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Spatial - Temporal Mapping of Ambient Air Pollutants ($PM_{2.5}$, PM_{10} and CH_4) in Minna Town, Niger State, Nigeria

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Abstract: The study analyses and mapped the spatio-temporal variation of ambient air pollution in Minna town. The spatio-temporal pattern of ambient air pollution level and identify air quality index in Minna town. Primary and secondary data were used. Portable handheld Aeroqual's Series 500 was used to take readings in parts per million (ppm) for gaseous air pollutants ($PM_{2.5}$, PM_{10} and CH_4) across selected sampled locations. Geographical information system (GIS) was used to analyzed the data. The total variance explained pollution causal parameter was 63.1% and the key index identified was Green House Gases (GHGs). Concentration levels of PM_{10}um particulate matter were recorded around Dutsin- Kura junction and Kure market (> 0.0078ppm), followed by Kasuwa gwari market. The least concentration was of PM_{10} NNPC Mega station, City gate. The $PM_{2.5}$ concentration was observed to be higher in Kasuwan Gwari Market, Dutsinkura junction, City Gate Shango and Gbeganu Junction Bida road while the lowest concentration of $PM_{2.5}$ was observed around College of Education locations like Kasuwan Gwari market, Dutsin kura junction, and Kure market recorded very high level (1084.61, 1086.72, and 1099.82 ppm) of CH_4 respectively during dry seasons. The study conclude that. pollutants concentration varies over space and time in Minna town. The findings recommend clean energy for the inhabitants in order to reduce release of pollutants into the environment from their means of livelihood.

Keywords: *Temporal, Pollutant, Concentration and Location.*

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I. INTRODUCTION

Air pollution is considered to be the most critical as there is no single minute that we cannot do without clean air (Manisalidis, Stavropoulou, Stavropoulos and Bezirtzoglou 2020). Air pollution occurs when gases, dust particles, fumes (or smoke) or odour are introduced into the atmosphere in a way that makes it harmful to humans, animals and plants (Joshi, 2022). Air pollution from both outdoor and indoor sources represents the single largest environmental risk to human health globally (Espanol, 2019). World Health Organization [WHO], 2014 warns that air pollution sources represent the greatest environmental risk to human health, evidenced in more than over 6 million premature deaths caused by exposure to contaminated air sources (Fernanda *et al.*, 2023).

Several studies like Bassols, Johnston, and Shields (2023) have shown that exposure to air pollution at an early age can impair lung function, and increase the risk of respiratory diseases as well as the probability of premature mortality. Generally, there are five (5) principal sources of atmospheric pollutants. This are industrial and mining processes, fuel combustion (including fuel wood burning, bush fire sand flaring of natural gas), waste disposal by burning, road traffic. And other abrasive forces which raise dust Particulate Matters (PM) from the ground and naturally occurring pollutants like pollen, spore sand bacteria (Bessagnet, et al., 2022). Many agricultural practices like land preparation, deforestation, slash-and-burn farming releases various air pollutant like $PM_{2.5}$ and PM_{10} (Rana, and Chopra, 2013). Also, rearing of animals and rice farming/ processing produce a lot of CH_4 . Particulate matter with an aerodynamic diameter of less than 2.5 μm ($PM_{2.5}$) is generated from various natural and anthropogenic sources Lee et al. (2020).

Dust particles arising from the frequent movement of vehicles along kpakungu Bida road through non-asphalted (under construction), poor environmental sanitation and

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failed portions of major roads, as most vehicles access the nation's capital through Minna Niger State. Findings revealed that high concentration of the pollutants in Minna metropolis are outrageously high and therefore detrimental to human health, livestock and crops.

Despite all these researches, there is scarcity of air pollutant mapping in Nigeria, especially in Minna, Niger State. The pollutant are spatio-temporal in nature, due to the continuously changing of environmental conditions resulting from the movement of pollutants and pollutant sources. The spatio-temporal variability of air pollutant from multiple locations comes with significant design challenges, this form the bases of this study. The study intend to carry out a comprehensive mapping of air pollutant, particularly on particulate matter (PM_{10}, $PM_{2.5}$ and CH_4), and more importantly spatial and temporal distribution of pollutants in Minna.

II. STUDY AREA

Minna is the administrative capital of Niger State. It lies within Latitude 9º36' 0" to 9º 38′ 0″ North of the equator and Longitudes 6º 31′ 0″ to 6º 34′ 0″ East of the Greenwich Meridian (Figure 3.2). In terms of distance, it is about 145 kilometers by road from Abuja, the Federal Capital Territory (FCT) of Nigeria. Out of Niger state's total area size of 76,363km^2, the study area covers about 110 km^2 and it's located at the south-eastern axis of the state, in the middle belt region of the country (Wakili, Nsofor, Suleiman and Mohammed 2017).

