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GIS and MATLAB modeling of criteria pollutants: a study of lower onitsha basin during rains

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Article Information	ABSTRACT
   Access by Smart Phone [QR code] *For any information:* *ask.author@journalbinet.com*	*The study of air pollutants SO_2, NO_2 and PM_{10} in lower Onitsha basin, a densely populated city was performed using GPS and Matlab modeling. The pollutants were studied in nine specific locations for 3 months of rains over 3 consecutive years with each georeferenced. The Matlab pollution model was generated by integrating the spatial database and measured pollution attributes database using a polynomial expression. SO_2 highest concentration (141 µg/m³) peaked in Upper Iweka at sampling point 1 before dispersing to lower concentrated regions in Awada and Resthouse. NO_2 peaked at 207 µg/m³ in Upper Iweka at sampling point 3 and driven by wind towards Borromeo area to very low concentration of 38 ug/m3. The PM_{10} peaked in Upper Iweka (180 µg/m³) and driven by rains towards Borromeo before increasing again in concentration levels at Awada. The AQI showed that SO_2 pollutants had acceptable air quality at all sampling points while NO_2 and PM_{10} air quality affected sensitive groups. SO_2 concentration levels exceeded the National air quality standard in Nigeria (NAQS) while NO_2 and PM_{10} were below the NAQS standard. The GIS plot showed that 3 metrological forces were driving pollutants from Upper Iweka and Awada to other sampling areas in the order of $SO_2> NO_2> PM_{10}$. The Matlab wind speed plot showed that there was an upward wind in upper Iweka driving the pollutants towards dispersal at some other region. Thus, Upper Iweka is an active point source pollution area and dispersed to Borromeo and Awada by scavenging rains under prevailing wind speed, wind direction and humidity. Hence calls for improved monitoring and regulation to address pollution.*

I. Introduction

Environmental pollution has remained a great concern to the nations of the world. Consequently, various techniques have been invented for monitoring air pollution using spatial processing and time series analysis (Ambare and Muhammed, 2013). For instance, NO_2 and PM pollutants were studied using

443

artificial neural network assemblage (ANN), for outdoor air quality. The modeling provided reliable predictions for NO_2 but unreliable data for $PM_{2.5}$ (Challoner et al. 2015). Another recent study in Baoding, China effectively used MATLAB grey model for near accurate prediction of ambient air quality (Ying et al. 2017). Similarly, the use of mapping to isolate and pinpoint certain air pollutants has seen more accurate pollution maps generated for densely populated cities (Rohde and Muller, 2015). While, GPS-assisted data collection has also enabled the successful assessment of vehicular exhaust emissions linked with activity travel-based data for assessment (Beckx et al. 2010). Additionally, GIS, GPS and sensors have measured air pollutants (CO, SO_2, NO_2) from vehicular emissions with greater accuracy for regulatory decisions (Partheeban et al. 2012). Hence, air quality monitoring will continue to play a major role using GPS, GIS, MATLAB, Artificial Neural Network (ANN) and internet coupled devices due to seasonal variations (Challoner et al. 2015; Wei et al. 2015), tremendous increase of vehicular emissions (Raju et al. 2012) and the need for real time pollution assessment (Jiayu et al. 2018). Moreover, nations are gradually moving towards reliance on published air quality monitoring data. Subsequently, researchers adapted a photochemical monitoring station for ozone monitoring in Mexico City with successful results (Palomera et al. 2016). In Jaipur city, India, studies performed on spatio-temporal analysis to evaluate relationship between air quality and local weather parameters provided a quick view of criteria areas within the city (Ankita et al. 2017). While a GIS personal and population exposure to PM_{10} and $PM_{2.5}$ have been studied in Dublin and Beijing respectively by Pilla and Broderick (2015); Zhao et al. (2017). In the USA, Los Angeles has gone a step further by utilizing longwave infrared hyperspectral imaging sensor (LWIR-HSI) to tracking and quantifying gaseous chemical plumes over a 530 km^2 region. The results supported routine regulatory activities and also has the capacity to provide identification and monitoring after environmental hazard occurrence (Buckland et al. 2017). Thus, spatial processing and time series analysis are necessary to test local compliance to standards, study environmental impact of new industries or emission changes associated with traffic and vehicular movement (Puliafito et al. 2003). To this end, researchers in a nation like Nigeria with low level of industrial compliance to emission standards, poor regulatory monitoring, excessive harmful vehicular emission (Nkwoada et al. 2016) would certainly need to key into this well-established area of atmospheric pollutant monitoring. This will chart the course for national ambient air quality compliance data as evidence for frequent regulatory monitoring, sanctions, fines and penalties were necessary. However, researchers have evaluated air pollutants in Niger delta, Nigeria using remotely sensed satellite. The result confirmed that the area needs urgent environmental remediation (Omotosho et al. 2015). Similarly, Yorkor et al. (2017) performed a study in Eleme, Port-Harcourt city; Nigeria using ANN attributed the pollutants to be vehicular and industrial source pollutions. On the other hand, a study of air pollutants by Balogun and Orimoogunje (2015) in Benin City, Nigeria, concluded that seasonal variation is a determinant factor to concentration of pollutants in the city. Comparatively, Onitsha is the commercial hub of southeast Nigeria and a densely populated city like Benin City. The city boast of similar heavy vehicular activities, more manufacturing industries, but deficient of environmental regulatory and compliance officers. Thus, this study will utilize GPS and MATLAB modeling to study for the first time SO_2, NO_2, PM_{10} pollutants in lower Onitsha basin during the rains.

II. Materials and Methods

The materials and method therein described the GIS/GPS and MATLAB assisted study of pollutants concentration densities in Onitsha lower basin. New model scripts were designed and applied into the General finite line model with ARCGIS 9.3; this improved the modeling approach and less time spent on GIS workflows. The software ARCGIS 9.3 was used to create specific scripts through workflow coding and commands in successions. Hence, the tool can be applied by the user for various adaptive studies such as a tool for calculating concentration of SO_2, NO_2, PM_{10}. The correlation was integrated to also evaluate peaks in relative humidity, wind speed and wind direction. The determined pollutant concentration levels were fitted into ARCGIS to determine the total concentration levels of the named pollutants at specific locations and measuring times. MATLAB 7.9 fitting software was used for plotting the graph of weighted coordinates against the mean concentrations in each location in Onitsha lower basin (Pilla and Broderick, 2015; Yorkor et al. 2017).

