American Journal of Public Health Research, 2019, Vol. 7, No. 1, 1-8
Available online at http://pubs.sciepub.com/ajphr/7/1/1
Published by Science and Education Publishing
DOI:10.12691/ajphr-7-1-1

Health Impact Analysis of Some Outdoor Atmospheric Aerosols ($Pm_{2.5}$, SO_2, CO & CH_4) in F.C.T Abuja and Environs, Nigeria

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Received December 10, 2018; Revised January 13, 2019; Accepted January 20, 2019

Abstract The analysis of some outdoor atmospheric aerosols such as $PM_{2.5}$, SO_2, CO and CH_4 in Federal capital territory (FCT) Abuja, Nigeria was carried out, the study covered all the six (6) area councils "AMAC, Abaji, Bwari, Kuje, Kwali and Gwagwalada" of the FCT. Analysis was conducted for a cumulative data of one year period (2017-2018) based on monitoring satellite data within altitude of 6 Km from the ground levels, which was collected by National Space Research and Development Agency (NASRDA), Abuja, Nigeria. The data came in NETCDF format, extracted by a specialized software called the Arc Map 10.4.1, converted and exported in DBF format which can be read by Microsoft excel. Result of the analysis shows the pollutant various Air Quality Index (AQI) and pollutant mean concentrations (PMC), also the AQI and the maximum concentration of each pollutant in all the study areas were compared with the respective annual standard set by WHO, SO_2 was found to be ten thousand (10,000) times above 20 $\mu g/m^3$, CO is within the safe range, 10 times lower than 0.01 ppm, $PM_{2.5}$ was (2) times lower than 10 $\mu g/m^3$ and CH_4 are above the WHO/NIOSH threshold limit value of 1000 ppm with 50 percent increment. The effect varies for a different group of people (sensitive to insensitive), therefore they are said to have a deterministic effect.

Keywords: *atmospheric aerosols, Air Quality Index (AQI), health impact analysis*

Cite This Article: M. S. Shehu, I. Umaru, and B.W. Tukura, "Health Impact Analysis of Some Outdoor Atmospheric Aerosols ($Pm_{2.5}$, SO_2, CO & CH_4) in F.C.T Abuja and Environs, Nigeria." *American Journal of Public Health Research*, vol. 7, no. 1 (2019): 1-8. doi: 10.12691/ajphr-7-1-1.

1. Introduction

An aerosols caused by air pollution are especially felt in areas that record high economic growth and rapid urbanization, These toxic matters confined in an aerosol may result in an infections induced asthma, difficulty in breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. The human health effects of poor air quality are far reaching, and principally affect the body's respiratory system and the cardiovascular system. The World Health Organization stated that about 3.3 million people die each year from causes directly attributable to air pollution, with approximation of 1.5 million death attributable to indoor and 1.8 to outdoors air pollution, Figure 1 is the map of the study area [1,2].

1.1. Environmental Impact of the Aerosols under Study

Excess mortality due to indoors and outdoors air pollution have reached a large population, especially in most developing countries. Children aged less than five years that lived in growing and developing countries are the most vulnerable population in terms of total deaths attributable to both indoor and outdoor air pollution. Some of these deadly pollution are $PM_{2.5}$, SO_2, CO & CH_4.

1.1.1. Particulate Matter ($PM_{2.5}$) Environmental Effects

The health impacts of particulate matter relate to its ability to penetrate deep into the respiratory tract. It is particularly harmful for those who have a pre-existing respiratory illness. It also has a strong association with circulatory disease and mortality. AQI value above "Moderate" category or PMC above 10 $\mu g/m^3$ is considered dangerous to inhabitant. Can affect animals in the same way it affects humans and it can also reduce visibility [4,5].

1.1.2. Sulphur Dioxide SO_2 Environmental Effects

High concentrations of SO_2 leads to temporary difficulties in breathing especially for those who within the sensitive group, people with respiratory problems such as asthma. Long-term exposure to high SO_2 concentrations can aggravate existing cardiovascular disease and respiratory illness. AQI value above "Moderate" category or PMC above 20 $\mu g/m^3$, it contributes to the acidification and eutrophication of soil and water [4,5].

