# SPATIO-TEMPORAL CHARACTERIZATION AND DYNAMIC MODELLING OF AMBIENT AIR QUALITY IN IMO STATE, NIGERIA

**BY**

**IBE, FRANCIS CHIZORUO,**
**B.Sc. (UNIUYO), M.Sc. (FUTO)**
**200847350084**4

**A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI**

**IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D.) IN ENVIRONMENTAL CHEMISTRY**

**December, 2016**

## CERTIFICATION

This is to certify that this research work "Spatio – temporal characterization and dynamic modelling of ambient air quality in Imo State, Nigeria"was carried out by me.Ibe, Francis Chizoruo (Registration No 2008473500844) in partial fulfillment for the award of the degree of Ph.D. in Environmental Chemistry in the Department of Chemistry, Federal University of Technology, Owerri.

.....
**PROF. P.C.NJOKU**
Principal Supervisor

13-12-16
.....
Date

.....
**PROF. J. I. ALINNOR**
Co – Supervisor

19/12/2016
.....
Date

.....
**Dr. A. I.OPARA**
Co – Supervisor

14/12/2016
.....
Date

.....
**PROF. M. O. C. OGWUEGBU**
Head, Chemistry Department

19-12-2016
.....
Date

.....
**PROF. B. C. ANUSIONWU**
Dean, School of Physical Science

.....
Date

.....
**PROF. (MRS.) N. N. OTI**
Dean, Postgraduate School

.....
Date

.....
PROF. S. A. ODOEMELAM
**External Examiner**

6/12/16
.....
Date

# DEDICATION

This work is dedicated to my beloved wife, Dr. (Mrs.) Bridget Onyekachi Ibe and our children; Chinonso, Ebubechi and Chibueze, whose love and support culminated to completion of this work.

# ACKNOWLEGDEMENTS

My greatest gratitude goes to the Almighty God, who gives knowledge and understanding for His unfailing love, mercy and support to me towards the completion of this academic programme.

I really appreciate the effort, love and concern of my supervisors: Prof. P. C. Njoku and Prof. J. I. Alinnor of the Department of Chemistry and Dr. A. I. Opara of the Department of Geology. These amiable professors gave me countlessideas and directions that positively changed my academic mindset. Their constructive criticisms and corrections were of immense benefit towards the completion of this academic programme and I am highly indebted to them.

I am very grateful to all my lecturers in the Department of Chemistry, FUTO, especially Prof. C. I Anonuso, Prof. A. A. Ayuk, D.Sc., Prof. E. N. Ejike, Prof. E. E.Oguzie, and other lecturers in the Department for their scholarly contributions to my academic life.

I am indeed indebted to my uncle, God father, a reverend of noteand a father, Rev Fr. C. N.Ibe, who ignited the academic flame in my life. His love, care, support, concern and encouragement motivated me to start a postgraduate programme.

I acknowledge with thanks the effort and encouragement of my mother, Mrs Violet O. Ibe for her prayers. I thank my brothers and sisters: Mr. Chidiebere Ibe, Mr. Jonathan Ibe, Mrs. Justina Mgboji, Mrs Theresa Ihejeto, Nda Calista, Eucheria and others for their love and support. I appreciate my mother in-law, Mrs. Ugo Louisa-Mary for her spiritual backing.

Finally, I appreciate the encouragement of my colleagues in the Department of Chemistry, Imo State University, Owerri. In a special way, I thank Prof. C. I. Ubochi and Assoc. Prof. V. O. Njoku, who always remind me of the need to complete the programme.

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## ABSTRACT

Spatio-temporal characterization and dynamic modelling of ambient air quality were carried out in Imo State, Nigeria. The study was aimedat evaluating the ambient air quality of Imo State and to present a dynamic model for prediction of atmospheric dispersion and concentration in the study area. Six atmospheric pollutants including$PM_{10}$, $NO_2$, $SO_2$, VOC, $H_2S$ and CO were measured using Haze Dust Particulate Monitor (10µm), Gasman Air Monitors, Aeroqual Series 300 and Ibrid MX6. The meteorological parameters, wind speed, ambient temperature, air flow, wave height, and wind direction, were measured with Multifunctional Microprocessor DigitalAnemometer, while difference in temperature of wet and dry bulb hygrometer was used to locate the relative humidity from a psychrometric chart and elevation was with GPS map 76.Air quality monitoring was conducted in wet and dry seasons, three times a day (morning, Afternoon and evening) in 4 locations with a total of 16 air sampling sites within the months of November, 2014 to June, 2015. The result showed that the mean concentration of the air pollutants in dry season ranged as follows: $PM_{10}$ (5.70 – 8.38) $mg/m^3$, $NO_2$ (0.37- 0.53) ppm, $SO_2$ (0.29- 0.61) ppm, VOC (0.47 - 1.14)$mg/m^3$, $H_2S$ (0.01 – 0.05) ppm and CO (0.29– 49.52) ppm, while in wet season the values were in the range; $PM_{10}$ (4.91– 7.34) $mg/m^3$, $NO_2$ (0.43- 0.59) ppm, $SO_2$ (0.43- 0.60) ppm, VOC (0.25- 1.06) $mg/m^3$, $H_2S$ (0.00 – 0.01) ppm and CO (26.42 – 41.77) ppm.Spatial variation of the air pollutants was observed in the study area as revealed by the GIS analysis which was illustrated with spatial variation maps, contour and 3-D surface plots.The Box and Whisker plots showed the characterization and distribution of the data in terms of lower quartile, upper quartile, median, minimum and maximum values. It indicates elevated level of CO, $PM_{10}$ and $SO_2$ in the afternoon and evening, higher concentration of VOC and $H_2S$ in the morning and $NO_2$ showing significant values in the morning and afternoon. The Dynamic models in most locations showed high $R^2$ indicating significant influence of the meteorological factors and previous day concentration (PDC) of the pollutants. The time series models showed that the concentration of the pollutants fluctuated within the period of study. The windrose models revealed the dominant wind speed,direction of dispersion and transportation of the air pollutants. One-way ANOVA ($p < 0.05$) revealed that the difference in mean values of the air pollutants were not statistically significantin some locations due to the influence of season, meteorological factors, location and time of measurement, while that of the meteorological variables were significant in some locations . High correlation was observed between $NO_2$ and $SO_2$, wind speed and air flow, while weak correlation was recorded between $PM_{10}$ and $SO_2$, VOC and CO, temperature and relative humidity. Hierarchical Cluster Analysis (HCA) grouped both the air pollutants into two major cluster and meteorological parameters into two clusters. The Principal Component Analysis (PCA) revealed two coherent components existing among the air pollutants and between the meteorological variables. The multivariate plots indicate that the meteorological parameters have great influence on the air pollutants.The mean concentration of the air pollutants obtained exceeded the Nigerian National Ambient Air Quality Standards (Nigerian NAAQS) and United States of America NAAAQS while $NO_2$ and $SO_2$ are within the permissible limit in some of the monitoring stations. Air Quality Index (AQI)analysis is within 51 – 300 (moderate – very unhealthy). In conclusion, the study has established the spatial and temporal attributes of the measured ambient air pollutants, the dynamics of atmospheric dispersion and prediction of air pollution events in the study area. The observed AQI within the study area is of great concern and therefore requires serious attention by environmentalists, researchers, regulatory bodies, and of course the government at the various levels.



Key Words: ambient air quality, air quality index, dynamic modelling, pollution emission, Spatio-temporal.

# CHAPTER ONE
# INTRODUCTION

## 1.1 Background of the study

There is no thinking that technology and urbanization has changed several aspects of human life. The populace benefits largely from the developments that emanate from these with many living in prosperity, but prosperity has a price. This price is paid by our environment that suffers daily from all kinds of pollution. This results in near destructon of the atmospheric environment, which increases the overall toxic burden of the environment (Njoku & Ibe, 2009). The problems associated with air pollution pose serious threat to environmental health in many cities of the world (Kan, Chen & Hong, 2009; Wong, Vichit-Vadakan, Kan & Qian, 2008; McCarthy, Hafner, Chinkin & Charrier, 2007). It is a well known fact that one of the basic requirements of human existence is clean air. But air pollution has continued to pose significant threat to this basic human need and environmental health worldwide (Hassan & Abdullahi, 2012). Due to the problems arising from atmospheric pollution, the Federal Government of Nigeria banned the sale and importation of smaller generators (popularly known as "I pass my neighbor") in consideration of the proliferation in causing air pollution and destruction of human lungs and breathing system (Vangard, 2015). It is regrettable that the sub-standard product is still being ignorantly smuggled into the country by some unscrupulous businessmen as at today.

The atmosphere or air is normally composed of 78.1 % $N_2$, 20.9 % $O_2$, 0.92 % Ar, 0.003 % $CO_2$, 0.4 % $H_2O$ (Table 1.1) and small quantities of several other gases depending on temperature (Clarke & Tomlin, 1999; Jiming & Guowen, 2002). Based primarily on temperature, the atmosphere is divided into four layers; (i) Troposphere which is the layer between the ground and a height of approximately 15 km at the equator and 10 km at the poles. The temperature of the troposphere falls with increasing altitude to a minimum of between 200 and 220 K (-73 °C to -53 °C) at the boundary between this layer and the next (tropopause). The troposphere is the layer that is believed to contain a significant proportion of the atmospheric pollutants. (ii) Stratosphere is the layer between the troposphere and about 50 km. There is little bulk mixing in this layer and the temperature is fairly constant except the upper region where absorption of UV radiation by ozone causes the temperature to rise approximately to 290 K (17 °C) (temperature inversion) until the upper boundary of the stratosphere is reached (the stratopause). (iii) Mesophere is the layer between 50 and 80 Km within which the temperature decreases almost linearly to approximately 175 K (98 $^{o}$C). (iv) Thermosphere is the uppermost layer of the

atmosphere, the temperature increase to approximately 1500 K (1227 $^{o}$C) (Baker, 1995; Manaham, 2001; Jiming & Guowen, 2002; Wright, 2003).

Air pollution which commenced with the use of fire for domestic purposes has gradually over the years changed the normal composition of the atmosphere. Its historical development has been characterized by steady increase in the amount of total emissions, and the invention of new sources of pollution emission as well as the emission of pollutants that had not formerly been emitted by man-made sources (Zell, Quarcoo, Scutaru, Vitzthum, Uibel, Mache & Michael, 2010). Generally atmospheric pollution is mainly anthropogenic with only a little contribution from natural hazards like volcanic eruption, tornadoes, etc.

Air pollution is one of the problems associated with the growing population of our cities. This has increased tremendously with urbanization and associated industrial development and growth in mobility which have deteriorated air quality and intensified air pollution in densely populated areas. The severity of the air pollution problems in the cities reflects the level and speed of development (APMA, 2002; Molina, Ivanor, Trakhtenberg & Monilna, 2004; Grutter, Arellano, Bezanilla, Friedrich, Plaza, Rivera & Stremme, 2014). Most of these pollutants are emitted from "fugitive" sources such as evaporation of solvents or leaks from industrial facilities, incinerators and flare stacks which can also be source of atmospheric emissions (FAP, 2014). Air pollution is severally defined as the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property (Odigure, 1998; Hellen, Hakola, Pirjola, Laurila & Pystynen, 2006; Tawari & Abowei, 2012). Air pollution may also be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment. These substances are naturally present in the atmosphere in low (background) concentrations which are usually considered to be harmless (Ewona, Osang, Obi, Udoimuk & Ushie, 2011). According to Gobo, Ideriah, Francis & Stanley (2012) air pollution is as old as civilization itself and emanates from nature and anthropogenic activities that creates pollution every day, all over the world.

Ferris (1978) and Otti, Nwajuaku & Ejikeme (2011) revealed that air pollution is the addition of harmful substance to the atmosphere resulting in damage to the environment, human health and quality of life. In nature, air pollution is created when volcanoes erupt (or volcanoes belched releasing enormous amount of ash and sulphur dioxide into the atmosphere); forest fires

and their smokes are blown by winds; and when winds whip up plant pollens and dust from deserts or road sides (Gobo et al., 2012). Air pollutants can be divided into two main groups- particulate and gaseous. The former include solid airborne particulates such as dust, fly ash, smoke, fog, soot, and fumes (due to fugitive emissions). Gaseous air pollutants include carbon monoxide, oxides of sulphur, oxides of nitrogen, hydrogen sulphide, ammonia, chlorine hydrocarbons, and hydrogen fluoride. These pollutants are generally refered to as primary air pollutants. These pollutants may interact with one another in the presence of an energy source such as UV radiation from sunlight to form new secondary air pollutants such as ozone and particulates like sulphates as shown in the equation (1.1 and 1.2) below

$O_2 + hv \longrightarrow O^{\cdot} + O$ photo-dissociation by UV light (1.1)

$O_2 + O^{\cdot} + M \longrightarrow O_3 + M$ in the presence of a third body (1.2)

Secondary air pollutants may also form from reactions with natural chemicals like formaldehyde and terpenes from plants (biogenic hydrocarbons) in the atmosphere as shown in the equation below

$2(CH_2O)$ (bacterial action) $\longrightarrow CO_{2\,(g)} + CH_{4\,(g)}$ (1.3)

(Clarke & Tomlin, 1999; Bhatia, 2002; Wright, 2003)

The result of air pollution is more than two million premature deaths each year attributable to the effects of urban outdoor and indoor air pollution as reported by World Health Organization and these effects are more prominent in developing countries (WHO, 2005). Imo State, South Eastern of Nigeria is not an exception to this ugly situation. The green house gases like carbon dioxide, water vapour, ozone, methane, nitrous oxide, and chlorofluorocarbons (CFCs) when released could negatively affect the environment considering their global warm potentials (Clarke & Tomlin, 1999). In recent years, studies in the United States, Europe and Asia have reported that human exposure to air pollutants are associated with a range of health effects: adverse respiratory effects (Oosterlee, Drijiver, Lebret & Brunkreef, 1996; Peters, Avol, Navidi, London, Gauderman, Lurmann & Thomas,1999a; 1999b; Brauer, Hoek, Van-Vliet, Meliefste, Fischer, Wijga & Brunekreef, 2002; Garshick, Laden, Hart & Caron 2003; Heinrich & Wichmann, 2004), adverse effects on children's lung development (Gauderma, Vora, McConnell, Berhane, Gilliland, Thomas & Peters, 2007), an increased risk of cardiopulmonary and stroke mortality related to close proximity to traffic (Hoek, Brunekreef, Goldbohm, Fischer &Van den, 2002; Maheswaran & Elliott, 2003), the onset of myocardial infarction within 1 hour after exposure to traffic during commuting activities (Peters, von Klot, Heier, Trentinaglia,

Hormann, Wichmann & Lowel, 2004) and perinatal health effects (Ritz & Yu, 1999; Ritz, Yu, Chapa & Fruin, 2000; Wilhelm & Ritz, 2003, 2005).

### 1.1.2 Air Pollution and the Environment

The present-day atmosphere is quite different from the atmosphere that existed before the Industrial Revolution of 1760, in terms of chemical composition. If the natural atmosphere is to be considered "clean", then this means that clean air cannot be found any where in today's atmosphere (Daly & Zannetti, 2007a).

Table 1.1: Showing the Chemical Composition of the atmosphere

| Gas | Symbol | % by volume (current atmosphere) | ppm (Natural atmosphere) | ppm (Current atmosphere) |
|---|---|---|---|---|
| Nitrogen | $N_2$ | 78.1 | | |
| Oxygen | $O_2$ | 20.9 | | |
| Argon | Ar | 0.92 | | |
| Helium | He | | 5.2 | |
| Krypton | Kr | | 1.14 | |
| Xenon | Xe | | 0.09 | |
| Neon | Ne | | 18.2 | |
| Carbon dioxide | $CO_2$ | | 280.0 | 370.0 |
| Methane | $CH_4$ | | 0.750 | 1.77 |
| Nitrous oxide | $N_2O$ | | 0.270 | 0.318 |
| Water Vapour | $H_2O$ | Variable 0.004 to 4 | | |

Source: (Builtjes, 2003)

It is therefore not easy to define "air pollution" Hence, one could claim that air pollution started when humans began burning fuels. In other words, all man-made (anthropogenic) emissions into the air can be called air pollution, because they alter the chemical composition of the natural atmosphere. The increase in the global concentrations of greenhouse gases $CO_2$, $CH_4$, and $N_2O$ (NOAA, 2014) (shown in Table 1.1), can be called air pollution using this approach, even though the concentrations have not been found to be toxic for humans and the ecosystem. One can refine this approach and only consider anthropogenic emissions of harmful chemicals as air pollution.

However, this refined approach has some drawbacks. Firstly, one has to define what "harmful" means. "Harmful" could mean an adverse effect on the health of living things, an adverse effect on anthropogenic or natural non-living structures, or a reduction in the air's visibility. Also, a chemical that does not cause any short-term harmful effects may accumulate in the atmosphere and create a long-term harmful effect (Daly & Zannetti, 2007a). For example, anthropogenic emissions of chlorofluorocarbons (CFCs) were once considered safe because they are inert in the lowest part of the atmosphere called troposphere. However, once these chemicals

enter the stratosphere, ultraviolet radiation can convert them into highly reactive species that can have a devastating effect on stratospheric ozone (Bhatia, 2002), as shown in Eq. 1.4 and 1.5

$$2Cl_2CF + hv \rightarrow 3Cl + ClCF_2 \quad (1.4)$$

These atoms react with ozone, destroying it and producing ClO (Bhatia, 2002)

$$Cl + O_3 \rightarrow ClO + O_2 \quad (1.5)$$

Similarly, anthropogenic $CO_2$ emissions from combustion processes were considered safe because they are not toxic, but the long-term accumulation of $CO_2$ in the atmosphere may lead to a climate change, which could then be harmful to humans and the ecosystem.

Another drawback of this approach is that it does not consider natural emissions as air pollution even though they can be very harmful, such as gases and particles from volcanic eruptions, and smoke from forest fires caused by natural processes (lightning strikes). So besides anthropogenic emissions, it is useful to also consider geogenic emissions and biogenic emissions as contributors to air pollution. Geogenic emissions are defined as emissions caused by the non-living world, such as volcanic emissions, sea-salt emissions, and natural fires (EEA, 2014). Biogenic emissions come from the living world; such as volatile organic compound (VOC) emission from forests and $CH_4$ from swamps (Builtjes, 2003).

Human activity can also influence geogenic and biogenic emissions. For example, human applications of nitrogen fertilizers in agriculture can result in increased biogenic emissions of nitrogen compounds from the soil (Kopacek & Posch, 2011). Also, humans can affect the biogenic emissions of VOC by cutting down trees or planting trees. Lastly, geogenic emissions of dust from the earth's surface can be altered if the surface is changed by human activity. So taking all of the above into account, it can be stated that;

"Air pollutant" is any substance emitted into the air from an anthropogenic, biogenic, or geogenic source, that is either not part of the natural atmosphere or is present in higher concentrations than the natural atmosphere, and may cause a short-term or long-term adverse effect (Daly & Zannetti, 2007a). Several authors have defined air pollution in different ways, but all the definitions point towards air deterioration or contamination.

Therefore, air pollution is the result of a complex phenomenon involving several aspects, like emission and chemical transformation processes, transport and dilution phenomena connected to the dynamic of atmospheric layers (Andria, Gavone, Di Lecce & Lanzolla, 2003). They further, stated that it is difficult to measure the air quality and to define unequivocally a quality standard to guarantee a suitable human and environmental healthiness. According to Ewona et al. (2013),

pollution usually refers to the presence of substances that are either present in the environment where it doesn't belong to or at levels greater than it should be. Also, Ukaigwe and Osoka (2013) posited that air pollution occurs when substances altering physical or chemical properties of the air, are added in sufficient concentration to produce a measurable deleterious effect on man or vegetation. Rai, Rajput, Agrawal & Agrawal (2011) stated that air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that may produce undesirable effects on man and ecosystem. They submitted that substance like gases (sulphur dioxide, nitrogen oxides, carbon monoxides, hydrocarbons, etc.), particulate matters (smoke, dust, fumes, aerosols, etc), radioactive materials and many others could have harmful effects on living things and materials. Heck, Taylor, Adams, Bingham, Miller, Preston & Weinstein (1988) concluded that it could interfere with biochemical and physiological processes of plants.

### 1.1.3 Types of Air Pollution

Air pollution usually results from anthropogenic activities and from natural occurrences. And could occur both outdoors and indoors, therefore air pollution may be viewed as being of two types;

#### 1.1.3.1 Outdoor air pollution

Outdoor air pollution is the release of several substances into the atmosphere, in concentrations that threaten the well being of living organisms or disrupt the function of the environment as a system leading to human health damages in various ways (Dimitriou & Christidou, 2011).

(a)   (b)

Fig. 1.1 Emissions from open burning of solid waste (a) and crude oil fire outbreak (b)

Air pollutants could be gaseous, solid particles, or liquid droplets. They can be products of either natural processes or human activities. Natural sources of air pollutants include volcanic activity,

forest fires and crude oil fire out break (Fig. 1.1b), organic decay or soil dispersion into the air by the wind. The main anthropogenic sources of air pollutants released in the atmosphere are human activities such as transportation (motor vehicles, aircrafts), burning of solid waste (Fig. 1.1a), burning of coal or other fossil fuels for energy demands, industrial processes, or use of chemicals in agriculture, and facilities like power plants, incinerators, landfills for waste deposition (EEA, 2006a; 2006b; EPA, 2007; Valent, Little, Tamburlini & Barbone, 2004). The major outdoor air pollutants produced by human activities include, among others;

• Carbon oxides, especially carbon monoxide (CO) and carbon dioxide ($CO_2$) emitted from automotive exhaust and combustion of fossil fuels;

• Nitrogen oxides ($NO_X$), especially nitrogen dioxide ($NO_2$) emitted from high temperature fossil fuel combustion and electricity production;

• Sulphur oxides ($SO_X$), produced in various industrial processes such the smelting of sulphur-bearing ores for extracting metals and electricity production;

• Volatile organic compounds (hydrocarbons, VOCs) that include a variety of substances released from power plants and from industries producing numerous products such as painting colours, cleaning products, pesticides, building materials, and furniture;

• Particulate matter (PM), that is solid or liquid air pollutants mainly emitted by power plants, aircrafts, motor vehicles, mining, and incinerators;

• Ground level ozone ($O_3$), air pollutant that results from photochemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight;

• Toxic metals particularly lead (Pb), cadmium (Cd) and copper (Cu) that are emitted from the transportation sector (motor vehicle exhaust), as well as from industrial procedures (production of painting colours, mining processes) (EEA, 2006a; 2006b; EPA, 2007).

Outdoor air pollution is a major problem mainly in urban areas because of over population. Increasing population in urban areas results in increasing demands in transportation, industrial production and energy, which constitute the main sources of outdoor air pollution (UNPF, 2007). Moreover, this problem has been intensified due to inadequate green open spaces in towns and cities, hence, their restricted possibility to improve air quality and reduce air pollution (Givoni, 1991).

#### 1.1.3.2 Indoor air pollution

According to Dimitriou & Christidou (2011), indoor air pollution refers to the amount of chemical, biological and physical contaminants in the air inside a building. Indoor air pollution could be worse than outdoor air pollution. There is a wide range of indoor air pollutant sources in houses including building materials, pressed wood products and furniture, central heating and cooling systems, several personal care or household cleaning products, painting colours, solvents, heating or cooking appliances (stoves, wood and gas burning fireplaces, gas heaters), tobacco smoke, office machines and a variety of other products used in daily activities (EPA, 2007, 2008, 2009). In addition, outdoor air pollutants are also traced in indoor spaces, such as radon (a natural trace component of soil and ground). The major source of indoor air pollution is household combustion of coal or biomass for cooking and heating. And it is estimated that more than half of the world's population relies on animal dung, wood, crop waste, or coal to meet their most basic energy needs (WHO, 2005). The major indoor pollutants that can practically be traced in any home are formaldehyde, asbestos, carbon monoxide, nitrogen oxides, sulphur oxides, benzene, polyaromatic compounds, particulate matter, toxic metals (lead, mercury, cadmium, and chromium), and volatile organic compounds (EPA, 2008, 2009; WHO, 2005)

### 1.1.4 Emission of Air Pollutants to the Atmosphere

#### 1.1.4.1 Sources of Natural Emissions to the Atmosphere

The primary components of pure dry air are nitrogen $N_2$ (78.1 %), oxygen $O_2$ (20.9 %), argon Ar (0.9 %), and carbon dioxide $CO_2$ (0.035 % or 350 ppm). Water vapour is present in amount which varies depending on temperature and relative humidity as indicated in Table 1.1. Analysis of air samples reveals the presence of hundreds of other substances in trace amounts. Some of these can be explained directly in terms of their emissions either from natural sources or human activity. Others must have arisen indirectly by chemical processes in the atmosphere. These are distinguished as primary and secondary pollutants. Within densely populated areas of land, the levels of most pollutants are dominated by the contributions for which humans themselves are responsible. However, nature is also a generator of what we call 'pollutants' and on a global scale the natural emissions may be comparable to human emissions (Clarke & Tomlin, 1999), as illustrated in Table 1.2.