Data acquisition: The acquisition of data was achieved by in-situ ground level measurement of SO_2, NO_2, PM_{10} in Onitsha study areas. Within each sampling station 4 points were selected which were 500 meters apart. The points were marked and georeferenced. The obtained readings were carried out for 3 months

with 72 hourly interval ranging from May 1st to July 1st which constitute rainy season peak period in Nigeria. Therefore, for the Onitsha study area with selected nine (9) sampling stations there are 6 x 9 experimental units. Experimental units mean six parameters to be tested x nine locations. Readings were taken at 3 months of rainy season which resulted to 54 experimental units. Each station has 4 points for sampling so that the Onitsha selected area has a total of two hundred and sixteen (216) determinations. Hence, in Onitsha there were obtained 1296 experimental units. This amounted to 5184 data for the rainy reason over a period of 3 years from 2013 to 2016 (Pilla and Broderick, 2015; Yorkor et al. 2017). A clear distribution of sampling locations was illustrated in Figure 01 (Google, 2018).

Equipment and calibration: Gas and Particulate monitors was carried out using Crown on gas monitor Model CE 89/336/EEC obtained from the Imo State Environmental Protection Agency. The equipment was used for NO_2, SO_2 and PM_{10}. $PM_{10}$was monitored by switching to Crown on Particulate Monitor Model No. 1000 with serial no. 298621. The Wind speed and direction were determined as windrose using a digital meter. Relative humidity and temperature were determined with the same Environmental Meter Model AE.09605 by Rumsey Environmental LLC, from Mechanical Engineering Department; Federal University of Technology, Owerri which is located in the Weather/Erosion monitoring unit in the institution. The sensors were recalibrated and stabilized by exposure for several hours in a sealed vessel at room temperature prior to measurement. NO_2 and SO_2gas were used as applicable. NO_2 gas concentrations ranging from 0-1000 ppb was used to recalibrate the SnO_2 sensor connected to evaluation circuit board which records sensor responses. This calibration was repeated for SO_2 gas sensor. The protocol for recalibration of particulate matter at PM_{10} to establish the sensitivity was applied and recorded. Recalibration of the monitors were done at Imo State Environmental Protection Agency (ISEPA) laboratories in Owerri using established and well reported methodologies Pilla and Broderick, 2015; Yorkor et al. 2017; GNI, 2007).
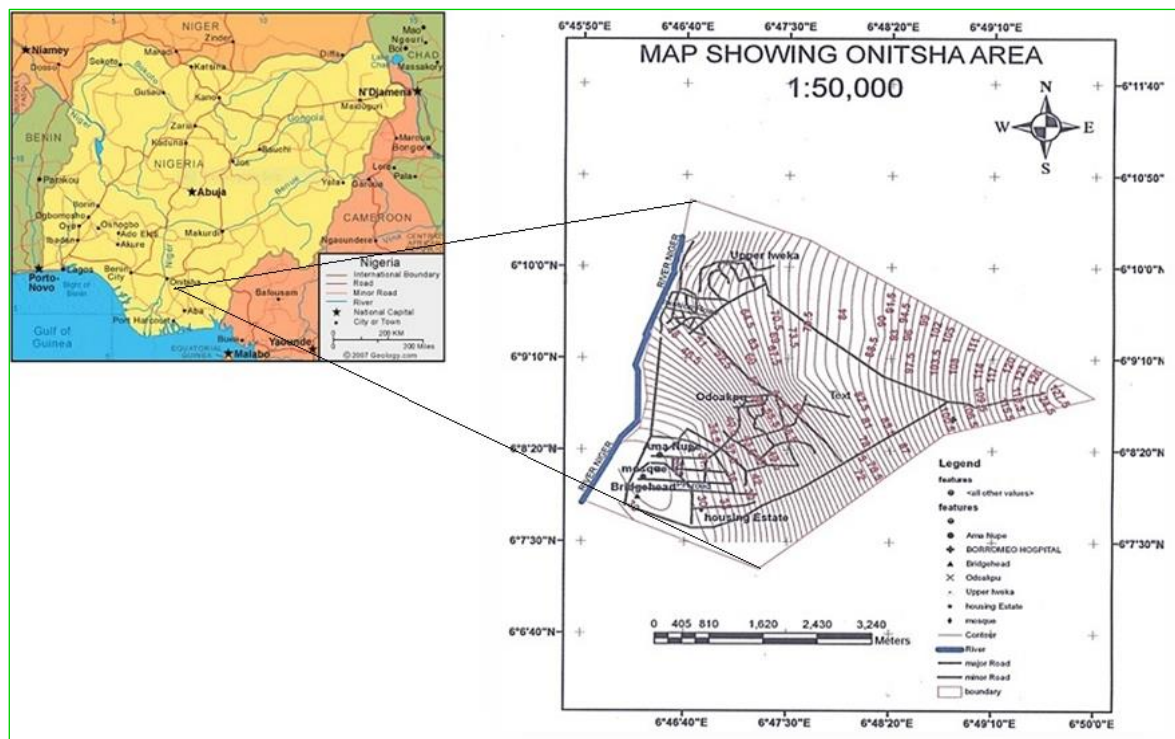

Figure 01. GIS and google map of study location: map of Nigeria and enlarged weighted coordinates (Google, 2018; GNI, 2017).

Location sampling: The Onitsha Lower Niger Basin are defined by the coordinates shown in table 01 below. The study area digitization was performed using maps downloaded from Google Earth Map. Digitization was carried out using Arc Map software. The dimensional scale was 1:50,000 for Onitsha. Four sites were chosen in each of nine locations identified in Onitsha as shown in table 02 below. While the geo-referenced coordinates are given in table 03.

Table 01. Onitsha latitude and longitude coordinates

N06⁰ 07ᴵ	E006⁰ 47ᴵ	N06⁰ 08ᴵ	E006⁰ 46ᴵ	N06⁰ 09ᴵ	E006⁰ 47ᴵ
N06⁰ 07ᴵ	E006⁰ 48ᴵ	N06⁰ 08ᴵ	E006⁰ 47ᴵ		

Table 02. Nine locations of Onitsha study area

Upper Iweka/Nitel	Port Harcourt road/Niger state	Feggie/Nupe Square
Mission road/waterside	Rest house/GRA	Christ the king college (CKC)
Uzodinma street	Borromeo hospital	Araba/Oraifite street/Abs.Ch.27

Table 03. Georeferenced coordinates of sampling stations in rainy season in Onitsha