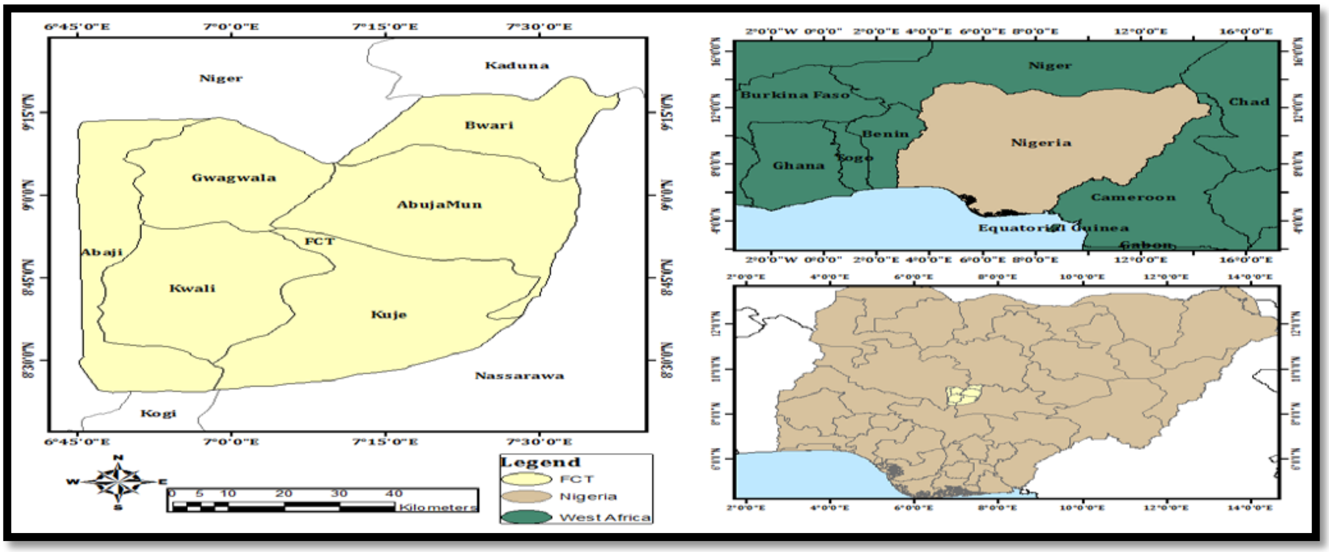

Figure 1. Map of FCT Abuja [3]

1.1.3. Carbon-monoxide (CO) Environmental Effects

At higher concentrations not normally found in ambient air, CO is poisonous, it causes an impaired vision and coordination, headaches, dizziness, confusion and nausea and it may induce fatigue in healthy people that may lead to death. May affect animals in the same way it affects humans. AQI value above "Moderate" category or PMC above 0.01 ppm [6].

1.1.4. Methane (CH_4) Environmental Effects

On a global scale, methane is a greenhouse gaseous aerosol. Although levels of methane in the environment are relatively low, its high "global warming potential" (21 times that of carbon dioxide) ranks it amongst the worst of the greenhouse gases. AQI value above "Moderate" category or PMC above 1000 ppm, uncovered pits and unventilated manure storage area are major sources of methane in the atmosphere [6].

2. Materials and Methods

Data was collected by National Space Research and Development Agency (NASRDA), Abuja Nigeria, through the ECMWF site. Which was extracted from the study regions for about three different time intervals: 00:00:00 to 06:00:00, 12:00:00 to 18:00:00 & 18:00:00 to 00:00:00. For 16 out of 24 hours daily throughout the year 2017. The coordinates of Abuja was used to select the area to be downloaded. The Atmospheric satellites information came in NETCDF format, which was extracted by a specialized software called the Arc Map 10.4.1, the processes are as follows. NETCDF layer was made together with the Copy Raster tools in the Multi-dimensional toolbox of Arc Map 10.4.1 respectively. After extraction, Abuja shape file was clipped from Nigeria and imported into the software according to districts in Abuja and then converted from features to points, from the tool in the data management toolbox and the coordinates of the points assigned using the "ADD XY CORDINATES" found in the coverage toolbox. The points and coordinates was used to extract values from the processed data using the "Extract multi-values to points" tool in the spatial analysis toolbox. The extracted values for the different districts were exported in DBF format which was read by Microsoft Excel. Finally the extracted values were imported into Excel window, the data cleaned, charts and graphs was plotted to show trends and relationships. The process was repeated for all the aerosols obtained.

2.1. Health Risk Assessment

Exposure to pollutant is defined as the event when person's body came in contact with a pollutants through dermal exposure and inhalation [6].

This section describes the assessment of the pollution mean concentration (PMC) which gives the absolute mean concentrations of the pollutant under study. The aim is to reduce a large volume of Data obtained from a daily mean to a monthly values. The pollutant mean concentration PMC was computed from equation 1.

$$\textit{Pollution mean concentration} = \frac{\textbf{Max. Conc} + \textbf{Min. Conc}}{2} \quad (1)$$

Where

Max. Conc. is the maximum concentration acquired daily for the period of one year [7].