Table 1.2: Natural emissions of S[38] and N[39] compounds

| Source | $TgSyr^{-1}$ | Source | $TgNy^{-1}$ |
|---|---|---|---|
| Volcanoes | 9.3 | Lightning | 8 |
| Biomass burning | 2.2 | Biomass burning | 5 |
| Marine biosphere | 15.4 | Soil—biogenic | 7 |
| Terrestrial biosphere | 0.35 | $NH_3$ oxidation | 0.9 |
| | | From stratosphere | 0.6 |
| Natural total | 27.25 | Natural total | 22 |
| Anthropogenic | 77 | Anthropogenic | 22 |

(Tg = Teragram, 1Tg = 1012 g) Source; (Clarke and Tomlin, 1999)

### 1.1.4.2 Sulphur Species.

Sulphur in the form of $SO_2$ and some $H_2S$ are emitted naturally from volcanoes as noted in Table 1.2. Significant amounts are emitted from biological processes. In the absence of air, biological decay results in emissions of hydrogen sulphide, $H_2S$, and organic compounds such as dimethyl sulphide (DMS). Carbonyl sulphide (COS) emissions also occur together with small amounts of carbon disulfide ($CS_2$) and dimethyldisulphide (DMDS). From the oceans the emissions related to phytoplankton are primarily of DMS. It is important to note that the greatest uncertainty in the amount of $SO_2$ in the atmosphere has to do with nonanthropogenic sulphur, which enters the atmosphere largely as $H_2S$ from volcanoes and from the biological decay of organic matter and reduction of sulphate. In this regard any $H_2S$ that enters the atmosphere is rapidly converted to $SO_2$, according to Eq. 1.6.

$$H_2S + {}^{3}/_{2}O_2 \rightarrow SO_2 + H_2O. \qquad (1.6)$$

The grouping together of all sulphur compounds is appropriate since $H_2S$ and organic sulfur compounds are converted to $SO_2$ in the atmosphere. Since the global $SO_2$ from combustion emissions is about 70-100 Tg S $yr^{-1}$ the natural sulphur emissions are of the order of one third or one quarter of the anthropogenic emissions. This assessment omits the largest single component of the atmospheric sulphur budget which is represented by the sulphate content of sea-salt aerosols. There is obviously a sharp vertical gradient of these aerosols and a large proportion that returns to the sea quite quickly. Emission figures of the order of 200 $Tgyr^{-1}$ are quoted for aerosols in the 10-20 m height range but the particle number concentrations in the free troposphere (> 2 km) may be 3 orders of magnitude lower than in the oceanic boundary layer (Bates, Lamb, Guenther, Dignon, & Stoiber, 1992)

### 1.1.4.3 Nitrogen Species.

Biological processes in soil lead to the release of all common nitrogen oxides, NO, $NO_2$, and $N_2O$. The amounts involved are very uncertain but for NO and $NO_2$ are of the order of 5- 10 Tg N $yr^{-1}$ (Clarke & Tomlin, 1999). Lightning and biomass burning are other major sources. Oxidation of $NH_3$ to NO occurs in the troposphere and some nitrogen in the form of $HNO_3$ is transferred to the troposphere from the stratosphere (Manahan, 2001). These sources total 20-30 Tg N $yr^{-1}$ (Table 1.2). In comparison the anthropogenic emissions of NO + $NO_2$ from combustion are about 20 Tg N $yr^{-1}$. Lee, Kohler, Grobler, Rohve, Sausen, Gallard, O., Klenner, Oliver & Dentener (1997) estimated the total global $NO_x$ emissions to be 44 $TgNyr^{-1}$ with an uncertainty range of 23-81 Tg N $yr^{-1}$. The major source of nitrous oxide, $N_2O$, is the release from soil especially in situations where fertilizer has been added. Smaller releases occur from the oceans and from combustion processes. The sources are not as well understood as the main loss mechanism which is decomposition in the stratosphere (6-10 $TgN_2O$ $yr^{-1}$). Also industrial emissions may occur during the production of nitric acid and adipic acid (an intermediate in the production of nylon). The other important nitrogen species is ammonia, $NH_3$. Its sources may be considered partly natural and partly anthropogenic since they are dominated by animal excreta. But there are also significant releases from biomass burning, crops, and the ocean (Dreve, 1997). Several estimates of global emissions place the total at around $50TgNyr^{-1}$. The sources of ammonia are difficult to quantify since the earth's surface can act as a source and a sink and the overall emission rate depends on soil and the climatic conditions (Bouwman, Lee, Asman, Dentener, Van der Hoek & Oliver, 1997)

### 1.1.4.4 Hydrocarbons

Methane is an important greenhouse gas (Gobo, 2002). The largest natural sources of methane are anaerobic fermentation of organic material in rice paddies and in northern wetlands and tundra, plus enteric fermentation in the digestive systems of ruminants) (e.g. cows). Methane is also released from insects, from coal mining, gas extraction, and biomass burning. Total emissions are 300-550 Tg $yr^{-1}$ and appear to be increasing at a rate of 50 Tg yr-1 (Digest of Environmental Statistics, 1996). Heavier hydrocarbons, such as isoprene, $\propto$ and $\beta$-pinene and other terpenes, are released directly to the atmosphere from trees (Bhatia, 2000) and can contribute to the formation of photochemical smog in high emission areas. Global emissions of these Biogenic Volatile Organic Compounds (BVOCs) are estimated to be 1150 Tg $Cyr^{-1}$ of

which 88% is from trees and shrubs and 10 % from crops (Guenther, Hewitt, Erickson, Geron, Gerald, Harley, Klinger, Scholes, Taylor & Zimmerman 1995).

### 1.1.5 Sources of Primary Air Pollutants

There are numerous human activities, which result in the release of potential toxic substances into the atmosphere (Campbell, Stedman & Stevenson, 1994). From human activities, the primary source of air pollutants today is the waste products released into the air from the exhaust of internal combustion engines, boilers and furnaces of industries, plants and homes. (Gobo et al, 2012). This was clearly captured as reported by Okere, Nwachukwu & Ezebuuiro (2013) that the excessive reliance on the use of automobile in Nigeria during recent history, although have numerous benefits to human life, the benefits, however, have been accompanied by changes in the environment that is detrimental to man. In many cities across Nigeria, driving private car is probably a typical citizen's most "polluting" daily activity, as emissions from millions of personal vehicles on the road add up (Okere et al., 2013). Karlssson (2004) noted that vehicle emissions significantly pollute air and require control. With increasing concern for air toxics and climate modification caused by exhaust emissions (Lilley, 2000; Marshall, Riley, McKone & Nazarott, 2003) there is need for stringent control policy especially in the state. This follows the recent introduction of the two stroke engine tricycle (Fig. 1. 11) popularly known as Keke and the 2-stroke engine motor cycle that has been in use in State state before keke. Two stroke engines are known for their incomplete combustion of fuel leading to the emission of noxious atmospheric air pollutants (Sengupta, 2003).

Also, Nigeria is the 6th largest producer of oil in the world, endowed with more gas reserves than oil (Adati, 2012; Odeyemi and Ogunseitan, 1985). In 2011, a total of 2,400 Billion Standard Cubic Feet (BSCF) of Natural Gas was produced by the sixteen oil companies; of the quantity produced, 1,781.37 BSCF (74 %) was utilized, while 619.03BSCF (26 %) was flared (Aston-Jones; 1998,). The Niger Delta news (2004) reported that Nigeria flares more gas than any other country in the world. About 75 percent of total gas production in Nigeria is flared (Fig. 1.2), and about 95 percent of the associated gas, which is produced as by-product of crude oil extraction (Adeniye, Olu- Sule & Anyaye, 1983; Akpojiri & Akumagba, 2005; Elisha & Tano, 2008; Baird, 2010). Majority of these activites takes place in the Niger Delta region to which Imo State belong. This therefore could deteriorate the air quality of the state. Again, the number of quarrying industries in Nigeria keeps on increasing. Although it contributes to the internally generated revenue, there is need to look at its effect on the environment in general (Bada,

Olatunde & Oluwafunmilayo, 2013). The different quarrying activities have different impacts on air quality as in the case of Okigwe in Imo State. Mineral exploration, mining and processing results in environmental damages including ecological disturbances, destruction of natural flora, pollution of air, land and water, instability of soil and rock masses, landscape degradation and radiation hazards (Aigbedion & Iyayi,2007).

Figure 1.2 Gas flaring in the Niger Delta (Oyekunle, 1999)

Dust is the main source of air pollution from quarry industries. The extent of pollution by dust depends on the local microclimate conditions, the concentration of dust particles in the ambient air, the size of the dust particles and their chemistry (Bada et al., 2013). Quarrying activities could lead to emission increase in the level of heavy metals in soil and vegetation in quarry environment (Bada & Fagbayibgo, 2009) and in the level of suspended particulates (PM) in the ambient air of quarry environment (Oguntoke, Aboaba & Gbadebo, 2009)

### 1.1.6 Primary Air pollutants

They are substances that are directly emitted into the atmosphere from sources. The main primary pollutants known to cause harm in high enough concentrations are the following:

• Carbon compounds, such as CO, $CO_2$, $CH_4$, and VOCs

• Nitrogen compounds, such as NO, $N_2O$, $NO_2$ and $NH_3$

• Sulphur compounds, such as $H_2S$ and $SO_2$

• Halogen compounds, such as chlorides, fluorides, and bromides

• Particulate Matter (PM or "aerosols"), either in solid or liquid form, which is usually categorized into these groups based on the aerodynamic diameter of the particles (Bhatia, 2002; GREENFACT, 2001; Wright, 2003; NAEI, 199);

1. Particles less than 100 microns, are called "inhalable" (GREENFACT, 2001) since they can easily enter the nose and mouth.

2. Particles less than 10 microns ($PM_{10}$, often labeled "fine" in Europe).

These particles are also called “thoracic” since they can penetrate deep in the respiratory system.

3. Particles less than 4 microns. These particles are often called “respirable” because they are small enough to pass completely through the respiratory system and enter the blood stream.

4. Particles less than 2.5 microns ($PM_{2.5}$, labeled “fine” in the US).

5. Particles less than 0.1 microns ($PM_{0.1}$, “ultrafine”) (USEPA, 1998).

#### 1.1.6.1 Carbon monoxide (CO)

Carbon monoxide is an odorless, colourless gas formed by incomplete combustion of carbon in fuel. The main source is motor vehicle exhaust, along with industrial processes and biomass burning (Piotrowska, Kordylewski, Ciolek &Moscicki, 2010). This air pollutant is usually emitted due to faulty or improperly adjusted appliances which can produce dangerous amounts of CO (several per cent in the flue gas) usually due to some abnormal limitations of the air supply (Roger, 2002). Carbon monoxide in the atmosphere can be attributed to the emission of carbon-containing species from vehicle exhaust to fuel consumption (Stedman & Bishop, 1991; Kirchstetter & Harley, 1999). We consider $CO_2$ and CO as the carbonaceous products during combustion process. Carbon monoxide emissions from internal combustion engines are more of a problem especially in developing countries like Nigeria. This calls for concern considering the rate of importation of fairly used vehicles and the introduction of three wheeler automotives (Figure 1.11) (keke) in the state (Okere et al., 2013). In petrol engines lacking any control devices, incomplete burnout of the fuel leads to high carbon monoxide and emissions, especially during idling and deceleration. Installation of catalytic converters results in reductions of 90 % for CO and hydrocarbons although significant emissions may take place under cold start conditions before the catalyst 'lights off'. Diesel engines have much lower carbon monoxide emissions than petrol engines (Department of the Environment, 1993). The percentage of CO emitted from automobiles in different cities and regions are shown in Table 1.3. Manahan (2001), noted that the residence time of carbon monoxide in the atmosphere is of the order of four months. And it is generally agreed that carbon monoxide is removed from the atmosphere by reaction with hydroxyl radical, $HO^{\bullet}$:

$$CO + HO^{\bullet} \rightarrow CO_2 + H \quad (1.7)$$

The reaction produces hydroperoxyl radical as a product:

$$O_2 + H + M \rightarrow HOO^{\bullet} + M \quad (1.8)$$

(M is an energy-absorbing third body, usually a molecule of $O_2$ or $N_2$)

$HO^{\bullet}$ is regenerated from $HOO^{\bullet}$ by the following reactions:

$HOO^{\bullet} + NO \rightarrow HO^{\bullet} + NO_2$ (1.9)

$HOO^{\bullet} + HOO^{\bullet} \rightarrow H_2O_2$ (1.10)

The latter reaction is followed by photochemical dissociation of $H_2O_2$ to regenerate $HO^{\bullet}$

$H_2O_2 + light \rightarrow 2HOO^{\bullet}$ (1.11)

Carbon monoxide binds to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. And low exposures can aggravate cardiac ailments, while high exposures cause central nervous system impairment or death. It also plays a role in the generation of ground-level ozone (DEFRA, 2013; The Habitable Planet, 2006)

#### 1.1.6.2 Volatile Organic Compounds (VOCs)

VOCs include a large group of chemicals with carbon and hydrogen atoms. The term Volatile Organic Compounds (VOCs) is used to describe organic material in the vapour phase excluding methane (Clarke & Tomlin, 1999). The more reactive VOCs can readily form other chemicals in the atmosphere. Photochemical smog is a product of such reactions. Major sources of VOCs include: vegetation, animal and forest fire (Lemieux, Lutes & Santoianni, 2004; Buzcu & Fraser, 2006) automobile emissions, leaks and spills at gasoline station and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft (USEPA, 2003; Ojiodu, Okuo & Ladan, 2012). There are many non-combustion sources of VOC emission of which the most important is the use of solvents, including those released from paints (Clarke & Tomlin, 1999; Son, Breysse & Yang, 2003). A number of individual VOCs (e.g., benzene, dichloromethane) have been assessed to be toxic under the Canadian Environmental Protection Act, 1999 (CEPA 1999). Evaporative losses of gasoline during storage and distribution are also significant. VOCs are important in atmospheric chemistry for the formation of photochemical smog. Various control measures are therefore being implemented so as to enable the European Member States meet their agreed obligation under a 1991 UNECE Protocol of reducing VOCs by 30 % relative to 1988 by 2000. Between 1990 and 1994 a 9 % reduction in VOC emissions across Europe was reported (EEA, 1997).

#### 1.1.6.3 Hydrocarbons and Polycyclic Aromatic Hydrocarbons (PAH)

Hydrocarbons include a broad family of pollutants that contain hydrogen and carbon. Sources of hydrocarbons include vegetation, vehicle emissions, leaks and spillage at gasoline

stations and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft traffic. Hydrocarbons are also emitted by fugitive sources such as evaporation of solvents or leaks at industrial facilities. Incinerator and flare stacks can also be sources (FAP, 2014). Polycyclic aromatic hydrocarbons are present as aerosols in the atmosphere because of their extremely low vapor pressures. These compounds are the most stable form of hydrocarbons having low hydrogen-to-carbon ratios and are formed by the combustion of hydrocarbons under oxygen-deficient conditions (Manahan, 2001). These are chemicals formed during incomplete combustion of gasoline, diesel, oil, coal, wood, garbage or other organic substances. Tobacco smoke and charbroiled meats are also common sources. Gas flaring is a significant source of these compounds (Malumfashi, 2008). According to DEFRA (2011), there are many different PAHs emanating from a variety of sources. This strategy uses benzo[a]pyrene (B[a]P) as a marker for the most hazardous PAHs. The main sources of B[a]P in the UK are domestic coal and wood burning, fires (eg accidental fires, bornfires, forest fires, etc), and industrial processes such as coke production. Road transport is the largest source for total PAHs.

#### 1.1.6.4 Nitrogen Oxides ($NO_x$).

Nitrogen oxides incorporate several species that exist in the atmosphere, which collectively are referred to as $NO_x$ and result principally from fossil fuel combustion, when nitrogen in the air that is used to burn the fuel gets oxidised. The most common $NO_X$ compounds are nitrogen dioxide ($NO_2$) and nitric oxide (NO). Nitric oxide is the primary product emitted directly but this is eventually oxidised by other pollutants present in ambient air to form $NO_2$. Motor vehicles are a major source of $NO_x$ emissions (NZ Transport Agency, 2013). The contribution of vehicular emission to $NO_x$ in the atmosphere in some cities and regions is shown in Table 1.3. Nitrogen oxides are of concern both because of their direct effects on human health, and because they react in the atmosphere (with VOCs) to produce photochemical ozone. Nitric oxide (NO) and nitrogen dioxide ($NO_2$) are released in combustion because molecular nitrogen ($N_2$) present in the air/fuel mixture splits and is oxidized. The higher the flame temperature, or longer the residence time the more nitrogen available to produce $NO_x$ (Roger, 2002). Although there are small emissions of $NO_x$ from industrial processes such as nitric acid production, the main emissions are from combustion. In stationary combustion plant, factors such as the fuel type, fuel nitrogen content, burner design, the intensity of combustion, the overall shape and size of the furnace, and the amount of excess air all influence NO formation and can be modified to

achieve a certain measure of control. However, this falls considerably short of eliminating the emissions (Clarke & Tomlin, 1999). Atmospheric transport also contributes significantly to the concentration of

Table 1.3: Proportion of Emission Due to Vehicle in Some Cities and Regions (%)

| City | CO | VOC | $NO_X$ | $SO_2$ | Particulates |
|---|---|---|---|---|---|
| Beijing | 39 | 75 | 46 | n.a | n.a |
| Budapest | 81 | 75 | 57 | 12 | n.a |
| Cochin | 70 | 95 | 77 | n.a | n.a |
| New Delhi | 90 | 85 | 59 | 13 | 37 |
| Colombo | 100 | 100 | 82 | 94 | 88 |
| Kathmandu | n.a | n.a | n.a | 3 | 12 |
| Lagos | 91 | 20 | 62 | 27 | 69 |
| Mexico city | 100 | 54 | 70 | 27 | 4 |
| OECD | 70 | 31 | 52 | 4 | 14 |
| Santiago | 92 | 81 | 82 | 25 | 10 |
| Sao Paulo | 97 | 89 | 96 | 86 | 42 |

Sources : Schwela & Zali, 1999; Onursal & Gautam, 1995; Zegras et al., 1995. Sited in Roger, 2002. Note OECD – Organization for Economic Cooporation and Development. (n.a means not available).

Nitrogen oxides emitted into the atmosphere (Carslaw, Ropkins, Laxen, Moorcrof, Marner, Williams, 2006; Wood et al., 2008; Timko et al., 2010). Nitrogen dioxide, $NO_2$, forms only a small fraction of the waste gases from combustion (usually less than 10 %) so the description $NO_x$ emissions' actually refers mainly to NO emissions (NAEI, 1998). Once in the atmosphere, oxidation of NO to $NO_2$ takes place, as described later, and the relative proportions of the two oxides may then be comparable. There is negligible nitrogen in gasoline or diesel fuels so the $NO_x$ arises from the $N_2$ and $O_2$ in the air. Nitrogen oxide emissions are high due to the high temperatures and pressures and are at a maximum during acceleration and minimum during idling. Diesel engines have comparable NOx emissions to petrol engines (Clarke & Tomlin, 1999). Upon exposure to air, NO combines rapidly with oxygen to form the secondary pollutant red-brown nitrogen (IV) oxide, $NO_2$,

$$2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)} \qquad (1.12)$$

At lower temperatures, nitrogen (IV) oxide dimerises to form colourless $N_2O_4$,

$$2NO_{2\,(g)} \rightarrow N_2O_{4\,(g)} \qquad (1.13)$$

Nitrogen (IV) oxide is a poisonous, choking gas, which causes some of the colour in smog. It dissolves readily in water, where it disproportionate to form nitric (V) acid and nitric (III) acid, and this is responsible for acid rain (Manahan, 2001).

$$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(g)} \quad (1.14)$$

In addition to contributing to ozone formation, NOx, in particular $NO_2$, is toxic, impairs respiratory function, and can damage lung tissue (Roger, 2002).

### 1.1.6.5 Sulphur oxide (SOx)

Sulphur dioxide ($SO_2$) has a strong pungent odour. Sulphur dioxide, arises from the sulphur present in most fuels amounting to 1-2 % weight in coal, 2-3 % in heavy fuel oils and decreasing amounts in lighter oil fractions. There are also non-combustion emissions from sulphuric acid plant and from the roasting of sulphide ores during non-ferrous smelting. According to FAP (2014) natural gas processing plants are responsible for close to half the emissions of this gas. Oil sands facilities and power plants are also major sources. Other sources include gas plant flares, oil refineries, pulp and paper mills, and fertilizer plants. Flaring of unwanted gases via flare stack in the ambient air is common in Nigeria (McEwen and Johnson, 2010).

During combustion, conversion to sulphur dioxide is virtually complete although about 5-10% may be retained by ash (Clarke and Tomlin, 1999; Ideriah et al., 2008). The limit for the sulphur content of diesel fuels has been progressively reduced and now stands at 0.05% in the USA and much of Europe. Typical gasoline sulphur content is about half this value. In the atmosphere, sulphur dioxide is oxidized further to sulphur trioxide ($SO_3$) by one of three possible ways, catalytic oxidation, photo-oxidation and oxidation by free radicals. The rate of catalytic oxidation is slow in dry air, but if aerosols are present that contain metal ions such as $Cu^{2+}$ or $Fe^{3+}$ it becomes much faster. Indeed, the higher the humidity, the faster the reaction. Photochemically, UV radiation energetically excites the sulphur dioxide molecule so that chemical reaction can occur between it and oxygen (Eq 1.15 and 1.16).

$$SO_{2\,(g)} + \text{light} \rightarrow SO_2{}^*{}_{(g)} \quad (1.15)$$

$$SO_2{}^*{}_{(g)} + O_{2\,(g)} \rightarrow SO_{3\,(g)} + O_{(g)} \quad (1.16)$$

where $SO_2$* represents the excited molecule.

Sulphur dioxide can form acidic compounds in the air; these compounds are responsible for acid deposition which has negative effects on aquatic and terrestrial ecosystems (Bhatia, 2002; Wright, 2003; FAP, 2014).

#### 1.1.6.6 Hydrogen Sulphide ($H_2S$)

Hydrogen Sulphide has the odour like a rotten egg. Hydrogen sulphide and total reduced sulphur comes from industrial fugitive emissions by way of petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, sewage treatment facilities, some pulp and paper plants, and animal feedlots (FAP, 2014). Natural sources include sulphur hot springs, sloughs, swamps and lakes.

#### 1.1.6.7 Particulate Matter (SPM, $PM_{10}$ and $PM_{2.5}$)

These are tiny particles of solid material or liquid aerosols present in the air. Particulate matter or suspended particulate matter (SPM) can be found in ambient air in the form of dusts, smoke, or other aerosols as illustrated in Table 1.4. These particulates could be of anthropogenic or natural origin. Direct sources of particulate matter include burning of fossil fuels (coal, oil wood) for power generation, heating and transportation; construction and industrial activities; as well as soil erosion (windblown dust), forest fires, volcanic eruptions, and pollen (Ideriah and Stanley, 2008). Particulate matter can occur as a secondary aerosol resulting from atmospheric transformation of gaseous pollutants emitted from combustion sources (e.g. power plants and automobiles) or natural sources such as forests. Particles can also result from condensation of volatile elements and species in the atmosphere. They can be of various size, shape and composition as indicated in the table below (Table 1.4). $PM_{10}$ can be inhaled through the nose and throat (FAP, 2014). Sources include soil dust, road dust, agricultural dust during harvest, forest fire smoke and recreational wood burning, vehicle exhaust emissions, and industrial emissions. McEwen & Johnson (2010) reported that gas flaring can also produce other pollutant emissions such as particulate matter (PM) in the form of soot or black carbon. Gas flaring can also produce soot and other pollutant species that have negative effects on air quality and the environment (Johnson & Kostiuk, 2000; Strosher, 2000; Johnson, Wilson and Kostiuk, 2001). An important source of particulate matter emission is from the quarry industry and quarrying activities which involves the process of making holes in rock, limestone or overburden with the aid of a drilling machine (drilling process), shattering the drilled limestone or overburden in a bid

to loosen the mass in smaller fragments (blasting process), etc, are instantaneous point sources of suspended particulate (Bada et al., 2013).

Table 1.4: Some Important Terms Describing Atmospheric Particles

| Term | Meaning |
|---|---|
| Aerosols | Colloidal- sized atmospheric particle |
| Condensation aerosols | Formed by condensation of vapours or reaction of Gases |
| Dispersion aerosol | Formed by grinding of solids, atomization of liquids, or dispersion of dust |
| Fog | The term denotes high level of water droplets |
| Haze | This denotes decreased visibility due to the presence of particles |
| Mist | Liquid particle |
| Smoke | Particles formed by incomplete combustion of fuel |

Source: Manahan, 2001; Wright, 2003.

According to Sjaak (2007), aerosols are small particles suspended in air with a lifetime of at least minutes, and are either emitted as primary aerosols or formed by the conversion of sulphur dioxide, nitrogen oxides, ammonia and organic compounds in atmospheric chemical reactions to sulphates, nitrates, and ammonium compounds, and non-volatile organic compounds.