Sampling station	Co-ordinates			
	Point 1	Point 2	Point 3	Point 4
Upper iweka/nitel	NO6⁰ 07.851' E 006⁰ 47.660'	NO6⁰ 08.095' E 006⁰ 47.447'	NO6⁰ 08.062' E 006⁰ 47.664'	NO6⁰ 07.933' E 006⁰ 47.470'
Ph road/niger st.	NO6⁰ 08.023' E006⁰ 47.405'	NO6⁰ 08.001' E006⁰ 16.124'	NO6⁰ 07.918' E006⁰ 46.098'	NO6⁰ 08.090' E006⁰ 46.125'
Egge/nupe square	NO6⁰ 08.074' E006⁰ 46.216'	NO6⁰ 08.102' E006⁰ 46.263'	NO6⁰ 08.084' E006⁰ 46.168'	NO6⁰ 08.179' E006⁰ 46.179'
Uzodinma str. Fegge	NO6⁰ 08.271' E006⁰ 46.395'	NO6⁰ 08.212' E006⁰ 46.399'	NO6⁰ 08.212' E006⁰ 46.520'	NO6⁰ 08.263' E006⁰ 46.522'
Mission rd./waterside	NO6⁰ 09.567' E006⁰ 46.762'	NO6⁰ 09.634' E006⁰ 46.511'	NO6⁰ 09.780' E006⁰ 46.583'	NO6⁰ 09.709' E006⁰ 46.773'
Rest house/gra	NO6⁰ 09.685' E006⁰ 47.019'	NO6⁰ 09.700' E006⁰ 47.044'	NO6⁰ 09.766' E006⁰ 47.038'	NO6⁰ 09.744' E006⁰ 47.032'
C.k.c	NO6⁰ 08.609' E006⁰ 47.469'	NO6⁰ 08.550' E006⁰ 47.494'	NO6⁰ 08.481' E006⁰ 47.341'	NO6⁰ 08.535' E006⁰ 47.244'
Borromeo hospital	NO6⁰ 08.745' E006⁰ 49.070'	NO6⁰ 08.618' E006⁰ 49.113'	NO6⁰ 08.591' E006⁰ 49.065'	NO6⁰ 08.557' E006⁰ 49.131'
Awada/oraifite st./abs. Channel 27	NO6⁰ 07.743' E006⁰ 48.180'	NO6⁰ 07.700' E006⁰ 48.204'	NO6⁰ 07.661' E006⁰ 48.085'	NO6⁰ 07.627' E006⁰ 48.099'

MATLAB assisted modeling: The pollution characteristics (model) of the study area was generated by integrating the spatial data base and measured pollution attributes data base using the polynomial expression (Raju et al. 2012; Jiayu et al. 2018; Palomera et al. 2016).

$$y_j = k_+ k_1 x_1 + k_2 x_2 + k_3 x_3 \ldots + k_n x_n$$

Where, y_j represents the coordinates for points 1, 2, 3, 4, in each location which constitutes the spatial data base, the pollution index at any given sampling station can be represented by a function y which depends on the contributions of the various concentrations of the identified pollutants, the windrose and the meteorological conditions such as relative humidity, temperature etc. So that at a given sample station with four sampling points, four simultaneous equations can be written to represent the air pollution index at that station. where y_1 = Pollution index at a given coordinate such as point 1, k is an empirical constant k_1, k_2, 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. The application of matrix algebra was used to solve the set of the simultaneous (Raju et al. 2012; Jiayu et al. 2018; Palomera et al. 2016; Park et al. 2013). Function results from solution to the simultaneous equations which imputes x_i and y_i values so that in MATLAB 7.9 Notation we can write:

$$G = inY(X) \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

$$K = G * yi \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

Where, G is the variable that outputs the inverse of the matrix X.

Air Quality Index (AQI): The air quality index (AQI) is an index system of number grading that indicates the level of pollution in the atmosphere. AQI determination is carried out by calculating the IAQI (Individual air quality index) for each pollutant. Where the formula is given below as

$$IAQI \ = \ \frac{IAQI_{HI} - IAQI_{Lo}}{BP_{HI} - BP_{LO}}\left(C_p - BP_{LO}\right) + IAQI_{LO} \dots\dots\dots\dots\dots\dots\dots (3)$$

The $IAQI_P$ is the individual air quality index for pollutants P (PM_{10}, SO_2, NO_2) and C_P is the daily mean concentration of the pollutant P. BP_{LO} and BP_{HI} are the nearest and lowest values of Cp The $IAQI_{LO}$ and $IAQI_{HI}$ are the individual air quality indexes in terms of BPHI and BPLO as shown in table 04. From the table 04, the IAQI maximum is 500. After the calculation of individual air quality index ($IAQI_P$) for each pollutant, the AQI would then be determined by selecting the maximum $IAQI_P$ as follows:

$$AQI \ = \ \max(IAQI_1, \dots. IAQI_n) \dots\dots\dots\dots\dots\dots\dots\dots (4)$$

Hence, the equation (4) demonstrates that AQI calculation is not the sum of all the pollutants involved but is the maximum value of IAQI obtained. Although NAAQS-2012, PM10, SO_2, NO_2 are included in the calculation, however, the air pollutant with a maximum IAQI when AQI is larger than 50 is then termed the principal pollutant. Whereas daily AQI less than 100 is supposed to be qualified using NAAQS-2012 (Wei et al. 2015; Park et al. 2013; Youping et al. 2018; Kanchan and Goyal, 2015).

Table 04. Air quality index (AQI) grading for pollutants

AQI values	0-50	51-100	101-150	151-200	201-300	301-400	401-500
Levels of health concern	Good	moderate	Unhealthy for sensitive groups	Unhealthy	Very Unhealthy	Hazardous	Hazardous
Colour code	Green	Yellow	Orange	Red	Purple	Maroon	Maroon
Meaning	Air quality is considered satisfactory	Air quality is acceptable, however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Everyone may begin to experience health effects: members of sensitive groups may experience more serious health effects.	Health alert: everyone may experience more serious health effects.	Health warning of emergency conditions. The entire population is more likely to be affected.	Health warning of emergency conditions. The entire population is more likely to be affected.

Adapted from: Environmental Protection Agency Durham, North Carolina USA (EPA, 2016).

