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PREDICTIVE AIR POLLUTION ASSESSMENT USING MATRIX ALGEBRA AND GIS/GPS IN AGULERI ANAMBRA STATE

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ABSTRACT. This study assessed the air pollution loads of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM_{10}) from Aguleri in Anambra State of Nigeria using matrix algebra and the geographical information system (GIS)/global positioning system (GPS) attachment to MATLAB. The pollutant values of SO_2 and NO_2 were obtained using the Crowcon Gas Monitor Model CE 89/336/EEC, while the PM_{10} values were obtained with the Crowcon Particulate Monitor Model No.1000 with the serial number 298621. The pollution characteristics of the study area were simulated using the polynomial expression $yi = k + k_1x_1 + k_2x_2 + k_3x_3 +\ldots k_nx_{n..}$ The predictive parameter constants, k, were determined with the solution to the simultaneous equations arising from the polynomial expressions using matrix algebra. MATLAB 7.9 curve fitting software was used to produce associated model equations from the fitted curves for the variations of SO_2, NO_2 and PM_{10} as a function of locations in Aguleri for both rainy and dry seasons. The evaluation of pollution models used for the study showed that constants from the fitted curves do not closely match constants from ab initio calculations. The corresponding coordinates in both GIS/GPS contour and surface plots revealed a pollution distribution concentration of 50% in Aguleri. The results revealed that the stations in Aguleri had a satisfactory air pollution index rating. This study serves as an improvement to air quality studies and a veritable tool for air quality management and policymaking.

Keywords: air pollutants; particulate matter; polynomial equations; seasons; software.

INTRODUCTION

Air pollution is a global phenomenon that has gradually distorted the Earth's climate, leading to the greenhouse effect, acid rain, flooding, high temperatures, death of aquatic

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species, and disease spread (Abdul-Lateef *et al.*, 2021; Abulude *et al.*, 2024; Chengyue *et al.*, 2021; Ilmas *et al.*, 2018; Omokpariola *et al.*, 2024; Tella and Balogun, 2022). Abdul-Lateef *et al.* (2021) reported that according to the World Health Organization (WHO), ambient and indoor air pollution have significantly increased mortality and morbidity rates, especially in developing countries. The WHO (2022) reported that the combined effects of ambient and household air pollution are associated with 6.7 million premature deaths annually, with an estimated 4.2 million premature deaths recorded worldwide in 2019, 89% of which occurred in low- and middle-income countries, particularly in the WHO South-East Asia and Western Pacific Regions.

The current population pressure in Nigeria, alongside urbanisation, modern agricultural practices, and industrialisation, has rapidly metamorphosed into air pollution (Abulude *et al.*, 2024; Omokpariola *et al.*, 2024). Abdulraheem *et al.* (2023) observed an increasing pattern in pollutants such as carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter of 2.5 micrometres in diameter ($PM_{2.5}$), particulate matter of 2.5 micrometres in diameter (PM_{10}), sulphur dioxide (SO_2), ammonia (NH_3) and non-methane volatile organic compounds arising from the population surge in Nigeria from 1980 to 2020. The total emissions such as CO, NOx, $PM_{2.5}$, PM_{10}, SO_2, NH_3 and NMVOC recorded increased from 1736 to 6210 Gg, 143 to 338 Gg, 126 to 551 Gg, 171 to 717 Gg, 19 to 60 Gg, 4 to 28 Gg and 471 to 1587 Gg, respectively. The author reported that emissions from wood fuel, transportation, and municipal waste are the major sources contributing to 63%, 16%, and 15% of the total CO emissions (Abdulraheem *et al.*, 2023). Environmental pollution modelling is a numerical tool used to describe the causal relationships between emission, discharge, and fluxes of various kinds through the natural environmental matrix. Such tools are of considerable importance in the agricultural field due to the overwhelming influence of land and water use for sustainable development (Lokeshwari *et al.*, 2014).

The agricultural non-point source (AGNPS) pollution model was developed to analyse non-point source pollution in agricultural watersheds. Within this framework, run-off characteristics and transport processes of sediments and nutrients can be simulated for each geographical map cell routed. This permits the run-off, sedimentation, encrustations and erosion in each cell in the watershed to be determined or simulated (Luo *et al.*, 2023; Zhu *et al.*, 2020). Thus, AGNPS can identify sources contributing to a potential pollution challenge and prioritise those locations where remedial measures could be initiated to improve land use quality. Such modelling can be applied to air pollution studies by the incorporation of a geographic information system (GIS), global positioning service (GPS), and remote or proximate sensing (Borah *et al.*, 2024; Firouraghi *et al.*, 2022; Khaslan *et al.*, 2024; Thakur *et al.*, 2017; Utbah *et al.*, 2023). Data from these systems can be processed in multiple dimensions on a digitised geographical map (Balogun *et al.*, 2011; Chaminé *et al.*, 2021; Najibullah, 2020).

In this process, GIS data layers required by models similar to AGNPS models can be created using appropriate statistical map treatment. The data generated will subsequently become spatial information for pollution studies (Khan and Jehangir, 2023; Matejicek, 2005; Tella and Balogun, 2022; Verma *et al.*, 2023). When air pollution attributes such as NO_2, SO_2, PM, and ozone (O_3) are available, GIS, GPS and digitised map formats can be extracted and combined with other data such as meteorological indices reformatted as needed for various geographical and best management practices in the total environment (Badach *et al.*, 2020; Seham *et al.*, 2022; Yerramilli *et al.*, 2011; Yoo, 2022).

With the increase in urbanisation, industrialisation, the number of vehicles, and other anthropogenic activities, researchers have employed more sophisticated methodologies such as machine learning, artificial intelligence, and the Internet of Things to solve air pollution problems (Abdul-Lateef *et al.*, 2021; Patra *et al.*, 2016; Zezhi *et al.*, 2024). Several studies of atmospheric pollution by attributes such as CO, NO_x, SO_x, hydrocarbons (C_nH_{2n+2}), and PM, which may or may not encapsulate metal species or volatile organic residues, have been carried out all over the world (Abdulraheem *et al.*, 2023; Daful *et al.*, 2020; Gerard, 2021; Jyethi *et al.*, 2016; Knepnick and Sebastian, 1990; Manisalidis *et al.*, 2020). Such studies, including research on emerging pollutants, are becoming widespread in Nigeria (Abam and Unachukwu, 2009; Augustine, 2012; Dimari *et al.*, 2008; Ediagbonya and Tobin, 2013; Egbuna *et al.*, 2021; Obisesan and Weli, 2019; Omofonmwan and Osa-Edoh, 2008; Mahmud *et al.*, 2023; Tawari and Abowei, 2012; Yalwaji *et al.*, 2022). However, only a handful of these studies have been able to relate physical, geographical, and meteorological data into a model which can respond to best management practices (Anyika *et al.*, 2018). The data available so far have been only a little better than baseline statistics comparing available physical concentrations of attributes with either WHO standards or FEPA equivalents. The level of air pollution monitoring or control in Nigeria is not comparable to that of large cities like Cairo, Tehran, and Johannesburg. These countries have established regular air pollution monitoring stations for many years. Therefore, the focal point of this work is to attempt an improved interpretation of air pollution assessment using GIS, GPS, and matrix algebra.

MATERIALS AND METHODS

Description of Study Area

Aguleri is an area north-north-east of Onitsha town bound by the coordinates 6º20′30E to E6º53′, and it is 24 km NNE from Onitsha main town. Aguleri, located in the River Anambra Basin, is an agrarian town with a population of about 300,000, as represented in Figure 1. The map was obtained from Google Earth using Arc View 3.0 software. Georeferencing of all data points in maps was done using GARMIN GPS 78 s chart plotting receivers. Nine locations were designated as sampling stations in Aguleri, and each designated sampling station was divided into four sampling points from where four samples were collected. The climate of Aguleri is tropical or savanna, with two distinct dry and wet seasons. It has an annual temperature of 87.66º, 1.46% higher than Nigeria's average temperature, with annual precipitation of 8.92 inches and 71.12% of rain annually. Aguleri has an elevation of zero feet above sea level. The points in each station have been georeferenced to enable the application of GIS/GPS analysis parameters summarised in *Table 1* and *Table 2*.