Metal oxides constitute a major class of inorganic particles in the atmosphere. These are formed whenever fuels containing metals are burned. For example, particulate iron oxide (Eq 1.17) is formed during the combustion of pyrite-containing coal. And these metals could arise from combustion of petroleum products and natural gas as reported by Idodo-Umeh and Ogbeibu (2010).

$$3FeS_2 + 8O_2 \rightarrow Fe_3O_4 + 6SO_2 \quad (1.17)$$

Organic vanadium in residual fuel oil is converted to particulate vanadium oxide. Part of the calcium carbonate in the ash fraction of coal is converted to calcium oxide and is emitted to the atmosphere (Eq.1.18) through the stack:

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2 \quad (1.18)$$

A common process for the formation of aerosol mists involves the oxidation of atmospheric sulphur dioxide to sulphuric acid, a hygroscopic substance that accumulates in atmospheric water to form small liquid droplets Eq.1.19:

$$2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4 \quad (1.19)$$

When basic air pollutants, such as ammonia or calcium oxide, are present, they react with sulphuric acid to form salts Eq1.20 and 1.21:

$H_2SO_4$ (droplet) + $2NH_{3\,(g)} \rightarrow (NH_4)_2SO_4$ (droplet) (1.20)

$H_2SO_4$ (droplet) + $CaO_{\,(s)} \rightarrow$ $CaSO_4$ (droplet) (1.21)

Under low-humidity conditions, water is lost from these droplets and a solid salt aerosol is formed. The preceding examples show several ways in which solid or liquid inorganic aerosols are formed by chemical reactions. Such reactions constitute an important general process for the formation of aerosols, particularly the smaller particles (Manahan, 2001).

Also, particulate matter largely from ocean spray origin in a coastal area receiving sulphur dioxide pollution may show anomalously high sulphate and corresponding low chloride content. The sulphate comes from atmospheric oxidation of sulphur dioxide to form nonvolatile ionic sulphate (Eq. 1.22), whereas some chloride originally from the NaCl in the seawater may be lost from the solid aerosol (Eq.1.23) as volatile HCl (Bhatia, 2002).

$2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$ (1.22)

$H_2SO_4 + 2NaCl$ (particulate) $\rightarrow Na_2SO_4$ (particulate) + 2HCl (1.23)

### 1.1.7 Secondary Pollutants

These pollutants are not directly emitted from sources, but instead form in the atmosphere from primary pollutants (also called "precursors"). The main secondary pollutants known to cause harm in high enough concentrations are the following:

• Ozone ($O_3$) formed from photochemical reactions of nitrogen oxides and VOCs,

• Sulphuric acid droplets formed from $SO_2$, and nitric acid droplets formed from $NO_2$,

• $NO_2$ and $HNO_3$ formed from NO,

• Sulphates and nitrates aerosols (e.g., ammonium sulphate and ammonium nitrate) formed from reactions of sulfuric acid droplets and nitric acid droplets with $NH_3$, respectively,

• Organic aerosols formed from VOCs in gas-to-particle reactions (Daly and Zannetti, 2007a).

#### 1.1.7.1 Ozone ($O_3$)

Due to the dramatic increase in transportation sector throughout the world, there has been atmospheric buildup of secondary air pollutants like $O_3$. According to Vingarzan (2004) and Oltman et al. (2006) the increasing emissions of pollutants from the combustion of fossil fuels, whether in power stations or vehicles, are leading to a global increase in the production of tropospheric ozone. Ozone is a widespread secondary photochemical air pollutant in many parts

of the world (Heath, 1994; Krupa, 1996). It is a secondary air pollutant that is not emitted as such by any specific source (Krupa & Manning, 1988). During the last few decades, the problem of tropospheric ozone as an air pollutant has intensified in several folds and assumed global concern (NRC, 2001). Ozone is important not only because of its phytotoxicity (Ashmore, 2005), but also because of its tropospheric concentration which has increased considerably (Anfossi Sanroni & Viarengo, 1991) and is likely to increase at an annual rate of 0.5-2.5 % (Coyle, Flower & Ashmore, 2003). The photochemical production of ozone in the troposphere relies on the presence of $NO_x$ and reactive organic compounds (Cape, 2007).

The ozone in the stratosphere protects living organisms from dangerous short wavelength ultraviolet radiation. The amount of ozone present is a delicate balance between the making and destruction of ozone that depends upon the existence of naturally occurring trace compounds. If any unnatural compound is added, it will provide extra catalytic species which can remove monatomic oxygen and the destruction of ozone will be enhanced. This appears to have been the case in what is known as the 'hole in the ozone layer (Bhatia, 2002; Wright, 2003).

#### 1.1.7.2 Natural Formation of Ozone

Ozone is generated naturally by the combination of molecular oxygen ($O_2$) with atomic oxygen (O) Eq. 1.24:

$$O + O_2 + M \rightarrow O_3 + M \quad (1.24)$$

Both monoatomic oxygen and the ozone molecule formed are unstable. For the reaction to proceed, excess energy must be absorbed by another molecule which does not take part in the reaction itself. This molecule, which could be nitrogen ($N_2$) or another oxygen molecule ($O_2$) is indicated by "M" in the equation as earlier explained. The free, unstable oxygen atom in Eq. 1.25 results from the splitting of nitrogen dioxide by light with a wavelength of 440 nm or less, which includes light in the far blue and violet parts of the visible spectrum:

$$NO_2 + \text{light} \rightarrow NO + O \quad (1.25)$$

The oxygen atom split off is in an unstable, excited state which promotes its combination with molecular oxygen in Eq. 1.24. Another important reaction is that of ozone with nitric oxide.

$$O_3 + NO \rightarrow NO_2 + O_2 \quad (1.26)$$

Oxygen produced in Eq. 1.26 will further recombine with atomic oxygen to generate ozone. Eq. 1.24 and 1.25 lead to ozone formation, whereas Eq 1.26 results in ozone removal. It is important to note that the final or equilibrium ozone concentration depends on the rates of each reaction

and the relative concentrations of $NO_2$ and NO. If all the monatomic oxygen in Eq. 1.25 leads to ozone formation, then the rate of formation will be determined by the rate of dissociation of $NO_2$ in Eq. 1.25, whereas the rate of destruction will depend on how much NO is present. These reactions represent one of the probable pathways by which ozone levels in remote locations are determined (Seinfeld, 1986; PPSS, 1996; Bhatia, 2002). But in industrialized and densely populated regions where NO emissions are large, the biogenic contribution of VOCs may provide the necessary precursors for ozone production (Fiore, Horowitz, Purves, Levy, Evans, Wang & Yantosca, 2005). The increasing emission of $NO_2$ in the urban areas significantly increases the ground level $O_3$ concentrations downwind of the emission source. High levels of $O_3$ may be found hundred or thousands of kilometers away from the original sources, often affecting remote rural areas (Prather, Ehhalt, Dentener, Derwent, Dlugokencky, Holland & Wang, 2001).

The scale of the problem of rise in tropospheric $O_3$ has increased in scope during the last 25 years as a result of increasing population density and transportation related activities particularly in the developing countries. Background concentration of $O_3$ in the troposphere has doubled in the last decade due to the presence of some ozone precursors listed in Table 1.5. Surface $O_3$ concentration has risen from an estimated pre- industrial concentration of 10 ppb to average summer concentrations between 30 and 50 ppb in the mid-latitudes of the northern hemisphere with episodic levels as high as 50-100 ppb (Morgan et al., 2006). It is predicted that surface $O_3$ may rise to 20 % over the next 50 years due to likely three fold increases in $NO_x$ emissions (Prather et al., 2001).

Table 1.5: Sources of ozone precursors

| $NO_x$ | VOCs |
|---|---|
| Natural sources | |
| Bushfires | Vegetation |
| Lightning | Bushfires |
| Bacterial action | |
| Anthropogenic sources | |
| Power generation | Motor vehicles |
| Industrial boilers | Fuel evaporation |
| Motor vehicle | Painting, solvent use |
| Incineration | Printing industry |
| Kilns | Wood processing |
| Jet engines | Off – road engines |

Source: (PPSS,1996)

According to Wang & Mauzerall (2004) daytime surface $O_3$ concentrations in July 2020 will exceed 55 ppb in most parts of China, and if the level of air pollution in our cities is

not controlled then this could also affect us considering increasing vehicular pollution being experienced in the state and Nigeria at large.

### 1.1.7.3 Smog

Smog is normally a mixture of smoke and fog (An, Co & Oanh, 2008). It is formed when the water content of air is high and it is so calm that smoke and fumes accumulate near their emission source (Wright, 2003). Originally the term 'smog' meant a combination of smoke and fog, but it has recently come to refer to a combination of fine particulate matter and ground level ozone. Smog can also contain other harmful components such as nitrogen oxides, volatile organic compounds, sulphur dioxide and carbon monoxide. The colour of smog is determined by these suspended particles and is often brown or deep grey but can also be white (ASC, 2010). It is a term coined from the words 'smoke' and 'fog' which arises from the condition of coal smoke and fog experience by the city of London in the early 19$^{th}$ Century (Andy, 2007).

Smog has a long history. In 1542, exploring what is now southern California; Juan Rodriguez Cabrillo named San Pedro Bay "The Bay of Smokes" because of the heavy haze that covered the area. Complaints of eye irritation from anthropogenically polluted air in Los Angeles were recorded as far back as 1868. Characterized by reduced visibility, eye irritation, cracking of rubber, and deterioration of materials, smog became a serious nuisance in the Los Angeles area during the 1940s. It is now recognized as a major air pollution problem in many parts of the world (Manahan, 2001). Fig. 1.3 is an illustration of a smoggy weather condition observed in Owerri on 15$^{th}$ December, 2014.

(a)  (b) 

Fig 1.3 A Smoggy Weather Condition in Owerri, 15th December, 2014 (Source: Field work, 15$^{th}$ December, 2014)

#### 1.1.7.4 Types of Smog

##### 1.1.7.4.1 Reducing Smog

Reducing smog arises in coal burning cities which can experience cool or cold, wet winter and where thermal or temperature inversion can trap cold, still air close to the Earth's surface (Andy, 2007). This condition could be possible in cities like ours where fuel containing sulphur is in use coupled with gas flaring by the oil and gas industries. Sulphur compounds were responsible for the traditional wintertime sulphur smog in London and Los Angeles. These anthropogenic pollutants have sometimes reached lethal concentrations in the atmosphere, such as during the infamous London episode of December 1952 (NAEI, 1998; Wright, 2003).

##### 1.1.7.4.2 Photochemical smog

Photochemical smog is oxidizing smog. The term "photochemical" reflects the fact that such smog occurs due to the influence of strong sunlight and high temperatures on anthropogenic air pollutants. It is like a chemical soup containing hundreds of different substances formed in the atmosphere as a result of free radical reactions brought about by ultraviolet (UV) radiation from the sun (thus called photochemical smog) and this was first observed in Los Angeles in the 1940s (Andy, 2007). It is a whitish yellow to brown haze, which irritates sensitive membranes and damages plants (Wark, 1998). This type of smog does not need either smoke or fog to form. The main source of primary pollutants for photochemical smog are VOCs and $NO_x$ especially $NO_x$ from automobile exhaust and the furnace of power plants. The main condition that promotes photochemical smog is the UV radiation, temperature or thermal inversion, windlessness and bowel-shaped cities which allow the collection of pollutants that are dispersed and hence worsen the smog. Petrol and diesel engines are also regarded as one of the main contributors to this smog problem since they emit large amounts of unburned hydrocarbons and oxides of nitrogen (Andy, 2007)

Photochemical smog is a noxious mixture of gases and particles produced when strong sunlight triggers photochemical reactions in the atmosphere (EPA, 2004). It contains a variety of potentially harmful organic compounds. Wright (2003) noted that the main pollutants that cause photochemical smog are NO, $NO_2$, hydrocarbons (HC), PAN (peroxyacetyl nitrate), ozone and the aldehydes. And the high temperatures found in combustion engines can give rise to highly reactive free radicals. Lefohn, Krupa & Winstanley (1990) noted that the principal component of

photochemical smog is ozone, a colourless gas, which occurs naturally in the atmosphere in about 15 to 35 ppb in unpolluted, remote regions.

#### 1.1.7.4.3 Chemistry of Photochemical Smog

The perturbation of natural ozone cycle (Eq. 1.24, 1.25 and 1.26) is caused by a series of reactions involving VOCs, most of which are emitted in the form of hydrocarbons. Other reactions are possible such as

$$H_2O_{(g)} + O_{(g)} \rightarrow 2OH^{\bullet}_{(g)} \quad (1.27)$$

$$N^{\bullet}_{(g)} + OH^{\bullet}_{(g)} \rightarrow NO^{\bullet}_{(g)} + H^{\bullet}_{(g)} \quad (1.28)$$

Atomic oxygen can react with the hydrocarbon molecules that is present in unburnt petrol fumes thus,

$$RH_{(g)} + O_{(g)} \rightarrow R^{\bullet}_{(g)} + OH^{\bullet}_{(g)} \quad (1.29)$$

One of the products of the incomplete combustion of petrol is carbon monoxide, CO.

The $OH^{\bullet}$ radical can react with the CO,

$$CO_{(g)} + OH^{\bullet}_{(g)} \rightarrow CO_{2(g)} + H^{\bullet}_{(g)} \quad (1.30)$$

Thus from Eq. 1.29, the production of the $OH^{\bullet}_{(g)}$ radical is clearly important in the formation of $NO^{\bullet}$. For $NO^{\bullet}$ the slow oxidation to $NO_2^{\bullet}$ occurs through,

$$2NO^{\bullet}_{(g)} + O_{2(g)} \rightleftharpoons 2NO^{\bullet}_{2(g)} \quad (1.31)$$

The free radical $HO_2^{\bullet}$ is also found in the atmosphere and reacts with $NO^{\bullet}$,

$$HO_2^{\bullet}{}_{(g)} + NO^{\bullet}_{(g)} \rightarrow 2NO_2^{\bullet}{}_{(g)} + OH^{\bullet}_{(g)} \quad (1.32)$$

$NO_2^{\bullet}$ absorbs solar radiation in the visible and near UV regions, i.e. $< 420$ nm, and undergoes the reaction,

$$NO_2^{\bullet}{}_{(g)} + UV \rightarrow NO^{\bullet}_{(g)} + O_{(g)} \quad (1.32)$$

The O atoms then react with oxygen in the presence of a third molecule M

(M = $O_2$ or $N_2$),

$$O_{(g)} + O_{2(g)} + M \rightarrow O_{3(g)} + M \quad (1.33)$$

Then, $$NO^{\bullet}_{(g)} + O_{3(g)} \rightarrow NO_2^{\bullet}{}_{(g)} + O_{2(g)} \quad (1.34)$$

From the reactions above it can be seen that $NO_x$ helps to make ozone. Eq. 1.32 shows how it produces the necessary O atoms) and to destroy it. Eq. 1.34 shows how NO produced in Eq.1.32 destroys the $O_3$. The hydrocarbons present in the atmosphere can also react with $OH^{\bullet}$ radicals, which could be from one of a large variety commonly found in urban areas, for example propane, hexane, benzene, toluene, xylene or hydrocarbons of natural origin such as isoprene.

$RH_{(g)} + OH^{\bullet}_{(g)} \rightarrow R^{\bullet}_{(g)} + H_2O_{(g)}$ (1.35)

(Note: R represents the part of the hydrocarbon chain that remains unreacted) The free radical $R^{\bullet}$ then reacts with oxygen,

$R^{\bullet}_{(g)} + O_{2(g)} \rightarrow ROO^{\bullet}_{(g)}$ (1.36)

The $ROO^{\bullet}_{(g)}$ species is called the peroxy radical. The peroxy radical will react with $NO^{\bullet}$,

$ROO^{\bullet}_{(g)} + NO^{\bullet}_{(g)} \rightarrow RO^{\bullet}_{(g)} + NO_2^{\bullet}{}_{(g)}$ (1.37)

Eq. 1.37 is an important part by which NO is oxidized without involving ozone. The specie $RO^{\bullet}$ is called the alkoxyl free radical. Therefore, $NO_2^{\bullet}$ produced in Eq. 1.34 can react via Eq. 1.32 to produce more oxygen atoms that will beget more ozone. Aldehydes, RCHO, are formed by the reaction of the alkoxyl radical with oxygen,

$RCH_2O^{\bullet}_{(g)} + O_{2(g)} \rightarrow RCHO_{(g)} + HO^{\bullet}_{(g)}$ (1.38)

In Eq. 1.38, $RO^{\bullet}$ has been replaced by $RCH_2O^{\bullet}$ to emphasize how the aldehyde group arise. Peroxy compounds, e.g. peroxyethanoyl nitrate (peroxyacetyl nitrate or PAN), are formed by the reaction,

$ROO^{\bullet}_{(g)} + NO_2^{\bullet}{}_{(g)} \rightarrow RCOONO_{2(g)}$ (1.39)

Petrol and similar fumes contain the reactive unsaturated alkenes. Ozone readily attacks the double bond to form a range of compounds,

$RCH{=}CH_{2(g)} + O_{3(g)} \rightarrow RCHO_{(g)} + H_2COO^{\bullet}_{(g)}$ (1.40)

The non-gaseous compounds also form as fine particles, giving rise to the haze which is observed during severe smog incidence (PPSS, 1996; Clarke & Tomlin, 1999; Manahan, 2001; Bhatia, 2002; Wright, 2003; EPA, 2004).

#### 1.1.7.4.4 Conditions for the Development of photochemical Smog

As earlier stated, the main constituents of photochemical smog are not emitted in significant quantities directly by human or natural processes. Rather, they are secondary pollutants arising from primary emission species (or precursors). The sources of these precursors are summarized in Table 1.5.

##### 1.1.7.4.4.1 Fuel Combustion

The release of a large proportion of anthropogenic $NO_x$ and VOC is intimately bond to the cycle of refining, distributing and use of a range of petroleum based products, notably fuels (PPSS. 1999) including gas flaring (Kindzierski, 2008). Approximately 60% of VOC emissions from vehicles result from exhaust gases containing incompletely burnt fuel, and 40% from evaporative losses during operation and refilling. Small engines such as those used to power

lawn mowers and other garden equipment, chain saws, outboard motors, and other off-road engines are also remarkably large emitters of $NO_x$ and VOC. And two stroke engines tend to be higher emitters than four stroke designs (Sengupta, 2003). On a global basis, approximately 30-50 % of $NO_x$ emissions are thought to be due to fossil fuel combustion (Seinfeld, 1986), with much of the remainder due to biomass burning. Many industrial activities produce $NO_x$ emissions, including electricity generation, the use of industrial boilers, high temperature incineration, smelting operations, kilns and other processes, especially those involving high temperatures (PPSS, 1996).

#### 1.1.7.4.4.2 Natural Emissions

Natural emission of $NO_x$ and VOC (commonly categorized as "forest" or "biogenic" emissions) are usually ignored, but this can constitute a significant proportion of the total $NO_x$ and VOC inventory. The characteristic smell of coniferous and eucalypt in the forests are due to the release of these hydrocarbons, especially alkenes such as pinene (conifers), cymene, limonene (eucalyptus) and isoprene which is emitted from broadleaved trees (PPSS, 1996; Bhatia, 2002). These emissions are thought to be responsible for the characteristic haze which affects the Blue Mountains of New South Wales and the Smoky Mountains in the eastern United States (PPSS, 1996). Bushfires can feature significantly in photochemical smog incidents, although their sporadic occurrence means they are not usually accounted for in emission inventories. Reports by Evans, Weeks, Eccleston & Packham (1977) in Western Australia and Hurst, Griffith and Cook (1994) in Northern Territory has shown that large quantities of both $NO_x$ and VOC are released by bushfires.

#### 1.1.7.4.4.3 Time of the Day

This is a very important factor that influences the amount of photochemical smog. The typical daily variation in the key chemical factors in photochemical smog formation is illustrated in Figure 1.4. It can be observed from the graph (Fig. 1.4) that early in the morning traffic increases the emissions of both nitrogen oxides $NO_x$ and non-methane hydrocarbons (NMHC) - a type of VOCs - as people drive to work. Later in the morning, traffic reduces and the nitrogen oxides and volatile organic compounds begin to react to form nitrogen dioxide and increase its concentration. As the sunlight becomes more intense later in the day, nitrogen dioxide is broken down (Eq. 1.32) and its by-products form increasing concentrations of ozone (Eq. 1.33). At the

same time, some of nitrogen dioxide can react with the volatile organic compounds to produce toxic chemicals such as PAN (Eq. 1.39). As the sun goes down, the production of ozone is stopped (An et al., 2008). The ozone that remains in the atmosphere is then consumed by several different reactions as shown in Eq. 1.40.

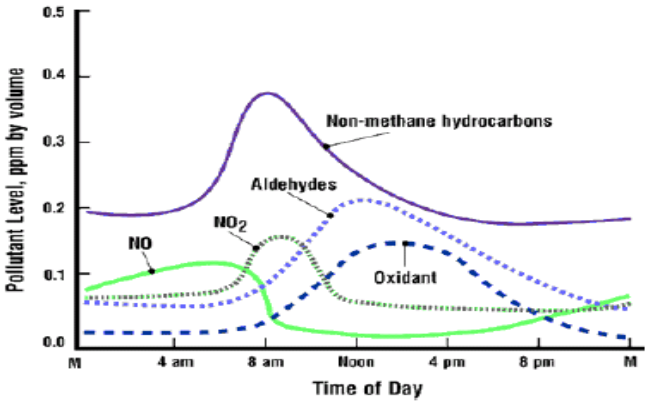



Fig. 1.4: Generalized reaction scheme for photochemical smog formation. (Carter, 1994)

### 1.1.8 Behaviour, Transport and Dispersion of Air Pollutants

Local air quality is significantly influenced by the rate of mixing of pollutants which are emitted. Therefore understanding of issues such as wind speeds and atmospheric stability is important. Accumulation of hazardous air pollutants in one location due to poor atmospheric stability conditions such as thermal inversion, extremely stable conditions is a frequent phenomenon for predicting the impact of gaseous pollutants on the flora and fauna of the surrounding environment (Latha & Shanmugan, 2010). Air pollutants show short term, seasonal and long term variations. Atmospheric conditions determine the fate of the air pollutants after their release into the atmosphere. The important and dominant mechanisms in the air pollutant dispersal are stated below.

#### 1.1.8.1 Meteorology and Weather

Meteorological phenomena affects weather, and in turn are affected by the chemical properties of the atmosphere. For example, before modern emission controls took effect, meteorological phenomena determined whether power plant stack gas heavily laced with sulphur dioxide would be dispersed high in the atmosphere with little direct effect upon human health, or would settle as a choking chemical blanket in the vicinity of the power plant. Los Angeles

largely owes its susceptibility to smog to the meteorology of the Los Angeles basin, which holds hydrocarbons and nitrogen oxides long enough to cook up an unpleasant brew of damaging chemicals under the intense rays of the sun (Manahan, 2001). Weather is defined in terms of seven major factors: temperature, clouds, winds, humidity, horizontal visibility (as affected by fog, etc.), type and quantity of precipitation, and atmospheric pressure. Variations and trends within a particular geographical region are the factors that compose weather, and described as climate, which could affect the extent of atmospheric pollution of an area.

#### 1.1.8.2 Wind and Air Masses

A major feature of the troposphere is the movement of huge masses of air with different pressures, temperatures, and moisture contents separated by boundaries called fronts. Horizontally moving air is called wind, whereas vertically moving air is referred to as an air current. Atmospheric air moves constantly, with behaviour and effects that reflect the laws governing the behaviour of gases. Gases moves horizontally and/or vertically from regions of high atmospheric pressure to those of low atmospheric pressure. Furthermore, expansion of gases causes cooling, whereas compression causes warming. A mass of warm air tends to move from Earth's surface to higher altitudes, where the pressure is lower; in so doing, it expands adiabatically (that is, without exchanging energy with its surroundings) and becomes cooler. So wind—air moving horizontally occurs because of differences in air pressure from high pressure regions to low pressure areas. Air currents (vertically moving air) are largely convection currents formed by differential heating of air masses. Air that is over a solar heated land mass is warmed, becomes less dense, and rises, to be replaced by cooler and denser air. Wind and air currents are strongly involved with air pollution phenomena. Wind carries and disperses air pollutants (Fig. 1.5). In some cases, the absence of wind can enable pollutants to concentrate in a region and undergo processes that lead to even more (secondary) pollutants (Manahan, 2001).

#### 1.1.8. 3 Wind Speed and Direction

The wind speed and direction play a major role in dispersion of air pollutants. The wind direction is the measurement of direction from which the wind is blowing, measured in points of compass viz. North, South, East, and West degrees (Sengupta, 2003). In general, low wind speeds result in high pollutant concentrations and vice versa. If we imagine the wind blowing across the top of a chimney (Fig. 1.5) emitting smoke at a constant rate, the volume of air into which the smoke is emitted is directly proportional to the wind speed. The concentration of smoke in the air is thus

inversely proportional to the wind speed. A similar description can be applied to a source distributed uniformly over a wide area, e.g. domestic emissions from a city. The concentration of pollutants in the hypothetical box of air into which the pollutants are mixed is proportional to the emissions rate and inversely proportional to the wind speed. In practice this picture is grossly oversimplified and the concentration of pollutants measured in urban areas rarely decreases with wind speed as rapidly as predicted (Clarke and Tomlin, 1999).