III. Results and Discussion

SO_2 concentration

The concentrations of the SO_2 gas was plotted using the box and whiskers chat as seen in figure 02 below. The sampling point 1 of upper Iweka coordinates/region gave the highest concentrations of SO_2 gas at 141 µg/m³. This value almost doubled the concentration at other sampling points except CKC point 2 and rest house point 3. The lowest recorded concentration of SO_2 was point 1 and point 2 of Mission road and Borromeo hospital respectively. A closer observation shows that there appear to be more concentrations of CO_2 at Fegge, Uzodinma, mission road before dispersing again from Resthouse to Awada. Thus, there may be a sloping region causing this pollutant undulation and dispersal. Another explanation could be that Fegge, Uzodinma and mission road could be point sources for SO_2 emission and which eventually gets concentrated at other regions such as upper Iweka, CKC and Awada regions. on the average sampling point 1 showed the highest concentration levels of SO_2 while sampling point 4 showed the lowest and point 5 was the average of the four sampling points.
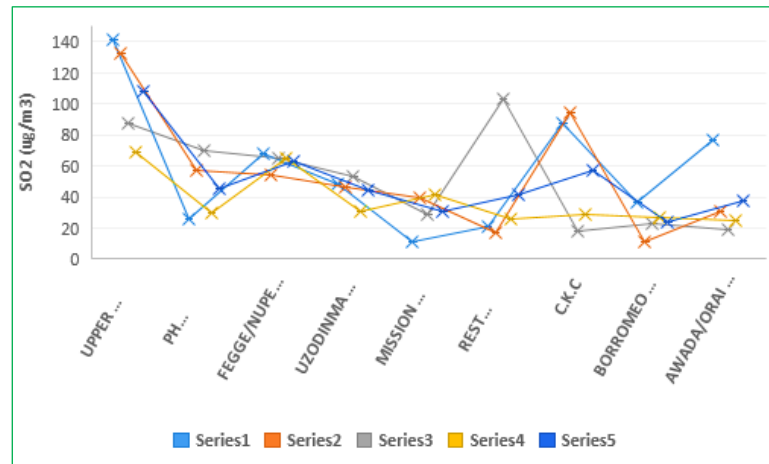
447

Figure 02. Box and whiskers plot for SO₂ concentration in Onitsha lower basin.

They result when compared to neighboring city of Aba as studied by Akuagwu et al. (2016) and Orlu as studied by Ibe et al. (2017) and showed that Onitsha lower basin was significantly polluted when compared to these cities. Also, the high concentration of SO_2 exceeded the study performed in selected areas of Lagos metropolis (Njoku et al. 2016).
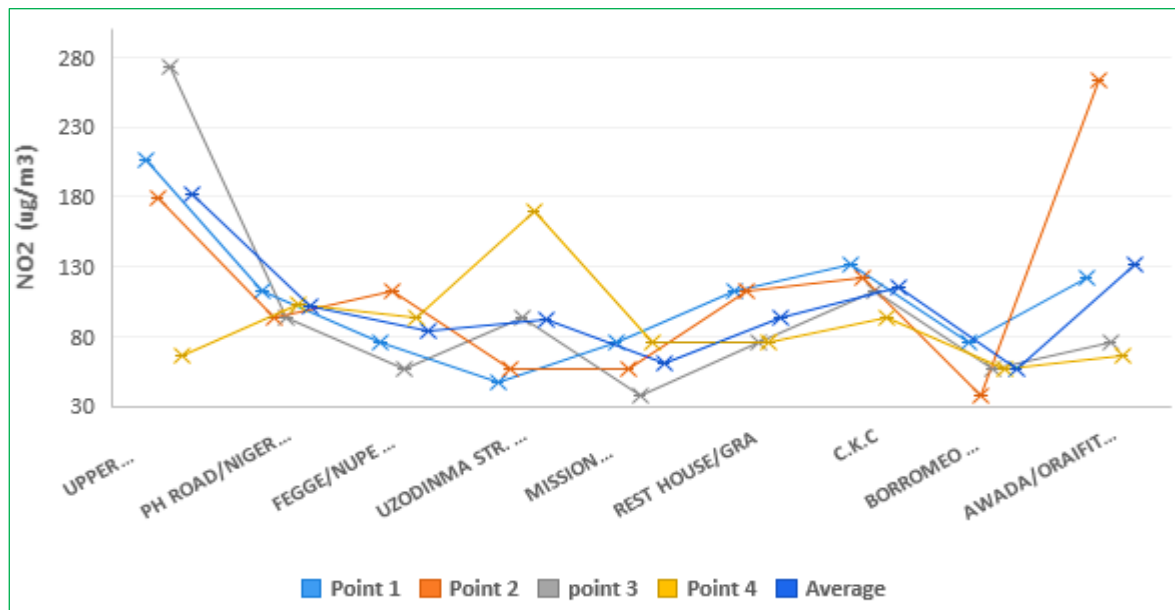

Figure 03. Box and whiskers plot for NO₂ concentration in Onitsha lower basin during rainy season.

NO₂ Concentration

The box and whiskers plot for NO₂ concentration is presented in figure 03 below showing the concentrations at various locations. The figure shows that Upper Iweka (point 3), had the highest concentration of NO₂ gaseous pollutants (207 μg/m³) while the lowest was Borromeo at 38 μg/m3 (point 4). The appearance of the figure seems to connote a kind of undulating wind driving the NO₂ molecules. These would have cause the molecules to experience dispersion at Upper Iweka and Awada. While aggregation is experienced at other sampling points. CKC and Borromeo experienced the lowest wind action, hence the highest level of aggregation. This idea is supported by the fact that at upper Iweka was high concentration of NO₂ whose concentration will reduce as it travels within the wind. These molecules will eventually get dispersed to other regions at small concentration. However, on the converse, the CKC and Borromeo and PH road may be point source pollutions due to agglomeration and low wind action. However, such free molecules may now be displaced towards a region of less dispersive wind and eventually remains high at such regions such as Upper Iweka and Awada area. A similar form of pollutant

movement was observed in SO_2 at Upper Iweka, mission road and Borromeo. Additionally, in both gases sampling point 4 were points of lowest concentration.

Similarly, the concentration of NO_2 exceeded the levels in Aba and Orlu and that of selected dumpsites, industrial area and residential area within Lagos metropolis (Akuagwu et al. 2016; Ibe et al. 2017; Njoku et al. 2016).

