Evaluation of Fuel Subsidy Removal Policy on Air Quality: A Case Study on Federal Capital Territory, Abuja, Nigeria

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ABSTRACT

There is a great deal of optimism that eliminating subsidies for fossil fuels will help to slow down climate change by discouraging the use of inefficient energy sources and leveling the playing field for renewable energy. This study aims to assess the effect of the fuel (Premium Motor Spirit) subsidy removal policy on air quality in the Federal Capital Territory (FCT), Abuja, Nigeria. Remote sensing with Google Earth Engine were employed to achieve the aim of this study. Data was collected two months before subsidy removal (April–May 2023) and after the ratification of the fuel subsidy removal policy (June–July 2023). Prior to the subsidy removal, the maximum and minimum concentration values of CO ranged from 0.0486 - 0.0415 mol/m^2 respectively which decreased to 0.0395 - 0.0333 mol/m^2 after subsidy removal. The maximum and minimum concentration values for NO_2 ranged from 0.000125 - 0.0000597 mol/m^2, which decreased to 0.0000838 - 0.000051 mol/m^2 respectively. The maximum and minimum concentration values of aerosols ranged from 0.482 - 0.0456, which also decreased to -0.256 - (-0.728) respectively. A paired sample t-test revealed a statistically significant ($p<0.05$) decrease in CO and aerosols ($p=0.033$ *and* $p=0.015$, respectively). Furthermore, the study revealed that though NO_2 emissions decreased, this decline was not statistically significant ($p= 0.368$). The study findings suggests that the removal of fuel subsidy in May 2023 led to a significantly better air quality in the Federal Capital Territory, Abuja. Using cleaner energy sources, public transport, and imposing tariffs on vehicles that are no longer safe for the road are some of the recommendations provided by this research.

Keywords: *Google Earth Engine, Sentinel, subsidy, air quality, Abuja, Nigeria.*

1.0 INTRODUCTION

Nigeria is fortunate to have a wealth of energy resources, from natural gas to crude oil, and these have been a significant source of income for the government ever since they were discovered in 1953 (Akinyemi et al., 2014). To ensure a general increase in social welfare aimed at assisting the underprivileged to take advantage of the country's resource advantages, petroleum subsidies were introduced in Nigeria in the 1960s (Akinyemi et al., 2014). Fuel subsidy indicates that the government pays a portion of the price that citizens are obliged to pay to alleviate the price burden on the usage of petroleum goods. (Onyeizugbe and Onwuka, 2012). Umar and Umar (2013) opined that both developed and developing nations use fuel subsidies to lower the price of production and, in some instances, to relieve citizens of the burden of rising prices.

According to Savio et al. (2022), traffic congestion is responsible for 34% of PM_{10}, automobiles are responsible for 37% of $PM_{2.5}$, and traffic volume and vehicle speed are two additional factors that influence the rate of emission. Every day, the environment is the recipient of harmful substances from the incomplete combustion of fossil fuels, particularly from exhausts and automobile emissions. Automobiles and fossil fuel-driven machines release well known gaseous contaminants such as NO_2, CO_2, SO_2 and particulate matter. People who breathe in these pollutants can have immunotoxic and allergic reactions. These reactions can have effects on respiratory health because they can lead to stuffy noses, wheezing, nasopharyngeal cancer, respiratory illness, asthma, coughing, pulmonary insufficiency, heart disease, and a general decline in lung function (Savio et al., 2022; Manisalidis et al., 2020; Olalekan et al., 2020; Stanley and Inuope, 2021).

There is a great deal of optimism that eliminating subsidies for fossil fuels will help to slow down climate change by discouraging the use of inefficient energy sources and leveling the playing field for renewable energy (Jewell et al., 2018). The fact that fossil fuel subsidies encourage excessive energy consumption and thereby degrade environmental quality is one of the reasons for the elimination of these subsidies (Wesseh and Atsagli, 2016). Therefore, this study aims to evaluate the effect of the fuel (Premium Motor Spirit) subsidy removal policy on air quality in FCT, Nigeria, by monitoring specific air quality parameters (CO, NO_2, and aerosols) using Sentinel 5P to compare pre-subsidy to post-subsidy fuel removal policy data and determine a statistically significant difference.