Min. Conc. is the minimum concentration acquired daily for the period of one year [7].

Health risk assessment is achieved by means of the Air Quality Index (AQI), and this was conducted in order to evaluate the health risks to the exposed inhabitants. According to the World AQI Computational differences, AQI is calculated in accordance to qualifications for "good," "moderate," "Unhealthy for sensitive group" and "hazardous Air. The standards used in the world as well as the WHO/NIOSH standard was compared and summarized in Table 5 and the health impact action recommendation was presented Table 7. Irrespective of the aerosols resident time (average hours of existence) for different pollutants, Table 7 recommend some cautions that should be taken at a certain altitude to avoid exposure, which may lead to death. Equation. 2 was applied in determination of the health category of the various pollutant at different area councils.

$$AQI = \left[\frac{(\rho_{obs} - \rho_{\min})(\sigma_{\max} - \sigma_{\min})}{(\rho_{\max} - \rho_{\min})} \right] + \sigma_{\min} \qquad (2)$$

$\boldsymbol{\rho_{obs}}$ is observed 24-hour average concentration in μg/m^3.
$\boldsymbol{\rho_{max}}$ is maximum concentration of AQI from category that contains the observed PM.
$\boldsymbol{\rho_{min}}$ is minimum concentration of AQI from category that contains the observed PM.
$\boldsymbol{\sigma_{max}}$ is maximum AQI value from category that corresponds to the observed PM.
$\boldsymbol{\sigma_{min}}$ is minimum AQI value from category that corresponds to the observed PM.

The Sub-indices for individual pollutants at a monitoring location are calculated using its 24 hourly average concentration value (8-hourly in case of CO and O_3) and health breakpoint concentration range. Air Quality Index formula (equation 2) is used based on the 24-hour standard with 16-hours average. AQI are presented in Table 6 and Table 7 represent the breakpoint for $PM_{2.5}$ for a different time interval. Some pollutants stay in the atmosphere for only a short period of time while others can last longer. Therefore, different time intervals are considered for acquiring data concentrations in different aerosol [8].

3. Results and Discussion

3.1. Trends in $PM_{2.5}$ Concentrations

The annual trend for $PM_{2.5}$ in all the six area councils of Abuja was shown in Figure 2. Concentration of $PM_{2.5}$ shows almost the same trend as that of CO and SO_2, The level of $PM_{2.5}$ In the atmosphere of Abuja shows a similar orientation in all the area councils with little increase in the month of January, June and December. The maximum is in Bwari area council, with concentration up to a value (4.8828) followed by Gwagwalada (4.2201), AMAC (3.9654), Kwali (3.8035) and Abaji (3.4356) and Kuje (2.7349) μg/m³. Kuje the least concentration among the rest, the concentration for all the area councils are below the WHO/NIOSH standard and also within a very Good category of AQI. Given that, the concentration in all the areas were about (2) times lower than the WHO/NIOSH standard of (10 μg/m³), AQI as presented in Table 1 and WHO comparism to the pollutant maximum concentration in Table 5. The concentration were very close for all the area councils. The concentration constantly reduced from the month of February to April. It shows a little increase in May to June and in August to October with the same magnitude. A constant trend is maintained all through and then it Increases rapidly from October to January. $PM_{2.5}$ in general are related to an outcome that might lead to a cardiovascular and respiratory disorder [9].

Table 1. Health Impact analysis results for $PM_{2.5}$ (μg/m³) in all the Six Area Councils

S.No	FCT Abuja Area Councils	Maximum value (μg/m³)	Minimum value (μg/m³)	Mean Value (μg/m³)	AQI (24 hrs) μg/m³	Health Category
1	Abaji	3.4356	2.1190	3.62375	15.0000	Good
2	AMAC	3.9654	3.2821	2.77725	11,0000	Good
3	Bwari	4.8828	4.0979	4.49033	19,0000	Good
4	Gwagwalada	4.2201	4.0001	4.05813	17.0000	Good
5	Kuje	2.7349	2.2329	2.48388	10.0000	Good
6	Kwali	3.8035	3.5335	3.63849	16,0000	Good