Table 1 – Georeferenced Coordinates for the Rainy Season in Aguleri

Sampling Station	Coordinates			
	Point 1	**Point 2**	**Point 3**	**POINT 4**
Aguleri Junction	N06º19.757' E006º52.628'	N06º19.755' E006º52.601'	N06º19.693' E006º52.612'	N06º19.689' E006º52.640'
Ifite Aguleri	N06º19.354' E006º53.212'	N06º19.371' E006º53.188'	N06º19.376' E006º53.212'	N06º19.356' E006º53.194'
Igboezuru Aguleri	N06º18.666' E006º54.622'	N06º18.666' E006º54.650'	N06º18.650' E006º54.645'	N06º18.677' E006º54.631'
Okpu Aguleri	N06º19.584' E006º53.514'	N06º19.563' E006º53.547'	N06º19.599' E006º53.538'	N06º19.562' E006º53.524'
Umuokpoto Aguleri	N06º19.758' E006º52.933'	N06º19.738' E006º52.966'	N06º19.736' E006º52.949'	N06º19.773' E006º52.963'
Enugu Otu Aguleri	N06º32.134' E006º55.279'	N06º32.087' E006º55.300'	N06º32.029' E006º55.319'	N06º31.366' E006º55.344'
Ezi Agulu Otu Aguleri	N06º21.480' E006º51.499'	N06º21.489' E006º51.517'	N06º21.496' E006º51.492'	N06º21.450' E006º51.496'
Umundeze Aguleri	N06º21.182' E006º51.290'	N06º21.168' E006º51.289'	N06º21.171' E006º51.302'	N06º21.171' E006º51.274'
Amaeze Aguleri	N06º20.570' E006º50.711'	N06º20.583' E006º50.678'	N06º20.565' E006º50.661'	N06º20.541' E006º50.683'

Table 2 – Georeferenced Coordinates for the Dry Season in Aguleri

Sampling Station	Coordinates			
	Point 1	**Point 2**	**Point 3**	**Point 4**
Aguleri Junction	N06º19.736' E006º52.632'	N06º19.738' E006º52.608'	N06º19.689' E006º52.611'	N06º19.689' E006º52.637'
Ifite Aguleri	N06º19.351' E006º53.213'	N06º19.376' E006º53.212'	N06º19.370' E006º53.193'	N06º19.355' E006º53.197'
Igboezuru Aguleri	N06º18.671' E006º54.631'	N06º18.665' E006º54.620'	N06º18.648' E006º54.654'	N06º18.669' E006º54.644'
Okpu Aguleri	N06º19.557' E006º53.520'	N06º19.570' E006º53.539'	N06º19.586' E006º53.535'	N06º19.582' E006º53.521'
Umuokpoto Aguleri	N06º19.740' E006º52.952'	N060º19.741' E006º52.965'	N06º19.765' E006º52.962'	N06º19.756' E006º52.947'
Enugu Otu Aguleri	N06º33.717' E006º54.104'	N06º33.694' E006º54.106'	N06º33.657' E006º54.115'	N06º33.657' E006º54.115'
Ezi Agulu Otu Aguleri	N06º21.496' E006º51.494'	N06º21.490' E006º51.507'	N06º21.458' E006º51.495'	N06º21.470' E006º51.504'
Umundeze Aguleri	N06º21.166' E006º51.291'	N06º21.175' E006º51.279'	N06º21.165' E006º51.292'	N06º21.175' E006º51.298'
Amaeze Aguleri	N06º20.574' E006º50.710'	N06º20.562' E006º50.662'	N06º20.567' E006º50.665'	N06º20.543' E006º50.684'

Experimental Design

Sulphur dioxide (SO_2), nitrogen oxide (NO_2), particulate matter (PM_{10}), relative humidity, and wind speed were assessed in the study area. The data obtained were applied to create the various concentration contours and model polynomial equations (matrix algebra). MATLAB 7.9 fitting software was used to plot the graph of weighted coordinates against the mean concentrations in each location in Aguleri (Pilla and Broderick, 2015; Yorkor *et al.*, 2017).

Data Acquisition

Data were acquired by measuring in situ ground-level concentrations of SO_2, NO_2, and PM10 using Crowcon Gas Monitors (Model CE 89/336/EEC) and a Crowcon Particulate Monitor (Model No. 1000, Serial No. 298621) from the Imo State Environmental Protection Agency. Wind speed, direction, and relative humidity were determined using a digital meter and Environmental Meter (Model AE.09605) from Rumsey Environmental LLC at the Federal University of Technology, Owerri.

Gas analysers and sensors, Model Lancom III, manufactured by Land Instrument International Pittsburgh, PA were operated using the Thermo Electron gas analysers procedure.

The sensor components were SnO_2, as used by Robert *et al.* (2011).

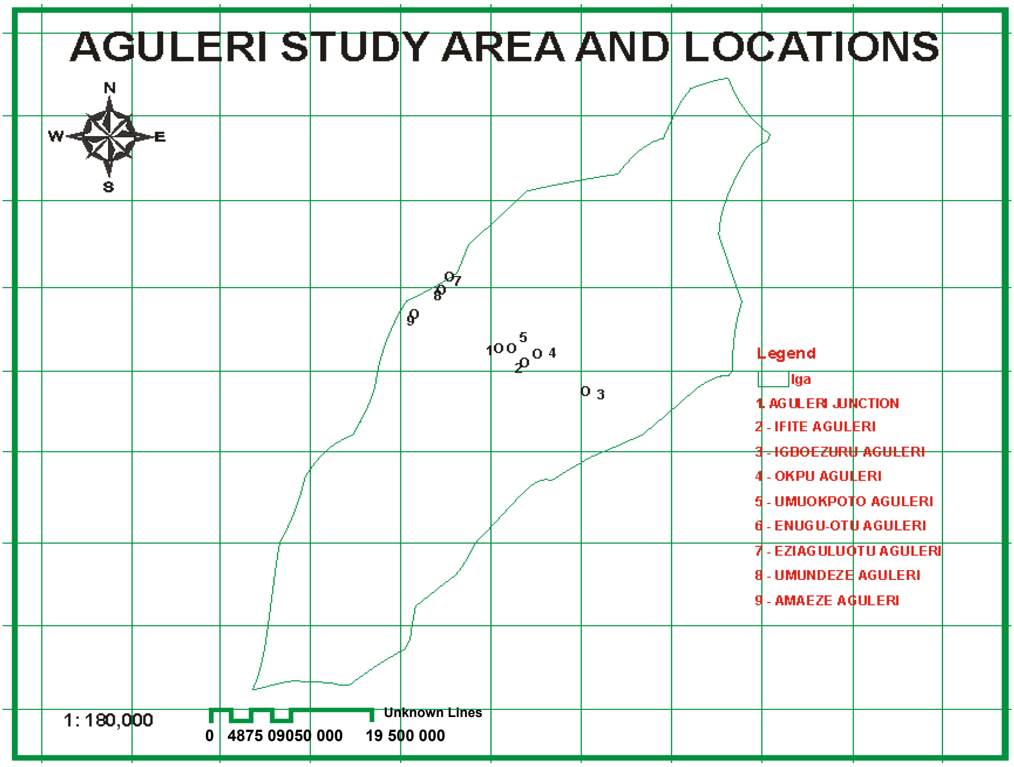

Figure 1 – Digitised map of study area and locations (Google Earth, 2018)

Calibration of Instruments Used

The sensors, initially factory calibrated, were recalibrated and stabilised using NO_2 and SO_2 gases, as detailed by Park *et al.* (2013) at the Imo State Environmental Protection Agency laboratories.