2.0 METHODOLOGY

2.1 Study Area

Nigeria's capital city, Abuja, is situated in the country's geographic center with GPS coordinates of 9°5′ N 7°32′ E and a total land area of 7,315 km^2. Four states encircle Abuja: Kaduna to the north, Niger to the west, Nasarawa to the east and southeast, and Kogi to the southwest (Figure 1). Abuja, was established on December 12th, 1991. Abuja serves as both Nigeria's administrative and political hub (2,824 sq. mi) (Kanee et al., 2020). Given that Abuja is the location of all Federal government parastatals and establishments, most of its residents are civil servants. The rainy season and the dry season are the two weather patterns that Abuja experiences each year. In between these two seasons, there is a brief period of harmattan (dusty haze, dryness, and intense coldness) caused by the northeast trade wind (Wambebe and Duan 2020). This harmattan lasts from late March until the end of October for the rainy season and from October until the end of March for the dry season (Wambebe and Duan, 2020) Its temperature ranges between 25˚C - 31˚C with an equitable climate that is neither too hot nor cold.

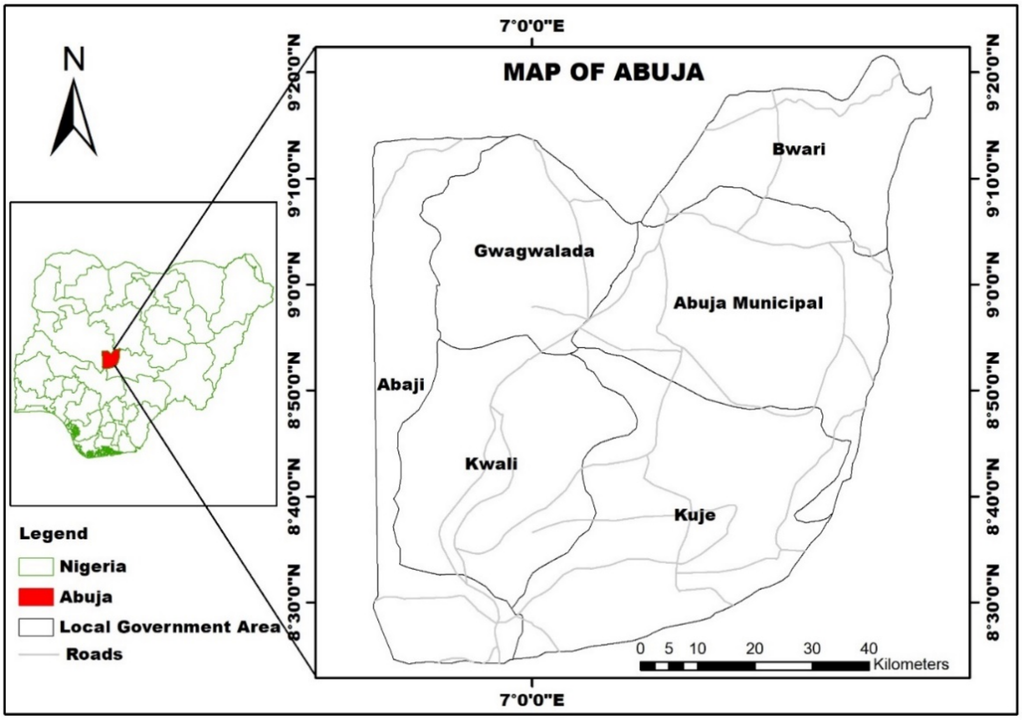

Figure 1: *Map of study area (FCT)*

2.2 Data type and analysis

The present investigation predominantly utilized secondary data obtained through the implementation of Sentinel-5 Precursor (Sentinel-5P), a mission instrument that collects data that can be used to assess air quality. The Sentinel-5P satellite mission is part of the Global Monitoring for Environmental and Security (GMES/Copernicus) programme (Virghileanu et al., 2020). Data on the study area was obtained through the Google Earth Engine. The shapefile of Nigeria was downloaded from the DIVA-GIS website. The Federal Capital Territory, which is the region of interest, was exported as a shapefile using ArcMap and imported into Google Earth Engine. In order to generate results through Sentinel-5P on Google

Earth Engine for the various months, a script of codes was run on the code editor, focusing on pollutants of interest. Sentinel 5p houses the TROPOMI sensor, which observes pollutants and gives results for their concentration in mol/m². Figure 2 shows the research methodology flow chart.