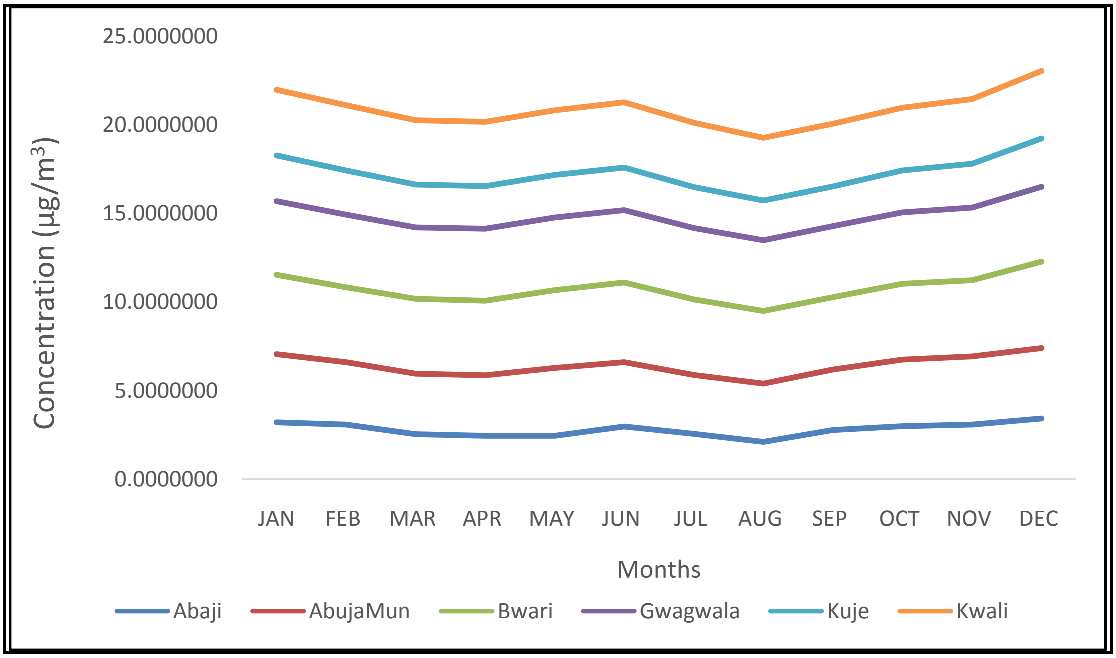

Figure 2. Particulate matter $PM_{2.5}$ (μg/m^3) monthly average data

3.2. Trends in Sulfur Dioxide Concentrations

The annual trend for SO_2 in all the six area councils of Abuja was shown in Figure 3 and Figure 4. There has been a significant changes in the level SO_2 throughout the year 2017, The level of SO_2 In the atmosphere of Abuja has rapidly increase in the month of January, which shows a maximum concentration up to a value (0.16 - $[1 \times 10^{-6})$, ppm in Kuje area council, followed by Gwagwalada (0.12 - 0.06), Kwali (0.10 - $[1 \times 10^{-6}]$), Bwari (0.08 - $[1\times 10^{-6}]$), AMAC (0.04 - $[1\times 10^{-6}]$) and Abaji ($[1 \times 10^{-6}] - 0.00$) ppm, which shows the least concentration just below the given threshold set by WHO, but SO_2 for the rest of the areas, from AMAC, Bwari, Gwagwalada, Kuje to Kwali. The concentration needs to be check, lest it becomes a major concern in the future. The concentration in those areas were about Ten thousand (10,000) times above the WHO standard of 20 µg/m^3 per year as presented in Table 5 and the AQI in Table 2. The concentration were almost the same in all the area councils and also below the threshold value from the month of February to December. It shows a higher trend from February to March, and then decreases rapidly from the month of April to September and then Increases rapidly from October to January [10].

Table 2. Health Impact analysis result for SO_2 (µg/m³) in all the Six Area Councils

S/No.	FCT Abuja Area Councils	Maximum value (ppm)	Minimum value (ppm)	Mean Value (ppm)	AQI (1/24 hr) (µg/m³)	Health Category
1	Abaji	0.0000011	0.0000001	0.0000006	0.090000	Good
2	AMAC	0.0416676	0.0000001	0.2083381	16.0001	Good
3	Bwari	0.0833342	0.0000001	0.0416672	57.0001	Moderate
4	Gwagwalada	0.1250009	0.0000001	0.0625005	84.0001	Moderate
5	Kuje	0.1666676	0.0000001	0.0833339	104.0001	Unhealthy for Sensitive Groups
6	Kwali	0.2083343	0.0000001	0.1041672	114.0001	Unhealthy for Sensitive Groups