Figure 1.5: Action of wind on Emission from a chimney

Wind direction has an important role in distributing and dispersing pollutants from stationary and mobile sources in horizontally (Fig. 1.5) long downwind areas. The wind speed is the measure of horizontal motion of wind relative to the surface of earth per unit time. The effect of wind speed on air pollution is two-fold. It determines the travel time from a source to a given receptor while on the other causes dilution of pollutants in downwind direction (Sengupta, 2003). The stronger the wind, the greater will be the dissipation and dilution of pollutants emitted. The knowledge of the frequency distribution of wind direction as well as wind speed is essential for accurate estimation of the dispersion of pollutants in the atmosphere. The frequency distribution of wind speed and direction varies considerably from month to month.

### 1.1.9 Inversions and Air Pollution

The complicated movement of air across the earth's surface is a crucial factor in the creation and dispersal of air pollution phenomena. When air movement ceases, stagnation can occur, with a resultant buildup of atmospheric pollutants in localized regions. This results in the formation of inversions.

#### 1.1.9.1 Temperature Inversions

Although the temperature of air relatively near the earth's surface normally decreases with increasing altitude, certain atmospheric conditions can result in the opposite condition—increasing temperature with increasing altitude. Such conditions are characterized by high atmospheric stability and are known as temperature (Figure 1.6) inversion. Because they limit the vertical circulation of air, temperature inversions result in air stagnation and the trapping of air pollutants in localized areas. Inversions can occur in several ways.

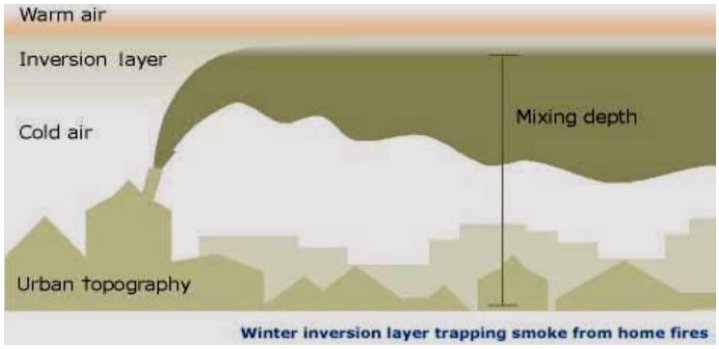



Fig. 1.6: Illustration of urban air pollutant trapped in an inversion

In a sense, the whole atmosphere is inverted by the warm stratosphere, which floats atop the troposphere with relatively little mixing. An inversion can form from the collision of a warm air mass (warm front) with a cold air mass (cold front). The warm air mass overrides the cold air mass in the frontal area, producing the inversion (Clarke & Tomlin, 1999; Manahan, 2001).

#### 1.1.9.2 Radiation inversions

These are likely to form in still air at night when the earth is no longer receiving solar radiation. The air closest to the earth cools faster than the air higher in the atmosphere, which remains warm, thus less dense. Furthermore, cooler surface air tends to flow into valleys at night, where it is overlain by warmer and less dense air (Manahan, 2001).

### 1.1.10 Reasons for Air Pollution

The reasons for air pollution are as follows:

#### 1.1.10.1 Uncontrolled Growth of Vehicle Population

Vehicles are one of the major sources of air pollution in our cities (Andria et al., 2003, Ojolo, Oke, Dinrifo & Eboda, 2007; Westerdahl, Wang, Pan & Zhang, 2008). Uncontrolled growth of vehicle population in all major cities/towns has resulted in high levels of air pollution (Fischer, Hoek, van Reeuwijk, Briggs, Lebret, van Wijnen, & Elliott, 2000; Hoek, Brunekreef, Goldbohm, Fischer & Van den Brandt, 2002; Patel, Chillrud, Correa, Feinberg, Hazi & Deepti,

2009). High vehicular traffic in urban centres results in air pollution buildup near the roadways and at traffic intersections (Hao, Hu & Fu, 2006; Hao & Wu, 2007). This is worsened by the absence of effective rapid mass transport system and intra-city railway networks which results in people using their own vehicles for commuting to workplaces. This results in uncontrolled growth of vehicles. And inadequate inspection and maintenance facilities result in high emission of air pollutants from vehicles. Emission can be reduced by proper and regular inspection and maintenance of vehicles. Improper traffic management system and road conditions also result in buildup of air pollutants near the roadways as the emissions are higher when the vehicle is not in motion (Smith, 1998).

#### 1.1.10.2 High population Density in Urban Centres

Many industrialized countries underwent unparallel economic growth, swelling urban populations which generated excessive emissions from automobiles, factories and refuse burning (World Bank, 1996). Population exodus to the urban centers results in increase in the number of vehicles (Hao et al., 2006), resulting in high levels of vehicular air pollution. According to UNPF (2007) reports, more than 50% of the human populations are living in urban areas and this fraction is still increasing, although urban areas currently cover only 0.5% of the Earth's land area (Schneider, Friedl & Potere, 2009). This large concentration of human activity causes unprecedented pressure on the environment, including the quality of air both inside the city (e.g., Gurjar, Butler, Lawrence & Lelieveld, 2008)

#### 1.1.10.3 Poor Fuel Quality

The use of poor quality fuel such as coal, diesel, petrol and fuel oil is a major source of pollution. Adulteration of fuel and fuel products also result in high emissions from vehicles. According to Roger (2002) fossil fuel use in transportation produces "local" pollutant emissions such as lead, PM, $NO_x$, $SO_x$, VOCs, CO and other toxins, but exactly what kinds of pollutants are produced in what proportions varies significantly based on a number of factors, including the vehicle and fuel used and the driving conditions of a particular trip. The emissions are dispersed into the ambient air according to atmospheric conditions, which also influence the extent to which they react to form secondary pollutants.

The availability of appropriate fuels, or the improper use of fuel in transport sector applications, is another important factor contributing to air pollution. Fuel is a factor in transport

emissions for a number of reasons. First, regulatory authorities may inappropriately specify the fuel. In hot climates, for example, the authorities' adoption of fuel specifications from colder climates may result in gasoline with higher light hydrocarbon content than necessary for local needs, resulting in excessive and unnecessary evaporative emissions. Secondly, vehicle operators may misfuel or use a fuel inappropriately. A common example is the use of leaded gasoline in vehicles with catalytic exhaust after treatment mechanisms. Thirdly, dishonest retailers may substitute or adulterate a fuel. In some instances, gasoline is adulterated with diesel, or both are adulterated with kerosene. Adulteration is often prevalent when there are significant price differences between different fuels (Roger, 2002). Although during the past few years, various measures have been taken to improve the quality of fuel such as reduction of sulphur in diesel, unleaded petrol etc (Sengupta, 2003).

#### 1.1.10.4 Gas Flaring and Petroleum related Activities

Gas Flaring is commonly practiced in the oil and gas industry, and it involves burning off unwanted, flammable gases through gas flare stacks (Fig. 1.2) (McEwen and Johnson, 2010). Gas flaring is an anthropogenic activity, which involves the wasteful emission of greenhouse gases that causes global warming (World Bank, 1995). The World Bank estimate as at 2000, put the annual volume of natural gas being flared and vented worldwide at about 110 billion cubic meters (bcm), enough to provide for the annual gas consumption of Central and South America or that of Germany and Italy (Gerner, Svensson & Djumena, 2004; Soeze, 2005). According to the World Bank (2012), global gas flaring has increased from 138 to 140 bcm in 2011 and Russia is the largest gas flaring country, followed by Nigeria, Iran and Iraq. Nigeria flared 14.6 bcm of its natural gas in 2011 and most of this occurred in the Niger Delta region (Egwurugwu, Nwafor, Oluronfemi, Iwuji & Alagwu, 2013) to which Imo State belongs.

#### 1.1.10.5 No Pollution Preventive Step in Early Stage of Industrialization

No pollution preventive steps were taken in early stage of industrialization which results in high levels of air pollutants in many areas.

#### 1.1.10.6 Poor Vehicle Design

Poor vehicle design especially 2-stroke two wheelers result in high emission of air pollutants. There is large number of two stroke two wheelers in most of the cities and these two-

wheelers are a significant contributor of air pollution (Sengupta, 2003). This can be controlled by the use of improved fuel vehicle technology (Hao et al., 2006).

#### 1.1.10.7 Wrong Siting of Industries

Wrong sitting of industries especially close to residential areas results in people getting affected due to air pollution.

#### 1.1.10.8 No Pollution Prevention and Control System in Small/ Medium Scale Industry

No pollution prevention and control system in most small/medium scale industries resulting in high level of air pollution.

#### 1.1.10.9 Poor Compliance of Standard in Small/Medium Scale Industries

Poor compliance of standard in small/medium scale industries also results in high levels of air pollution.

#### 1.1.10.10 Old Process Technology

Old process technology employed in many industries especially in small scale industries results in high emission of air pollutants.

#### 1.1.11.10 Effects of Air Pollution

It seens like the first impact of air pollution was between 4 December and 9 December 1952 when the most infamous 'pea-souper' smogs was recorded in the UK, which caused a range of cardiovascular and respiratory disorders which ultimately resulted in 4,000 deaths above what would normally be expected for that time of the year. Ninety per cent of those deaths occurred in people who were 45 years old or over, and the deaths of infants below the age of one were doubled (Wrght, 2003).

Air pollution has a significant impact on the chemistry of the atmosphere. It has become one of the most visible environmental problems in many countries (Wang & Mauzerall, 2005) including Nigeria. This is a major issue in the increasing number of megacities around the world (Cassiani, 2013). Recent studies have tried to quantify the effects caused by ambient air

pollution; e.g., within the “Global Burden of Disease” project of the World Health Organization (WHO) it has been estimated that worldwide, close to 6.4 million years of healthy life are lost due to long-term exposure to ambient particulate matter (WHO, 2002; WHO, 2003). Also according to another WHO report, more than 2 million premature deaths each year are attributable to the effects of urban outdoor and indoor air pollution and these effects are more prominent in developing countries (WHO, 2005), and Imo State, a part of Nigeria is not an exception.

The levels of human exposure to air pollutants vary with different activities, e.g., driving on the road, living/working near or away from the road. For example, people are exposed to elevated air pollution within few hundred meters from roadways (Zhu & Hinds, 2002; Zhang & Wexler, 2004, 2005). Wu and Hao (2002) showed that the concentrations of $PM_{10}$, $PM_{2.5}$ and $PM_1$ decrease substantially on the top of a high-rise residential building compared to their ground-level values near roadways. Some of the effects of air pollution are stated below;

#### 1.1.11.1 Environmental Effect of Air pollution

Aerosol particles that reduce visibility are formed by the polymerization of the smaller molecules produced in smog-forming reactions. Materials are adversely affected by some smog components. Rubber has a high affinity for ozone and is cracked and aged by it. Indeed, the cracking of rubber used to be employed as a test for the presence of ozone. Ozone attacks natural rubber and similar materials by oxidizing and breaking double bonds in the polymer (Manahan, 2001).

The phrase 'acid rain' has come to be used very loosely to mean almost with acidification, anything that has do whether or not rain is actually involved (Clarke & Tomlin, 1999). Three particular effects have received the most attention. Historically, the first of these was the increased acidification of lakes and streams in Scandinavia leading to loss of fish and other aquatic organisms. This was attributed to the acidity of rain polluted by sulfur and nitrogen oxides and the UK was blamed as being the chief culprit. Similarly the north-eastern USA was blamed for acidification in Canada. Acidification of fresh waters in the UK itself was also observed later (HMSO, 1988a).

The second type of environmental damage is damage to forests. The effects became very noticeable in Germany in the early 1980s with the worst effects being noted in the south-west (the Black Forest) and on the eastern border with the Czech Republic. Since then other countries

have reported similar phenomena (HMSO, 1988b; UK Department of Environment, 1993). Although the reasons for the damage have been the subject of much debate, it seems likely to be a combination of factors. Predisposing factors include drought and high altitude, and in some cases disease plays a role. Some forests in the former Eastern European countries suffer from the effects of very high $SO_2$ levels but this was not the case elsewhere. Possible mechanisms include:

i. The effect of ozone initiating an attack on cell walls, with subsequent further deterioration being due to acid rain or acid mists and fogs leaching nutrients and resulting in the breakdown of chlorophyll.
ii. Reduced root growth and nutrient uptake follow, acidification of the ground with consequent effects on the soil chemistry including elevation of mobile aluminium levels which can damage the roots.
iii. Excess deposition of nitrogen (as nitrate and ammonium) which can have a variety of effects. In the ground $NH_4^+$ can release $H^+$ during the process of being oxidized to $NO_3^-$ by bacteria.

Given the complexity of the biological and chemical processes mentioned it is clear that control of the effects of 'acid rain' on biological systems must focus on all the relevant pollutants $SO_2$, $NO_x$, $NH_3$, and hydrocarbons (as precursors of ozone) (Clarke & Tomlin, 1999).

The third problem associated with acid rain is the attack on stonework and the decay of famous cathedrals and other buildings constructed of limestone (HMSO, 1989). Both wet and dry deposition of sulfur dioxide is involved. Under moist conditions $SO_2$ or sulfuric acid will convert calcium carbonate to gypsum, $CaSO_4.2H_2O$. Since the sulfate is more soluble than the carbonate, the reacted stone can be removed by dissolution. The solid gypsum also occupies a larger volume than the original carbonate and this leads to spalling of material from the surface. In polluted urban areas a black 'crust' of soot and gypsum builds up on stonework not washed by rain. A combination of these factors leads to a rate of loss of stone which depends on the deposition rate of $SO_2$ to the surface. Deposition to a moist surface is more rapid than to a dry surface so the fraction of time the surface is wetted as well as the $SO_2$ concentration is important. It is generally assumed that in urban areas the dry deposition of $SO_2$ gas is the major factor rather than the acidity of rain itself (Clarke & Tomlin, 1999).

Furthermore, a study on corrosion effect of gas flaring on galvanized roofing sheet in Imo State, Nigeria by Ovri and Iroh (2013) reported that release of acidic gases like $NO_x$, $H_2S$ and $SO_2$ that are very soluble in water is responsible for the corrosion of galvanized roofing sheets in

the study area due to the formation of $H_2SO_4$. Also, research on the effect of gas flaring on buildings in the oil producing rural communities by Nkwocha and Pat-Mbano (2010) revealed a strong association between emissions from the flare point and some impacts observed on the buildings in the area. These results showed that the most probable air pollutants that caused these observed impacts were $SO_2$, $NO_2$ and $PM_{10}$ as they matched the criteria for causative agents in this case. The emission of some of these air pollutants has effects on global warming which is already manifesting in the form of rain spells which in turn is raising the episodes of running water, landslide and flooding, modification of human comfort (Binbol & Uzochukwu, 2008), loss and decline in biodiversity, melting of ice, increasing sea level (Audu, Balogun, Nwoga, Garba, Kalejauye – Matti, Amadi & Audu, 2010), increasing evaporation from both water bodies and moist soils (Anuforom, 2010), increasing transpiration and high pests and diseases incidences (Audu et al.,2010).

#### 1.1.11.2 Effect of Air Pollution on Human Health

Air pollution can harm human health by direct inhalation and by other routes of exposure. Many air pollutants affect the respiratory and cardiovascular systems. Air pollution levels sometimes cause acute health effects, including asthma, and may contribute to chronic disease (pulmonary fibrosis and emphysema) (Woodward, Guest, Steer, Harman, Scicchitano, Pisanello & McMichael, 1995). Exposure to air pollutants poses a serious health threat to residents of major urban centers around the world (Li, Sarnat, Raysoni, Sarnat, Stock, Holguin, Greenwald, Olvera & Johnson, 2011). High concentration levels of air pollutants have been shown to have general adverse effects on human health (Allen, Criqui, Diez Roux, Allison & Shea, 2009, Hulgiun, Flores, Ross, Cortex & Molina, 2007, Moshammer, Hutter, Hauck & Neuerger, 2006). This is compounded with the establishment of new industries such as cement factories, metallurgical and petro-chemical industries and hot mix asphalt facilities which has increasingly contributed to the concentration of most air pollutants **(**Osuntokun, 2004). Human exposure to air pollutants may result in a variety of health effects depending on the type of pollutant; the magnitude, duration and frequency of exposure; and the associated toxicity of the specific pollutant. People come in contact with pollutants in the air both indoors and outdoors during their daily activities (Hanninen, Economopoulos & Ozkaynak, 1999). Air pollution is a problem for all of us. However, some groups of people are especially sensitive to common air pollutants such as particulates and ground-level ozone. Sensitive populations include children, older adults, people who are active outdoors, and people with heart or lung diseases, such as asthma.

Exposure to atmospheric pollution has been linked to a number of respiratory illnesses, like acute respiratory infection (Mishral, 2003), chronic bronchitis (Pandey, 1984; Regalado, Perez-Padilla & Sansores, 2006), asthma (Mishral, 2003), chronic obstructive pulmonary disease (COPD) (Erhor & Kolawole, 2002; Orozco-Levi, Garcia-Aymerich & Villar, 2001), tuberculosis (Perez-Padilla, 2001) and possibly lung cancer (Mumford, 1995; Zhao, Wang, Aunan, Seip & Hao, 2006). It has been reported that carbon monoxide causes blood clotting when it reacts with haemoglobin, which cuts the supply of oxygen in the respiration system after long exposure (Ojolo et al., 2007). This is more common in urban centres with a high level of commercial activity (Gibbs, Betty, Dolaty & Angento, 1995; Glen, Zelenka & Graham, 1996; Johnson et al., 2000). High levels of pollution are more often in urban cities that are densely populated with low standard of living (Addy and Pietrass, 1992; Washington, Leonard, Roberts, Young, Sperling & Bottha, 1998). According to Sunyer, (2001), decreased lung capacity and lung cancer could result from long-term exposure to toxic air pollutants. Also, it has been reported that due to environmental warming in Nigeria (caused by gas flaring), tropical illnesses (pneumonia, anemia, meningitis, number of children running temperature and so on) are on the increase (Audu, 2013).

#### 1.1.11.3 Effect of Air Pollution on Agriculture

In view of worldwide shortages of food, the harmful effects of air pollution on plants is of particular concern (Manahan, 2001). All plants have some tolerance to air pollution, for instance to ozone, as it is naturally present in the atmosphere. However, at elevated concentrations, ozone is potentially injurious to horticultural crops, ornamentals, commercial and non-commercial forest trees, native shrubs and annual plants. The ozone dose which may cause adverse effects varies between species and is influenced by plant nutrition, water availability, weather and other factors (PPSS, 1996). Sulphur dioxide, nitrogen oxides and secondary air pollutant, ($O_{3)}$ are identified as major threats to crop production. These gases have important and increasing impacts on the livelihoods and well being of producers and consumers through effects on urban and suburban crop production. Air pollution has the potential to reduce both the yield and the nutritional quality of the crop plants (Rai, Agrawal & Agrawal, 2010; Ashmore & Marshall, 1999).

Injury to plants as a result of pollutants has been classified as either chronic or acute. An acute $SO_2$ is viewed as a short duration high level of $SO_2$. On broad- leaved plants, acute $SO_2$

injury symptoms consist of bifacial, marginal and/or interveinal necrosis and chlorosis on leaves at the full stage of development. The necrotic areas can range in colour from white to reddish brown to black depending on the plant species. In monocotyledonous plants, acute injury symptoms start at the tip of the leaves and spread downward as necrotic and chlorotic streaks with occasional reddish pigmentation. Chronic $SO_2$ exposure may or may not result in foliage injury symptoms depending upon plant susceptibility. It is important to note that reductions in plant growth and productivity from chronic exposure may occur without development of visible chronic foliar injury (Legge & Krupa, 2002).

In case of $SO_2$ and $NO_2$, visible injury usually results from exposure to pollutant concentrations above a point around an order of magnitude greater than the threshold for growth and yield reductions in absence of visible, i.e. chronic injury, however, in case of $O_3$, acute visible symptoms can be produced on sensitive species within a range of approximately twice the maximum natural concentration of this pollutant. Thus, visible $SO_2$ and $NO_2$ injury is largely confined in the field to severely polluted locations or on the occasion of large industrial accidental releases. In contrast, visible $O_3$ injury is recorded more frequently over worldwide areas when an elevated level of this pollutant occurs. Acute injury by these pollutants vary in their form of various necrotic lesions, ranging from a fine stipple to large patches of dead tissue, with colouration ranging from white to brown black (Rai, Rajput, Agrawal & Agrawal, 2011)

This problem is made worse where there is gas flaring like the case of some part of Imo State. For instance, the oxides of sulphur and nitrogen from the flared gas combine with water in the atmosphere to form various types of corrosive acids that alter and damage various soil parameters (Ubuoh, 2011). Ogodo, (2003) reports that acid deposition from gas flare have deleterious effects on the fertility, pH and microbial spectrum of the surrounding soils. It impoverishes soils (Schnabel, 1993, Grant & Trattner, 1995). Also reports have been made about free disposal of gas through gas flaring which generates tremendous heat that causes heating and increased water loss (by transpiration) effects on nearby plants, with severe wilting and death ensuing (Mauseth, 1998; Okeke & Okpala, 2014).

### 1.1.12 Control and Prevention of Air Pollution

Prevention and control of air pollution is of utmost importance considering the damages and effects of air pollution on human health and the environment. This no doubt prompted legislation against the emission limit of certain gases considered harmful to man and the

environment. On global scale, pollution control standards are the result of complex negotiations among nations. Typically, developed countries, having already gone through a period of rapid (and dirty) industrialization, are ready to demand cleaner technologies. Less developed nations, hoping for rapid economic growth, are less enthusiastic about pollution controls. They seek lenient deadlines and financial help from developed countries to make the expensive changes necessary to reduce pollutant emissions in their industrial processes.

The truth is that efforts should be intensified by the government of Nigeria at all levels to enforce stringent environmental legislative measures on industries and oil companies that still emit air pollutants so as to eradicate gas emission in the shortest possible time in order to protect the environment and its habitats from total destruction. The effort of Federal and State Environmental Protection Agencies like FEPA now NESREA (Federal Environmental Protection Agency and now National Environmental Standards and Regulations Enforcement Agency) should be redoubled to monitor, control and if possible prevent the emission of noxious gaseous pollutants into the atmosphere.

Efforts should be intensified by the government of Nigeria at all levels to enforce stringent environmental legislative measures on oil companies that still practice gas flaring so as to eradicate gas flaring in the shortest possible time in order to protect the environment and its habitats from total destruction.

To control and prevent air pollution, air quality monitoring which is a critical activity in air quality management is important. Continuous monitoring data for common pollutants such as CO, $NO_x$, $O_3$, $SO_2$, and particulate matter (TSP or $PM_{10}$) are recorded at many sites around the world. A global monitoring network, the GEMS/AIR programme, was initiated by the WHO in 1973, and in 1975 became part of the Global Environment Monitoring System GEMS, now jointly managed by WHO and UNEP (UNEP/GEMS web site). GEMS/AIR was implemented to strengthen urban air pollution monitoring and assessment capabilities, to improve validity and comparability of data among cities, and to provide global assessments on levels and trends of urban air pollutants, and their effects on human health. Approximately 170 monitoring stations in 80 cities in 47 countries participate in the programme measuring $SO_2$ and suspended particulate matter (55 cities in 33 countries) with other stations measuring $NO_2$, CO, $O_3$, and Pb (Clarke & Tomlin, 1999).

Unfortunately similar monitoring activities seem not to be on-going in our cities, here in Imo state. Even though, the UN climate negotiations that ended in Bangkok, Thailand on Friday,

9th October, 2009; failed largely to deliver any substantive progress on target for reducing GHGs emissions (Ejiofor, 2011), countries like Nigeria should intensify effort to stop gas flaring for the benefit of her air environment.

## 1.2 Statement of the Problem

Imo State is one of the thirty six states of the Federal Republic of Nigeria located in the South Eastern part. According to the general household census of 2006, Imo State has a population of about 3,934,899 (FRN Official Gazette, 2007). The State is comprised of 27 local government areas with 3 senatorial Zones which include Owerri zone, Okigwe zone and Orlu zone. The State is made up of 640 autonomous communities (Imo State Ministry of Local Government Affairs, 2013). Imo state is one of the nine states in the Niger Delta region of Nigeria. The state is rich in natural resources including crude oil and natural gas mainly within Ohaji, Egbema and Oguta areas. The oil industries located within this region has contributed immensely to the growth and development of the country which is a fact that cannot be disputed, but unsustainable oil exploration activities has rendered the Niger Delta region to be one of the most severely petroleum damaged ecosystems in the world (Adati, 2012). The oil wells in Niger Delta region have taps to large quantities of natural gas, with an estimated reserve of about 1,422 billion cubic meters (Odeyemi & Ogunseitan, 1985). Most part of these gases have been continuously flared in the Niger Delta region since 1970 (NNPC, 1984).

Figure 1.7: Emissions from gas flare stack

The emissions emanating from this gas flaring as shown in Fig. 1.7 and crude oil related activities within the state and other neighbouring states could result in deterioration of the air quality of the state.