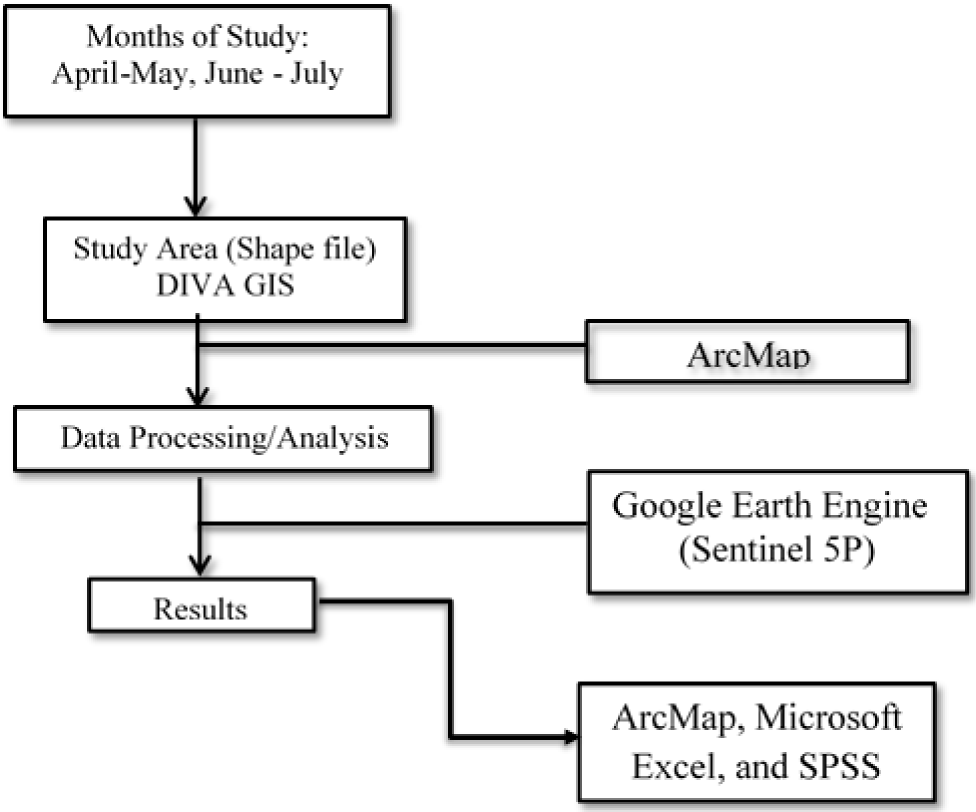

Figure 2: *Research Methodology Flow Chart*

The dataset for analysis of atmospheric pollutants using Google Earth Engine is as follows.

***Table 1:** Dataset for analysis of CO, NO_2, and Aerosols*

Parameter Analysed	Image Collection	Band Used	Unit
CO	COPERNICUS/S5P/NRTI/L3_CO	CO column number density	mol/m²
NO_2	COPERNICUS/S5P/NRTI/L3_NO2	NO_2 column number density	mol/m²
Aerosols	COPERNICUS/S5P/OFFL/L3_AER_AI	Absorbing aerosol index	-

In achieving the aim of the study, the researchers obtained air quality data for two months preceding and succeeding the enactment of the fuel subsidy removal policy. Essentially, data for the months of April and May representing pre-subsidy removal data and June and July of the same year 2023 representing post –subsidy removal data was collected and analyzed. Data obtained for the parameters of interest was analyzed for spatial variation, trend and to determine significance difference between the pre and post subsidy removal regimes. For the analysis of spatial variation, the use of GIS was employed to map the air quality parameters for the period of study over the study area. This is to give a clear and unambiguous spatial analysis of each parameter as well as depict concentrations (as illustrated by the corresponding legends of figures) of each parameter in various areas within the study area. Analyzes for the trends were carried out by adopting the use of Microsoft Excel package. This was done essentially to determine if the air quality parameters were increasing or decreasing in concentration throughout the study period. Finally, statistically significance difference ($P \leq 0.05$) was determined to ascertain if the air quality parameters significantly varied ($P \leq 0.05$). This was done using paired sample t test on SPSS 20.0 software package.

3.0 RESULTS

Table 2 shows the concentration values of CO, NO_2 and aerosols obtained pre (April-May, 2023) and post (June-July, 2023) fuel subsidy removal policy in the FCT, Nigeria. The range of maximum and minimum values for the air parameters recorded pre subsidy removal were 0.0486 - 0.0415 mol/m^2 for CO, 0.000125 - 0.0000597 mol/m^2 for NO_2, and 0.482 - 0.0456 for aerosols. The range of maximum and minimum values recorded post subsidy removal was 0.0395 - 0.0333 mol/m^2 for

CO, 0.0000838 - 0.000051 mol/m^2 for NO_2, and -0.256 - (-0.728) for aerosols. The average mean concentration values recorded pre subsidy removal was 0.0451±0.005 for CO, 0.0000924 ±0.000046, for NO_2 and -0.492 ±0.334 for aerosols. The average mean values recorded post the fuel subsidy removal was 0.0364±0.0044 for CO, 0.0000674±0.000023 for NO_2, and -0.492±0.334 for aerosols. A paired sample t-test revealed a statistically significant ($p<0.05$) decrease in CO and aerosols (with p-values of 0.033 and 0.015, respectively). Furthermore, the study revealed that though NO_2 emissions decreased, this decline was not statistically significant (*p= 0.368*).