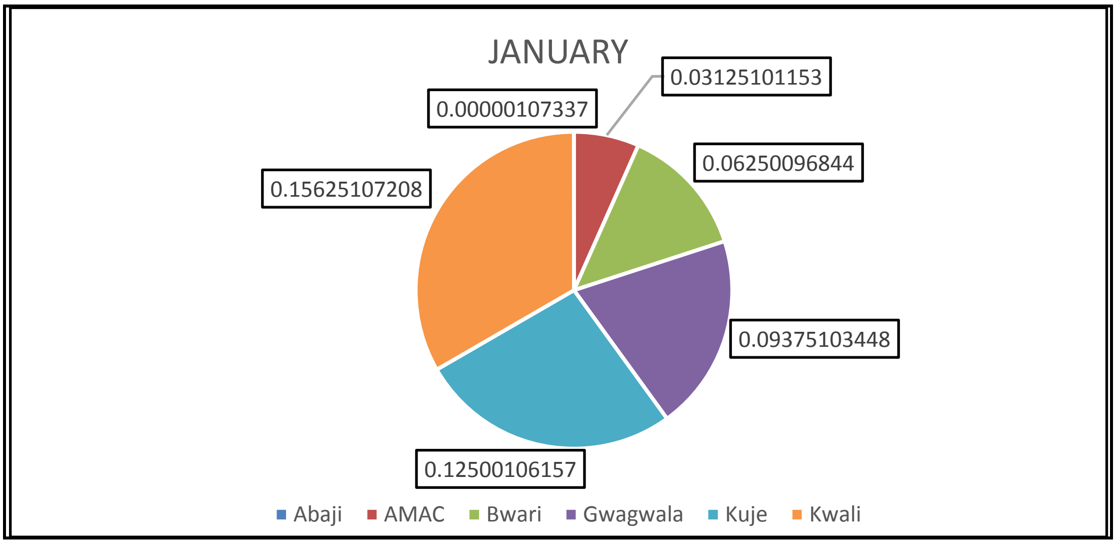

Figure 3. Sulphur dioxide SO_2 (ppm) average data for the month of january

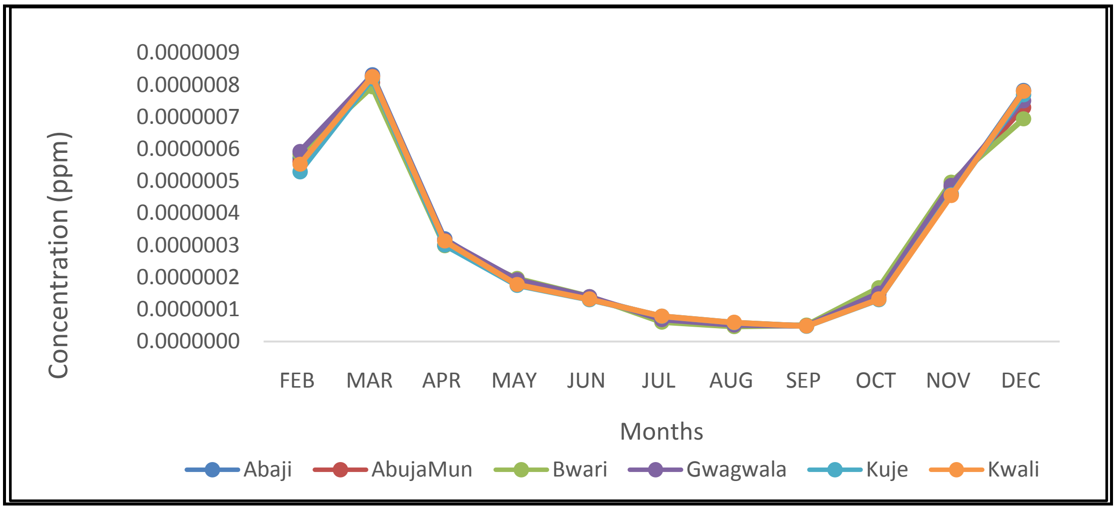

Figure 4. Sulphur dioxide SO_2 (ppm) monthly average data from February to December.

3.3. Trends in Carbon Monoxide Concentrations

The annual trend for CO in all the six area councils of Abuja was shown in Figure 5. Concentration of CO shows a little similarities with that of SO_2, The level of CO in the atmosphere of Abuja shows a rapid increase in the month of January, with some little differences in all the area councils. The maximum is in Kwali area council, with concentration up to a value (0.0015886), followed by Abaji (0.0015929), Kuje (0.0015696), Gwagwalada (0.0015448), Bwari (0.0014706), and AMAC (0.0014587) ppm. AMAC shows the least concentration among the rest, the concentration for all the area councils are within the safe range, almost 10 times lower than the WHO standard (0.01ppm) and all the values fall under a Good category of AQI as presented in Table 3 and WHO comparism to the pollutant maximum concentration in Table 5. The concentration were very close for all the area councils. Which constantly reduced from the month of February to July. It shows a little increase within July and August, Also another decrease of the same magnitude to September. A constant increase were maintained to September and then, it Increases rapidly from October to January.