Air Quality Index (AQI)

The AQI indicates the pollution level in an area's atmosphere by calculating the individual air quality index (IAQI) for each pollutant using *Equation 1*:

$$\mathrm{IAQI} = \frac{\mathrm{IAQI_{HI}} - 1\mathrm{AQI_{LO}}}{\mathrm{BP_{HI}} - \mathrm{BP_{LO}}} \times \times (\mathrm{C_P} - \mathrm{BP_{LO}}) + 1\mathrm{AQI_{LO}} \quad (1)$$

Here, $IAQI_P$ represents the IAQI for pollutants (PM10, SO_2, NO_2), C_P stands for the daily mean concentration of the pollutant, BP_{LO} and BP_{HI} are the nearest and lowest values of C_P, and $IAQI_{LO}$ and $IAQI_{HI}$ are the IAQIs in terms of BP_{HI} and BP_{LO} as shown in *Table 3*. *Table 3* shows that the IAQI maximum exceeds 100. After calculating the $IAQI_P$ for each pollutant, the AQI is determined by selecting the maximum $IAQI_P$ as expressed in *Equation 2*:

$$\mathrm{AQI} = \max(\mathrm{IAQI_1}, \ldots\ldots\ldots \mathrm{IAQI_n}) \quad (2)$$

According to Anyika *et al.* (2018), *Equation 2* shows that AQI evaluation is not the sum of all the pollutants involved but is the maximum value of IAQI obtained.

The AQI category and ratings prescribed by the United States Environmental Protection Agency (USEPA) for pollution evaluation are presented in *Table 3*.

MATLAB Model Set-Up for Pollution Analysis

The pollution characteristics model was generated by integrating the spatial and pollution attributes databases using a polynomial expression (*Equation 3*), with coordinates for points 1–4 forming the spatial database and the pollution index at any sampling station represented by function y, depending on pollutant concentrations, if the wind rose, and meteorological conditions, resulting in four simultaneous equations (*Equations 4–7*) for each station (Jiayu *et al.,* 2018; Palomera *et al.*, 2016; Raju *et al.*, 2012).

$$y_j = k + k_1x_1 + k_2x_2 + k_3x_3 \ldots + k_nx_n \quad (3)$$

$$y_1 = k + k_1x_1 + k_2x_2 + k_3x_3 \quad (4)$$

$$y_2 = k + k_1x_4 + k_2x_5 + k_3x_6 \quad (5)$$

$$y_3 = k + k_1x_7 + k_2x_8 + k_3x_9 \quad (6)$$

$$y_4 = k + k_1x_{10} + k_2x_{11} + k_3x_{12} \quad (7)$$

where y_1 = pollution index at a given coordinate, such as point 1, k is an empirical constant k_1, k_2, and k_3, are constants which modify the empirical pollutant concentrations and are the constants for the variables SO_2, NO_2 and PM_{10}, respectively.

Table 3 – Air Quality Index, USEPA (2000)

AQI Category	AQI Rating
Very Good (0–15)	A
Good (16–31)	B
Moderate (32–49)	C
Poor (50–99)	D
Very Poor (100 or over)	E

In the particular case under study, x_1 was the SO_2 concentration at point 1, x_2 was the NO_2 concentration at point 1, and x_3 was the PM_{10} concentration at point 1.

Then, x_4, x_5 and x_6 were the SO_2, NO_2, and PM_{10} concentrations, respectively, at point 2. x_7, x_8 and x_9 were the SO_2, NO_2, and PM_{10} concentrations, respectively, at point 3. x_{10}, x_{11} andx_{12} were the SO_2, NO_2, and PM_{10} concentrations, respectively, at point 4.

The solution of the set of simultaneous equations (Jiayu *et al.*, 2018; Park *et al.*, 2013; Palomera *et al.*, 2016; Raju *et al.*, 2012) can be achieved using matrix algebra where k represents the constants to be determined after solving the set of four simultaneous equations by applying matrix algebra explicitly.

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{pmatrix} = \begin{pmatrix} 1 & 141 & 207 & 117 \\ 1 & 133 & 179 & 164 \\ 1 & 88 & 273 & 160 \\ 1 & 69 & 66 & 175 \end{pmatrix} \times \begin{pmatrix} k_1 \\ k_2 \\ k_3 \\ k_4 \end{pmatrix} \quad (8)$$

where X is, therefore, the 4 × 4 matrix of which the first column was constant (i.e., 1), the second column was for the SO_2 index, the third column was for the NO_2 index, the fourth column was for the PM_{10} pollution index, y_i represents the value of the coordinates at the sampling stations, and then the INPUT was x_i, y_i.

The function results from the solution to the simultaneous equations, which inputs x_i and y_i values so that the MATLAB 7.9 notation results in *Equation 9* and *Equation 10*.

$$G = \text{in v } (x) \quad (9)$$

$$k = G^* y_i \quad (10)$$

where G represents the variable that outputs the inverse of the matrix X and the solutions.

RESULTS

Air Pollutant Concentration in Aguleri during the Rainy Season

The values presented in *Table 4* and *Table 5* show the average for each of the four points.

Model Development

The values of k obtained from the matrix algebra are presented in *Table 6, Table 7, Table 8* and *Table 9*.

MATLAB-Assisted Model Development

MATLAB-assisted fitted curves for variations in the concentration of SO_2, NO_2, and PM_{10} as a function of coordinates in the Aguleri study area during rainy and dry seasons are shown in *Figure 2*, *Figure 3, Figure 4, Figure 5, Figure 6* and *Figure 7* using the Aguleri Junction study location.

DISCUSSION

Evaluation of Pollution Models

The data generated revealed that the Ab Initio air pollution model developed from the fitted curves (*Figure 2*, *Figure 3, Figure 4, Figure 5, Figure 6* and *Figure 7*) does not match constants from Ab Initio calculations closely enough in *Table 6, Table 7, Table 8* and *Table 9*. This could be because Ab Initio calculations were an average of all variations at a station as a linear summation.

Constants from MATLAB fitted curves represent the effect of one parameter as a pollutant at a given time and across all locations of the study area.

Therefore, to a greater extent, the above plots represent a much more theoretical evaluation of pollution as a function of a single component and in tandem with the result of a non-point source event-based medium, which accounts for the simultaneous effects of all pollution indices.

Table 4 – Summary of Pollutant Data in Aguleri during the Rainy Season

STATION	SO_2 (μg/m^3)	NO_2 (μg/m^3)	PM_{10} (μg/m^3)	Relative Humidity %	Wind Speed ms^{-1}	Wind Direction (^{O})
Aguleri Junction	12.95 ± 0.01	75.20 ± 0.03	61.25 ± 0.01	73.50 ± 0.01	1.88 ± 0.01	233.20 ± 0.02
Ifite Aguleri	7.85 ± 0.01	61.10 ± 0.01	32.00 ± 0.01	68.40 ± 0.01	1.47 ± 0.01	210.50 ± 0.02
Igboezuru Aguleri	4.15 ± 0.02	47.00 ± 0.02	22.00 ± 0.02	66.90 ± 0.01	1.65 ± 0.02	236.90 ± 0.01
Okpu Aguleri	3.00 ± 0.01	37.60 ± 0.01	20.00 ± 0.20	70.00 ± 0.02	1.50 ± 0.03	243.80 ± 0.01
Umuokpoto Aguleri	2.90 ± 0.02	42.30 ± 0.20	28.00 ± 0.01	63.80 ± 0.01	1.16 ± 0.01	240.90 ± 0.02
Enugu Otu Aguleri	0.97 ± 0.01	21.15 ± 0.01	10.25 ± 0.01	69.50 ± 0.02	1.25 ± 0.03	251.70 ± 0.02
Ezi Aguluotu Aguleri	0.95 ± 0.02	11.75 ± 0.02	5.00 ± 0.01	74.10 ± 0.01	1.07 ± 0.01	193.80 ± 0.02
Umundeze Aguleri	1.10 ± 0.02	14.10 ± 0.01	6.50 ± 0.01	68.30 ± 0.01	1.20 ± 0.02	175.50 ± 0.01
Amaeze Aguleri	2.35 ± 0.01	44.65 ± 0.01	25.50 ± 0.01	68.50 ± 0.20	1.64 ± 0.01	197.30 ± 0.20