Table 2: *Recorded concentration values of CO, NO_2 and Aerosols for the months of April - May, June - July 2023*

	Mean value Pre- subsidy removal April - May		**Mean value post-subsidy removal June - July**		**p-Value**
Parameters	**X̅±SD**	**Max-Min**	**X̅±SD**	**Max-Min**	
CO (mol/m^2)	**0.0451**±0.005	0.0486-0.0415	**0.0364**±0.0044	0.0395-0.0333	P<0.05 (0.033)
NO_2 (mol/m^2)	**0.0000924** ±0.000046	0.000125-0.0000597	**0.0000674**±0.000023	0.0000838 -0.000051	p>0.05 (0.368)
Aerosols (-)	**0.264** ±0.309	0.482-0.0456	**-0.492** ±0.334	-0.256-(-0.728)	p<0.05 (0.015)

X̅±SD = average mean generated from values across the months ± standard deviation; max–min = maximum and minimum values for each parameter. P≤0.05 = significant difference, p> 0.05 = no significant difference.

Figure 3a shows the spatial concentration of CO in the six local government areas in FCT during the months of April-May 2023 (pre - subsidy removal policy), and June-July (post - fuel subsidy removal policy). The spatial map of April-May 2023 reveals that Abuja Municipal Council (AMAC), Gwagwalada, Abaji, and Kwali had the highest concentration, while Bwari and Kuje recorded the lowest.

For the month of June-July (post - subsidy removal policy), the map showed that Bwari, Kuje, and the eastern and southern parts of Kwali had the lowest values. The North-East, East, and South East of Gwagwalada and Southern Abaji had the highest concentration. Bwari and Kuje recorded the lowest concentration, followed by some parts of AMAC and parts of Gwagwalada.

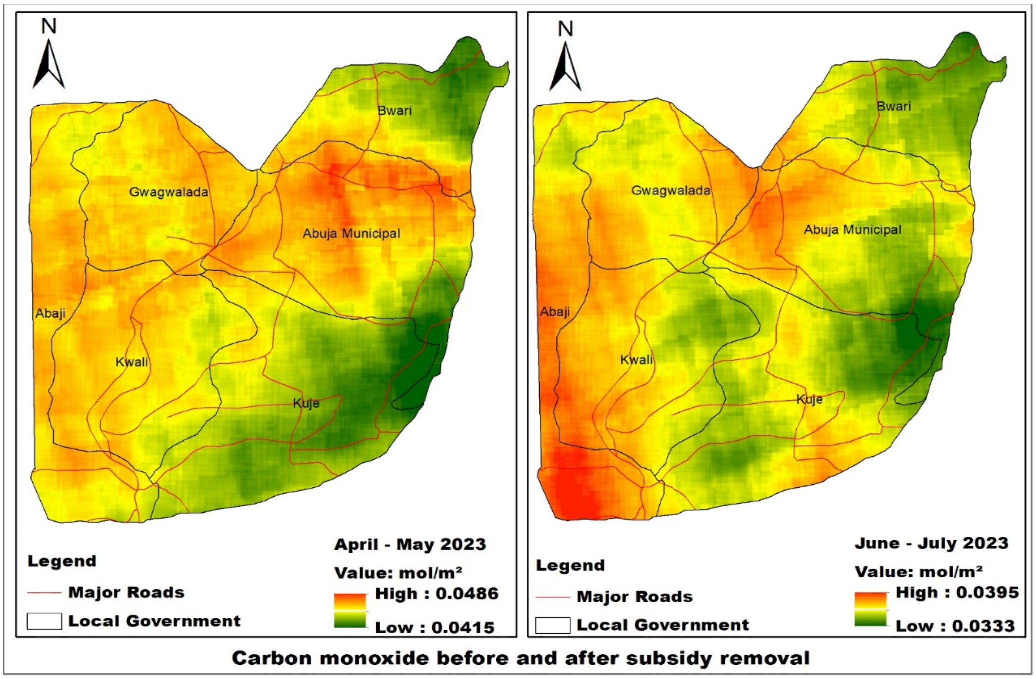

Figure 3a: *Map of concentration of CO pre and post- subsidy removal*

The bar chart in figure 3b shows the trend of CO pre and post subsidy removal. The months of April-May had a mean concentration of 0.0451 mol/m^2, whereas in June-July had 0.0364 mol/m^2. From the chart, we can see a downtrend in the concentration of CO; this clearly shows a reduction in the level of CO after the policy was passed.