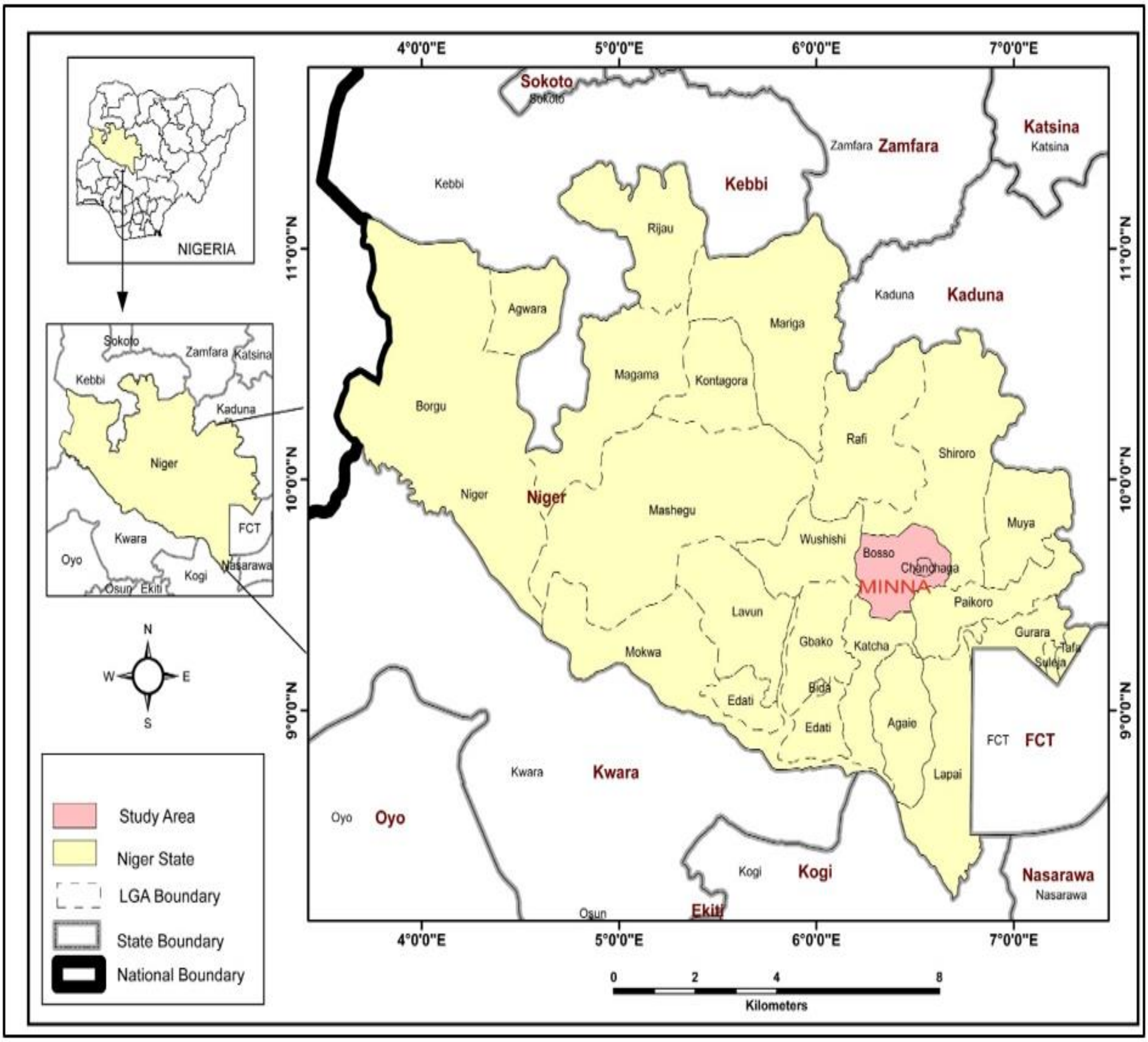

Fig 1 Map of Niger State Showing the Study Area
Source: Niger State Ministry of Land and Survey (2020).

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Minna has a Tropical savanna climate (Köppen-Geiger classification: Aw) with a pronounced dry period**.** The climate of Minna is the result of the general atmospheric circulation of air masses over the earth modified by surface topography and elevation. The principal air masses affecting the weather of Minna are the Tropical maritime (mT) and the Tropical Continental air masses (cT).

The rainfall pattern shows a distinct and fairly South-North gradient in which the annual rainfall decreases from the Southern fringe (Samson and Ellis, 2024). The annual rainfall ranges from around 1,600mm to 1,230mm. The total annual rainfall received was 1,209.7mm.

The highest mean monthly temperature is recorded in March with about 30.5ºC (Anon, 2021). Furthermore, it experiences high temperatures all the year round, the mean annual temperature increases northward from about 30ºC to 37ºC. Average temperature and sunshine duration per year were 27°C and 2672 hours, March and September were the warmest and coldest months with corresponding average temperature values of 30.2°C and 24.9°C respectively.

III. METHODOLOGY

Field work was carried out on selected sites of the study areas to collect air samples. Air quality monitoring station positioned approximately 1.5m from the nearest road were selected according to specific legislation to guarantee the representativeness of the study locations for the measurement of suspended particulate matter (PM_{10}, $PM_{2.5}$) and methane (CH_4). The Aeroqual commercial sensors used for this study were S500 portable monitors and were positioned at 1.5m elevation above the ground at different focal locations in Minna and were used to collect air samples (July-September 2023 and December 2022- January and Febuary 2023), which covered two seasons (wet and dry) in Minna.

Portable handheld Aeroqual's Series 500 was used to take readings in parts per million (ppm) for the gaseous air pollutants ($PM_{2.5}$, PM_{10} and CH_4) across selected sampled locations. The sensor was calibrated and tested at the laboratory before being taken to the field for operation. For each of the 15 selected location, readings were taken thrice a day for three different months at each seasons and statistical analysis was conducted to show variations within a particular area and across the study area as well as within and across pollutants.