Similarly, the presence of stone mining sites (Fig. 1.8) in Okigwe is a huge source of particulate matter emission into the atmospheric environment of the state. These quarry products are most often evacuated or transported to different parts of the country by heavy duty trucks (Figure 1.10a) that could contribute significantly to air quality deterioration. This no doubt contributes much to the level of air pollution in the state. The high volume of vehicular traffic (Fig. 1.10b) being experienced in Owerri and the introduction of the two stroke engine tricycle popularly known as keke (Fig. 1.9) as a means of transportation. Two stroke engines are known for their incomplete combustion of fuel leading to the emission of


(a)

(b)

Figure 1.8: Hips of stones at some stone mining sites in Okigwe


(a)

(b)

Figure 1.9: Two stroke engine automotive (keke)

(a)  (b) 

 **(c)**

Figure 1.10: Traffic emissions from busy urban road

noxious atmospheric air pollutants (Sengupta, 2003). This is coupled with the increasing human population in the city which could result to serious anthropogenic emissions. Similarly the presence of an industrial layout in the city of Owerri is a possible source of air pollution that could degenerate the air quality of the state. It is in view of these stated facts that this research was necessitated to ascertain the spatio-temporal characterization of ambient air quality in Imo State, Nigeria.

## 1.3 Objectives of the Study

The main objective of the study is to evaluate the spatio-temporal characterization and dynamic modeling of ambient air quality in Imo State, Nigeria. The specific objectives of the study include to;

i. Determinate the concentration of ambient air pollutants $NO_2$, CO, $SO_2$, $PM_{10}$, VOC and $H_2S$, the meteorological and environmental factors that may influence the concentration level of atmospheric pollutants and carry out a detailed analysis of the possible and environmental influence of meteorological factors on air pollutant concentration using multivariate plots.

ii. Compare the result of this study with ambient air quality standards in order to determine the potential for adverse health effects and need for control strategies.

iii. Carry out a detailed statistical analysis of the atmospheric pollutant concentrations and determinate the temporal correlation of the air pollutants using time series analysis.

iv. Assess the dynamics of atmospheric dispersion using windrose models and model the spatial variation of the measured air pollutants in the study areas.

v. Estimate the air quality index (AQI) of the study area using measured atmospheric parameters.

vi. Develop a dynamic equation for modeling atmospheric dispersion, inversion and turbulence in the study area. This model will also be predictive.

## 1.4 Significance of the Study

i. One of the basic requirements of human existence is clean air, and air pollution has been globally recognized as posing significant risk to both man and his environment. This study therefore presents the real picture of the ambient air quality in parts of Imo State.

ii. Most of the pollution indices analyzed in this study, nitrogen oxides ($NO_2$), carbon monoxide (CO), sulphur dioxide ($SO_2$), and particulate matter ($PM_{10}$), are ubiquitous in the ambient environment. These atmospheric pollutants pose the greatest negative effects on the environment. Models that can elucidate the spatial variation of these pollutants in time and space like the time series model using Matlab software. The spatial variation models showing the distribution of the pollutants in a mapped layer using Arc GIS and surfer software is of immense benefit for the management of air pollution problems.

iii. Furthermore, the time series analysis carried out in this study will facilitate the analysis and characterization of the nature of temporal correlation of the pollutants, which is useful for the prediction of future atmospheric pollution events.

The dynamic models developed in this study will enable the prediction or forecasting of air pollution dynamics in the study area.

iv. In addition, the influence of meteorological and environmental parameters (wind speed, ambient temperature, elevation, relative humidity, wind direction and wave height) on the concentration of ambient air pollutants is an important factor when discussing air pollution events. The use of Gapher 10 software to model the dominant wind dynamics (wind speed and wind direction using the Wind Rose) and Surfer 12 software to develop multivariate plots showing the effect of these parameters on the air quality of the study

area is very significant in this work. This will as well provide more information on the effect of meteorological parameters on the observed air pollution level.

v. There is paucity of air pollution study data in Nigeria, especially in Imo State and the few studies were independently executed (Chiemeka, 2010; Ubuoh & Akhionbare, 2011; Nkwocha & Pat-Mbano 2010; Okeke & Okpala 2014). Most of the reports are mainly observation of one day air quality data. The huge data acquired and the robustness of this study therefore makes it an important air quality data base.

vi. The findings of this work will possibly further provide a guide in proffering recommendations that could assist researchers, town planners and individuals in mitigating and ameliorating the various risks associated with exposure to air pollution in the State.

vii. Finally, the research findings will surely be of immense benefit to researchers, policy makers and government agencies in formulation of appropriate environmental policies and mitigation measures for reduction of air pollution based events in the State.

## 1.5 Scope of the Study

This research work measured six atmospheric pollutants which include sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), particulate matter ($PM_{10}$), volatile organic compounds (VOC) and hydrogen sulphide ($H_2S$). Similarly, seven metrological variables which include relative humidity, wind speed, wind direction, wave height, elevation, ambient temperature and geographical coordinates of the sampling stations were measured. The study was carried out in Imo State within the areas selected for the study ranging from Owerri, Orlu, Egbema and okigwe. A total of four air quality monitoring sites were chosen in each of these locations.

The study was carried out in two phases, that is dry and wet seasons within the areas stated above, this was carried out for a period of six months, within the months of November, 2014 to June, 2015. In each month, the air pollutants were monitored once weekly in the morning, afternoon and evening. An area was selected in each location which seems to be less polluted by virtue of the low commercial or economic activities to serve as the control sample location. The six air pollutants at 16 air monitoring location amounts to a total of six thousand nine hundred and twelve (6,912) rounds of air quality data sampling. The six meteorological

parameters measured also amounts to 6,912 rounds of air sampling. In all, together with elevation and coordinates, the research work involves a total of thirteen thousand, eight hundred and fifty six (13,856) round of air quality data sampling.

# CHAPTER TWO

# LITERATURE REVIEW

Several scholars have carried out studies on ambient concentration of atmospheric pollutants. In a study to evaluate levels of pollutants in ambient air in Abuja by Hassan and Abdullahi, (2012) observed varying concentrations of hydrogen sulphide ($H_2S$), carbon monoxide (CO) and low explosive limit gases. They indicated that the high concentrations of pollutants detected in Abuja municipal area council could be attributed to increased population growth, increased production of gaseous wastes and increased number of industries.

Gobo et al. (2012), on assessment of air quality and noise around Okrika communities in Rivers State, Nigeria, reported poor air quality in the study area. They submitted that the concentrations of the air pollutants such as hydrogen sulphide ($H_2S$), volatile organic compounds (VOC), nitrogen (iv) oxide ($NO_2$), sulphur (iv) oxide ($SO_2$) and ammonia ($NH_3$) exceeded the permissible limits and therefore pose serious environmental and health problems in the area. They further concluded that the ground level concentration resulting from industrial, traffic and domestic emissions were variable according to the meteorological/weather conditions prevailing at the time.

Mapoma, Tenthani, Tsakama and Kosamu (2014) carried air quality assessment of CO, $NO_2$ and $SO_2$ levels in Blantyre, Malawi using a statistical approach to a stationary environmental monitoring station. The results indicate that CO levels were below the Malawian limit value and the observed levels of $NO_2$ and $SO_2$ were significantly higher than allowable Malawian

Standards. Variations in hourly, diurnal, monthly and seasonal CO, $SO_2$ and $NO_2$ were apparent. They concluded that variations in local weather affected the disparity in hourly and diurnal values. ANOVA confirmed significant variations in monthly observations, with higher wet season concentration of CO, $SO_2$ and $NO_2$ than dry season values.

de Souza, Silva, Fernandes and Braga (2014), analyzed the temporal variation of the concentration of CO in the centre West of Brazil. The study was conducted in the state of South Mato Grosso from 2001 to 2012 using the MOPITT sensor onboard the Terra Satellite. The result of the study concluded that CO comes principally from incomplete combustion of vehicles engines and biomass burnings. A direct correlation of the CO concentration in the state of South Mato Grosso was observed precisely during the months of drought (August to October), for which the number of fire outbreaks were the highest in the year.

An assessment of seasonal variation of air pollution in Benin City, Southern Nigeria was carried out by Balogun and Orimoogunje, (2015). Sampling for the study covered a period of six months, between mid-October 2013 and mid-April 2014 with reference to CO and particulate matter (PM). The results revealed that the dry season mean values of particle counts for PM and CO concentration were characterized by higher concentration of the pollutants, while the rainy season mean values of particle counts for PM and CO concentration were characterized by less concentration of the pollutants. The study concluded that seasonality significantly influenced the concentration of the pollutants in the city.

Mikhailyuta, Taseiko and Lezhenin (2007), investigated the seasonal variations of air pollutant concentrations for Krasnoyarsk non-uniform urban territory with respect to CO, NO, $NO_2$, $SO_2$, and $O_3$ using a mobile gas-analysis laboratory. There result revealed that the detected differences in seasonal variations are a consequence of the microclimatic inhomogeneities of the city territory, which they said is due to the effects of wind speed and space-time distribution of the atmospheric pollutants.

Subrata, Srimanta and Raj, (2010), investigated the seasonal variation of ambient air quality status of Burdwan town, India, using GIS approach. Concentration of $SO_2$, $NO_2$ and RSPM were measured once a week for 24 hour in both pre-monsoon and post monsoon season. Statistical analysis showed significant monsoonal effect on mean difference of RSPM, $SO_2$ and $NO_2$ concentration. Post monsoon concentration of ambient $SO_2$ and $NO_2$ were observed to be higher than pre-monsoon, suggesting longer residence times of these pollutants in the atmosphere due to stagnant conditions and low mixing height. Spatial distributions of pollutants

throughout the town in both seasons were represented by digital elevation model (DEM). They concluded that in comparison to pre-monsoon there was a significant increase of clean and fairly clean area and decrease of moderately polluted area of the town during post monsoon.

Ubuoh and Akhionbare (2011), in their study titled "effects of pig production on ambient air quality of Egbeada in Mbaitoli LGA of Imo State, Nigeria'', reported that the concentration of the parameters; odour, $NO_2$, $SO_2$, $NH_3$, CO, $H_2S$, $CH_4$, and PM decreased with increase in the distant from the piggery that was influenced by wind speed of 0.2 m/s, and that apart from methane, all other indices were above the WHO/FMENV (World Health Organization/ Federal Ministry of Environment) Standards for ambient air quality. This they believed has very serious epidemiological implication on human health and the environment.

Assessment of some air pollutants and their corresponding air quality index at selected activity areas in Kaduna metropolis by Mohammed and Caleb (2014), determined the atmospheric concentration levels of CO, $SO_2$, $NO_2$, $PM_{10}$ and noise level at some commercial and residential areas using air monitoring devices. Ambient air temperature and relative humidity were measured at each point. They concluded that air quality index (AQI) analysis showed that the concentration of toxic gases emitted from the exhaust pipes of vehicles were of major health concern, especially CO which has the highest concentration in all the sampled points. Their work indicated that the morning and evening hours posed the greatest risk compared to afternoon hours with moderate concentration of $NO_2$, $SO_2$ and $PM_{10}$ except CO.

Similarly, Oriola, Alade and Adekala, (2013) in their work "Evaluation of air quality in a confined poultry house" reported a correlation between the concentrations of ammonia and nitrous oxide gases in a closed poultry structure with bird mortality rate. The poultry house was demarcated into 3, and the 2 gaseous pollutants in each of the demarcation were monitored for three days and analyzed in a laboratory to determine the concentration of each of the pollutants in the house. The concentrations of ammonia, ($NH_3$), range between 0.60 and 9.99 $mg/m^3$ while the concentrations of nitrous oxide, ($NO_2$), ranged between 9.82 and 25.00 $mg/m^3$. They showed that the average concentration distribution of $NO_2$ was approximately three times the value of $NH_3$ in all the 3 divisions at the time of sampling. The sources of the two gaseous pollutants were traced to decomposition of poultry waste present in the pens. The mortality rate of birds in the sampled poultry ranges between 3 and 11, and this follow closely the distribution pattern of $NH_3$ in the poultry house. They concluded that the mortality rate recorded in the poultry showed much similarity with the distribution of $NH_3$ concentration in all the divisions as well as the

sampling times, and that $NH_3$, and not $NO_2$, as pollutant was largely responsible for the mortality rate. However, there is a combined adverse effect of the two pollutants on the bird's mortality.

Analysis of particulate pollutant ($PM_{2.5}$) and gaseous pollutant (CO) at Jabalpu, India was carried out by Kalpana and Srivastava, (2015). They showed that the concentration of particulate matter ($PM_{2.5}$) of 24 hr average was higher than the permissible limit at the selected sites in Jabalpur city, which was polluted due to dust from construction activities and due to vehicular emission. On the other hand, carbon monoxide (CO) was below the standard limit prescribed by Indian Central Pollution Control Board. They concluded that it was observed that local people were suffering from allergic problems such as eyes and skin irritation, asthma and lung diseases etc.

Nkwocha and Pat-Mbano, (2010) in their study of the effect of gas flaring on buildings in the oil producing rural communities of River State, Nigeria, posited that $SO_2$, $NO_2$ and $PM_{10}$ were the major pollutants that may have acted as causative agents of the observed impacts (corrosion of roof tops, colouration of walls, leakage of roof tops etc), due to their toxic properties. According to their findings, there was high positive correlation between pollution levels and the level of impact on the sampled buildings.

A similar study by Okeke and Okpala (2014) on the effects of gas flaring on selected arable soil quality indicators in the Niger Delta, Nigeria, revealed that heat and other atmospheric inputs generated in the process affect soil properties in various ways. They submitted that the overall nutrient concentrations were lower in the polluted area than the control area, indicating pollution of the soil.

Furthermore, a report on evaluation of indoor air pollutants in selected hostels of some tertiary institutions in Owerri, Nigeria by Ogukwe et al., (2014) identified $NO_2$, $SO_2$, $H_2S$, $NH_3$ and $CH_4$ as the constituting indoor air pollutants in the studied area. They concluded that the monthly mean values of the pollutants detected were affected by some meteorological variables like wind speed, temperature, relative humidity, and irradiance.

Air quality assessment in the vicinity of quarry site, a research work by Bada et al (2013) reported that CO, $CO_2$ and suspended particulates were detected while $SO_2$, $NO_2$ and $O_3$ were below detection limit. They concluded that suspended particulates were the most significant of the air pollutants analyzed. The mean levels of the total suspended particulates decreased significantly ($p<0.05$) with distance from the crushing section to Jagun village. The highest levels of $PM_{2.5}$, $PM_{10}$ and TSP were generated at the crushing section. They suggested that for

sustainable quarry activities, quarry site should be located in the interior surrounded by adequate vegetations which would act as sinks and blockage for various emissions emanating from the quarry.

In addition, a research work by Okuo and Okolo (2003) on the levels of As, Pb, Cd, and Fe in total suspended particulate matter (TSPM) in ambient air of artisan's workshops in Benin City, Nigeria, revealed that the concentrations of TSPM for the three workshops ranged from 583 – 20,166 µg/$m^3$. They concluded that the value of TSPM obtained violated both FEPA (Federal Environmental Protection Agency) and WHO standard, and that the measured levels of TSPM, the elemental concentrations and enrichment factor of the hazardous elements such as Pb and As calls for concern by all stake holders.

In a related work, Chiemeka, (2010) in his work titled "Air aerosol metal constituent and concentration at Okigwe, Nigeria", determined the concentrations of eleven elements (Ca, K, Mg, Fe, Zn, Mn, Cu, Ni, Cr, Cd, and Pb) by analyzing the deposited dust that was collected during an average of 30 days sampling period by Atomic absorption spectrophotometry. The concentration of dust sample was collected by direct deposition method under gravity on a Whatmann Filter Paper. The dust sample was collected for a period of 24 hrs per day for a total of 30 day from 4$^{th}$ February to 5$^{th}$ March, 2008.

Pan, Wang, Tang and Wu (2013) carried out work on the spatial distribution and temporal variations of atmospheric sulfur deposition due to precipitation, particles and gases at ten sites in Northern China. Continuous measurements were carried out between December 2007 and November 2010. Daily rainwater and event-based snow samples were collected using an automatic wet-dry sampler and a clean plastic bucket, respectively. Dry-deposited particles were also collected monthly using a surrogate surface made of polyurethane foam (PUF) filter, which was placed in a glass bucket. All of the precipitation samples were stored, transported, filtered and analyzed. The concentrations of $SO_4^{2-}$ in the filtrates samples were determined using an ion chromatography system (Model ICS- 90, Dionex Corporation, Sunnyvale, CA, USA). The total S deposition flux in the target area ranged from 35.0 to 100.7 kg S $ha^{-1}$ $yr^{-1}$. The 3-yrs average total S deposition for the ten sites was 64.8 kg S $ha^{-1}$ $yr^{-1}$, with 68 % attributed to dry deposition (mainly $SO_2$) and the rest to wet deposition. Their findings revealed that the spatial distribution of the total flux was consistent to that of dry deposition. Higher values were observed at industrial and urban sites than at agricultural and rural sites. They noted that the seasonal variation in the total S deposition was not obvious across the entire year because of opposite

seasonal trends in wet and dry deposition. They concluded that wet deposition without significant spatial and interannual differences, was influenced by the volume of precipitation, the air-column concentrations of S compounds and in-cloud scavenging. Similar to the wet deposition, the dry-deposited sulfate was also less dependent on the surface concentration. The regional differences in $SO_2$ dry deposition were mostly explained by the ambient concentration, which is closely associated with local emissions. They reported that spatial pattern of total S deposition resembled that of the emission inventory, indicating a dramatic anthropogenic input on the regional S level.

In a similar study, Kim, Lee, Song, Kim Ma, Lee, Cha and Lee (2015) analyzed the temporal and spatial distribution of tropospheric $NO_2$ over Northeast Asia using OMI data during the years 2005–2010. The study was aimed at examining the main characteristics of tropospheric $NO_2$ concentrations over the Northeast Asia, using the Ozone Monitoring Instrument (OMI) data from 2005 to 2010. The study revealed that the annual mean $NO_2$ concentrations (AMNC) had an increasing trend mainly due to increasing $NO_2$ emissions in China except during the 2008 Beijing Olympic Games period, while the reduction policies of South Korea and Japan led to a stagnant or decreased concentration of $NO_2$ in the area. Their report indicated that seasonal changes in $NO_2$ concentrations showed apparent increasing trend in winter and no significant trend in summer. These results indicate that an increase in AMNC in Northeast Asia was attributable to the increasing $NO_2$ concentrations in winter, which suggests the importance of $NO_2$ management to improve air quality in the Northeast Asia.

Effects of quarry activities on some selected communities in the lower Manya Krobo District of Eastern Region of Ghana, was investigated by Nartey, Nanor and Klake (2012) with reference to $PM_{10}$. The study revealed that levels of $PM_{10}$ daily concentration exceeded daily minimum Ghana EPA standard for 24 hours average. They concluded that out of fifteen readings taken in the study area, 86.7% were above the Ghana EPA standard. Air pollution due to quarry dust was very high during the dry season as $PM_{10}$ concentration was highest in January.

Characteristics of pollutants and their correlation to meteorological conditions at a suburban site in the North China Plain (NCP) were carried out by Xu, Zhao, Ran, Deng, Liu, Ma, Lin, Xu, Yan, He, Yu, Liang and Chen (2011). Measurements of surface trace gases, including $O_3$, $NO_x$, $SO_2$ and CO together with meteorological data and satellite data were carried out to understand the causes of the observed variations in the trace gases during the field campaign. Detailed statistical analyses were made in order to provide information on the levels of the

measured air pollutants and their characteristics. They concluded that in comparison to measurements from other rural and background stations in the NCP, relatively high concentrations were detected in Wuqing, presumably due to regional mixing and transport of pollutants. That local meteorology had deterministic impacts on air pollution levels, which have to be accounted for when evaluating other effects on pollutant concentrations. They stated that trace gas concentrations showed strong dependence on wind, providing information on regional pollution characteristics, while $O_3$ mixing ratio showed clear dependencies on temperature and relative humidity.

Furthermore, Olatunji and Akinsoji (2013) investigated the ambient air quality and noise level around some base trans-receiver stations (BTSs) in Ibadan, South West Nigeria, in order to determine the health and safety of emission from BTSs operations. Their report showed that the atmospheric levels of carbon monoxide (CO), nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), hydrogen sulphide ($H_2S$), ammonia ($NH_3$), total hydrocarbons (THC) and suspended particulate matter (SPM) were measured at selected sampling points (upwind and downwind) in twenty base trans-receiver stations spread over nine Local Government Areas within Ibadan and its suburbs. The atmospheric concentrations of CO, $NO_2$, $SO_2$, THC and SPM were < 0.0001-1.0, < 0.000-0.3, < 0.0001-0.6, < 0.0001-27.1 ppm respectively, while $H_2S$ and $NH_3$ were not present in measurable levels. The detected SPM and noise level were 80.9-165.9 $\mu g/m^3$ and 43.4-77 dB. The measured air quality parameters did not exceed the Federal Ministry of Environment (FMENV) stipulated threshold concentrations for potential air contaminants in the ambient air, except for $SO_2$ and THC which measured higher than the limit set by FMENV.

Ojolo et al. (2007), determined the effects of vehicular emissions on human health, vegetations, and environments in three locations of Lagos (Oshodi, Mushin and Apapa), Nigeria while a fourth location (Fola Agoro) was used as a control since it is believed to have low levels of pollution. The investigation was carried out with the use of questionnaires and laboratory experiments. Experiments were conducted on rainwater collected from each location to determine the level of acidity, pH, and the presence of dissolved substances such as $NO_3^-$, $SO_4^{-2}$ and $CO_2^{-2}$ in them. Physical effects on vegetations, buildings and structures were also observed. The results obtained from questionnaire showed that on the average, 28.3 %, 16.6 %, 23.3 %, 18.3 %, 13.3 % were respectively affected by sleeplessness, running nose, heavy eyes, asthmatic attack, and headache respectively.

Time series evaluation of ozone concentrations in Malaysia based on location of monitoring stations was carried out by Norrimi, Nor, Nuru and Ahmad, (2013). In accessing the variability of ozone concentration across Malaysia, four stations were selected. These results demonstrated that Kajang stations recorded highest ozone concentration followed by Bakar Arang, Seberang Perai and Jerantut. Kajang also recorded highest number of exceedences with 25 cases in 2009. They concluded that, urban areas faced severest $O_3$ pollution compared to sub urban, industrial and background areas.

Wang and Mauzerall, (2006) evaluated the impacts of air pollution in China on public health and its implications for future air pollution and energy policies. Their objective was to establish a link between energy consumption and technologies with air pollution concentrations, and the resulting impacts on public health in eastern China. Zaozhuang, a city in Eastern China heavily dependent on coal, was used as a case study to quantify the impacts of air pollution on public health in Eastern China in 2000. In addition, they studied the benefits of improved air quality and health that could be obtained by 2020, relative to business-as-usual (BAU). This was through the implementation of best available emission control technology (BACT) and advanced coal gasification technologies (ACGT). They concluded that despite significant uncertainty associated with each element of the integrated assessment approach. Substantial benefits to public health could be achieved in this region of Eastern China through the use of additional pollution controls and particularly from the use of advanced coal gasification technology (ACGT).

Air quality indices (AQI) to understand the ambient air quality in vicinity of dam sites of different irrigation projects was carried out by Ravikumar, Prakash and Somashekar, (2014) in Karnataka State, India. Ambient air quality monitoring was carried out in the vicinity of dam and nearby residential sites in four river basins in Karnataka with reference to SPM, RSPM, $SO_2$ and NOx, employing Envirotech APM-460 Respirable Dust Sampler. High AQI values were observed in all four river basins which could severely pollute the environment compared to other monitored stations, owing to the construction activities in the area. They concluded that air pollution due to particulate matters is considered a major serious worldwide public health problem for residents because of its synergetic action. They AQI can be useful in establishing a meaningful assessment of air pollution in the common man's perception.

Similarly, Prakash and Bassin, (2010) analyzed the ambient air quality using air quality index (AQI). RSPM, $SO_2$ and $NO_2$ for the year 2009 at three different locations in Delhi city at

Mayapuri, Town Hall and Sarojini Nagar respectively for industrial, commercial and residential locations were considered for the analysis. They reported that the overall AQI was found to fall under the category 'poor' and 'very poor' owing to RSPM and SPM, respectively.

## 2.1 Modeling and Air Pollution Monitoring

Modeling of air pollutants is an important numerical tool that can be used to describe the causal relationship between emissions, meteorology, atmospheric concentrations, deposition, and other factors. Indeed air pollution measurements gives important quantitative information about ambient concentrations and deposition, but they can only describe air quality at specific locations and times, without giving clear guidance on the identification of the causes of the air quality problem (Builtjes, 2003). Air pollution modeling, instead, can give a more complete deterministic description of the air quality problem, including an analysis of factors and causes (emission sources, meteorological processes, physical and chemical changes, etc), and some guidance on the implementation of mitigation measures (Daly & Zannetti, 2007b).

The impact of improved fuel quality and vehicular technology were studied by Sabapathy (2008) in Bangalore, India. The city implemented fuel quality and vehicular technology policies. The average monthly concentrations of $SO_2$, $NO_x$, SPM and RSPM were monitored at four different time and periods to determine if there were any improvements in the air quality due the vehicle technology and fuel quality policies implemented in the city. The monthly average concentrations for the four pollutants in each time period were analyzed by a one-way single-factor analysis in order to test the hypothesis that pollution levels in each time period are lower than the preceding time periods. The results of the study showed that the air quality of the city improved significantly even though there was significant increase in vehicular traffic in the city.