Figure 4a shows the spatial concentration of NO_2 in the six local government areas in FCT during the months of April-May 2023 (pre - subsidy removal policy), and June-July (post - fuel subsidy removal policy). The northeastern part of AMAC and the southern Bwari local government area recorded the highest concentrations, while the other four local government areas had low concentrations. For the month of June-July, 2023, the northeastern part of AMAC and the southern Bwari local government area recorded the highest concentrations, while the other four local government areas had low concentrations.

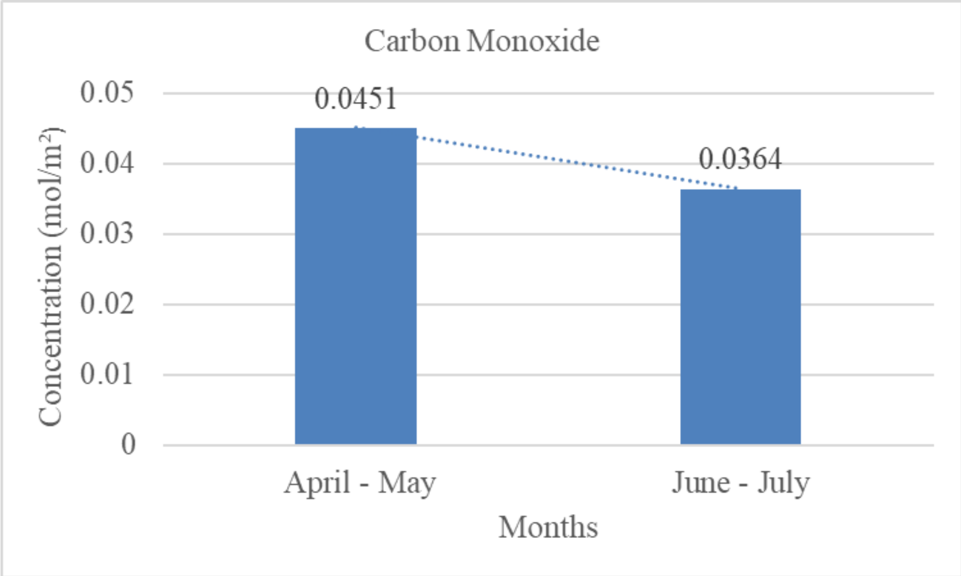

Figure 3b: *Trend of CO pre and post subsidy removal*

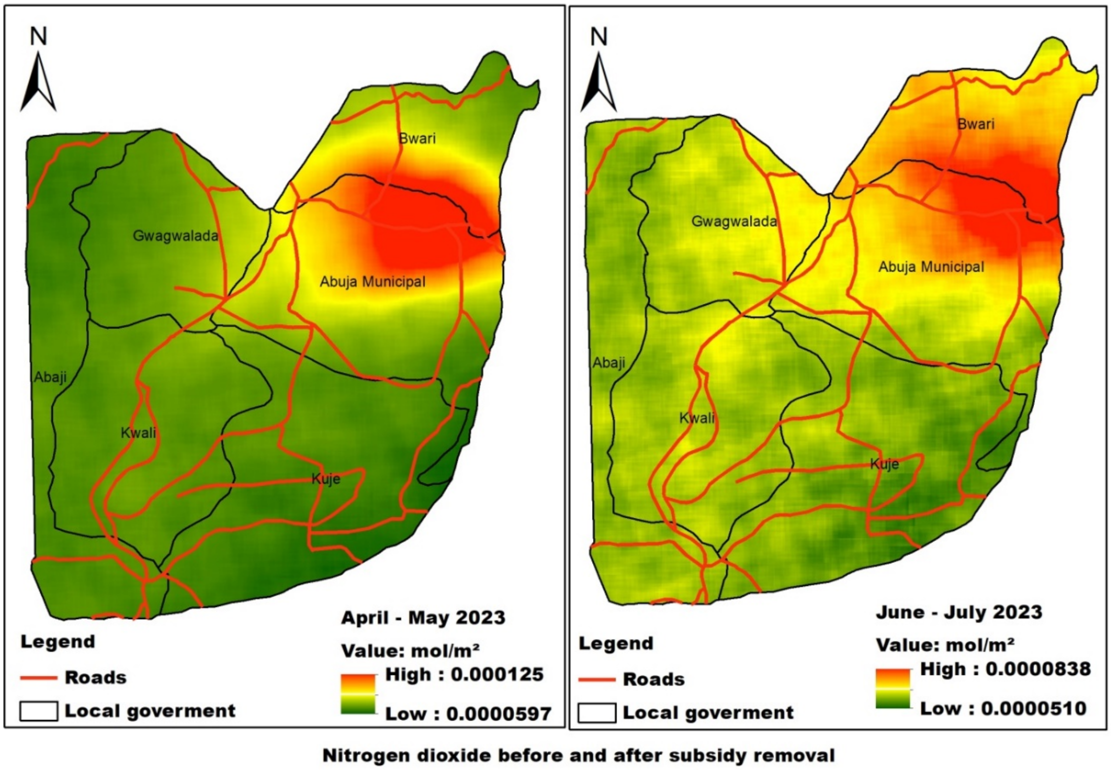

Figure 4a: *Showing concentration of NO_2 pre and post subsidy removal*

