5.3 CONCLUSION

The industrial areas of Ibese and Papalanto shows significant rise in SO_2 and NO_2 within the study area when compared to Abeokuta and other areas low urban area.

The frequent appearance of Abeokuta in the high class of NO_2 and SO_2 could be attributed to urban traffic pollution while the frequent appearance of Ibese and Papalanto in the very high and high class of NO_2 and SO_2 could be as a result of the cement industries located within the two industrial area.

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