Spatial interpolation is a critical aspect of Geographic Information Systems (GIS) that is allows to estimate values for locations where data is not available. By using various statistical techniques, spatial interpolation helps in predicting and visualizing data patterns across a geographic area. The first step is data collection, where the relevant data points are gathered from various sources such as field surveys. These data points have the necessary attributes and spatial coordinates for interpolation. After the data was collected, it was cleaned and organized to ensure consistency and accuracy. The study adopt Inverse Distance Weights (IDW) spatial interpolation method with the application of the GIS framework to map and address the spatial distribution of ambient air quality, because of its practicability and applicability in the study.

IV. RESULTS AND DISCUSSION

The average annual spatial distribution of Particulate matter (PM_{10}) around Minna for both dry and wet season is presented in Figure 2 and 3. The results on the spatial distribution of particulate matter for dry seasons show that Ebitu Ekiwe road (GRA), Kateren Kwari, and College of Education Minna recorded very low (7.72, 8.83, and 9.10 $\mu g/m^3$) concentration of PM_{10}, while Citygate Shango, Dutse kura junction and Kure market recorded low (11.19, 11.92, and 12.46 $\mu g/m^3$) level concentration of PM_{10} (Figure 2).

Also, the spatial distribution of PM_{10} for wet season shows that Ebitu Ekiwe road (GRA), Kateren Kwari, and College of Education Minna showed very low level (3.29, 3.32, and 3.02$\mu g/m^3$) of PM_{10} within the study area whereas, Access roundabout, Eastern bypass (Mechanic village), and Kure market recorded low level (3.50, 3.80, and 3.09 $\mu g/m^3$) of PM_{10} in the study area (Figure 3).

Apparently, findings show that the spatial distribution of PM_{10} in Minna town ranges between very low to low levels of concentration of the pollutant. Virtually all year (dry and wet) it is obvious that Ebitu Ekiwe road (GRA), Kateren Kwari, and College of Education Minna recorded very low (8.83 $\mu g/m^3$) while it is only in Kure market that low level of concentration which in turn is highly variable across the seasons. This result is line with Ugonabo et al.,(2023) who reported that PM_{10} (μ/gm^3) have more spread during dry seasons than in wet seasons. Mostaghim et al., (2024) the highest PM_{10} level due to a low average precipitation in autumn while the lowest levels in summer. Chauhan et al.,(2022) indicated that seasonal variation shows relatively a higher concentration of PM_{10} in the winter season, which may be due to stable meteorological conditions and increased biomass burning in winter.

Kalander and Al-Harahsheh (2023) reported that the highest concentration of dust was in Al-Rumaithiya station with concentration of 146–330 $\mu g/m^3$, followed by Al-Jahra station with concentration of 108–199 $\mu g/m^3$, and the lowest was in Al-Fahaheel station with of concentration of 108–177 $\mu g/m^3$.

Ugonabo et al.,((2023) report that in Ogui New Layout, during the dry season, the air pollutants (PM_{10}) had maximum values of 225 $\mu g/m^3$ and minimum values of 184 $\mu g/m^3$ while during the wet season, (PM_{10}) had maximum values of 202 $\mu g/m^3$ and minimum values of 108 $\mu g/m^3$. Vaddiraju (2019) reported that PM_{10} concentration of 146 $\mu g/m^3$ which was the highest concentration observed at the center of the town with minimal space.

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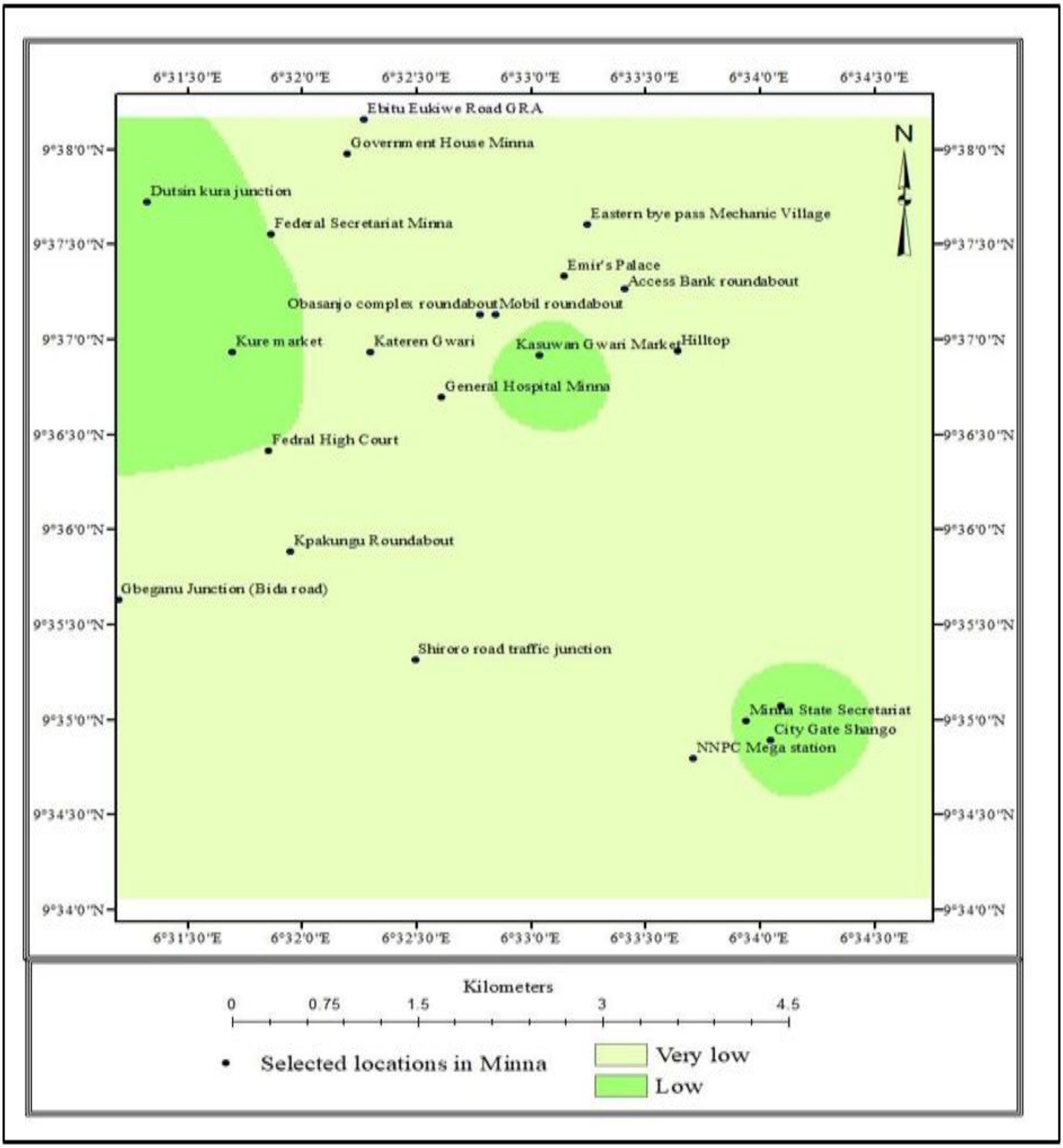