The bar chart in figure 4b shows the trend of NO_2 pre and post subsidy removal, for the months of April-May, NO_2 had a concentration of 0.00009235 mol/m^2, June-July had a mean concentration of 0.0000674 mol/m^2. From the chart there is a downtrend in the concentration of NO_2, this clearly shows a reduction in the level of NO_2 after the fuel subsidy removal policy was passed.

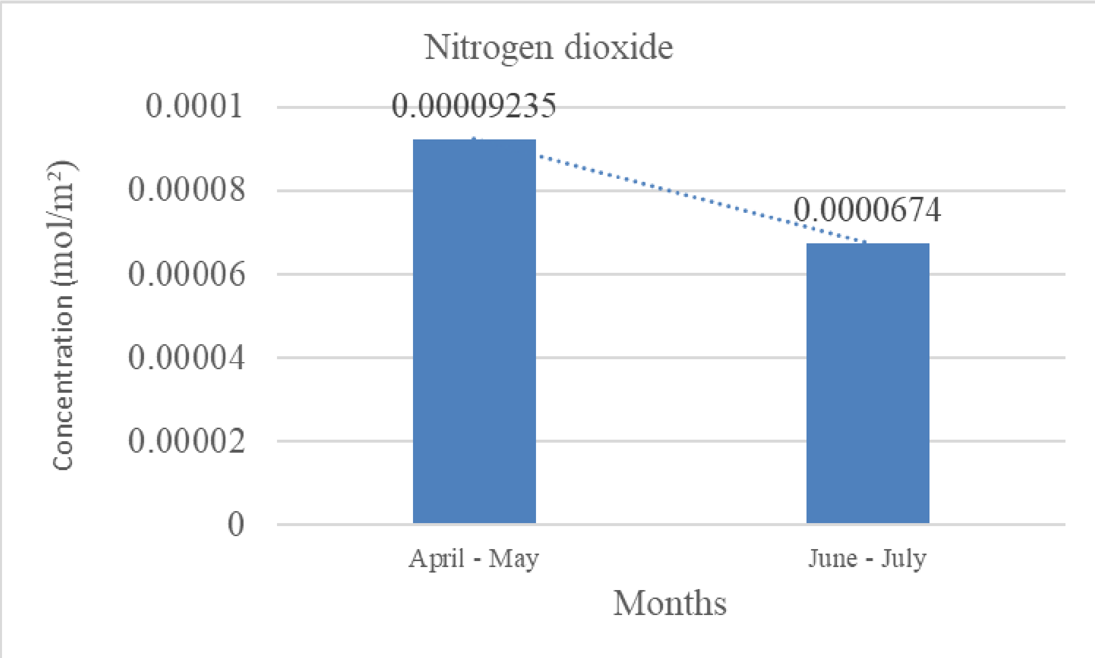

Figure 4b: *Trend of NO_2 pre and post subsidy removal*

Figure 5a shows the spatial distribution of aerosols in the six local government areas in Abuja during the months of April-May 2023 (before the fuel subsidy removal policy was announced), and June-July (after the fuel subsidy removal policy was announced). In April-May, AMAC and Gwagwalada recorded the highest value, while Kuje, Kwali, parts of Abaji, and Bwari local government area recorded the lowest. In June-July, parts of AMAC, and parts of Bwari recorded high levels of aerosols, while the other three local governments had relatively low levels of aerosols.