PM_{10} Concentration

The movement of the gaseous pollutant PM_{10} was plotted below as shown using box and whiskers. A close observation shows that in all the three-gaseous pollutant that Upper Iweka had the highest concentration. For PM_{10} the highest concentration was 180 ug/m3 at Upper Iweka and lowest was at point 4 in Borromeo (69 ug/m3). There seem to be an overall gradual; decrease in concentration of PM_{10} from upper Iweka up to Borromeo before a noticeable increase in PM_{10} concentration. However, PH road and Fegge area had high agglomeration while Awada and CKC gave the most dispersed regions. Hence it would be suggested that the wind may have a direction that disperses the pollutants from Upper Iweka to Borromeo and then displaced at Awada region. Alternative description would mean that Borromeo would be a point source pollution, which gets displaced upwards and eventually concentrates at neighboring areas. Interestingly CKC levels of the NO_2 was higher than that of Rest house before decreasing at Borromeo and rising again at Awada; a typical wind action at plain surfaces. A correlation was seen in SO_2, NO_2 and PM_{10} that Upper Iweka is major area of pollutant concentration while Borromeo is the least point of pollutant concentration before experiencing displacement at Awada sampling points. Also PH road, Fegge, Borromeo and rest house showed active agglomeration than all other sampling sites. While Awada, Upper Iweka, CKC were active points of dispersion. This behavior of PM_{10} was similarly observed in NO_2 and SO_2 and hence of the this above listed sampling points would be described as having active point source pollution or areas of hilly descent.
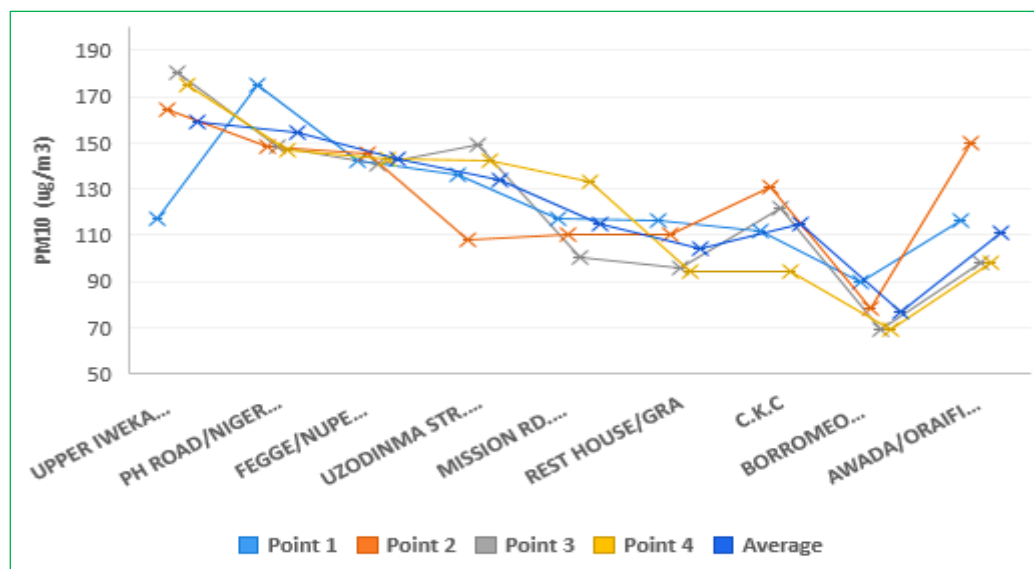

Figure 04. Box and whiskers plot for PM_{10} concentration in Onitsha lower basin.

The PM_{10} results obtained were between 70 -190 ug/m³ and even a similarly lower concentration levels were seen when compared with study carried out in Port Harcourt during rains with maximum in Oginigba as 34 ug/m³ and minimum in Omuanwa as 2.9 ug/m³. These showed a correlation that PM_{10} is affected by rains which causes a decrease in its concentration levels. hence the scavenging effect of atmosphere is paramount which dissolves the PM_{10} pollutants (Akinfolarin et al. 2017). However, the values of studied Onitsha lower basin exceeded the concentration in Imo state (Opara et al. 2016), Aba and Orlu.

Air Quality Index

The calculated AQI for the individual pollutants where plotted in figure 05 below. The bar columns were presented in respective colour codes shown in table 04. A closer look and comparison from table 04 shows the simplicity in using colour codes in representing the bar columns for AQI values. The SO_2 AQI (yellow code) plot showed that only Rest house, C.K.C and Upper Iweka had AQI greater than 50 hence, a moderate health concern for unusually sensitive people within those areas. However, the SO_2 air quality was satisfactory at all other sampling areas as indicated by their green bar columns. The AQI for NO_2 at Upper Iweka and Awada demonstrated acceptable air quality but presents possible health effects to members of sensitive group. This is demonstrated by the Orange and yellow codes and several points exceeding AQI 50 value. The other sampling areas had yellow codes (> 50) that indicated moderate health concern to sensitive group. Only Fegge, Uzodinma and Borromeo maintained satisfactory air quality (< 50: green code). The PM_{10} demonstrated a higher level of individual pollutant level than SO_2 and NO_2. At Awada, Borromeo, CKC, Mission, Uzodinma and Fegge, the AQI values exceeded AQI 50 but below 100. Hence the yellow codes indicated that PM_{10} air pollution is persistent at these regions. Although air quality is classed as satisfactory, however, unusually sensitive persons living within these regions may experience moderate health challenges from time to time. On the other hand, AQI values obtained from Upper Iweka (points 2, 3, 4 and average) and PH road (1 and average) exceeded the AQI 100 value. Hence the Orange coding demonstrates that sensitive persons may experience health effects but not the general public. Subsequently, we can summarize that pollutant level existed in the form $PM_{10}> NO_2> SO_2$. In addition, the air quality at upper Iweka was worse than other sampling areas. Other major pollutant (SO_2, NO_2, PM_{10}) affected areas were CKC and Resthouse areas.
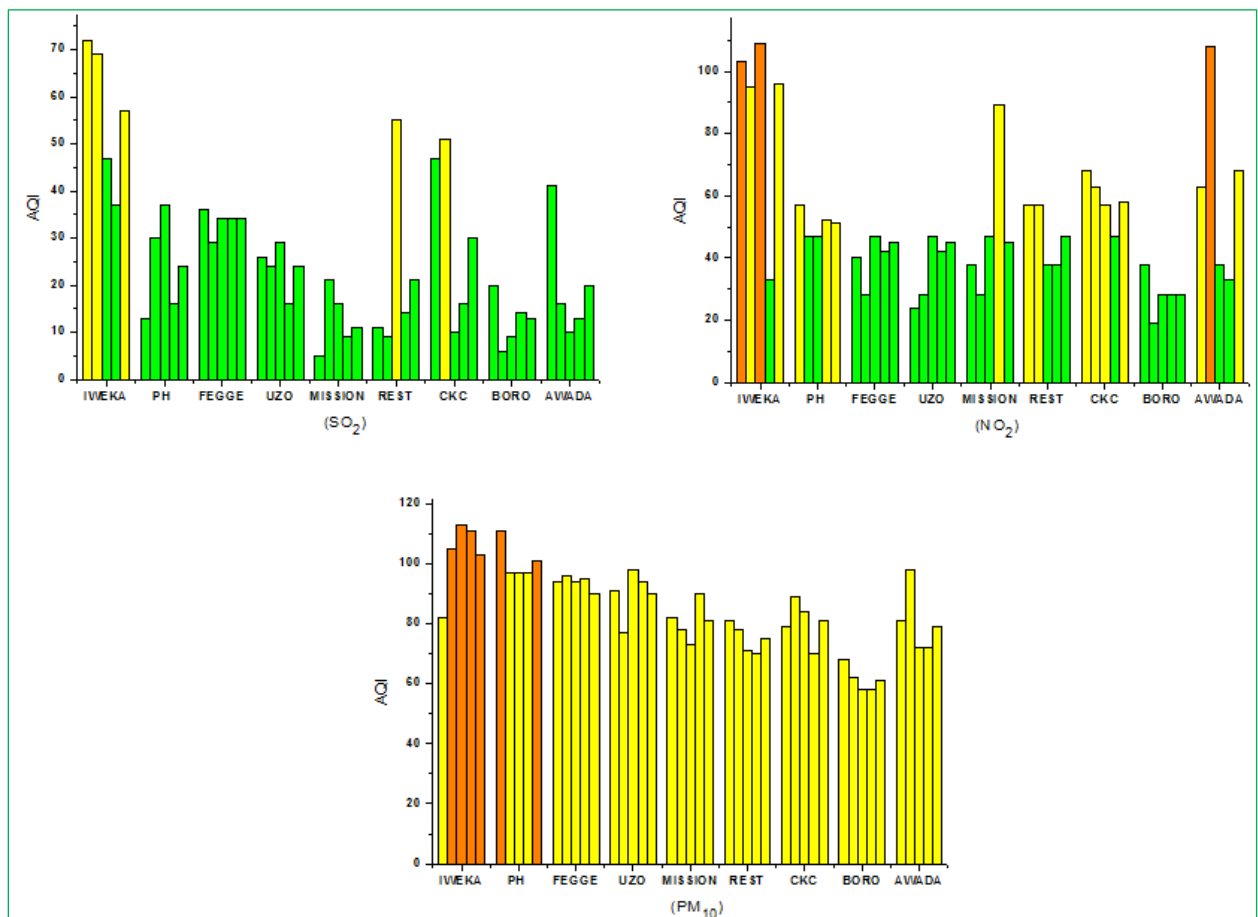