3.4. Trends in Methane (CH_4) Concentrations

Methane CH_4 is not considered as one of the pollutants that impact health by National Air Quality Index, worldwide. [11] Therefore the reported analysis on CH_4 was comparism of WHO According to AAI guidelines and the CH_4 concentrations in all the area councils. The annual trend for CH_4 in all the six Area councils of Abuja were shown in Figure 6. The same trend were maintained in all the area councils throughout the year 2017, The level of CH_4 In the atmosphere of Abuja was constantly changing across the year with a significant rates, it shows a rapid increase in the month of January to February, March to April, July to December and a decrease from February to March, April down to July, it shows a maximum concentration up to a value 1786.52 ppm in Kuje, area council, followed by AMAC (1785.22), Kwali (1784.90), Abaji (1784.76) Gwagwalada (1784.16) and Bwari (1783.99) ppm, These concentrations of CH_4, are above the threshold limit value of 1000 ppm, their implication are harmful to the habitant and the environment. The NIOSH threshold limit value of CH_4 is 1000ppm, as presented in Table 5. When is at 50,000 to 150,000 it implies a potentially explosive and at 500,000 ppm may lead to Asphyxiation as stated by Attah Atia in his study **[11]**.

But As a result of human negligence, methane emissions have started to pose a negative effect in our environment over time. As larger amounts of permafrost melt and increase CH_4 levels, we must reduce other forms of methane producing activities in order to live sustainably.

Table 3. Health Impact analysis result for CO (µg/m³) in all the Six Area Councils

S/No.	FCT Abuja Area Councils	Maximum value (ppm)	Minimum value (ppm)	Mean Value (ppm)	AQI (8 hrs) µg/m³	Health Category
1	Abaji	0.0015929	0.0009998	0.0012964	0.0050000	Good
2	AMAC	0.0014587	0.0009769	0.0012076	0.0040000	Good
3	Bwari	0.0014706	0.0009568	0.0012137	0.0040000	Good
4	Gwagwalada	0.0015448	0.0009770	0.0012609	0.0050000	Good
5	Kuje	0.0015696	0.0010035	0.0012865	0.0050000	Good
6	Kwali	0.0015886	0.0009990	0.0012938	0.0050000	Good

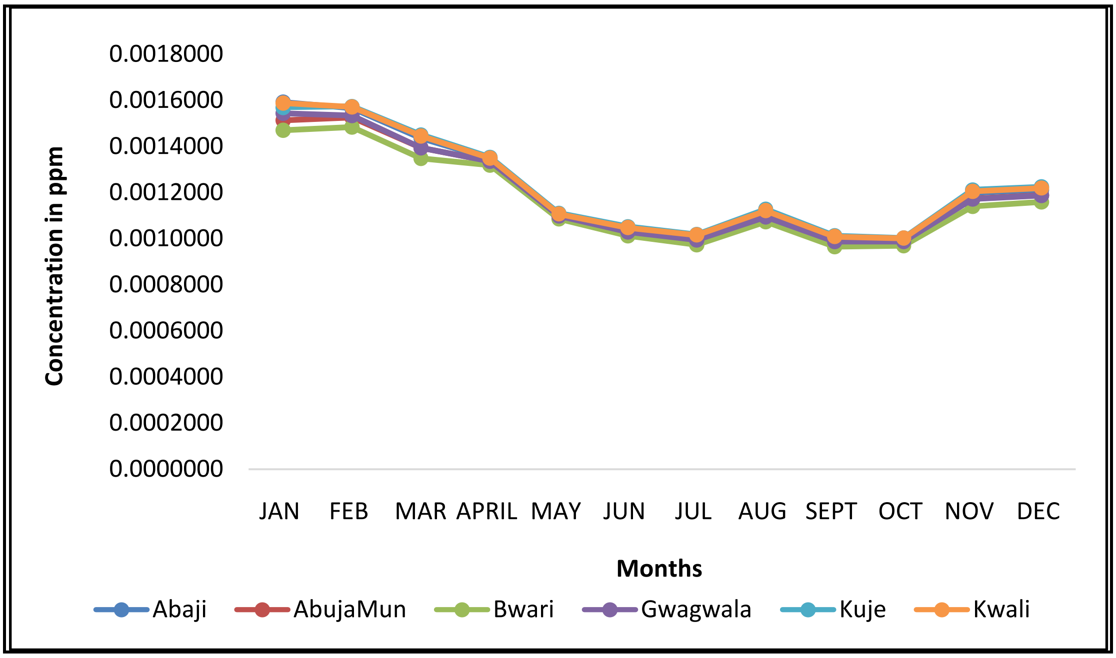

Figure 5. Carbon monoxide CO (ppm) monthly average data in all the area councils

Table 4. Health Impact analysis result for CH_4 (ppm) in all the Six Area Councils