An industrial complex was modeled by Sivacoumar, Bhaanarkar, Goyal, Gadkari, and Aggarwal (2001) to ascertain the impact of $NO_x$ emission emanating from different air pollution sources within the complex, industries, vehicles, etc using Gaussian dispersion model. Considerations of their model includes production capacities, raw materials utilized in the industries within the complex, fuel consumption, stack emission characteristics, vehicular count survey and meteorological data collected using wind monitoring instrument. Result of their model showed that 53 % of $NO_x$ were contributed from the industries and statistical evaluation

of the model performance evaluation showed high level of agreement between the two with 68 % accuracy.

Ando (2000) in his work "Models for Air Quality Management and Assessment" proposed black box approach for air pollution modeling. The approach was aimed at predicting air pollution scenario based on the expected cause depending on the concentration of air pollutants and meteorological parameters. Ando intended that the proposed model could be used to forecast and estimate air pollutants based on the perceived cause of the air pollution which could find application in the determination of better air pollution emission control measures.

In a related report, Raos, Zivkovic, Zivkovic and Todorovic, (2005) proposed a black-box modeling tool based on the application of an artificial neural network. The aim was to obtain a model of air pollution control device. They assumed a nonlinear, non-stationary dependence between the bearing gas parameters (temperature, humidity and pressure), the bearing gas flow volume and the pollutant concentration. The nonlinear dependence was obtained through measurements. In order to obtain the approximation of the mapping between the bearing gas parameters and flow on one side, and the pollutant concentration on the other, they applied an artificial neural network capable of learning unknown nonlinear mappings using only measurement data. The statistical model (Eq. 2.1) was adopted.

$$y_k = h(u_k) + v_k \text{ , } k = 1,2,... \qquad (2.1)$$

where u is the vector of independent (input) variables, y is the vector of dependent (output) variables and v is the noise representing the ignorance about the functional relationship between u and y. The goal of the modeling was to find a deterministic nonlinear function h(.).

Hosseinibalam and Hejazi, (2012) investigated the relationship between monitored ($NO_2$, $SO_2$ and $O_3$) ambient air quality data and meteorological factors, such as wind speed, wind direction, temperature, air pressure and sunshine hours. This was achieved through multiple linear regressions. The procedure facilitated the prediction of meteorological parameters associated with high air pollution concentrations, hence the prediction of concentrations by using the developed regression models. The regression procedure was accomplished by defining each day in terms of seven meteorological elements (air dry-temperature, wet- temperature, relative humidity, pressure, sun shine, wind direction and wind speed during April 2005-March 2006). These elements were measured three times daily. A stepwise regression procedure was performed to determine which environmental factors can account for the high air pollution concentrations. The dependent variables were the mean values of $SO_2$, NOx, CO and $O_3$, and the

independent variables used in the regression procedure are daily values of air dry-temperature (T), wet-temperature (TW), relative humidity (RH), pressure (P), sun shine (SS), south-north velocities (V), west- east velocities (U) and air pollution concentration of the previous day (PDC). According to the results obtained by multiple linear and stepwise regression analysis, it was observed that there is a strong relationship between $SO_2$ and $O_3$ in Lale station, and the coefficients of determination ($R^2$) for the regression models range from 0.51 to 0.89. The statistical models proved that weather variables such as temperature, pressure and PDC have a significant impact on the concentration of the monitored air quality parameters.

Ocak and Turalioglu (2008) studied the relationship between daily CO (carbon monoxide), $NO_x$ (nitrogen oxides), $O_3$ (ozone) concentration with the pollutant concentration of previous day and meteorological factors (wind speed, temperature, relative humidity) which was statistically analyzed using the stepwise multiple linear regression analysis with the general equation $Y = A + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + E.$ (2.2)

where A is constant of regression, B is coefficient of regression and E is error.

Their findings revealed that $O_3$ concentration increases with increasing wind speed, temperature, relative humidity and previous day's $O_3$ concentration. The model was good for $O_3$, but for $NO_x$ was weak.

Statistical modeling of changes in concentrations of atmospheric $NO_2$ and $SO_2$ was carried out by Szyda, Zivkovic, Zivkovic and Todorovic, (2009) at Szczawno Zdrój in Poland within the period of 1989-2003. Changes in averaged concentrations across years were modeled by 5 regression models: linear, logarithmic, 2nd degree polynomial, 3rd degree polynomial and 4th degree polynomial. The result showed changes in average yearly concentrations of pollutants during the 1980s and 1990s indicating considerable improvement of air quality regarding $NO_2$ and $SO_2$ contents. A noticeable tendency toward a decrease in air pollution results from limiting of $SO_2$ emission sources This they noted was due to closure of burdensome industrial plants, installation of devices for sulphur removal from fumes, and substantial reduction of air pollution coming from the Czech Republic and Germany

# CHAPTER THREE

# MATERIALS AND METHOD

## 3.1 Study Area

The study was carried out in Imo State. Fig. 3.1 respresents the map of Imo State showing air pollution monitoring locations. Imo state is located in the southern rain forest region of Nigeria. It is situated between latitude $5^0$ and $6^0$ 3'N and longitude $6^0$ 15' and $7^0$ 34' E. The area is dominated by plains with elevation ranging from 50-200 m above sea level. The annual rainfall is about 2500 mm to 4000 mm, which is concentrated almost entirely between April and October, with average relative humidity of about 80 % and up to 90 % during the wet season. The maximum air temperature ranges from 28 $^0$C to 38 $^0$C, while the minimum air temperature range from 19 $^0$C to 24 $^0$C (Chiemeka, 2010; Ubuoh & Akhionbare, 2011; Okoro, Chen, Chineke & Nwofor 2014 a, b). The research work covers the three cities of the State which include Owerri, Orlu and Okigwe as indicated in Fig. 3.1, and the characteristics of the locations of the air monitoring sites are stated in Table 3.1 to 3,4

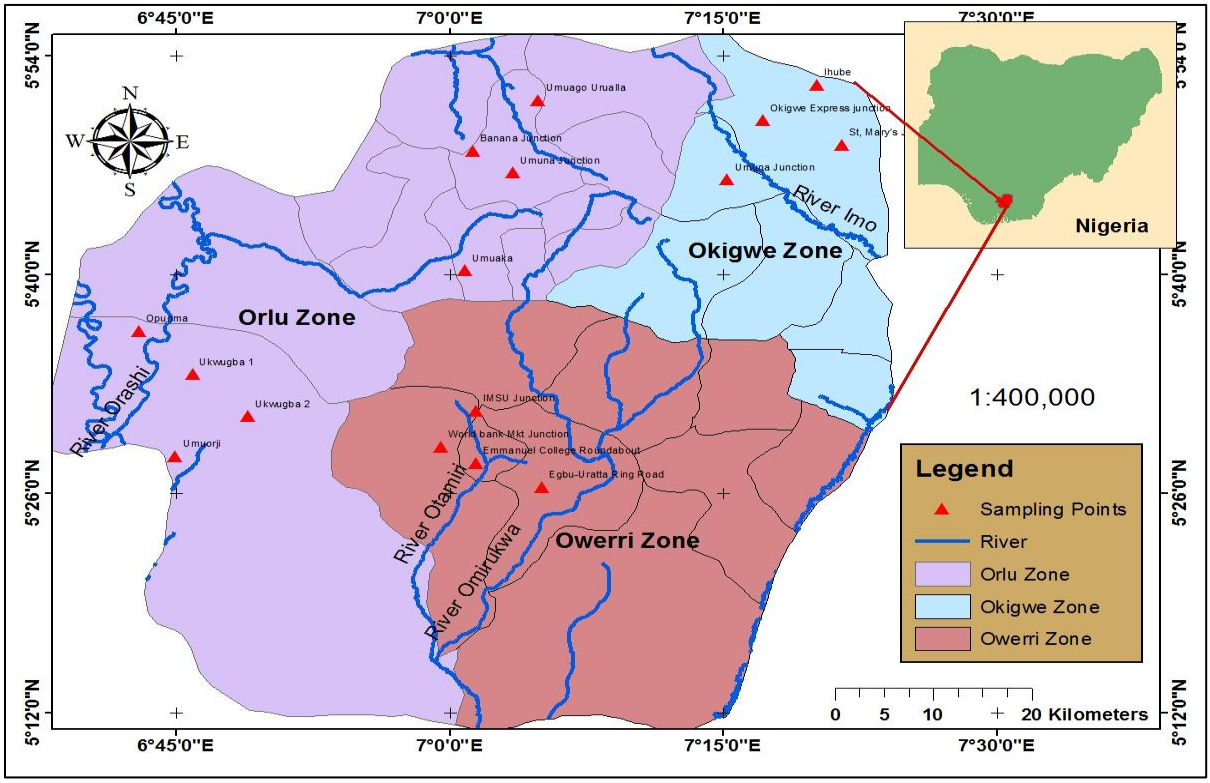



Fig 3.1 Map of Imo State showing air pollution monitoring locations

## 3.2 Air monitoring Locations and Sites

Air qualities were monitored at different locations and sites within the study area. The locations and sites were carefully chosen based on;

- security of air monitoring equipments and field workers,
- accessibility to the locations,
- freedom from any obstacle to free flow of air in the vicinity,
- time constraint in accessing the study location.

Also the locations and monitoring sites chosen in this study were to reflect the activities going on in the area. The geographical positions of the sites were referenced with GARMIN GPSmap76 as indicated in Tables 3.1 to 3.4 below, showing air quality monitoring locations, characteristics, elevation and geographical co-ordinates. In each location an area was chosen to serve as the control as shown in table Table 3.1 to 3.4 and Fig. 3.1.

Table 3.1: Owerri Air quality Monitoring Locations, Characteristics, Elevation and Geographical Co-ordinates.

| S/N | Location | Latitude | Longitude | Elevation | Characteristics |
|---|---|---|---|---|---|
| 1 | IMSU Junction | $5^0$30'27.91"N | $7^0$01'18.13"E | 101 m | High vehicular, keke and human traffic, enormous commercial activity, commercial and residential buildings |
| 2 | Emmanuel College Roundabout | $5^0$28'19.68"N | $7^0$02'11.08"E | 99 m | High vehicular, keke, motorcycle and human traffic, commercial activity, commercial and residential buildings, petrol stations, nearby market, motor park and waste dump site |
| 3 | World bank Mkt Junction | $5^0$28'54.78"N | $7^o$00'09.08"E | 99 m | Market, high vehicular, keke and motorcycle traffic, commercial activities artisans workshops, waste dump site etc |
| 4 | Egbu-Uratta Ring Road (Control) | $5^0$28'32,20"N | $7^0$04'51.61"E | 131 m | Low vehicle and motorcycle traffic, few residential buildings, no commercial activity in the area |

Table 3.2: Okigwe Air quality Monitoring Locations, Characteristics, Elevation and Geographical Co-ordinates

| S/N | Location | Latitude | Longitude | Elevation | Characteristics |
|---|---|---|---|---|---|
| 1 | Umuna Junction | $5^0$46'04.52"N | $7^0$15'13.73"E | 124 m | Heavy duty truck, small vehicular and few motorcycle traffic, small commercial activities. |
| 2 | Okigwe Express junction | $5^0$49'14.15"N | $7^0$20'13.65"E | 176 m | High heavy duty truck, small vehicular and motorcycle traffic, commercial activities, petrol stations artisans workshops. |
| 3 | St, Mary's Junction | $5^0$50'00.49"N | $7^0$23'21.78"E | 226 m | High vehicular and motorcycle traffic, commercial activities, nearby market, road under construction. |
| 4 | Ihube (control) | $5^0$51'00.22"N | $7^0$22'42.24"E | 254 m | Very low vehicular and motorcycle traffic, , no residential building and no commercial |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | activities, the area is mountainous. |

Table 3.3: Orlu Air quality Monitoring Locations, Characteristics, Elevation and Geographical Co-ordinates

| S/N | Location | Latitude | Longitude | Elevation | Characteristics |
|---|---|---|---|---|---|
| 1 | Umuaka | $5^0$40'15.50"N | $7^0$00'50.92" E | 180 m | High vehicular and motorcycle traffic, market, motor park, many commercial activities artisans workshops |
| 2 | Banana Junction | $5^0$47'54.79"N | 7001'14.86E | 208 m | High vehicular and motorcycle and human traffic, many commercial activities artisans workshops, commercial and residential buildings |
| 3 | Umuna Junction | $5^0$47'41.79"N | $7^0$02'19.94" E | 196 m | High vehicular and motorcycle and human traffic, market, motor park, many commercial activities artisans workshops |
| 4 | Umuago Urualla (control) | $5^0$51'09.36"N | $7^0$04"51.68" E | 196 m | Very Low vehicular, motorcycle and human traffic, no commercial activities, few residential buildings. |

Table 3.4: Egbema Air quality Monitoring Locations, Characteristics, Elevation and Geographical Co-ordinates

| S/N | Location | Latitude | Longitude | Elevation | Characteristics |
|---|---|---|---|---|---|
| 1 | Umuorji | $5^0$30'36.44"N | $6^0$44'49.75" E | 42 m | Residential buildings, very little commercial activities, very low vehicular and motorcycle traffic, gas flaring activities in neighbouring towns |
| 2 | Ukwugba 1 | $5^0$33'24.67"N | $6^0$'45'10.49" E | 42 m | Gas flaring activities, crude oil flow stations low commercial activities, residential buildings moderate vehicular and motorcycle traffic, few artisans' workshops, palm oil processing activities. |
| 3 | Ukwugba 2 | $5^0$32'39.94"N | $6^0$46'03.52" E | 34 m | No commercial activity, gas flaring in nearby towns residential building, low vehicular and motorcycle traffic, presence of crude oil well heads |
| 4 | Opuoma (control) | $5^0$35'38.80"N | $6^0$44'41.81" E | 41 m | very low vehicular and motorcycle traffic very scanty residential buildings, palm oil processing activities, no other visible commercial activities |

### 3. 3 Air Quality Parameters monitored

According to Wong, Tam, Lau, Ng, Yu, Wong, and Yeung, (2012) there are variations with respect to the selection of key air pollutants, as individual countries or jurisdictions seek to include pollutants that pose the most significant impact on their residents. Air pollutants commonly used in AQI or API (Air Quality Index or Air Pollution Index) includes nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), carbon monoxide (CO), suspended particulate matter ($PM_{10}$). Also, Hosseinibalam and Hejazi (2012) noted that nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), carbon monoxide (CO) and suspended particulate matter ($PM_{10}$) are among the main air pollutants.

Therefore, the research work monitored six key atmospheric pollutants including sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), particulate matter ($PM_{10}$), Volatile organic compound (VOC) and hydrogen sulphide. Also 7 metrological variables (relative humidity, wind speed, wind direction, wave height, air flow, elevation and ambient temperature) and geographical coordinates of the sampling stations were determined.

### 3.4 Reason for Choosing the Air Pollution Parameters measured

i. $SO_2$, $NO_2$, CO and $PM_{10}$ are among the air pollutants commonly use in air pollution index/ air quality index (API/AQI) (Wong, Tam, Lau, Ng, Yu, Wong & Yeung, 2012).
ii. These atmospheric pollutants are ubiquitous in urban air, widely recognized as posing a potential risk to population health and they are commonly regulated at national and international level (Sharad, 2009).
iii. $SO_2$ and $NO_2$ contribute so much to acid rain (Ideriah & Stanley, 2008) and sulphurous smog could results from high concentrations of sulphur dioxide due to burning of sulphur containing fossil fuels (Wright, 2003).
iv. $NO_2$ is one of the main pollutants that cause photochemical smog (Bhatia, 2002).
v. $SO_2$ is regarded as being the most important phytotoxic air pollutant emitted from industrial sources and $NO_2$ as the second most important (Fowler & Cape, 1982; Ashmore, 2005).
vi. This is also supported by the evidence that $SO_2$ and $NO_2$ are positively and significantly associated with mortality (Stieb, Judek & Burnett, 2002).
vii. $H_2S$ is considered as a broad spectrum toxicant due to most organs and systems are susceptible to its effects (Lana, 2006).

viii. Long term effect of VOC could result in loss of coordination, leukemia, anaemia, cancer and damage to liver, kidney and central nervous system (Eljarrat & Barcelo, 2003; Boughedaoui, Bounoue & Keddam, 2006).

ix. CO is of concern because of it's toxicity to humans, could reduce mental health, eventually leads to death and it contributes to the formation of $CO_2$ and ozone, greenhouse gases that warm the atmosphere (Manahan, 2001; Ocak & Turalioglu, 2008; DEFRA, 2013).

x. $PM_{10}$ is of concern because exposure to particulate matter emitted from anthropogenic processes, like incomplete combustion of coal, petrol and diesel fuels in furnaces, domestic heating systems and vehicle engines could cause respiratory distress, lung impairment and increased mortality (WHO, 1999).

xi. There has been a report of high level of particulate matter in most Nigerian cities (Akeredolu, 1989; Ikamaise, Obioh, Ofoezie & Akeredolu 2001; Koku & Osuntogun, 2007; Ngele & Onwu, 2015).

xii. In a 2002 report of the Air Pollution in the Megacities of Asia project (APMA, 2002), it was quoted that in Bangladesh's capital Dhaka, air pollution annually causes 3,580 premature deaths, 10 million restrictive activity days and 87 million respiratory symptom days at an economic cost of US$ 60-270 million.

xiii. The atmospheric variables relative humidity, wind speed, wind direction ambient temperature, air flow, elevation and wave height are considered here because these parameters could influence the concentration of ambient air pollutants (Ocak & Turalioglu, 2008; Hosseinibalam & Hejazi, 2012).

## 3.5 Data Collection/ Air Quality Monitoring

Sampling was carried out during wet and dry seasons. This is line with submission of Wong et al., (2012), who noted that network of air quality monitoring stations are set up to measure ambient concentrations of common pollutants at fixed intervals. The research work took place within the months of November 2014 to June 2015. This involves three months of dry season, starting from 3rd November 2014, three weeks in December and January then to 7th February 2015. Three months of wet season air quality monitoring starting from 6th April 2015 to 26th of June 2015 at the locations stated in Fig. 3.1 and Table 3.1 - 3.4.

## 3.6 Experimental Design

The atmospheric pollutants; $SO_2$, $NO_2$, CO, VOC, $H_2S$ and $PM_{10}$ were monitored in the geo-referenced locations stated in Fig. 3.1 and Table 3.1 - 3.4 for a period of six months during wet and dry seasons. This involves three months of dry season and three months of wet season air monitoring, three times a day, in the morning, afternoon and evening at the air quality monitoring sites. That is, 6 air pollutants at 16 air monitoring sites were measured 3 times a day, once a week and 4 times a month for six (6) months, which is a total of six thousand nine hundred and twelve (6,912) rounds of air quality data sampling.

In each round of ambient air sampling, 6 meteorological parameters were measured, in this case 6 meteorological parameters also equals to six thousand nine hundred and twelve (6.912) rounds of air sampling. In all, the research work involves a total of thirteen thousand, eight hundred and twenty four (13,824) round of air quality data sampling, in addition to elevation and coordinates that were measured once, that is 13,856, which is an enormous data set handled in this research work.

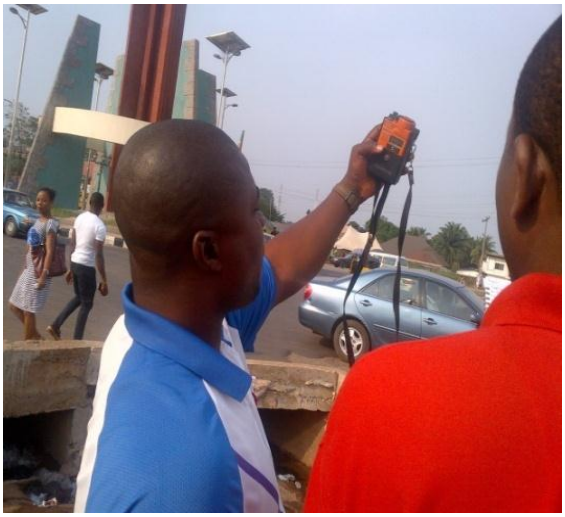
## 3.7 Instrument and Method of Air Sampling

Air samples were measured at a height of about 2 m above ground level at different locations including the control air sampling sites in the study areas as shown in Fig. 3.2. The procedure involved turning the knob to check the energy of the battery which shows “red light” beeping if the battery has energy, and turning the knob again to the gas mark which shows “green light” with beeping which indicates readiness. Then, the gas monitor is raised up and a reading taken from the display screen when the reading becomes steady. The particulate monitor when switched on is allowed for few minutes and then set range switch to “Hi” position before sampling. The instruments used in the research work are shown in Fig. 3.3a to 3.3h. Concentrations of the gaseous air pollutants (CO, $SO_2$ and $NO_2$) were measured using Gasman hand held gas monitor (Crowcon Instruments Ltd, England), $H_2S$ was measured with Aeroqual Series 300 (Aeroqual Ltd New Zealand), VOC was monitored with Ibrid MX6 (Industrial Scientific, USA ), particulate matter ($PM_{10}$) was measured with Haze-dust particulate monitor ($PM_{10}$) 10 µm, model HD 1000, Environmental Device Corporation, USA, while meteorological parameters were measured with Multifunctional Microprocessor digital meter Anemometer, model Am-4836C, China, relative humidity was determined by taking wet and dry bulb temperature of the hygrometer, and this was used to locate the relative humidity from a

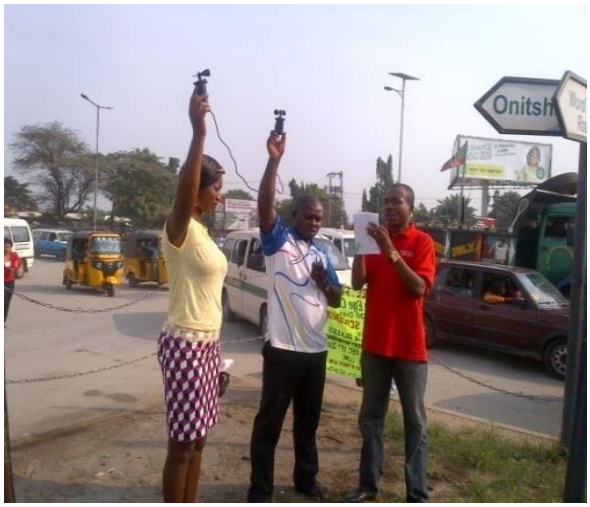
psychrometric chart or relative humidity table, while geographical coordinates and elevation were determined with Garmin, GPSmap 76. These instruments were provided by Laboratory Services and Environmental Research Department/UNIDO RAC for Pollution Monitoring and Assessment, Ministry of Environment and Petroleum, Imo State and Prime Mover Consult, Port Harcourt, also provided field assistance.

### 3.8 Calibration of the Air Pollution Monitors

The particulate monitor is factory calibrated, but it is important to perform the zero adjustment for particulate monitor in a clean environment; this is done with respect to the environment being monitored. $PM_{10}$ monitor is zeroed with the provided trim stick so that the display reads +0.001/-0.002 $mg/m^3$. After the adjustment the range switch is set at low position, this is done before it is taken to the field for $PM_{10}$ sampling. The gas monitors for $SO_2$, $NO_2$, $H_2S$, VOC and CO were reported as having been factory calibrated which is usually repeated every six months by experts.



(a)




(b)

(b)

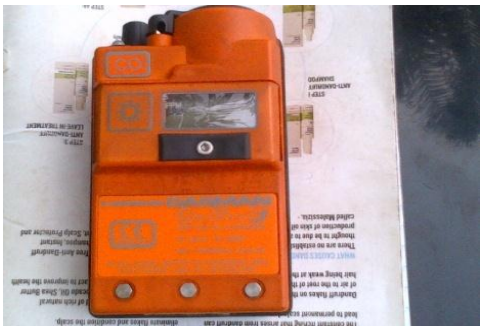
(d)

Fig 3.2 Air pollutants sampling at some monitoring locations

(a) Gasman $SO_2$ monitor

(b) Gasman $NO_2$ monitor


(c) Haze dust particulate monitor



(d) Gasman CO monitor


(e) Aeroqual 300 series for $H_2S$ gas

(f) VOC monitor (Ibrid MX6)

(g) Microprocessor digital Anemometer


(h) Garmin GPSmap76

Fig 3.3 Picture of some instruments used for air quality monitoring

### 3.9 Method of Data Interpretation

The air quality data obtained were evaluated and interpreted with descriptive statistics which relates to the organization and summarization of data and inferential statistics that draw conclusions as it regards to processes that generated the data (Wilks, 2006). Results were displayed using tables, charts and graphs. Box and whiskers plots were used to display the distribution of the underlying data in terms of the median, minimum, maximum, upper quartile and lower quartile values of the result.

One-way Analysis of Variance (ANOVA) ($P < 0.05$), Pearson product-moment correlation co-efficient, r, Hierarchical Cluster Analysis (HCA) and Principal Components Analysis (PCA) were computed with IBM SPSS Statistical Software version 20.