Figure 05. Color coded AQI plot for SO_2, NO_2 and PM_{10}.

Effect of meteorological parameters

The effect of meteorological parameters on the studied variables were plotted in the figure 06 below. The diagram showed that the wind speed was well below $10ms^{-1}$ and had little or no effect on the SO_2, NO_2, and PM_{10} determinants. The average plot of NO_2 and SO_2 were almost superimposable at each sampling point. The highest NO_2 was at CKC at $155ug/m^3$ while SO_2 at CKC was $57ug/m3$. Hence, this may be

450

emanating from a similar source. On the other hand, the PM_{10} was highest at upper Iweka (159 ug/m³) but adjusted to similar undulating movement at CKC, Borromeo and Awada. This similarity is a pointer that the gaseous pollutants were affected by similar metrological parameters.
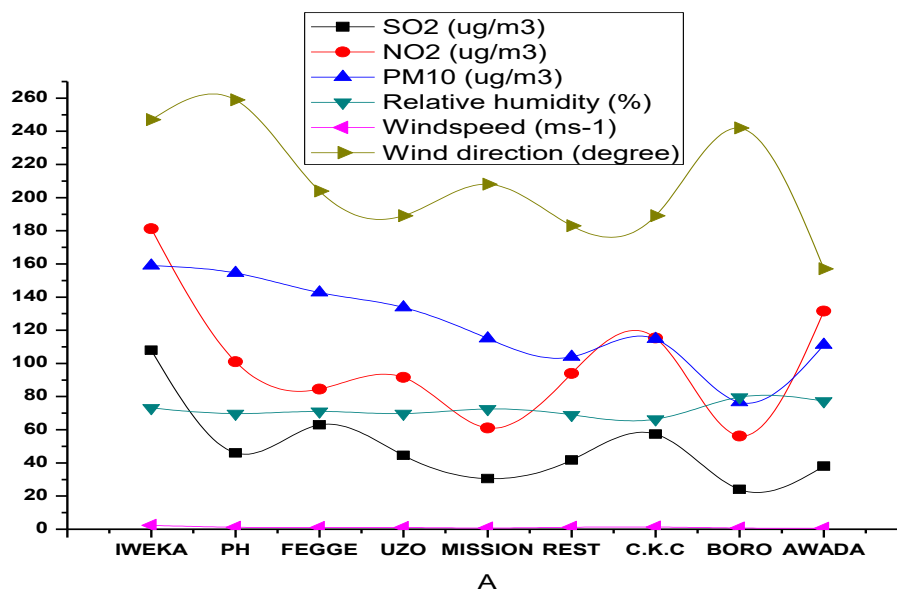

Figure 06. Effect of meteorological parameters on the average concentration of pollutants.

This pollutant movement was seen as an active undulating wind or slopping region from a point source as found in SO_2 concentration in section 4.1, or low wind action from point source as found in NO_2 section 4.2 or active points of dispersion by PM_{10} in section 4.3. Consequently, almost remained equal except at Borromeo and Awada. This high humidity may also be a contributory factor to low levels of gaseous pollutants at Borromeo. However, it was observed that Awada had high humidity but experienced greater wind director. This wind direction may be the force driving higher levels of PM_{10} and NO_2 at Awada sampling point. Hence, the results suggest that SO_2, NO_2, PM_{10} dispersal are significantly affected by wind direction and humidity. In addition, it would be noted that PM_{10} was the least affected by meteorological parameters. In addition, it also demonstrated the importance of rainfall in the scavenging of SO_2, NO_2, and PM_{10} criteria air pollutants (Ravindra et al. 2003).

Data application and implication

SO_2 Pollutant: The maximum determined SO_2 concentration was in upper Iweka at 141 µg/m³, while the minimum was 70 µg/m³. In Nigeria, FEPA (stationary sources) and National air quality standard (NAQS) (ambient limit) for SO_2 is 26000 µg/m³ and 50 µg/m³ respectively (FEPA, 1991). Hence, SO_2 concentrations at upper Iweka exceeded the national air quality standard for ambient air. The SO_2 concentrations at Fegge/Nupe also exceeded 50 µg/m³, while the average concentrations for all sampling points in CKC was 57 µg/m³ and also exceeded the Nigerian standard. Hence, this study points out to the weakness of FEPA standards (26000 µg/m³) in Nigeria to effectively access criteria pollutants and hence requires a review. Because this ratio is high compared to other nations. Moreover, upper Iweka, CKC and Fegge/Nupe should be areas of local monitoring concerns for SO_2 pollution. While Borromeo and Mission road are areas with good air quality. The WHO standard for SO_2 air pollutant is 20 µg/m³ for 24h period and annual mean of 50 µg/m³ (Said et al. 2016). Thus, the determined concentrations were below WHO standards as similarly described using the NAQS of Nigeria (50 µg/m³).