Table 5 - Summary of Pollutant Data in Aguleri during the Dry Season

STATION	SO_2 (μg/m^3)	NO_2 (μg/m^3)	PM_{10} (μg/m^3)	Relative Humidity %	Wind Speed ms^{-1}	Wind Direction (^{O})
Aguleri Junction	37.27 ± 0.01	131.60 ± 0.01	171.25 ± 0.01	62.90 ± 0.02	1.30 ± 0.01	202.75 ± 0.02
Ifite Aguleri	18.30 ± 0.01	103.40 ± 0.01	104.50 ± 0.01	54.70 ± 0.01	1.79 ± 0.01	200.50 ± 0.02
Igboezuru Aguleri	12.45 ± 0.02	63.45 ± 0.03	78.50 ± 0.02	53.50 ± 0.20	1.20 ± 0.01	224.75 ± 0.01
Okpu Aguleri	10.45 ± 0.01	54.05 ± 0.01	59.50 ± 0.01	56.00 ± 0.02	1.31 ± 0.01	232.25 ± 0.01
Umuokpoto Aguleri	11.15 ± 0.02	75.20 ± 0.03	69.75 ± 0.02	49.10 ± 0.01	0.76 ± 0.01	238.00 ± 0.02
Enugu Otu Aguleri	6.82 ± 0.01	42.30 ± 0.01	30.00 ± 0.01	50.70 ± 0.01	0.64 ± 0.01	218.25 ± 0.03
Ezi Aguluotu Aguleri	7.17 ± 0.02	47.00 ± 0.01	38.50 ± 0.01	52.60 ± 0.01	0.45 ± 0.01	168.50 ± 0.02
Umundeze Aguleri	6.85 ± 0.01	63.45 ± 0.01	47.00 ± 0.01	54.60 ± 0.01	1.02 ± 0.01	136.00 ± 0.01
Amaeze Aguleri	12.45 ± 0.01	98.70 ± 0.01	64.50 ± 0.01	52.70 ± 0.01	1.57 ± 0.01	124.00 ± 0.01

Table 6 – Summary of Explicit Polynomials Obtained as Solutions (Aguleri, rainy season)

Station	Pollution index model
Aguleri junction	$0.6023-9.4x10^{-5}SO_2+1.6x10^{-5}NO_2+9.4x10^{-6}PM_{10}$
Ifite Aguleri	$0.6039+3.5x10^{-5}SO_2+4.02x10^{-6}NO_2+9.6x10^{-6}PM_{10}$
Igboezuru Aguleri	$0.6109+9.1x10^{-5}SO_2+3.0x10^{-6}NO_2-2.7x10^{-5}PM_{10}$
Okpu Aguleri	$0.6575+2.52x10^{-3}SO_2-4.011x10^{-1}NO_2+3.6x10^{-4}PM_{10}$
Umuokpoto Aguleri	$0.6044-2.5x10^{-4}SO_2+1.9x10^{-5}NO_2+5.0x10^{-5}PM_{10}$
Enugu Otu Aguleri	$0.7385-2.0x10^{-4}SO_2-5.6x10^{-4}NO_2+3.6x10^{-5}PM_{10}$
Ezi Agulu Otu Aguleri	$0.6107-1.5x10^{-3}SO_2-8.5x10^{-5}NO_2+6.0x10^{-5}PM_{10}$
Umundeze	$0.6049-5.0x10^{-4}SO_2-3.7x10^{-5}NO_2$
Amaeze	$0.5944+1.2x10^{-4}SO_2-3.0x10^{-6}NO_2-3.3x10^{-5}PM_{10}$

Table 7 – Summary of Explicit Polynomials Obtained as Solutions (Aguleri, dry season)

Station	Pollution index model
Aguleri junction	$0.6020-1.5x10^{-5}SO_2+8.5x10^{-6}NO_2+1.2x10^{-6}PM_{10}$
Ifite Aguleri	$0.4609+7.9x10^{-3}SO_2-6.1x10^{-6}NO_2+3.9x10^{-6}PM_{10}$
Igboezuru Aguleri	$0.6092+4.0x10^{-6}SO_2+1.4x10^{-5}NO_2-9.0x10^{-5}PM_{10}$
Okpu Aguleri	$0.6100-3.8x10^{-5}SO_2+6.0x10^{-6}NO_2-1.4x10^{-4}PM_{10}$
Umuokpoto Aguleri	$0.6053+7.2x10^{-5}SO_2+2.0x10^{-6}NO_2-5.0x10^{-6}PM_{10}$
Enugu Otu Aguleri	$0.7319+1.15x10^{-4}SO_2-2.5x10^{-5}NO_2-8.0x10^{-5}PM_{10}$
Ezi Agulu Otu Aguleri	$0.6090+1.4x10^{-4}SO_2+2.4x10^{-5}NO_2-8.0x10^{-5}PM_{10}$
Umundeze	$0.6054-7.4x10^{-4}SO_2-2.1x10^{-5}NO_2-5.0x10^{-5}PM_{10}$
Amaeze	$0.5869-5.8x10^{-5}SO_2-5.3x10^{-6}NO_2+1.25x10^{-4}PM_{10}$

Table 8 – k Values obtained as simulated linearisation of pollution indices (Aguleri, rainy season)

Station	K	k_1	k_2	k_3
Aguleri junction	0.6023	–0.000094	0.000016	0.0000094
Ifite Aguleri	0.6039	0.000035	0.00000402	0.0000096
Igboezuru Aguleri	0.6109	0.000091	0.000003	–0.000027
Okpu	0.6575	0.00252	–0.4011	0.00036
Umuokpoto Aguleri	0.6044	–0.00025	0.000019	0.00005
Enugu Otu Aguleri	0.7385	–0.0002	–0.00056	0.000036
Ezi Agulu Otu Aguleri	0.6107	–0.0015	–0.000085	0.00006
Umundeze	0.6049	–0.0005	–0.000037	0
Amaeze	0.5944	0.00012	–0.000003	–0.000033

Table 9 – k Values obtained as simulated linearisation of pollution indices (Aguleri, dry season)

Station	K	k_1	k_2	k_3
Aguleri junction	0.6020	–0.000015	0.0000085	0.0000012
Ifite Aguleri	0.4609	0.0079	–0.0000061	0.0000039
Igboezuru Aguleri	0.6092	0.000004	0.000014	0.000009
Okpu Aguleri	0.6100	–0.000038	0.000006	–0.000014
Umuokpoto Aguleri	0.6053	0.000072	0.000002	–0.000005
Enugu Otu Aguleri	0.7319	0.000151	–0.000025	–0.00008
Ezi Agulu Out Aguleri	0.6090	0.00014	0.000024	–0.00008
Umundeze Aguleri	0.6054	–0.00074	–0.000021	–0.00005
Amaeze Aguleri	0.5869	–0.000058	–0.0000053	0.000125