Arc GIS software version 10.2 was used to model the spatial variation map of the air pollutants under investigation in the study area. 3-D surface plots and contour plots of the air pollutants concentration were modeled using Surfer 12. Grapher 10 was used to develop the multivariate plots in order to show the relationship between the air pollutants and the meteorological variables. Similarly, Grapher 10 was used to model the wind rose diagram to elucidate the dominant wind direction and speed during the study. Sim – Air Quality software was used to develop the air quality index of the area under investigation. This was done using Eq. (3.2)

$$Ip = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (C_P - BP_{Lo}) + I_{Lo} \quad (3.1)$$

Where: Ip = the index for pollutant p

Cp = the rounded concentration of pollutant p

$BP_{Hi}$ = the breakpoint that is ≥ Cp

$BP_{Lo}$ = the breakpoint that is ≤ Cp

$I_{Hi}$ = the AQI value corresponding to $BP_{Hi}$

$I_{Lo}$ = the AQI value corresponding to $BP_{Lo}$

Furthermore, time series models were developed with Matlab 7.9 software in order to analyze and characterize the nature of the temporal correlations, or relationships with time, which is useful for forecasting future atmospheric pollutions events. The dynamic equations (models) were developed with Matlab 7.9 software, so as to be able to explain the migration and transportation of atmospheric pollutants. The dynamic equations were developed, taking into

considerations of the effect of five meteorological parameters [wind speed (WS), ambient temperature (AT), relative humidity (RH), air flow (AF) and wave height (WH)] and previous day concentration (PDC) of the measured atmospheric pollutants ($PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$). Multiple linear regression analysis were used and the dynamic equation for five independent variables were expressed as shown in Eq. (3.2) without previous day concentration and Eq. (3.3) with previous day concentration of the atmospheric pollutants.

$$y = b + b_1WS + b_2AT + b_3RH + b_4AF + b_5WH \quad (3.2)$$

$$y = b + b_1WS + b_2AT + b_3RH + b_4AF + b_5WH + b_6PDC \quad (3.3)$$

Where y is the dependent variables ($PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$), b is the regression constant, while WS, AT, RH, AF and WH are the independent variables and $b_1$, $b_2$….$b_n$ are the regression coefficients.

(It is important to note that most analysis could not be carried out on $H_2S$ due to low concentration of the air pollutant below the detection limit of the instrument in most of the locations sampled.)

# CHAPTER FOUR
# RESULTS AND DISCUSSION

## 4.1 Concentration of Air Pollutants in Dry Season

The summary of atmospheric pollutant concentration observed in the study locations in dry season is presented in Tables 4.1 to 4.6, while the raw air quality results are placed in appendix 10. The results are the summary of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ concentration recorded in the morning, afternoon and evening in the four zones studied with a total of 16 air quality sampling sites. The result as presented in Tables 4.1 - 4.6 indicates the maximum and minimum values, mean, standard deviation and variance. In Table 4.1, the mean value of $PM_{10}$ ($mg/m^3$) ranged 5.70 to 8.38. The highest mean value 8.38 $mg/m^3$ of $PM_{10}$ was recorded in the afternoon at Egbema while the lowest mean value was observed at Owerri in the morning. $PM_{10}$ result obtained from Okigwe showed a maximum value 12.38 $mg/m^3$ and a minimum value of 3.45 $mg/m^3$.

Table 4.1: Summary of $PM_{10}$ concentration ($mg/m^3$) in dry season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 8.93 | 11.33 | 9.34 | 10.20 | 12.38 | 11.13 | 8.91 | 10.13 | 9.20 | 9.93 | 10.63 | 10.15 |
| **MIN** | 4.55 | 5.43 | 6.04 | 3.45 | 5.00 | 5.25 | 5.13 | 6.35 | 6.80 | 6.00 | 6.38 | 6.08 |
| **MEAN** | 5.70 | 7.39 | 7.49 | 7.42 | 8.33 | 8.01 | 7.01 | 7.87 | 7.69 | 7.42 | 8.38 | 7.88 |
| **SD** | 1.21 | 1.62 | 1.04 | 1.86 | 2.19 | 1.91 | 1.02 | 1.35 | 0.85 | 1.16 | 1.46 | 1.47 |
| **VAR** | 1.45 | 2.63 | 1.08 | 3.46 | 4.78 | 3.66 | 1.03 | 1.81 | 0.72 | 1.35 | 2.14 | 2.16 |

(where M = morning, A = afternoon, E= evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

The mean $PM_{10}$ level obtained in this study is elevated when compared with the 24 hours and annual average guidelines of Nigerian NAAQS (National Ambient Air Quality Standards) (FRN Official gazette, 2011) and US NAAQS (US National Ambient Air Quality Standards) (EPA, 2010) of (150 $\mu g/m^3$). A similar result has been reported in a related study conducted in major towns located in South East States of Nigeria (Ngele & Onwu, 2015). Elevated values of $PM_{10}$ recorded in some study locations could be attributed to population growth, urbanization, industrialization, and increase in vehicular traffic, which could contribute significantly to the deterioration of air quality standards (Ravindra et al., 2001). Egbema is a rural area though with gas flare starks within and around the area (Egwurugwu et al., 2013), which could contribute to

$PM_{10}$ level. Agricultural activities in this area could have contributed significantly to the observed $PM_{10}$ level. This is supported by the fact that agricultural activities are responsible for approximately 18% of $PM_{10}$ emissions arising from wind erosion, tillage operations, animal movement and others as reported by Rhonda, (2015). Other agricultural practices such as bush burning may have contributed to the $PM_{10}$ level in this area (Arslan et al., 2010). The elevated $PM_{10}$ level observed in Okigwe area could be due to quarry and stone mining activities in this area. This is agreement with Nartey et al (2012), who submitted that dust emission is one of the major effects of quarrying activities. The episodic dust events of Sahara desert and its associated trans-boundary transportation (Roda, Bellot, Avila, Escarra, Piiiol &Terradas, 1993; Marconi, Sferlazzo, Becagli, Bommarito, Calzolai, Chiari, di Sarra, Ghedini, Gómez-Amo, Lucarelli, Meloni, Monteleone, Nava, Pace, Piacentino, Rugi, Severi, Traversi & Udisti, 2014), may have contributed to the elevated $PM_{10}$ level in the study locations.

The result presented in table 4.2 is the summary of $NO_2$ concentrations in (ppm) observed in dry season. It indicates that the mean value of $NO_2$ in (ppm) recorded in the study locations ranged from 0.37 to 0.53. The highest mean value, 0.53 ppm, was observed at Egbema in the afternoon, while the lowest mean value, 0.37 ppm, was recorded in the morning at Owerri. Also a maximum value of 0.65 ppm was recorded in the morning at Egbema, while a minimum value of 0.25 ppm was observed at Okigwe in the morning. The mean values of $NO_2$ recorded in this study as shown in Table 4.2 are above the US NAAQS 1 hour limit of 100 ppb and annual limit of 53 ppb (EPA, 2010). Mohammed and Caleb, (2014) reported elevated concentration of the air pollutant in the evening. Increased concentration of $NO_2$ has been reported in winter (Kim et al., 2015).

Table 4.2: Summary of $NO_2$ concentration (ppm) in dry season

| | **Owerri** | | | **Okigwe** | | | **Orlu** | | | **Egbema** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 0.46 | 0.56 | 0.51 | 0.63 | 0.63 | 0.53 | 0.63 | 0.63 | 0.52 | 0.65 | 0.64 | 0.63 |
| **MIN** | 0.26 | 0.33 | 0.39 | 0.25 | 0.25 | 0.28 | 0.42 | 0.37 | 0.42 | 0.31 | 0.44 | 0.35 |
| **MEAN** | 0.37 | 0.46 | 0.45 | 0.44 | 0.49 | 0.45 | 0.49 | 0.50 | 0.48 | 0.49 | 0.53 | 0.47 |
| **SD** | 0.06 | 0.06 | 0.05 | 0.11 | 0.11 | 0.09 | 0.07 | 0.06 | 0.04 | 0.10 | 0.07 | 0.08 |
| **VAR** | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

Table 4.3 is the summary of $SO_2$ concentrations in (ppm) observed in dry season. The result shows that the highest mean value of 0.61 ppm and maximum value of 0.92 ppm was recorded in the evening at Egbema. The lowest mean value of 0.29 ppm was observed at Okigwe in the morning, while the minimum value of 0.19 ppm was recorded in the morning at Owerri. Ubuoh and Akhionbare, (2011) reported $SO_2$ mean value of 0.60 ppm in Egbeda, Mbaitoli LGA Imo state Nigeria. Also, Olatunde and Akinsoji (2013) in related study carried out in Ibadan, Nigeria reported a similar result. Higher mean value of 1.4 $mg/m^3$ was reported for $SO_2$ in a similar study in Port Harcuort (Weli & Ayoade, 2014). The mean values of $SO_2$ reported in the present study as shown in Table 4.3 for Egbema in the afternoon and evening exceeded the US NAAQS 3 hour's 0.5 ppm limit for $SO_2$

Table 4.3: Summary of $SO_2$ concentration (ppm) in dry season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 0.66 | 0.56 | 0.85 | 0.41 | 0.51 | 0.50 | 0.55 | 0.63 | 0.60 | 0.58 | 0.83 | 0.92 |
| **MIN** | 0.19 | 0.26 | 0.39 | 0.21 | 0.21 | 0.20 | 0.33 | 0.32 | 0.33 | 0.26 | 0.24 | 0.42 |
| **MEAN** | 0.37 | 0.39 | 0.49 | 0.29 | 0.39 | 0.34 | 0.42 | 0.48 | 0.45 | 0.47 | 0.55 | 0.61 |
| **SD** | 0.14 | 0.10 | 0.12 | 0.06 | 0.09 | 0.09 | 0.07 | 0.10 | 0.09 | 0.11 | 0.18 | 0.16 |
| **VAR** | 0.02 | 0.01 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

The result shown in Table 4.4 is the summary of CO concentration (ppm) observed in dry season. It indicates that the mean value of CO (ppm) ranged from 35.81 to 49.52. The highest mean value of 49.52 was observed in the evening at Egbema, while the lowest mean value was recorded in the morning at Owerri. Maximum value of 50 to 52 ppm were recorded in all the locations except Orlu. The mean values of these results indicate elevated values of CO above permitted limit in all the study locations. Higher mean values were observed at Egbema which also could be linked to gas flaring activities within and around

Table 4.4: Summary of CO concentration (ppm) in dry season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 40.75 | 46.75 | 50.75 | 50.00 | 48.00 | 49.25 | 46.75 | 47.25 | 49.25 | 52.00 | 50.00 | 50.50 |
| **MIN** | 31.25 | 31.00 | 38.25 | 33.00 | 35.50 | 35.25 | 37.75 | 37.00 | 38.25 | 44.25 | 39.00 | 47.75 |
| **MEAN** | 35.81 | 39.25 | 43.75 | 43.17 | 44.60 | 45.17 | 42.42 | 43.29 | 42.33 | 46.92 | 46.23 | 49.52 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SD** | 3.40 | 4.87 | 4.21 | 5.13 | 3.48 | 3.81 | 2.64 | 2.91 | 3.22 | 2.35 | 3.36 | 0.92 |
| **VAR** | 11.57 | 23.76 | 17.76 | 26.28 | 12.11 | 14.53 | 6.98 | 8.48 | 10.39 | 5.52 | 11.30 | 0.85 |

(where M = morning, A= afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

this location. These values are far above Nigerian NAAQS and US NAAQS. Elevated values of CO were observed in the afternoon and evening compared to morning hours as shown in Table 4.4, which could be due to higher vehicular and commercial activities in the area (Johnson et al., 2000; Ojolo et al., 2007). Elevated levels of CO have been reported due to incomplete combustion in vehicle engines and biomass burnings (de Souza et al, 2014). Lower mean values of CO were reported in Blantyre, Malawi (Mapoma et al., 2014).

Table 4.5 is the summary of VOC concentrations in ($mg/m^3$) observed in dry season. The result presented in Table 4.5 indicates that the mean values of VOC ($mg/m^3$) ranged from 0.47 in the evening at Okigwe to 1.33 in the morning at Egbema. The lowest minimum value (0.30 $mg/m^3$) was recorded at Okigwe in the evening, while the highest maximum value of 2.76 was observed in the evening at Egbema. Again, elevated mean values of VOC were recorded in Egbema which also may not be unconnected to gas flaring and crude oil related activities in this location. Higher mean values (5.20 $mg/m^3$) of VOC has been reported (Gobo et al, 2012). Ojiodu et al. (2012) reported that VOCs concentrations observed in the study location depends mainly on industrial activities such as industrial solvent usage, petrochemical processes, storage and distribution of chemicals, combustion processes, vehicular / petroleum product emission and meterological factor such as wind speed, direction of wind, humidity, rainfall and temperature.

Table 4.5: Summary of VOC concentration ($mg/m^3$) in dry season

| | **Owerri** | | | **Okigwe** | | | **Orlu** | | | **Egbema** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 0.88 | 0.85 | 0.65 | 0.95 | 0.78 | 0.63 | 1.29 | 0.95 | 0.90 | 1.53 | 1.25 | 2.76 |
| **MIN** | 0.53 | 0.48 | 0.35 | 0.63 | 0.40 | 0.30 | 0.83 | 0.70 | 0.51 | 1.13 | 0.95 | 0.90 |
| **MEAN** | 0.73 | 0.61 | 0.51 | 0.83 | 0.62 | 0.47 | 1.07 | 0.84 | 0.67 | 1.33 | 1.10 | 1.14 |
| **SD** | 0.11 | 0.10 | 0.09 | 0.11 | 0.12 | 0.11 | 0.14 | 0.09 | 0.10 | 0.12 | 0.09 | 0.52 |
| **VAR** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.27 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

Table 4.6 is the summary of observed $H_2S$ concentrations (ppm) in dry season. The result as shown in Table 4.6 indicates that the air pollutant was not detected or below detection limit (0.001 ppm) of the instrument (Aeroqual 300 series) used for sampling in most of the air

sampling locations. The mean values of $H_2S$ (ppm) ranged from 0.001 to 0.05. The highest mean value (0.05 ppm) was recorded in the afternoon at Owerri. A maximum value of 0.06 ppm was recorded at Egbema in the morning. Gobo et al. (2012) reported a mean value of 0.20 ppm of $H_2S$ in a related study conducted in Okirika, River State in dry season. The gas, hydrogen sulphide results from natural and anthropogenic activities. About 90 % of the total hydrogen sulphide emitted into the ambient environment results from natural emissions (US EPA, 1993). Hill, (1973) reported that hydrogen sulphide is emitted naturally via broad based and anaerobic bacterial reduction of sulphates and sulphur-containing organic compounds. Hydrogen sulphide occurs naturally in crude petroleum, natural gas, volcanic gases, and hot springs and in groundwater sources (OSU, 2001).

Table 4.6: Summary of $H_2S$ concentration (ppm) in dry season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 0.02 | 0.10 | 0.01 | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 | 0.06 | 0.01 | 0.01 |
| **MIN** | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| **MEAN** | 0.01 | 0.05 | 0.01 | 0.01 | 0.01 | ND | 0.01 | 0.01 | 0.00 | 0.02 | 0.00 | 0.01 |
| **SD** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | ND | 0.00 | 0.02 | 0.00 | 0.01 |
| **VAR** | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | ND | 0.00 | ND | 0.00 | 0.00 | 0.00 | 0.00 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance, ND = not detected)

## 4.2 Concentration of Air Pollutsnts in Wet Season

Tables 4.7 to 4.17 are the summary of atmospheric pollutant concentrations recorded in the study locations in wet season, while the raw results are also presented in appendix 10. The Tables are the summary of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ concentrations recorded in the morning, afternoon and evening in the four zones studied. Table 4.7 shows the summary of $PM_{10}$ concentrations ($mg/m^3$) observed in wet season. The results indicate that in wet season the $PM_{10}$ ($mg/m^3$) mean values ranged from 4.91 in the morning at Egbema to 7.34 in the afternoon at Okigwe. The maximum value 10.10 $mg/m^3$ was observed at Okigwe in the evening, while the minimum value 3.73 $mg/m^3$was recorded in the morning at Orlu. The mean values of $PM_{10}$ observed in wet season are also elevated when compared with the permitted emission limit of Nigerian NAAQS and US NAAQS (150 $\mu g/m^3$).

Table 4.7: Summary of $PM_{10}$ concentration ($mg/m^3$) in wet season

| | Owerri | Okigwe | Orlu | Egbema |
|---|---|---|---|---|

| | M | A | E | M | A | E | M | A | E | M | A | E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAX** | 6.43 | 7.30 | 7.31 | 6.93 | 9.20 | 10.10 | 6.95 | 8.51 | 8.88 | 5.70 | 8.73 | 8.12 |
| **MIN** | 4.18 | 4.90 | 5.38 | 4.89 | 6.35 | 6.86 | 3.73 | 5.60 | 6.40 | 3.90 | 6.18 | 6.09 |
| **MEAN** | 5.20 | 5.92 | 6.44 | 6.19 | 7.34 | 6.78 | 5.03 | 6.90 | 7.20 | 4.91 | 7.00 | 6.33 |
| **SD** | 0.61 | 0.64 | 0.54 | 0.58 | 0.78 | 0.90 | 0.86 | 0.86 | 0.75 | 0.55 | 0.78 | 0.64 |
| **VAR** | 0.37 | 0.41 | 0.30 | 0.34 | 0.61 | 0.81 | 0.74 | 0.74 | 0.56 | 0.30 | 0.60 | 0.41 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

The result presented in Table 4.8 is the summary of $NO_2$ concentrations (ppm) observed in wet season. It indicates that the concentration of $NO_2$ in (ppm) ranged from 0.43 in the morning at Orlu to 0.59 in the afternoon at Egbema. The result further revealed that the highest maximum value of 0.76 ppm was recorded at Okigwe in the evening, while the lowest minimum value of 0.33 was observed at Orlu in the morning. The results also indicate elevated values $NO_2$ which exceeded the US annual NAAQS limit of 53 ppb. The elevated $NO_2$ level in the wet season could still be attributed to vehicular traffic, use of three engine tricycles and the increased use of power generating sets (Ibe, Njoku, Alinnor & Opara, 2016). Also meteorological factors such as wind speed, wind direction, elevation, airflow, temperature and relative humidity may have influenced the observed $NO_2$ level in the wet season. Mapoma et al., (2014) noted that lower wind speed and steady wind direction could reduce the dilution of air pollutant concentrations. They further stated that elevated temperatures cause lower level air to rise, which could increase the concentration of atmospheric pollutants.

Table 4.8: Summary of $NO_2$ concentration (ppm) in wet season

| | **Owerri** | | | **Okigwe** | | | **Orlu** | | | **Egbema** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | E | M | A | E | M | A | E | M | A | E |
| **MAX** | 0.63 | 0.63 | 0.57 | 0.68 | 0.75 | 0.76 | 0.55 | 0.61 | 0.60 | 0.61 | 0.70 | 0.71 |
| **MIN** | 0.35 | 0.45 | 0.45 | 0.38 | 0.43 | 0.51 | 0.33 | 0.43 | 0.44 | 0.40 | 0.50 | 0.54 |
| **MEAN** | 0.45 | 0.51 | 0.52 | 0.50 | 0.58 | 0.59 | 0.43 | 0.49 | 0.52 | 0.51 | 0.59 | 0.56 |
| **SD** | 0.08 | 0.06 | 0.03 | 0.08 | 0.09 | 0.07 | 0.06 | 0.05 | 0.05 | 0.07 | 0.07 | 0.06 |
| **VAR** | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

The summary of $SO_2$ concentrations (ppm) observed in wet season is presented in Table 4.9. The result shows that the mean value of $SO_2$ (ppm) in wet season ranged from 0.43 in the morning at Orlu to 0.59 in the afternoon at Owerri. Also the highest maximum value of 0.81 ppm was recorded in the evening at Owerri, while the lowest minimum value of 0.32 ppm was observed at Okigwe in the morning. The results indicate that higher mean values of $SO_2$ were

recorded in Owerri. The mean $SO_2$ level observed in some of the locations exceeded the US NAAQS 3 hour's 0.50 ppm limit. Sulphur dioxide occurs naturally in the environment in hot springs and volcanoes, is produced from the decay of vegetation on land, in wetlands and in oceans. Sulphur dioxide is emitted from exhaust into the atmosphere by cars, buses and trucks (DEH, 2005).

Table 4.9: Summary of $SO_2$ concentration (ppm) in wet season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 0.64 | 0.77 | 0.81 | 0.57 | 0.63 | 0.66 | 0.61 | 0.68 | 0.67 | 0.61 | 0.78 | 0.70 |
| **MIN** | 0.38 | 0.49 | 0.52 | 0.32 | 0.39 | 0.45 | 0.38 | 0.45 | 0.47 | 0.37 | 0.44 | 0.45 |
| **MEAN** | 0.50 | 0.59 | 0.58 | 0.43 | 0.51 | 0.54 | 0.51 | 0.58 | 0.60 | 0.48 | 0.58 | 0.46 |
| **SD** | 0.08 | 0.09 | 0.06 | 0.08 | 0.07 | 0.06 | 0.08 | 0.08 | 0.08 | 0.08 | 0.10 | 0.10 |
| **VAR** | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

(where M= morning, A= afternoon, E= evening, Min = minimum value, Max = maximum value, SD= Standard deviation, VAR= variance)

Table 4.10: Summary of CO concentration (ppm) in wet season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **MAX** | 31.75 | 37.00 | 40.00 | 39.75 | 45.00 | 46.25 | 37.50 | 40.50 | 43.75 | 35.00 | 40.50 | 44.25 |
| **MIN** | 21.25 | 32.25 | 36.25 | 28.50 | 38.75 | 39.75 | 23.50 | 29.50 | 34.75 | 18.75 | 26.25 | 36.50 |
| **MEAN** | 28.06 | 34.90 | 38.19 | 34.58 | 41.77 | 43.63 | 31.75 | 37.44 | 41.44 | 26.42 | 35.08 | 40.08 |
| **SD** | 2.68 | 1.72 | 1.38 | 3.05 | 2.02 | 1.97 | 3.56 | 2.89 | 2.42 | 4.32 | 3.72 | 2.45 |
| **VAR** | 7.21 | 2.95 | 1.91 | 9.30 | 4.08 | 3.89 | 12.68 | 8.35 | 5.88 | 18.65 | 13.86 | 5.99 |

(where M = morning, A = afternoon, E= evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

Summary of CO concentrations (ppm) observed in wet season is presented in Table 4.10. The mean value of CO (ppm) obtained in wet season as shown in Table 4.10 ranged from 26.42 in the morning at Egbema to 43.63 in the afternoon at Okigwe. Apart from higher mean values of CO observed at Okigwe, the maximum value of 46.25 (ppm) was also recorded at the same location while the minimum value of 18.75 ppm was observed at Egbema. The values of CO recorded in some of the locations in the wet season also exceeded the 8 hour (9 ppm) and 1 hour (35 ppm) limit of US NAAQS.

Table 4.11: Summary of VOC concentration ($mg/m^3$) in wet season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | E | M | A | E | M | A | E | M | A | E |
| **MAX** | 0.70 | 0.55 | 0.38 | 0.75 | 0.53 | 0.43 | 0.85 | 0.53 | 0.38 | 1.23 | 1.05 | 0.88 |
| **MIN** | 0.45 | 0.25 | 0.15 | 0.45 | 0.28 | 0.18 | 0.48 | 0.33 | 0.18 | 0.78 | 0.60 | 0.40 |
| **MEAN** | 0.56 | 0.40 | 0.25 | 0.62 | 0.41 | 0.28 | 0.62 | 0.43 | 0.27 | 1.06 | 0.79 | 0.60 |
| **SD** | 0.09 | 0.10 | 0.08 | 0.10 | 0.08 | 0.06 | 0.10 | 0.06 | 0.06 | 0.15 | 0.14 | 0.14 |
| **VAR** | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 |

(where M = morning, A = afternoon, E= evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance)

The results presented in Table 4.11 are the summary of VOC concentrations ($mg/m^3$) observed in wet season. The results indicate that the mean value of VOC ($mg/m^3$) in wet season ranged from 0.25 in the evening at Owerri to 1.06 in the morning at Egbema. The maximum value of 1.23 was also recorded at Egbema in the morning, while the minimum value of 0.15 was observed in the evening at Owerri. Again, elevated value of VOC was observed at Egbema which could still be linked to activities of the protroleum industries within and around this area.

Table 4.12: Summary of $H_2S$ concentration(ppm) in wet season

| | Owerri | | | Okigwe | | | Orlu | | | Egbema | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | E | M | A | E | M | A | E | M | A | E |
| **MAX** | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 |
| **MIN** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| **MEAN** | 0.00 | ND | ND | 0.01 | 0.00 | ND | 0.01 | ND | ND | 0.01 | 0.01 | ND |
| **SD** | 0.00 | ND | ND | 0.01 | ND | ND | 0.01 | ND | ND | 0.01 | ND | ND |
| **VAR** | 0.00 | ND | ND | 0.00 | ND | ND | 0.00 | ND | ND | 0.00 | ND | ND |

(where M = morning, A = afternoon, E = evening, Min = minimum value, Max = maximum value, SD = Standard deviation, VAR = variance, ND = no detected)

Table 4.12 is the summary of $H_2S$ (ppm) concentrations observed in wet season in the study locations. The results show that the mean value of $H_2S$ recorded in wet season ranged from 0.001 to 0.01. In wet season, the air pollutant was not detected in most of the air quality monitoring sites due to its low background concentration below detection limit of the instrument. Ubuoh and Akhionbare, (2011) recorded a 0.24 ppm of $H_2S$, 200 m away from a pig farm in Imo State, while Gobo et al (2012) observed a mean value of 0.1 ppm in the entire air sampling sites in Okirika, Rivers State in rainy season. This is comparable to the result of this study.