The major sources of SO_2 pollutant are combustion power plants, fossil fuel and petroleum refining (Popp, 2006). Consequently, upper Iweka, CKC and Fegge/Nupe should be areas of local monitoring concerns for SO_2 because these emitted gases will eventually form acid rain due to its low acidic pH value and affect the environment through corrosion of materials, damage to crops and forests, nutrient leaching and

451

contaminating drinking water. Additionally, since SO_2 residence time is 2 to 4 days and its main dispersion is by oxidation (Griffin, 2006). The enforcement of standards and map transport within areas of upper Iweka, CKC and Fegge/Nupe and gas transport are required for SO_2 pollutant control in Onitsha Lower basin.

NO₂ Pollutant: The maximum values of NO_2 determined was 109 μg/m³ at Upper Iweka, while the minimum value was measured at Borromeo to be 19 μg/m³. The values when compared with FEPA (stationary sources) and National air quality standard (NAQS) (ambient limit) for NO_2 is 75000 μg/m3 and 1000 μg/m3 respectively (FEPA, 1991). Thus, the levels of NO_2 at all sampling points were below Nigeria standard and accordingly, all areas have good air quality with respect to NO_2. Additionally, WHO 1h mean is 200 ug/m3, while annual mean period is 40 μg/m³ (Said et al. 2016) Subsequently, the average concentration of NO_2 for all sampling points exceeded 40 μg/m³ except at Borromeo with 28 μg/m³.

Since the average level of NO_2 exceeded WHO mean annual level, there is therefore the possibility of reacting with water to form acid rain in all sampled regions. These would lead to material corrosion and damage to crops. Moreover, the NO_2 residence time is 2-5 days, while principal sinks occur through oxidation, deposition, photolysis and dissolution in oceans and surface waters. Thus, if the major sources were fossil fuel combustion driving the NO_2fluxes, there is the need for monitoring trans-boundary fluxes from stationary and mobile sources. Also, the use of selective non-catalyst reduction technology in such combustion processes will further reduce the release of nitrogen oxides (Popp, 2006; Griffin, 2006).

PM₁₀ Pollutants: The maximum determined PM_{10} concentration was 111 μg/m³determined at both Upper Iweka and pH road. The minimum determined concentration was at Borromeo at 58 μg/m³. Their comparison to Nigeria, FEPA (stationary sources) and National air quality standard (NAQS) (ambient limit) for PM_{10} is 25000 μg/m³and 150 μg/m³ respectively. Accordingly, the concentration levels were lower than FEPA and NAQs standards. Also, this illustrated the inability of FEPA at such high standard (25000 ug/m3) to effectively evaluate criteria pollutants that are noxious even at low concentrations. The WHO standard for PM_{10} is 20 μg/m³for 24h period and annual mean of 50 μg/m³ (FEPA, 1991). Thus, the sampled area exceeded the WHO standard with respect to PM_{10}. But since PM_{10} has particle size < 10um, they are mostly released by combustion of fossil fuels, motor vehicles, agricultural burning and industrial activities.

Such activities can prevent suns radiation from reaching the earth when they act as cloud nuclei. they effect is reduced visibility, depletion of soil nutrients, acidification of surface water and destruction of sensitive ecological forests and farm crops. Consequently, there should be controls for industrial facilities, motor vehicles and use of cleaner burning gasoline and diesel fuels (Akinfolarin et al. 2017; Opara et al. 2016; Popp, 2006; Griffin, 2006).

GIS plot
The GIS plot was shown in figure 07 below. These provided a better and elaborate description of the concentrations of the pollutant relative to their respective positions. The highest concentration of SO_2 (A) can be clearly seen to be Upper Iweka and Awada and was similarly observed in NO_2 plot (B). Borromeo and Mission road/waterside were the lowest points of concentration for NO_2 and SO_2 respectively. The contours showed that that pollutants spreads from Awada and Upper Iweka to other sampling regions. Three or more central forces were active in SO_2, while about two could be seen in NO_2. This demonstrated that SO_2 is more quickly dispersed than NO_2. A similar dispersion movement was observed in PM_{10} with Upper Iweka showing highest concentration and spreading towards CKC. One central force was observed in PM_{10} and hence, dispersed at a speed slower than NO_2. Summarily the SO_2 was the most active gaseous pollutant and more easily dispersed by metrological forces (wind speed, wind direction, humidity) than NO_2 and PM_{10}. These showed a correlation with section 4.5 that the studied pollutants were affected by metrological factors in the order of $SO_2 > NO_2 > PM_{10}$.
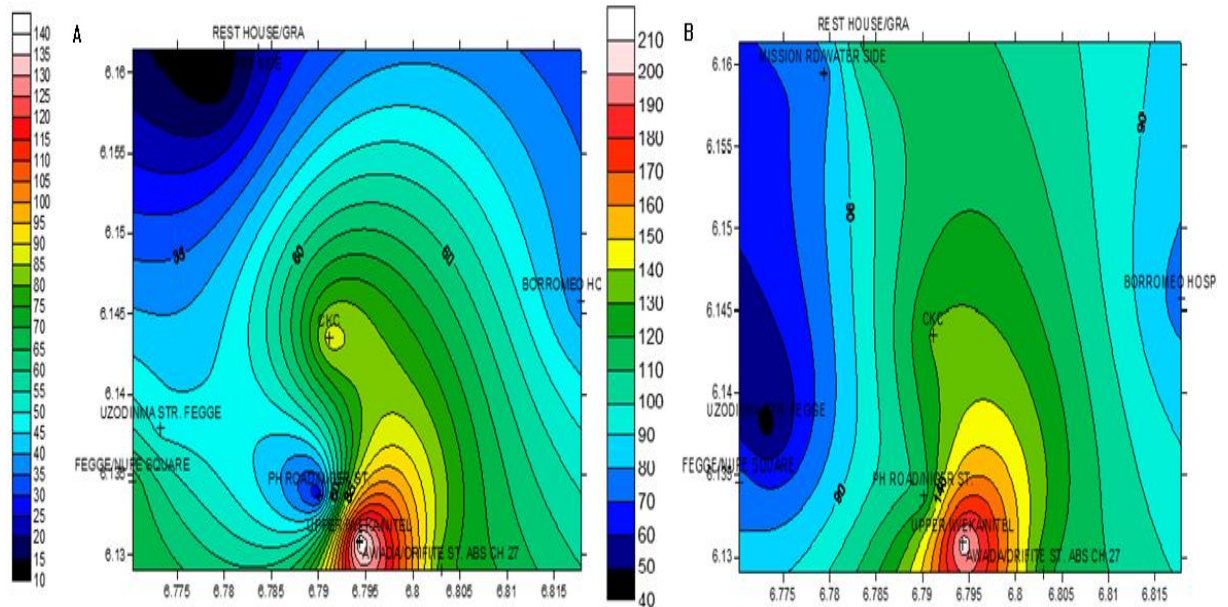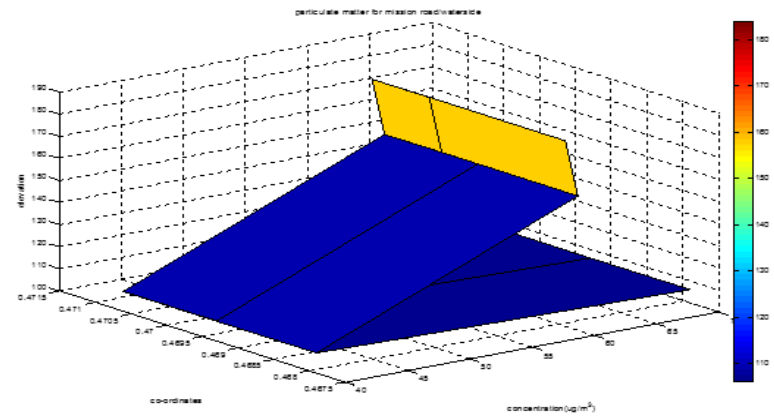
Figure 07. GIS surface plot for (A) SO$_2$ and (B) NO$_2$ Pollutants.
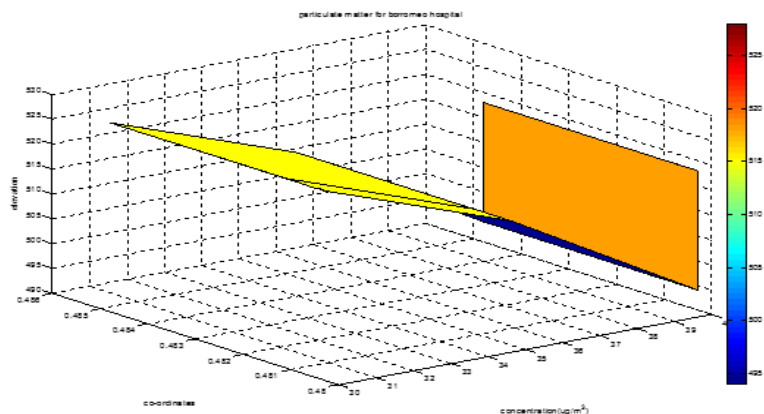
MATLAB results