S/No.	FCT Abuja Area Councils	Maximum value (ppm)	Minimum value (ppm)	Mean Value (ppm)	Health Category
1	Abaji	1784.76	1764.57	1774.67	Unhealthy
2	AMAC	1785.22	1762.73	1773.98	Unhealthy
3	Bwari	1783.99	1761.49	1772.74	Unhealthy
4	Gwagwalada	1784.16	1763.27	1773.72	Unhealthy
5	Kuje	1786.52	1764.30	1774.72	Unhealthy
6	Kwali	1784.90	1764.60	1774.75	Unhealthy

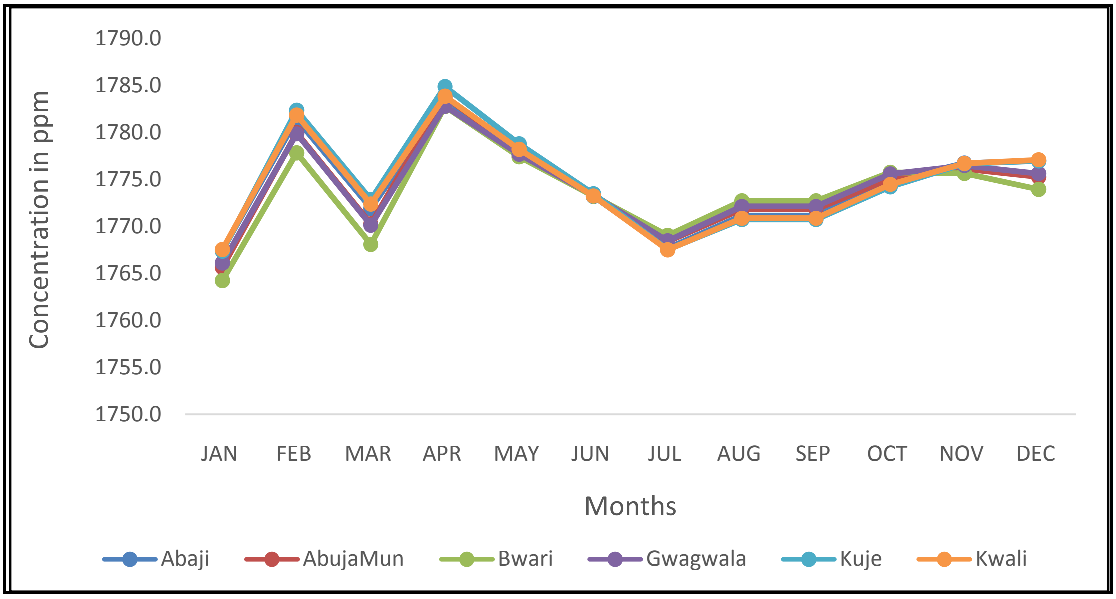

Figure 6. Methane CH_4 (ppm) monthly average data in all the area councils

Table 1 to Table 4 shows the health impact analysis result based on AQI method, for $PM_{2.5}$, CO & SO_2 respectively, which reveals the following category for all the area council. For SO_2 in Abaji is "Good", AMAC "Good", Bwari "Moderate", Gwagwalada "Moderate", Kuje Unhealthy for Sensitive Groups" and Kwali "Unhealthy for Sensitive Groups". But CO and $PM_{2.5}$ AQI are found to be "Good" Category for all the area councils.

The AQI Analysis conform to a study from the literature, reported by Abam and Unachukwu, titled "Vehicular emission and air quality standard in Nigeria" the result of the AQI rating for CO & SO_2 with concentration within (3.3-8.7 ppm) was carried out at nine locations in some selected areas in Cross river, Calabar State, Nigeria for 3 different days, and the highest values was observed to be at a traffic congestion and traffic. intersection, the AQI for CO varies from "moderate" to "Unhealthy/Hazardous", SO_2 with concentration within (0.04-0.15ppm), AQI varies from "Unhealthy to Hazardous or poor to very poor" health category [12].

By comparing a study in 2015 by Abam & Unachukwu. [12] with this research of 2017-2018 by M.S.Shehu *et al.* it can be understood that there is a great improvement in the air quality of F.C.T. Abuja. According to the AQI Analysis result as presented in the study.