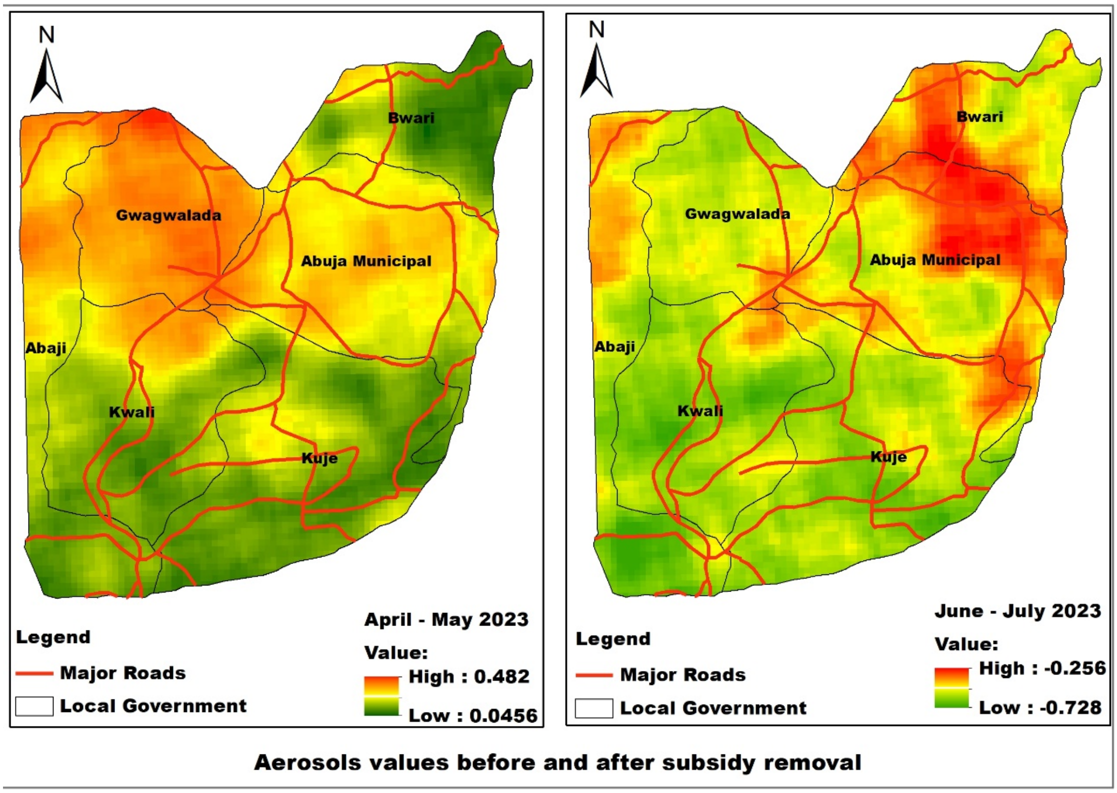

Figure 5a: *Map showing values of Aerosols pre and post subsidy removal*

The bar chart in figure 5b shows the trend of aerosols, pre and post subsidy removal. For the month of April-May, the mean value was 0.2638. In June-July, the mean value was -0.492. From the chart, we can see a downtrend in the concentration of aerosols; this clearly indicates a reduction in the level of aerosols after the fuel subsidy removal policy was passed.

4.0 DISCUSSION

The levels of NO_2, CO, and aerosols all decreased in June-July as a result of the declaration and implementation of the fuel subsidy removal policy. This decline can be attributed to higher fuel prices. According to the National Bureau of Statistics (2023), citizens paid an average retail price of N545.83 for fuel in June 2023, which is significantly higher compared to the N238.11 price in May 2023, representing a 129.23% increase in the price of fuel due to the policy, which led to a decline in anthropogenic activities that emit pollutants. Because of Nigeria's difficult economic situation, a significant number of the country's population lives below the poverty line (Jaiyeola and Bayat, 2020) which makes it harder for residents to buy fuel

(O'Roark, 2007) and as a result, makes them less likely to engage in anthropogenic activities that lead to the release of these atmospheric air pollutants. Due to the high cost of fuel, citizens chose to use public transportation, carpool, and even walk instead of using their personal vehicles, which resulted in a significant decrease in the use of generators and unnecessary human movement with vehicles. There was a significant difference recorded for CO, with a p value of 0.033. This outcome is also consistent with research by Roy et al. (2020), which demonstrated a decrease in CO concentration following the COVID-19 lockdown, and Sharma et al. (2020), who measured a 10% decrease in CO concentration during the COVID lockdown period in India.