Fig 2 Spatial Distribution of Particulate Matter (PM_{10}) In Minna (Dry Season)
Source: Authors Analysis, 2024

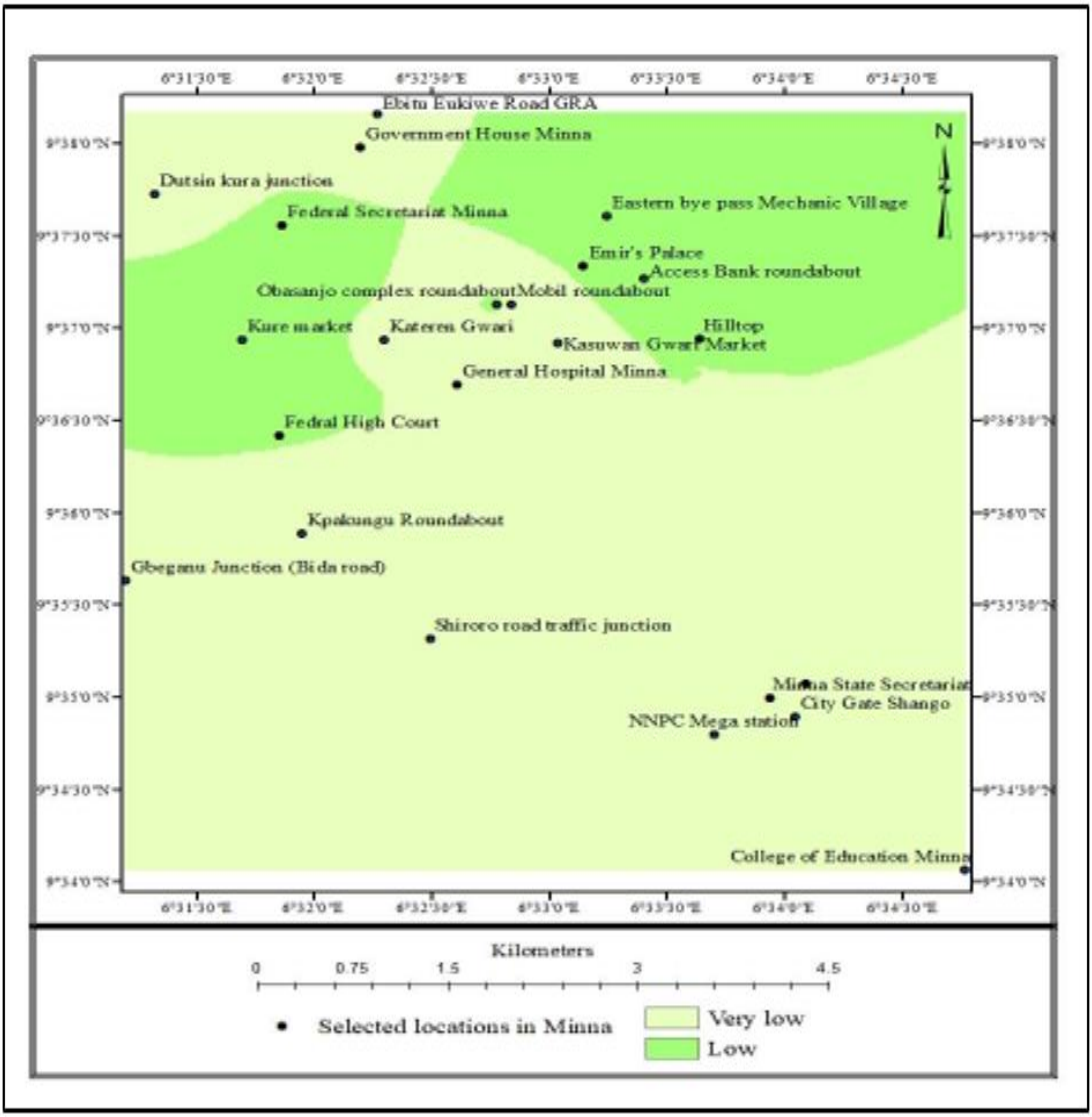

Fig 3 Spatial Distribution of Particulate Matter (PM_{10}) In Minna (Wet Season)
Source: Authors Analysis, 2024