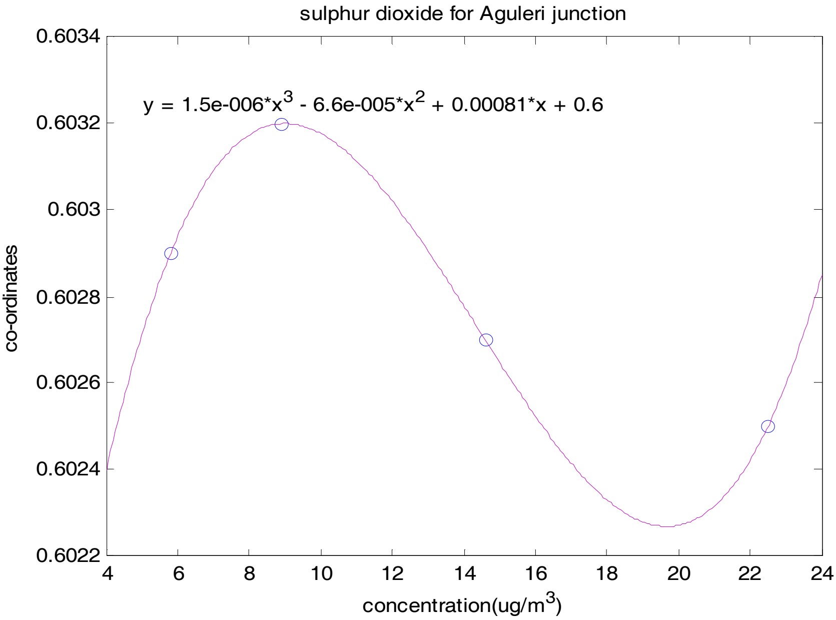

Figure 2 – MATLAB Curve of SO_2 for Aguleri Junction, Aguleri (rainy season)

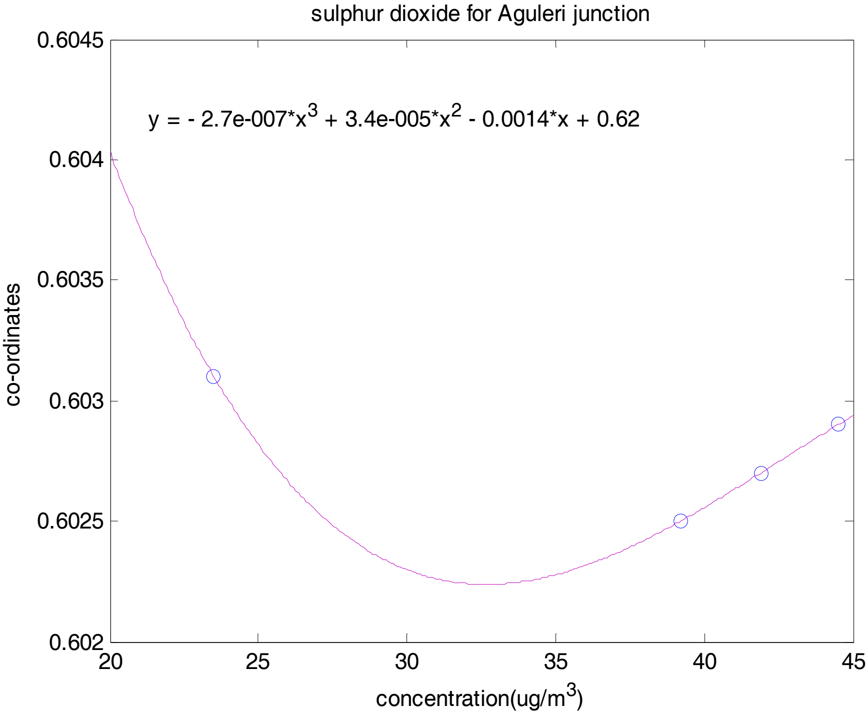

Figure 3 – MATLAB Curve of SO_2 for Aguleri Junction, Aguleri (dry season)

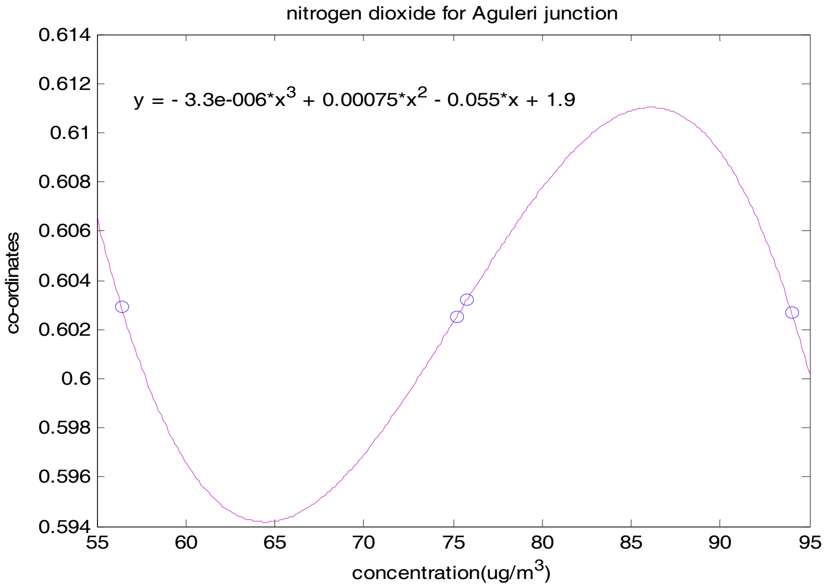

Figure 4 – MATLAB Curve of NO_2 for Aguleri Junction, Aguleri (rainy season)

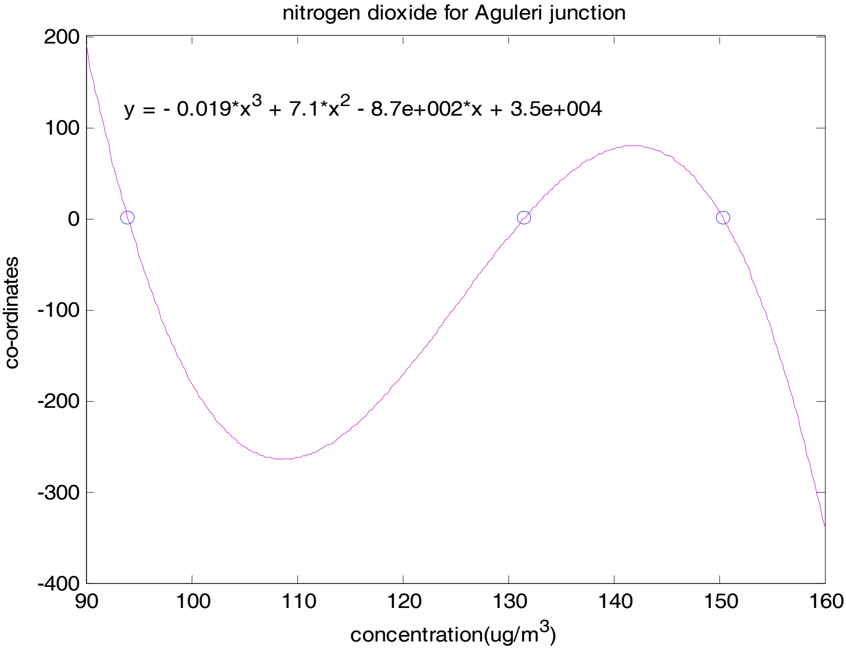

Figure 5 – MATLAB Curve of NO_2 for Aguleri Junction, Aguleri (dry season)