The Matlab assisted plot for PM$_{10}$ was significant and hence shown in figure 08 below. The Upper Iweka had been described as an area of active pollutants. The Matlab windspeed showed that there was an upward wind in upper Iweka driving the pollutants towards dispersal at some other region. The wind action appears forceful and later a still blowing wind which aided the movement of pollutants. The other Matlab surface plots showed that mission road generally experienced similar concentrations levels of PM$_{10}$ at most sampling points. The Awada and Borromeo were previously described as lower regions having lower PM$_{10}$ concentrations. Hence, while Awada would peak at some point before dispersing, the Borromeo region would vary a little in its concentration level with upward increase in concentration when descending/dispersing to other regions. Both the abrupt movement and change in concentration experienced was initially demonstrated in figure 06. Consequently, both the Matlab and GIS plots confirmed that during rains, metrological factors act as scavengers to air pollutants.
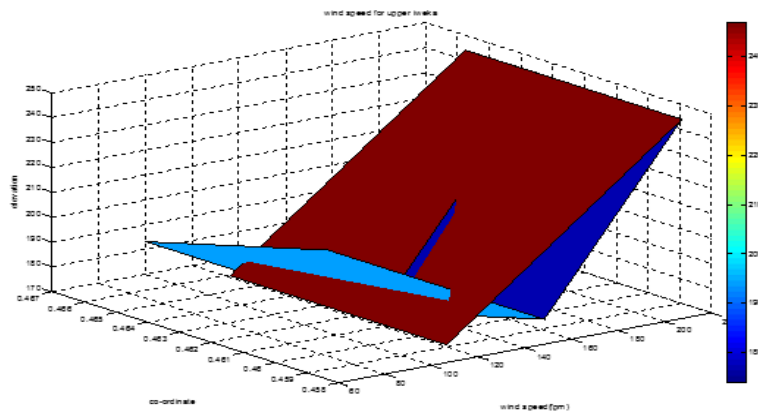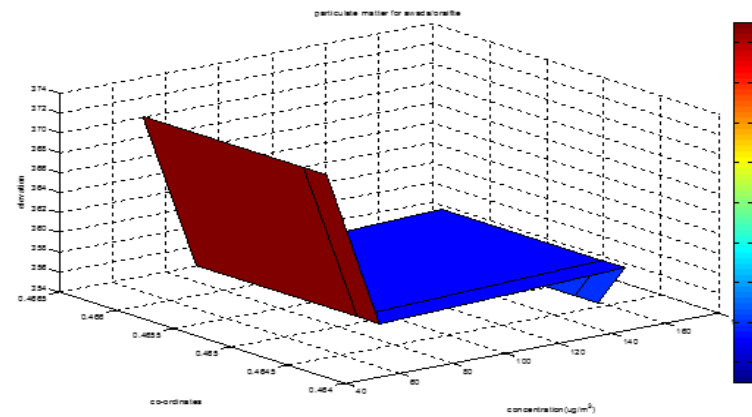
Figure 08. Matlab assisted plot for Awada, Borromeo, Mission road and wind speed for Upper Iweka region.

IV. Conclusion

The study of air pollutants utilizing spatial processing and time series analysis has seen accurate results for regulatory purposes in densely populated cities. GPS and MATLAB modeling utilized in this study for SO_2, NO_2 and PM_{10} pollutants during rains in Lower Onitsha basin. The named pollutants were studied at different measuring times in nine locations for 3 months of rains in three consecutive years. A Matlab model was generated by polynomial equations while GIS coordinates were mapped using ARCGIS 9.3. All the 3 pollutants showed highest concentrations at Upper Iweka and dispersed towards Awada, Borromeo or Rest house. AQI showed that PM_{10} and NO_2 may affect sensitive groups at Upper Iweka, Awada and PH road. SO_2 levels were below WHO standard but NO_2 and PM_{10} average concentrations exceeded the WHO standard. Additionally, the study revealed the inability of FEPA at such high standard (26000 for SO_2, 75000 for NO_2 and 25000 for PM_{10} $\mu g/m^3$) to effectively evaluate criteria pollutants that are noxious even at low concentrations The Metamodeling and GIS mapping identified wind speed, wind direction and humidity as effective scavengers of SO_2, NO_2 and PM_{10}. Hence, the study demonstrated that Upper Iweka is a major point source pollution and scavenged by wind speed, wind direction and humidity under prevailing rains in onitsha lower basin.

Conflict of Interest

The authors declare that no conflict of interest exists.

V. References

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