The average annual spatial distribution of Particulate matter ($PM_{2.5}$) around Minna for both dry and wet season is presented in Figure 4 and 5. The results of the spatial distribution of particulate matter for dry seasons shows that Ebitu Eukiwe (GRA), Kateren Gwari, and College of Education Minna recorded very low concentration (5.80, 6.67, and 6.69µg/m^3) of $PM_{2.5}$ in the study area whereas, Gbegamu junction (Bida road), Dutsin kura junction, and Kure market recorded low level (7.55, 8.34, and 8.57 µg/m^3) of $PM_{2.5}$ level of concentration in the study area (Figure 4).

Equally, the spatial distribution of Particulate matter ($PM_{2.5}$) around Minna in the wet season shows that Ebitu Eukiwe (GRA), Kateren Gwari, and College of Education Minna recorded very low level (2.30, 2.33, and 2.11µg/m^3) of $PM_{2.5}$ concentration within the study area while, Eastern bypass (mechanic village), Access roundabout, and Kure market recorded low level (2,66, 2.46, and 2.84 µg/m^3) of $PM_{2.5}$ concentration in the study area respectively (Figure 5).

The findings from this revealed that across all the season (dry and wet), locations like Ebitu Eukiwe (GRA),

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Kateren Gwari, and College of Education, Minna recored low level of $PM_{2.5}$ concentration while only Kure market often has low level concentration of $PM_{2.5}$ which could be attributed to several factors amongst which is season dynamics that easily create oscillation in climatic elements.

The seasonal variation shows relatively a higher concentration of $PM_{2.5}$, in the winter season, which may be due to stable meteorological conditions and increased biomass burning in winter(Chauhan, et al.,2022).

Rusmili (2023) report that the concentrations of $PM_{2.5}$ in 2019 were not randomly distributed because economic activities occurred regularly in certain areas in Peninsular, and haze episodes occurred at that time while, in the year 2020, the concentrations were randomly distributed due to a movement control order that only allowed a few industrial and transportation operations in certain areas during a certain period in the COVID-19 era.