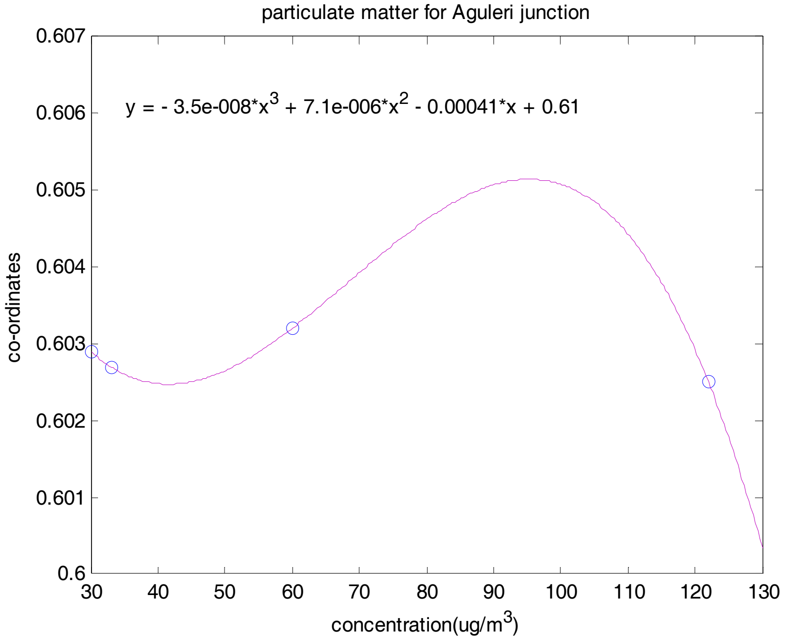

Figure 6 – MATLAB Curve of PM_{10} for Aguleri Junction, Aguleri (rainy season)

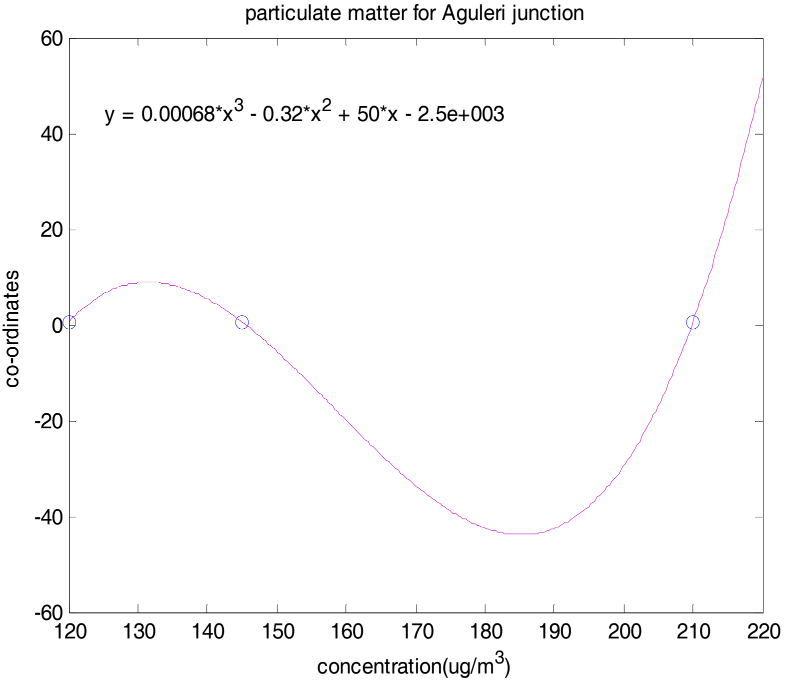

Figure 7 – MATLAB Curve of PM_{10} for Aguleri Junction, Aguleri (dry season)

In order to achieve this, the pollution indices were treated as objects in geographical space and location and their respective positions were monitored by the application of GIS/GPS contour mapping of concentration densities, as shown below.

Application of GIS/GPS Mapping of Concentration Densities of Pollutants

The concentration range of pollutants in Aguleri was 50%, as presented typically for Point 1 in *Figure 8, Figure 9* and *Figure 10.* The corresponding three-dimensional (3D) surface plot in *Figure 8* of the Aguleri junction was mononodal, and the area of very low NO_2 concentration was clearly shown in the colour scheme. The surface plot in *Figure 10* for PM_{10} at the same point in Aguleri was significant because the concentration of PM_{10} was shown to be very low at 6.43ºN and 6.92E.

The difference between the two GIS plots of NO_2 was that the GIS plot of *Figure 8* is two-dimensional, while the GIS surface plot of *Figure 9* is 3D and gives a clearer view of the pollution vector density at the sampling stations for NO_2 for Aguleri at point 1 for the rainy season. It gives the view of real life.

Effect of pollutant characteristics as a function of meteorological parameters

Air pollutant concentrations as a function of meteorological parameters, as shown in *Figure 11* and *Figure 12*, revealed that over 50% of relative humidity affects the dispersion (concentrations) of the selected pollutants in all the nine sampling stations, and the variations were in the order of $NO_2 > PM_{10} > SO_2$ for the rainy season but $PM_{10} > NO_2 > SO_2$ for the dry season.