4. Summary of Result and Appendices

Table 5. Standard Based on Who/Aai/Niosh Guidelines

Aerosol	Max. Concentration acquired	Approved Standard (WHO/AAI/NIOSH). [10,13]
PM_2	4.8828 μg/m³	10 μg/m³ or 0.00001 ppm. [10,13]
SO_2	0.20 ppm	20 μg/m³ or 0.00002 ppm. [10,13]
CO	0.0015886 ppm	0.01ppm. [10,13]
CH_4	1786.52 ppm	1000 ppm [10,13]

Table 6. Air Quality Standards (AQI)

AQI (24-hour) AQI (μ g/m³)	**Breakpoints $PM_{2.5}$ μ g/m³**	**Breakpoints CO (ppm)**	**Breakpoints SO_2 (ppm)**	**Color codes**
Good (0 – 50)	0 – 15.4	0.0-4.4	0.000-0.034	Green
Moderate (51 – 100)	15.5 – 40.4	4.5-9.4	0.035-0.144	Yellow
Unhealthy for Sensitive Groups (101 – 150)	40.5 – 65.4	9.5-12.4	0.145-0.224	Orange
Unhealthy (151 – 200)	65.5 – 150.4	12.5-15.4	0.225-0.304	Red
Very Unhealthy (201 – 300)	150.5–250.4	15.5-30.4	0.305-0.604	Purple
Hazardous (301 – 400)	250.5-350.4	30.5-40.4	0.605-0.804	Maroon
Hazardous (401 – 500)	350.5-500.4	40.5-50.4	0.805-1.004	Green

Table 7. Smoke particles guide recommended actions for public health officials

AQI Category (AQI values)	1–3-hour Average	8-hour Average	24-hour Average	Recommended actions. [14]
Good (0–50)	0–38	0–22	0–15.4	• If smoke event forecast, implement Communication plan [14].
Moderate (51–100)	39–88	23–50	15.2–40.4	• Issue public service announcements advising public about health effects and symptoms and ways to reduce exposure. Distribute information about exposure avoidance [14].
Unhealthy for sensitive Groups (101–150)	89–138	51–79	40.5–65.4	• If smoke event projected to be prolonged, evaluate and notify possible sites for cleaner air shelters, If smoke event projected to be prolonged, prepare evacuation plans [14].
Unhealthy (151–200	139–351	80–200	65.5–150.4	• Consider 'smoke day' for schools (no school that day), possibly based on school environment and travel considerations. Consider cancelling public events [14].
Very Unhealthy (201–300)	352–526	201–300	150.5–250.4	• Consider closing some or all schools (newer schools with a central air cleaning filter may be More protective than older, leakier homes) • Cancel outdoor events (such as concerts And competitive sports) [14].
Hazardous (> 300)	> 526	> 300	> 250.5–500	•Cancel outdoor events (such as concerts and competitive sports), Close schools, Consider closing workplaces not essential to public health and If PM level is projected to remain high for a prolonged time, consider evacuation of sensitive populations [14].

5. Conclusions

The fact that all the health risk assessment methods applied had yielded to a closely related result, is indeed an evidence that aerosol SO_2 and CH_4 in all the area councils of FCT Abuja will pose a negative effect. WHO threshold is considered and were found to be below the threshold for $PM_{2.5}$ and CO, but for SO_2 and CH_4 were above all standard. Since the effect varies from person to person, therefore they are said to have a deterministic effects. The result of the $PM_{2.5}$, SO_2, CO & CH_4 seasonal impact analysis shows that the pollutant concentrations in all the area councils were found to be higher in dry than in wet season with maximum of about a percentage 33.33 % drop from 1.5×10^{-3} to 1.0×10^{-3}ppm for CO, result which reveals a lower decrease compared to a study reported by F.P. Lympson in 2015, on carbonmonoxide emission impact on human health in Abuja, Nigeria. During the wet season CO was 5 ppm 8 hourly mean below all standards which rises slightly to above 15 ppm 8 hourly mean between Tukpechi, Tuje town and Chibiri districts, which is aproximately about 66.66 % drop [15,16]. A long-term exposure can aggravate an existing heart or lung conditions which might lead to death.

Acknowledgments

This research was supported by Baze University Abuja, (BU) and Nasarawa State University, Keffi (NSUK). In affiliation with the Climatic Change and Modelling Division, Department Of Strategic Space Applications of the National Space Research and Development Agency (NASRDA), Abuja The authors also appreciate Mr. Tola Adedeji of (NASRDA), Dr. Hamman tukur Gabdo and Dr. O.K.Oyewole of Physics Department, Baze University Abuja, Nigeria, for their contributions.

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