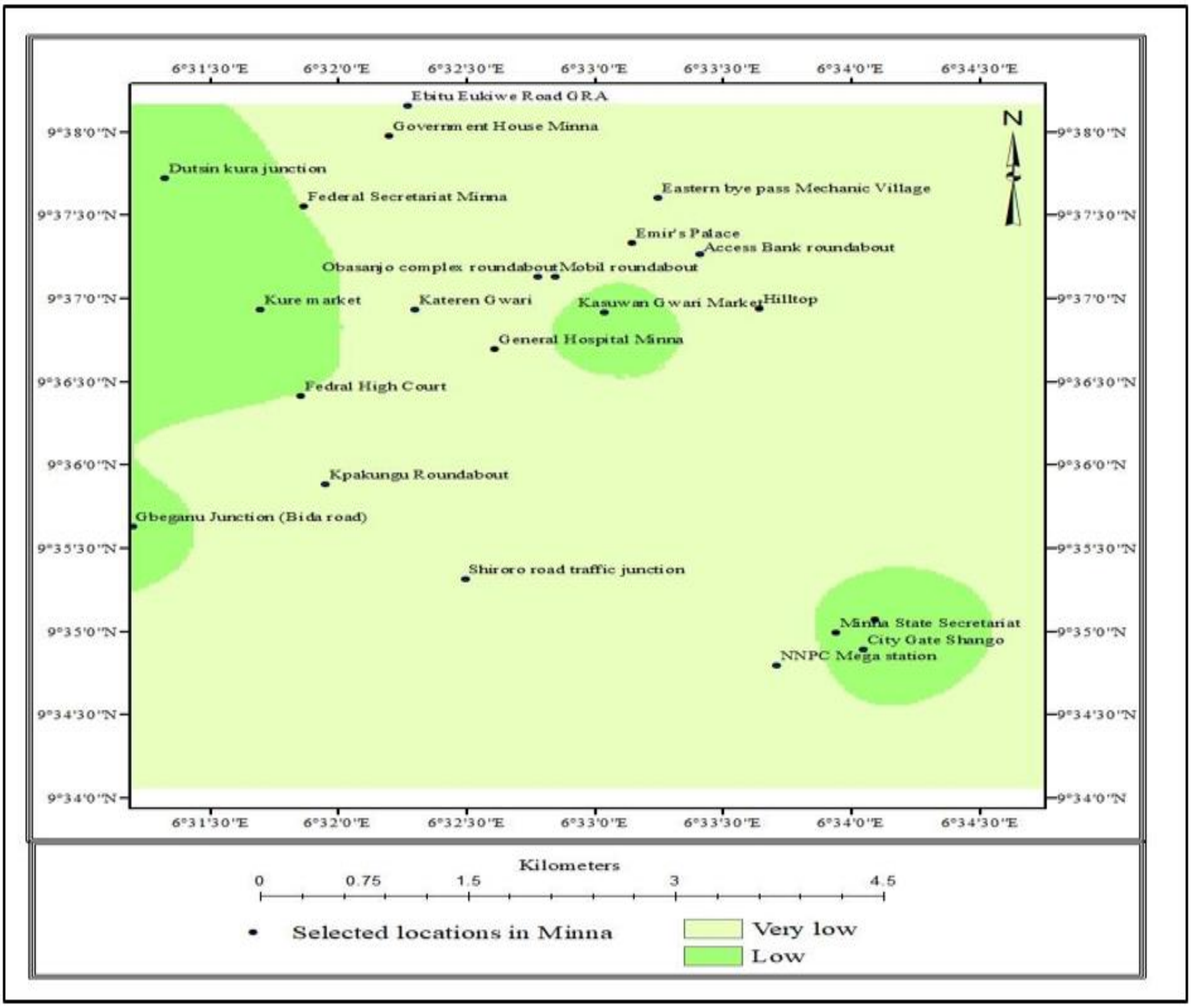

Fig 4 Spatial Distribution of Particulate Matter ($PM_{2.5}$) In Minna (Wet Season)
Source: Authors Analysis, (2024)

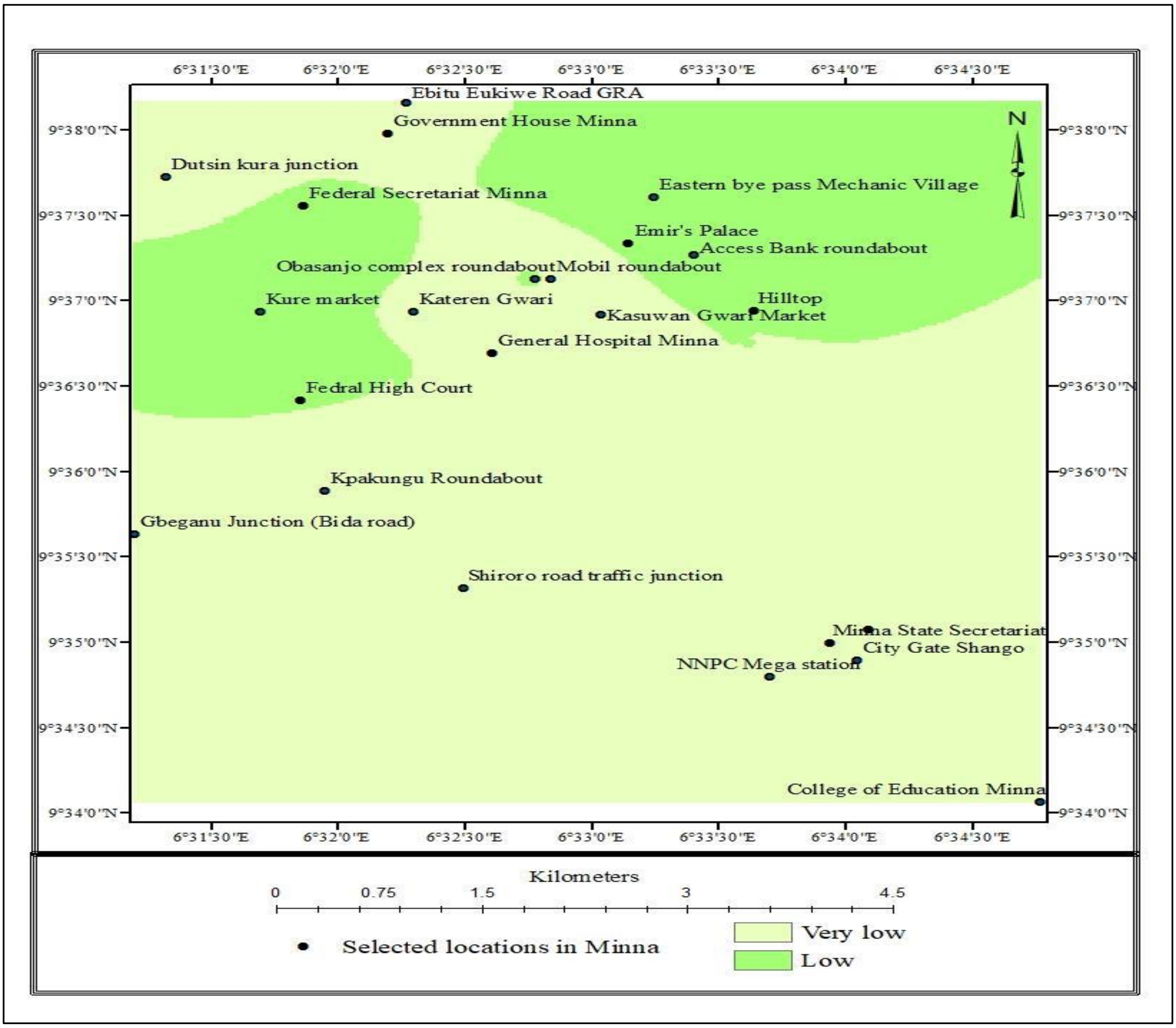

Fig 5 Spatial Distribution of Particulate Matter ($PM_{2.5}$) In Minna (Wet Season)
Source: Authors Analysis, (2024)

The average annual spatial distribution of Methane (CH_4) around Minna for both dry and wet season is presented in Figure 6 and 7. The results of the spatial distribution of CH_4 for dry season in the study area reveals that NNPC mega filling station, Access bank roundabout, and Gbegamu junction (Bida road) recorded moderate level of (1069.90, 1073.01, and 1075.79 ppm) CH_4 concentration in the identified study location. Also, locations like Kateren Gwari, Kpakungu road roundabout, and Citygate Shango recorded high level (1077.60, 1077.72, and 1078.01 ppm) of CH_4 in the study area, while locations like Kasuwan Gwari market, Dutsin kura junction, and Kure market recorded very high level (1084.61, 1086.72, and 1099.82 ppm) of CH_4 respectively (Figure 6).