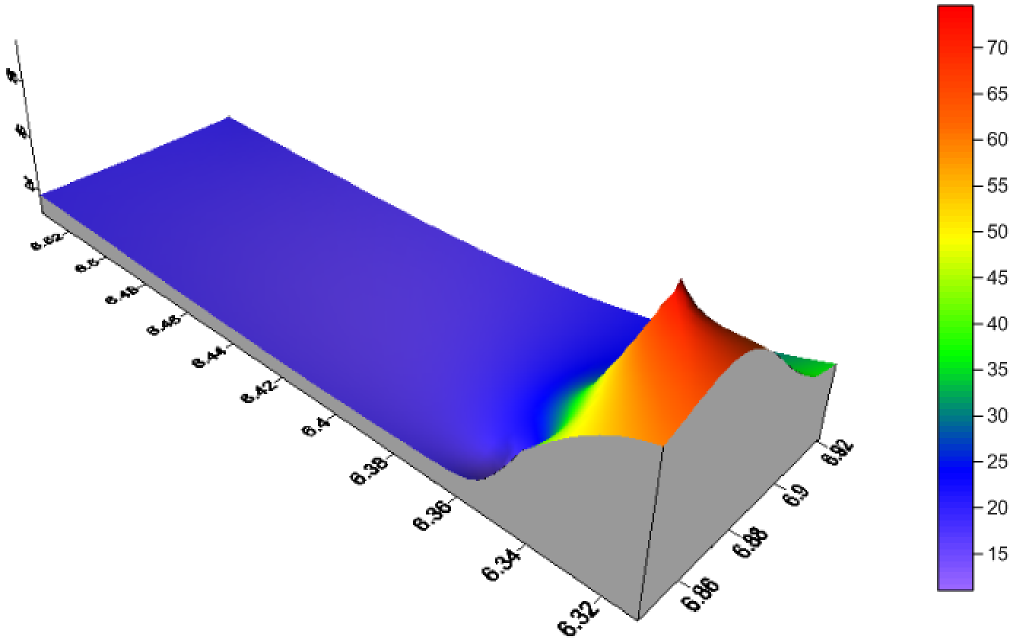

Figure 8 – GIS Surface Plot of NO_2 for Aguleri (rainy season) Point 1

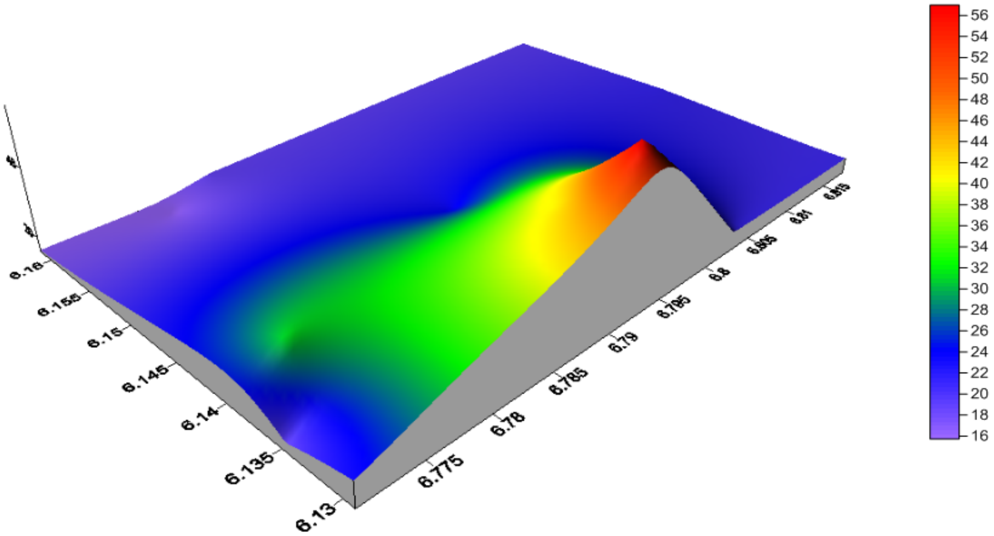

Figure 9 – GIS Surface Plot of SO_2 for Aguleri (dry season) Point 1

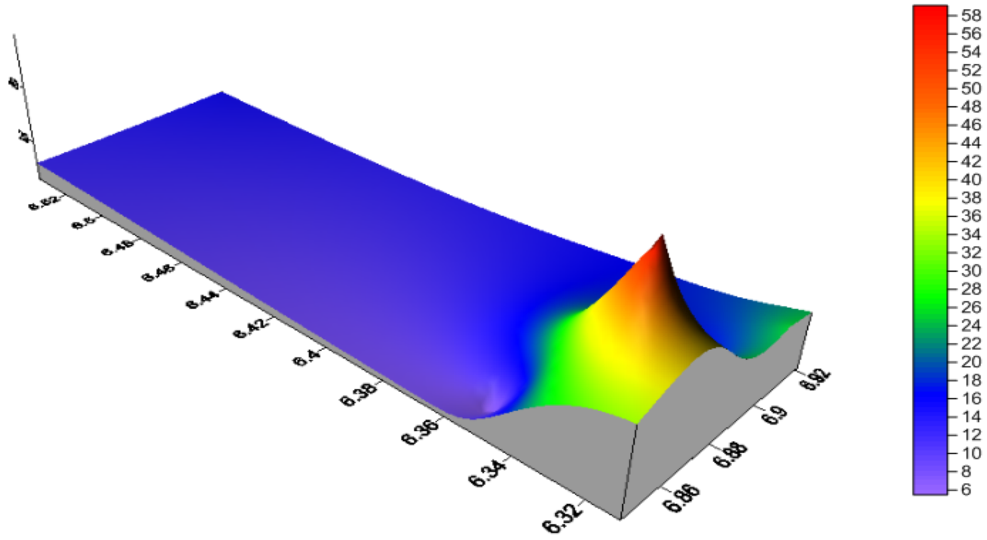

Figure 10 – GIS Surface Plot of PM_{10} for Aguleri (Rainy Season) Point 1

The wind speed was observed to be very low (< 10 m/s) and had little or no impact on the selected pollutants.

However, the effect of wind speed was more pronounced in the dry season than in the rainy season. Relative humidity varies directly with elevation; therefore, lower elevation gives lower relative humidity, less dispersion, and higher pollutant concentrations.

Many meteorological parameters vary inversely with air pollutant concentrations (Anyika *et al.*, 2018; Rahman *et al.*, 2006)

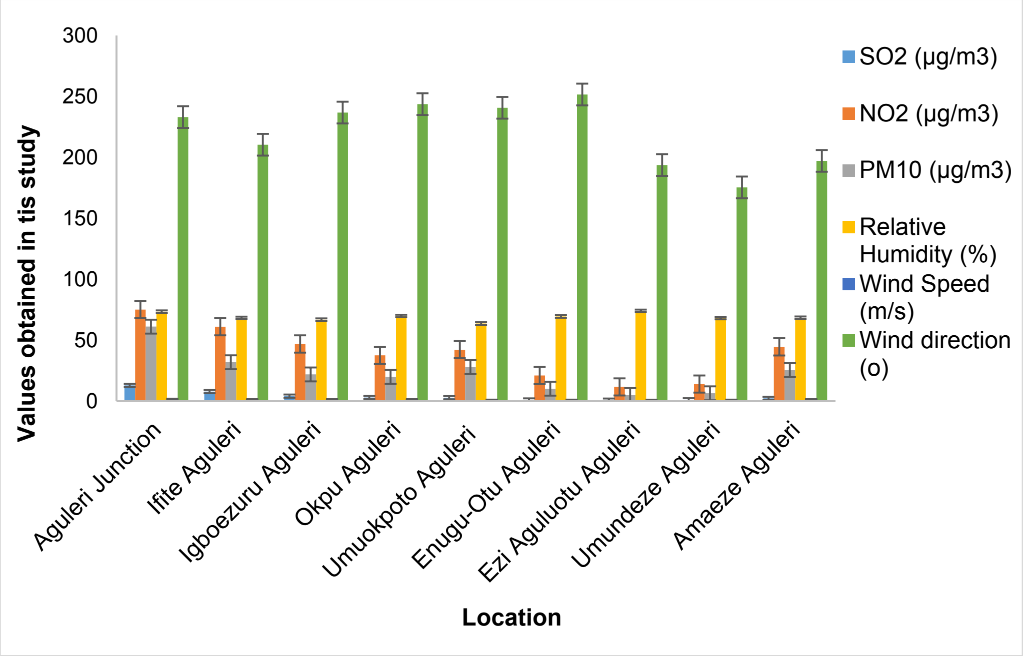

Figure 11 – Effect of meteorological parameters on the average concentration of pollutants during the rainy season

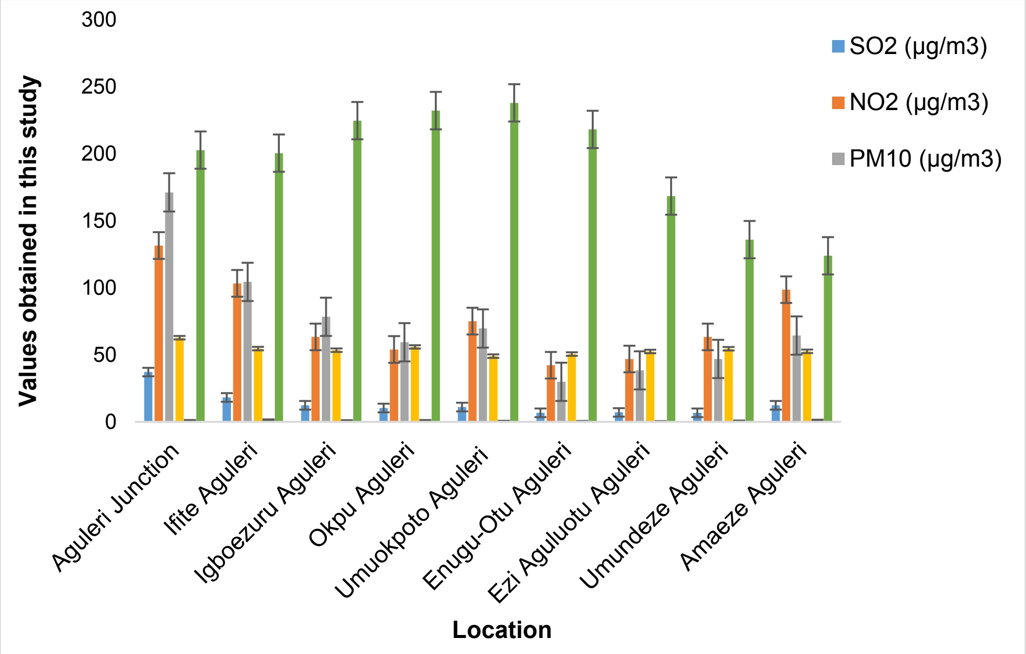

Figure 12 – Effect of meteorological parameters on the average concentration of pollutants during the dry season

AQI

The results of the AQI, as presented in *Table 10* and *Table 11*, *Figure 13* and *Figure 14*, show that all the locations in both the rainy and dry seasons were below a 50 AQI rating.