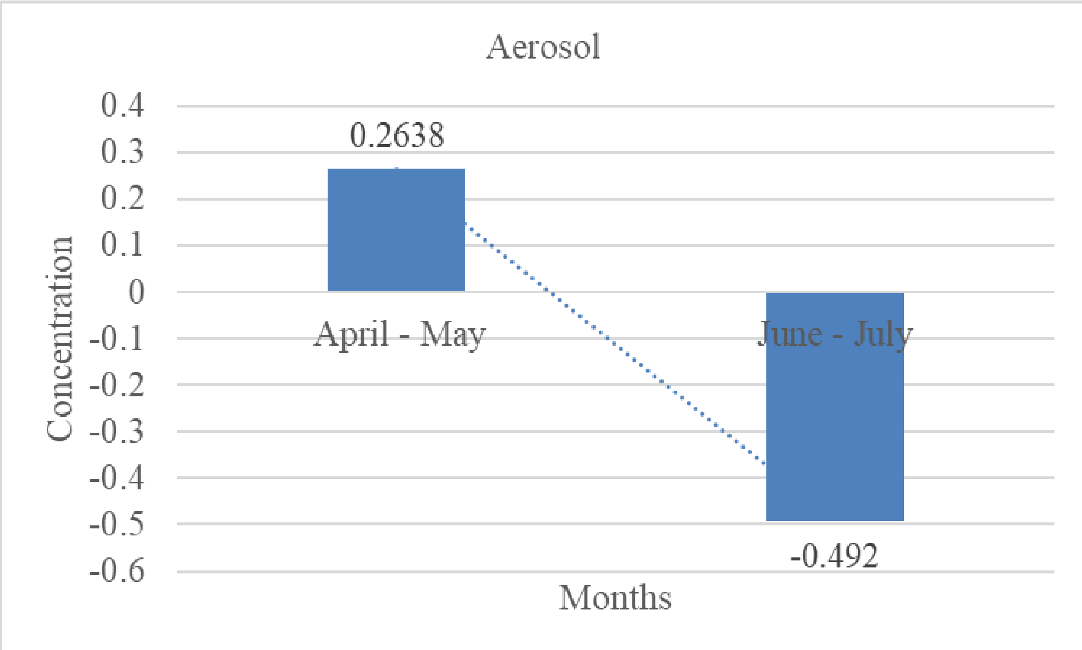

***Figure 5b**: Bar chart showing the trend of Aerosols pre and post subsidy removal*

Aerosols are suspended solid or liquid particles (Colbeck and Lazaridis, 2010) with sizes ranging from 0.001 to 100 μm (Pandey et al., 2006). There was a significant difference recorded for aerosols, with a p value of 0.015. In connection with this, Roman-Gonzalez et al. (2020) also reported a decrease in aerosols in Peru due to the stay-at-home policy. The results corroborate research by Roy et al. (2020), who discovered a reduction in $PM_{2.5}$ concentration after the COVID-19 lockdown, and Sharma et al. (2020), who recorded a 31% decrease in $PM_{2.5}$ concentration during the COVID lockdown period in India. The findings of this research also concur with those of Lian et al. (2020) and Mazlan et al. (2023), who discovered a decrease in

$PM_{2.5}$ and aerosol concentrations after the COVID-19 lockdown. Less fuel was burned because there were fewer vehicles on the road, which reduced the amount of CO and aerosols that vehicles released. According to Savio et al. (2022), vehicle exhaust accounts for 50% of particulate matter pollutants; therefore, reducing the number of cars on the road played a significant role in lowering particulate matter and CO concentrations.

Furthermore, the study revealed that, though NO_2 emissions decreased, this decline was not statistically significant (p-value 0.368). Because of the policy, fewer people were buying fuel in the months of June-July, which resulted in a decrease in the NO_2 concentration. These findings are in line with some other researchers' findings who have investigated related topics. For instance, Roy et al. (2020), Le et al. (2020), Shami et al. (2022), and Gharibvand et al. (2023) reported that the NO_2 concentration dropped following the COVID-19 lockdown when the majority of the population was at home, compared to the pre-COVID period.

5.0 CONCLUSION

This study finds that the implementation of the fuel subsidy removal policy made it more difficult for citizens to purchase fuel due to the sudden increase in fuel prices all around the country, which led to a reduction in their anthropogenic activities that caused the release of atmospheric air pollutants. In the FCT, it was proven that the air quality improved significantly in the months of June-July after the policy was passed. Air pollutants like CO and aerosols, which are harmful air pollutants decreased. Aerosols had the greatest reduction in values when compared to the other pollutants, owing primarily to a decrease in the number of cars on the road causing a reduction of the combustion of fuel from cars. These findings demonstrated that the policy of eliminating fuel subsidies had a positive impact on air quality in the FCT, providing cleaner air to residents.

The study recommends reducing reliance on fuel-powered generators, using renewable energy sources like solar, and opting for environmentally friendly vehicles like electric and hybrid cars. The study also recommends an extended study to further buttress the findings of this study. Furthermore, Government may investment in mass transit systems, tariffs on non-roadworthy cars, and subsidies for newer, cleaner cars may help reduce air pollution. Additionally, promoting public transport and providing subsidies for the purchase of newer cars may help discourage the use of old, air-polluting cars.

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