Equally, the spatial distribution of CH_4 in the dry season in Minna shows that locations like NNPC mega filling station, Access bank roundabout, and Gbegamu junction (Bida road) recorded moderate level (1073.44, 1076.90, and 1082.49 ppm) of CH_4 concentration while locations like Kateren Gwari, Kpakungu road roundabout, and Citygate Shango recorded high level (1086.78, 1084.88, and 10.89.62 ppm) of CH_4, Also, very high level (1102.09, 1105.96, and 2225.58 ppm)of CH_4 was identified in Gwari market, Dutsin kura junction, and Kure market locations respectively (Figure 7).

.Generally, the finding revealed that CH_4 concentrations were moderate in selected areas like NNPC mega filling station, Access bank roundabout, and Gbegamu junction (Bida road). It was high in Kateren Gwari, Kpakungu road roundabout, and Citygate Shango. Equally, locations like Gwari market, Dutsin kura junction, and Kure market were characterized with very high concentration of CH_4 respectively (Figure 7).

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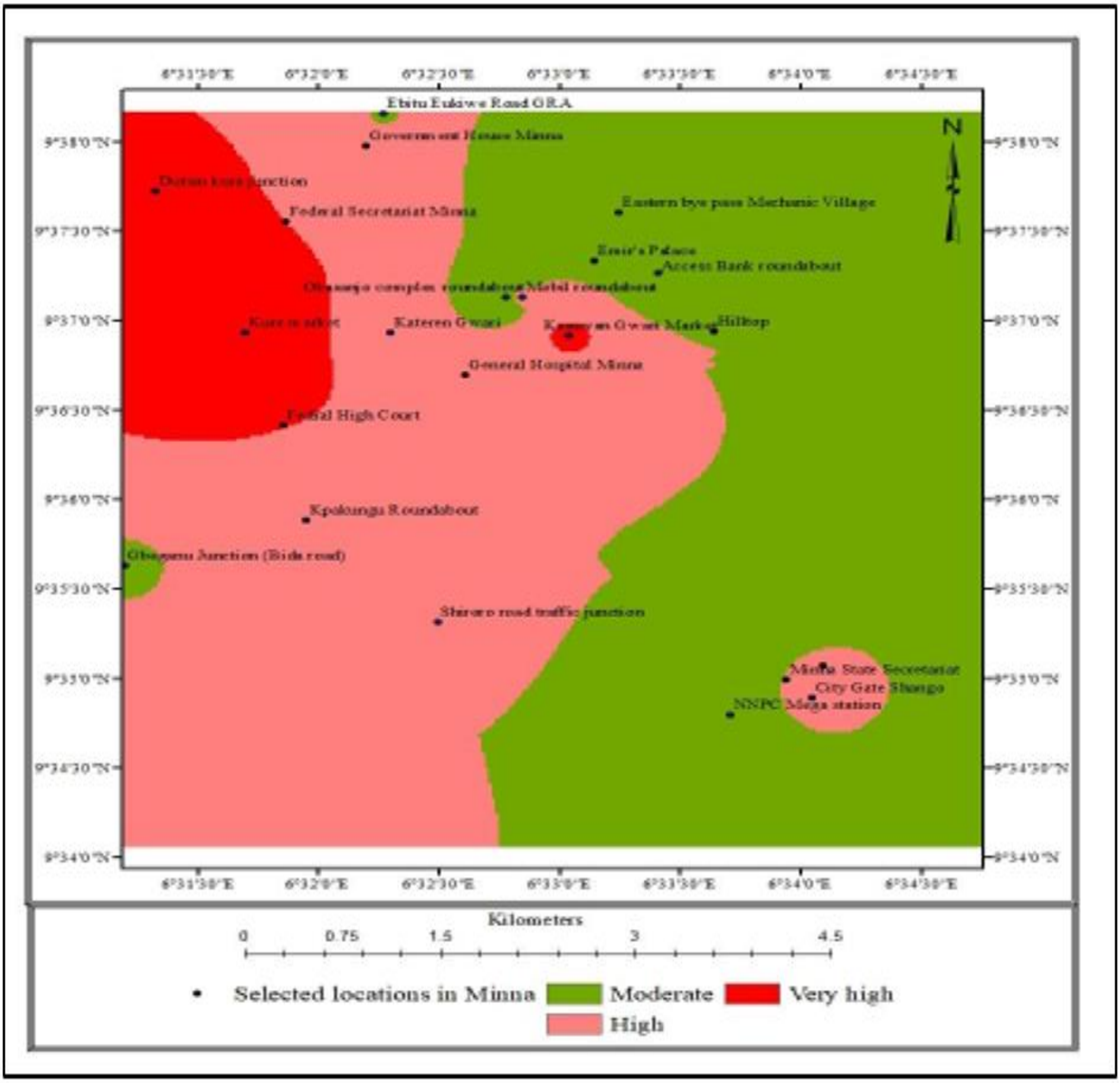