A cursory look at the air quality of the study locations using the rating by USEPA (2000) for determining ambient air quality in *Table 3* showed that the AQI rating for all the stations in the Aguleri study area for both rainy and dry seasons was very good (A category) with the exception of Aguleri Junction and Ifite Aguleri which had an AQI rating of good (B category).

The good AQI ratings of two areas suggest that these areas have fewer anthropogenic activities, while the very good AQI ratings of other areas suggest these areas have very few anthropogenic activities from very few vehicles and the absence of industries.

The AQI rating of good indicates no general health effect on the general public, but extreme measures must be taken to avoid incidences of hazardous activities.

Table 10 – Air quality index of Aguleri (rainy season)

Sampling Stations	Point 1	Point 2	Point 3	Point4	Description
Aguleri Junction	28.00	27.20	25.40	23.40	good
Ifite Aguleri	22.00	20.30	20.30	19.42	good
Igboezuru Aguleri	7.00	8.00	6.80	7.80	very good
Okpu Aguleri	5.00	6.00	5.60	6.60	very good
Umuokpoto Aguleri	3.00	5.00	5.50	5.45	very good
Enugu-Out Aguleri	3.50	4.00	4.00	4.40	very good
Ezi Agulu Out Aguleri	3.70	3.00	3.00	3.00	very good
Umundeze Aguleri	2.50	2.90	2.50	2.50	very good
Amaeze Aguleri	2.00	2.00	2.00	2.00	very good

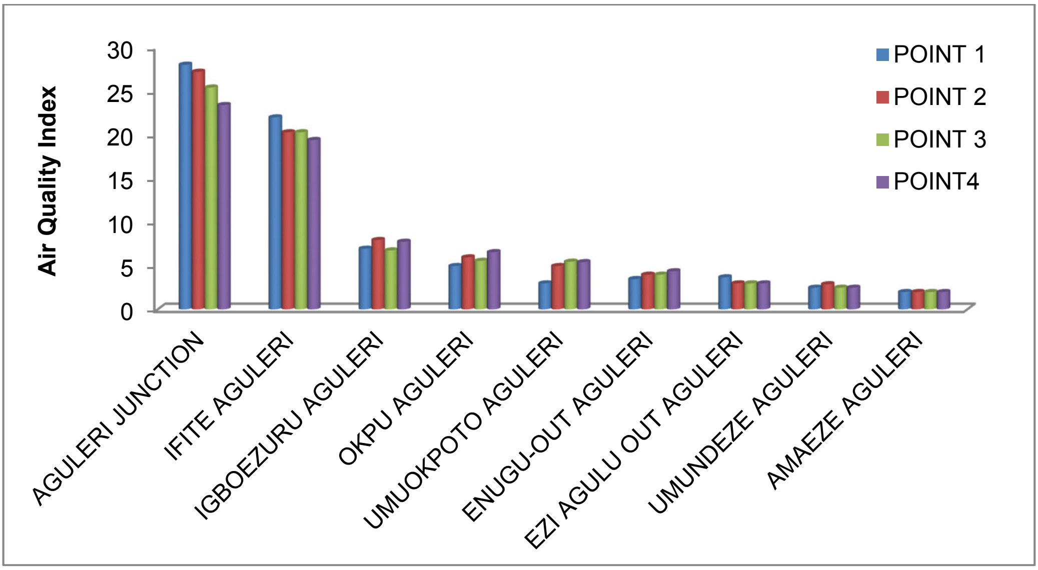

Figure 13 – Air quality index of Aguleri (rainy season)

Table 11 – Air quality index of Aguleri (dry season)

Sampling Stations	**Point 1**	**Point 2**	**Point 3**	**Point4**	**Description**
Aguleri Junction	32.00	31.70	32.50	29.80	good
Ifite Aguleri	29.00	28.50	26.00	25.00	good
Igboezuru Aguleri	8.50	8.50	6.00	7.50	very good
Okpu Aguleri	6.50	6.50	6.00	6.90	very good
Umuokpoto Aguleri	6.50	6.50	5.60	6.60	very good
Enugu-Out Aguleri	3.50	3.50	2.00	2.50	very good
Ezi Agulu Out Aguleri	5.2	5.20	2.00	4.20	very good
Umundeze Aguleri	7.1	7.10	7.00	6.10	very good
Amaeze Aguleri	5.7	5.70	7.00	4.70	very good

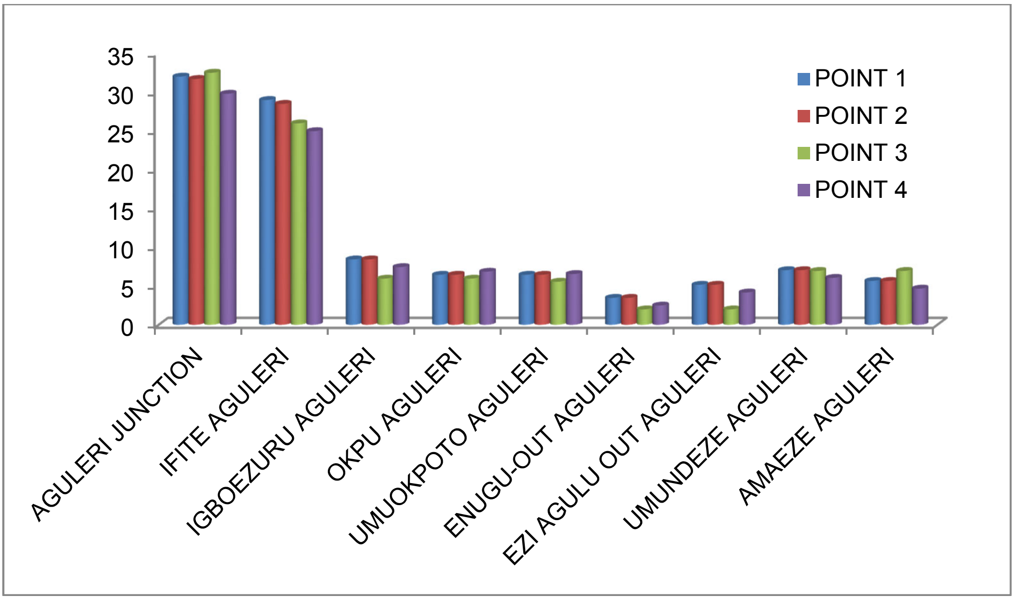

Figure 14 – Pollution index (air quality index) of Aguleri I (dry season)

CONCLUSIONS

This study has shown that the evaluation of pollution models generated from ab initio constants obtained as an average of all variations at a station in a linear summation was more reliable than constants from fitted curves, which were a function of a single component. It has been shown that GIS contour surface plots used to obtain air pollution characteristics on surfaces gave more reliable data than tabulated values.

This study reveals that GIS vector density plots for air pollution characteristics can be used to predict air pollution as a function of industrial clustering. The solution of model polynomials representing air pollution characteristics can be used to predict pollution attributes as a function of data space. The predictor constants generated by solving the model simultaneous equations using MATLAB 7.9 representing modifiers of air pollution were efficient. The study has demonstrated the predictive power of GIS/GPS in the rendering of air pollution in terms of objects in data space and their interaction with meteorological parameters. The meteorological variables like relative humidity serve as effective scavengers for SO_2, NO_2 and PM_{10} pollutants and vary in both rainy and dry seasons. The information obtained from this study could lead to best environmental management practices and the establishment of efficient pollution control departments, as in many developed and advanced countries. However, some limitations encountered in this study were predominantly difficulties in the collection of the samples due to the hostility of youth in Aguleri and difficulties measuring with instruments and digital sensors from the various environmental agencies. In future air pollution assessments, this study recommends using more mathematical analysis involving polynomial equations as formulated, which should be performed by iteration.

Author Contributions: Conceptualization by ALC and OC; methodology by ALC; analysis by ALC; investigation by ALC; resources ALC; data curation by ALC and OC; writing by ALC and OC, review by OC. All authors declare that they have read and approved the publication of the manuscript in this present form.

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