Fig 6 Spatial Distribution of Methane (CH_4) In Minna (Dry Season)
Source: Authors Analysis, (2024)

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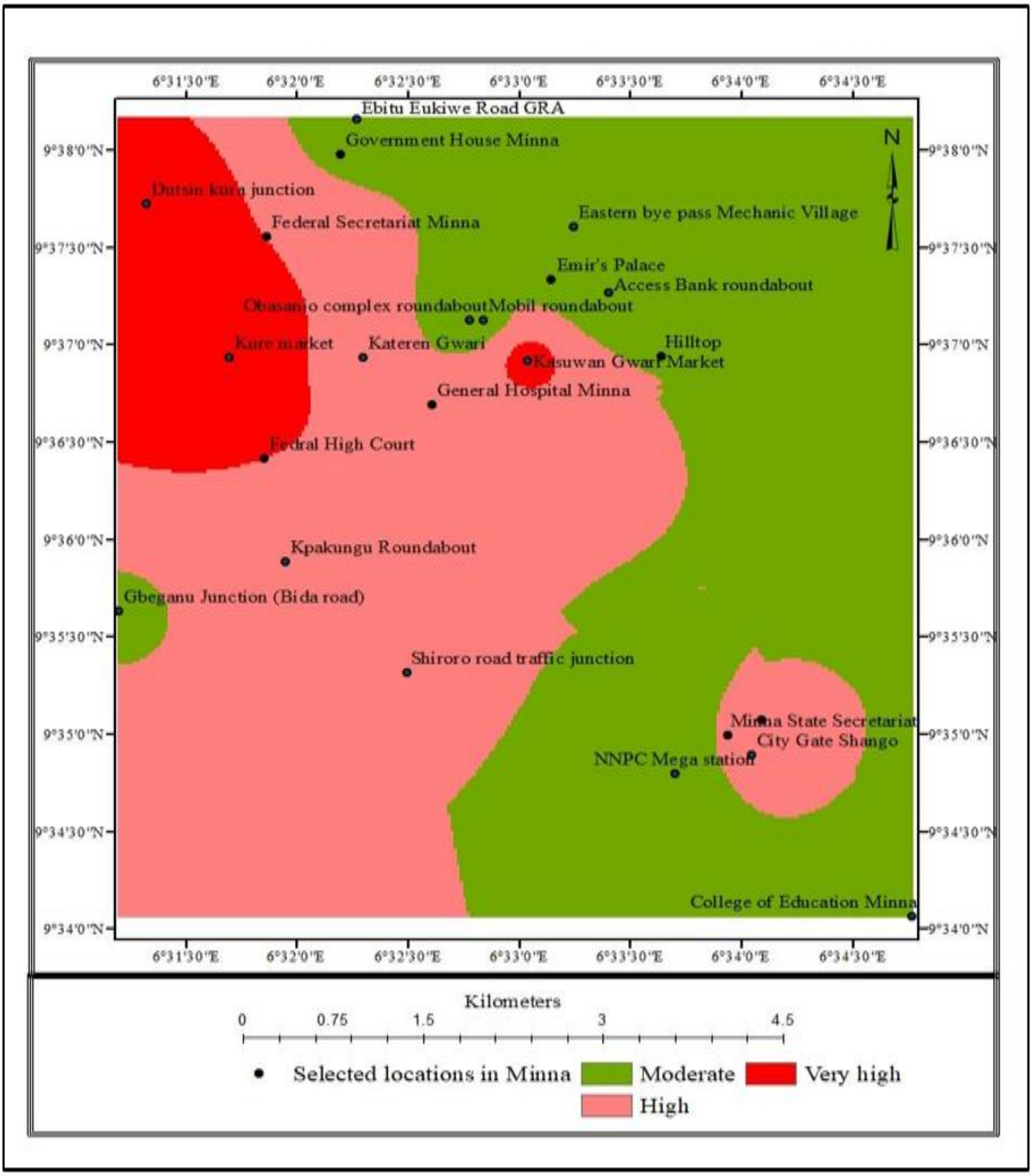

Fig 7 Spatial Distribution of Methane (CH_4) In Minna (Wet Season)
Source: Authors Analysis, (2024)

V. CONCLUSION AND RECOMMENDATIONS

The PM_{10} concentration was observed to be higher in the morning and lower in the afternoon across most locations. Kasuwan Gwari Market and Dutsinkura junction recorded significantly the highest PM_{10} concentration. The lowest PM_{10} concentration was recorded at Mobil roundabout, College of Education and NNPC Mega station. The $PM_{2.5}$ concentration was observed to be higher in Kasuwan Gwari Market, Dutsinkura junction, City Gate Shango and Gbeganu Junction Bida road while the lowest concentration of $PM_{2.5}$ was observed around College of Education. The CH_4 concentration was observed to range from 0.107 to 0.122 ppm and the spatial variation across different locations and

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duration during dry seasons while during wet seasons it ranges from 1.057 to 1.230 ppm. The findings recommended that Kanteren Gwari mechanic village should be relocated to outside of the town because of its proximity to residential areas where human population is concentrated and to avoid exposing the populace from being vulnerable to the menace of air pollution.

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