## 4.3 Presentation of Result of Measured Meteorological Parameters

Results of measured meteorological parameters are presented with contour and 3-D surface plots. The raw results of the measured meteorological parameters are presented in Appendix 11.

### 4.3.1 Dry Season Contour and 3-D Surface Plots of Meteorological Parameters

The dry season contour and 3-D surface plots of the measured meteorological parameters including; wind speed, wind direction, ambient temperature, relative humidity wave height, elevation, and air flow for dry season are presented in Fig. 4.1 to 4.14. The observed level of each meteorological parameter is shown with colours and values of the colours are also clearly indicated with the unit of the meteorological parameter.

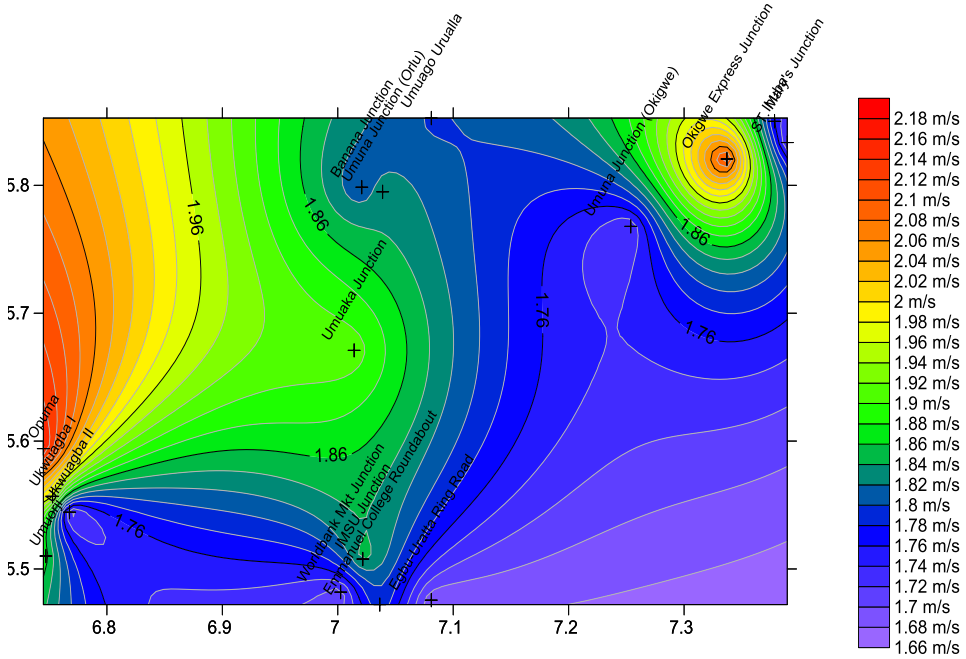



Fig. 4.1: Contour plot of wind Speed (dry season)

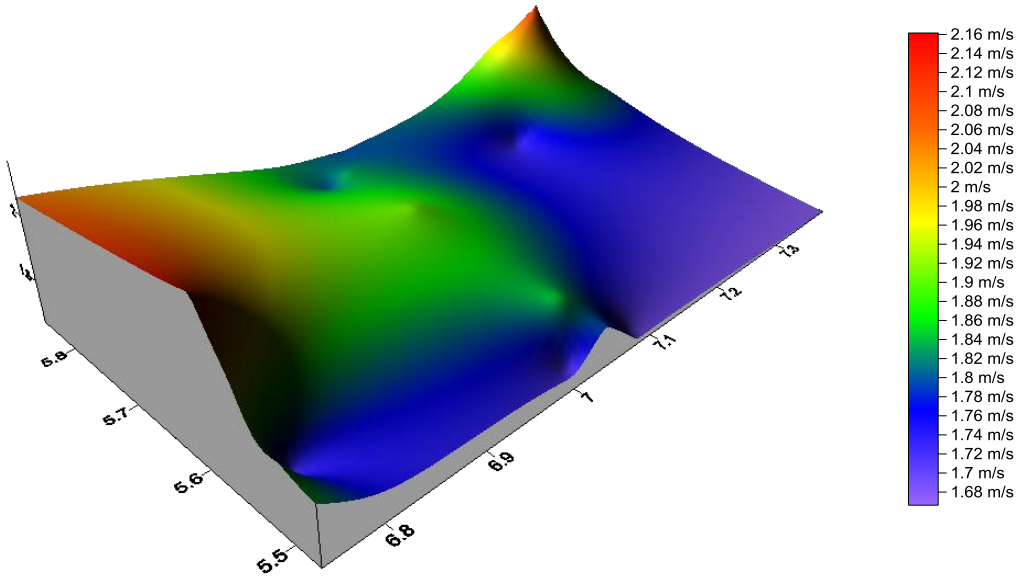



Fig.4.2 : 3-D surface plot of wind Speed (dry season)

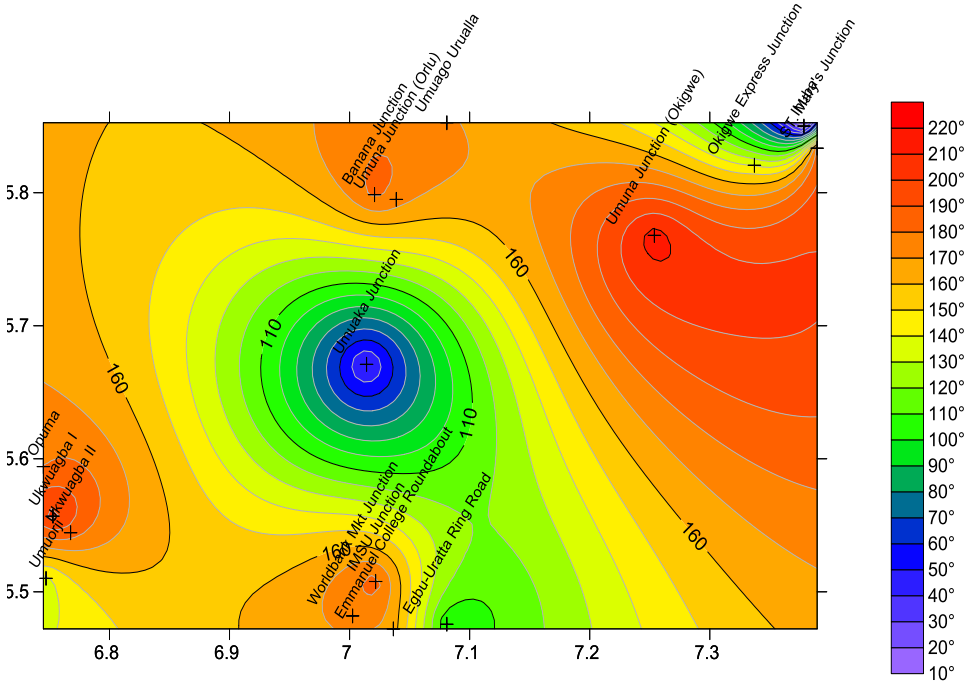



Fig. 4.3: Contour plot of wind direction (dry season)

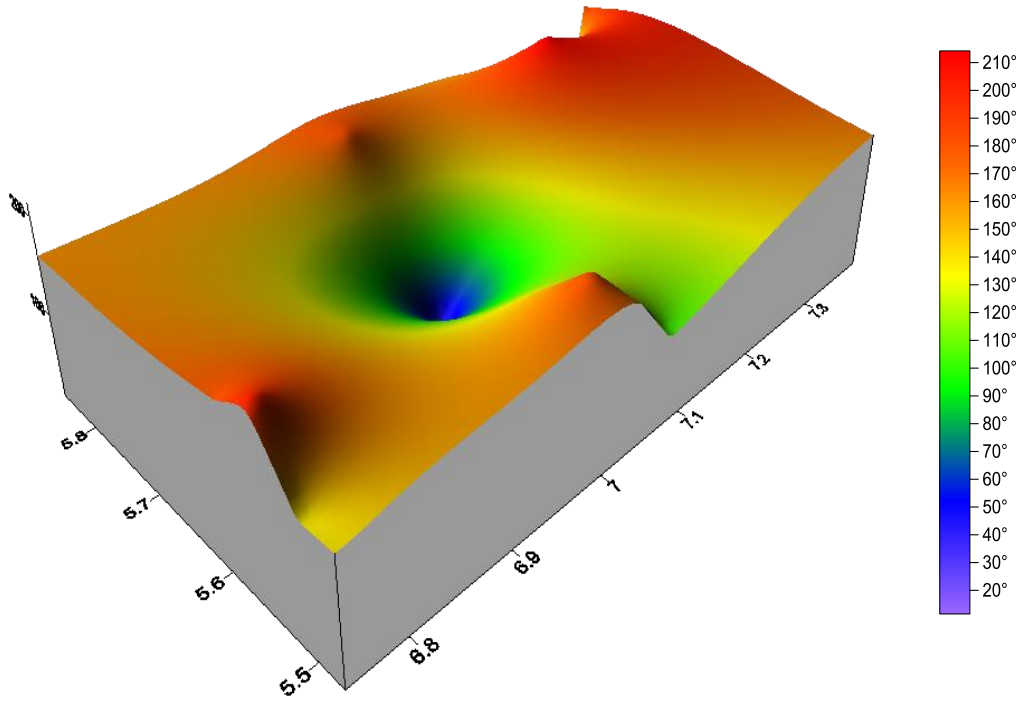



Fig.4.4: 3-D surface plot of wind direction (dry season)

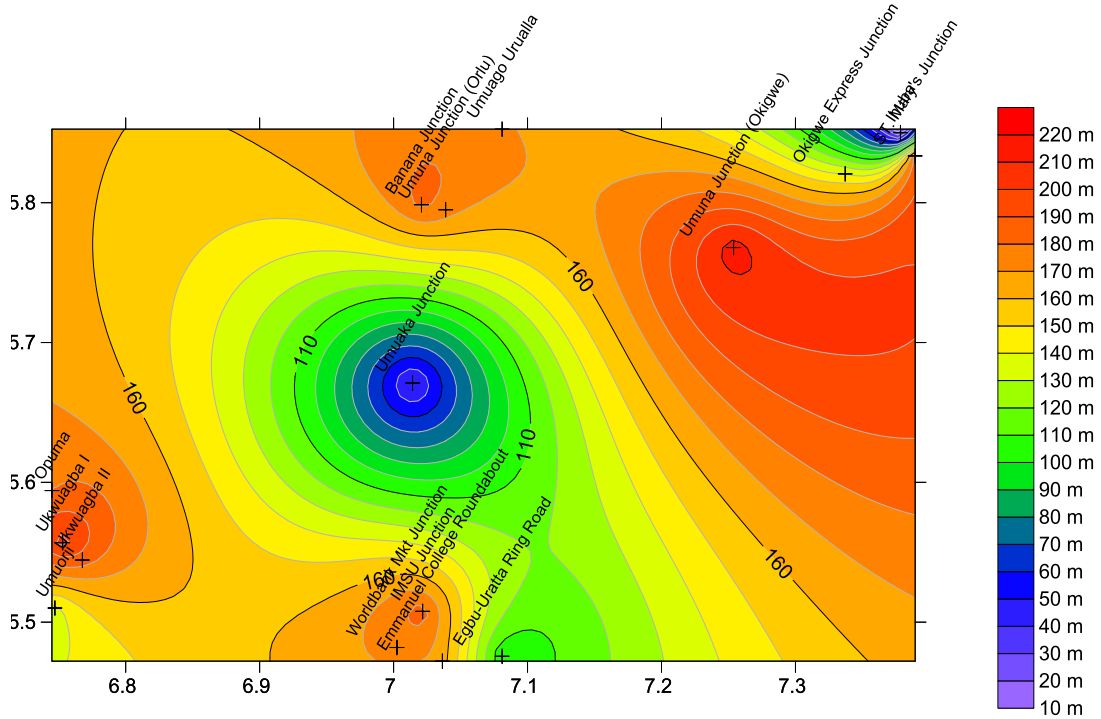



Fig. 4.5: Contour plot of wave height (dry season)

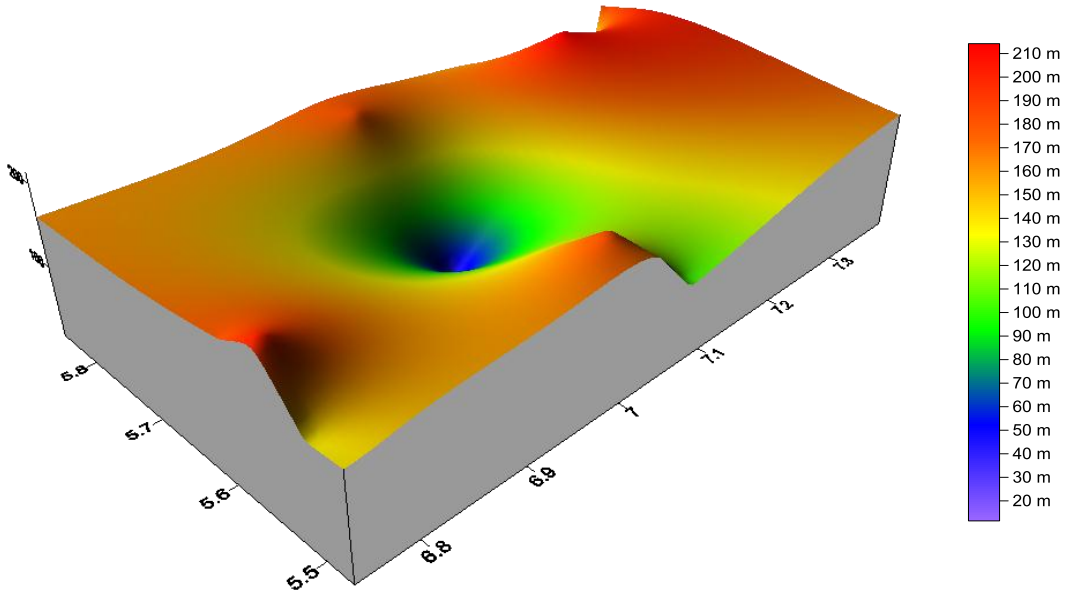



Fig. 4.6: 3-D surface plot of wave height (dry season)

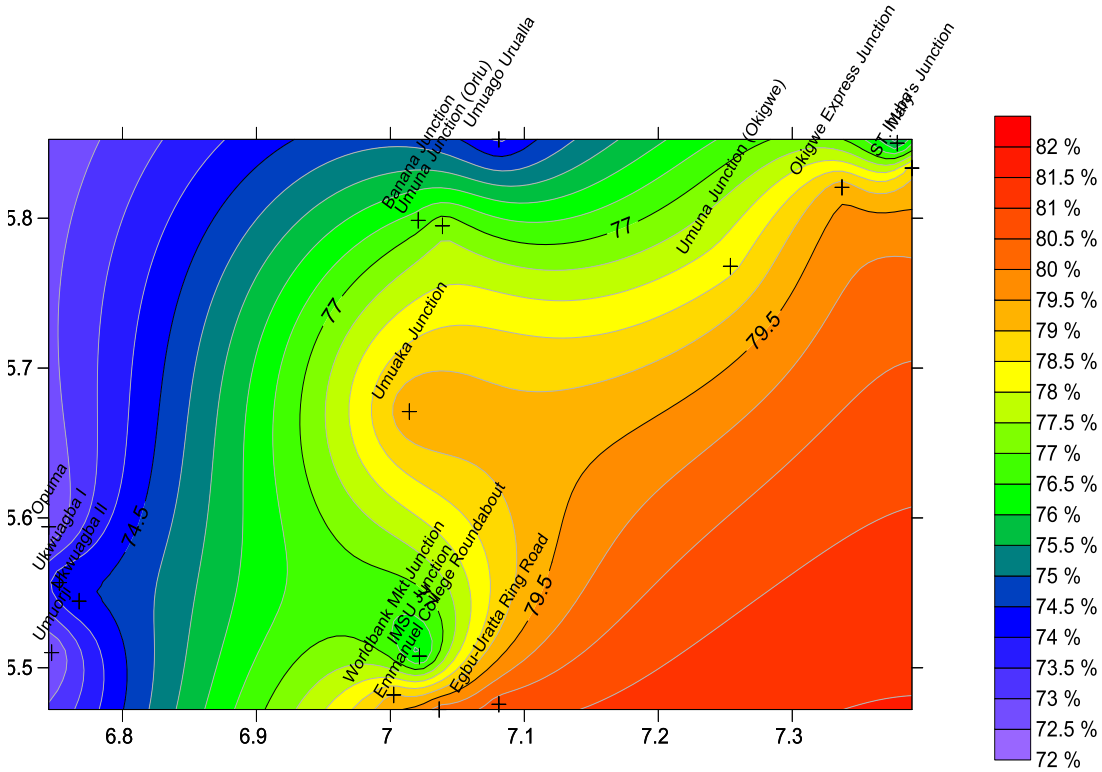



Fig. 4.7: Contour plot of relative humidity (dry season)

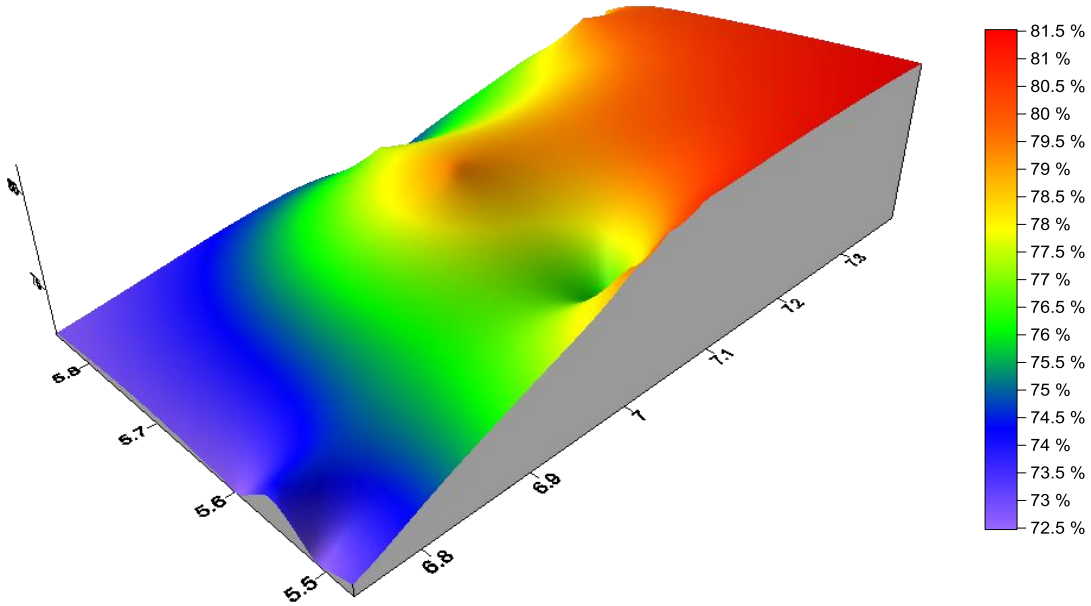



Fig.4.8: 3-D surface plot of relative humidity (dry season)

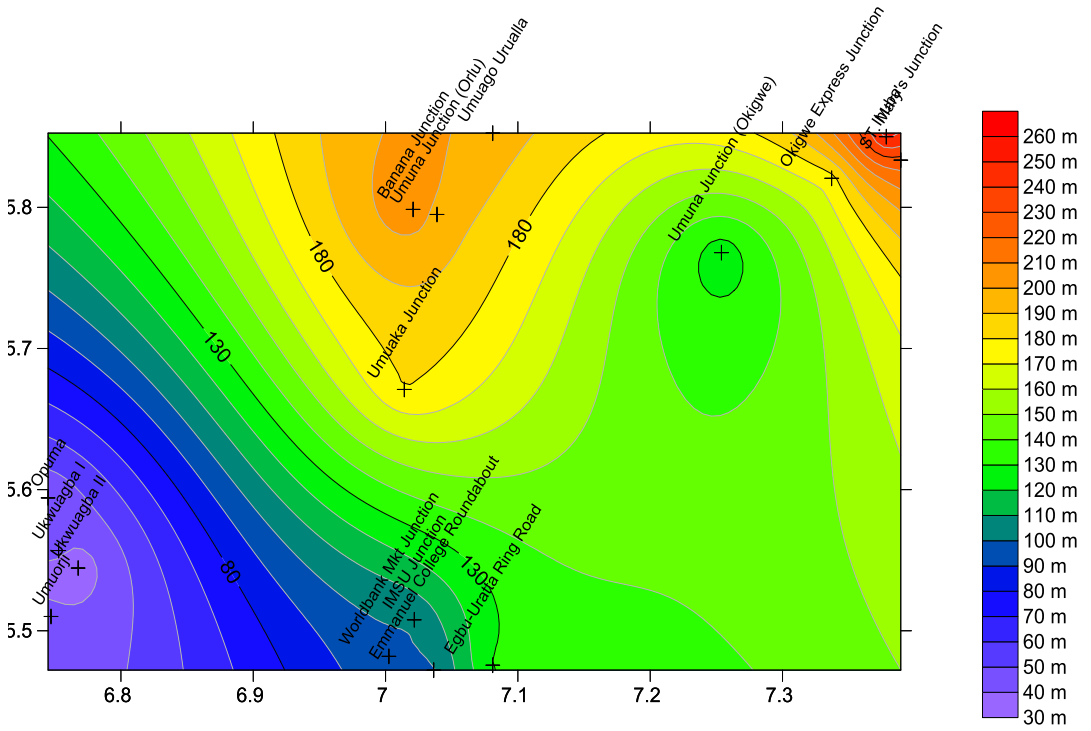



Fig. 4.9: Contour plot of elevation (dry season)

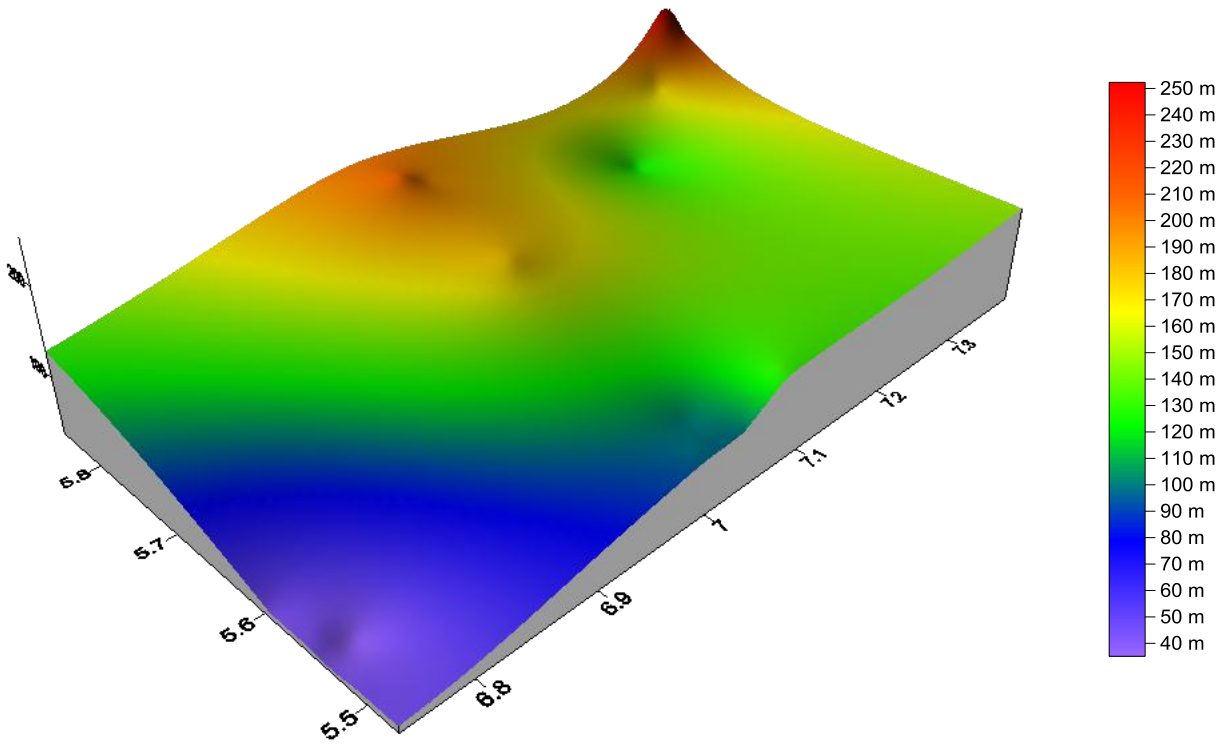



Fig. 4.10: 3-D surface plot of elevation (dry season)

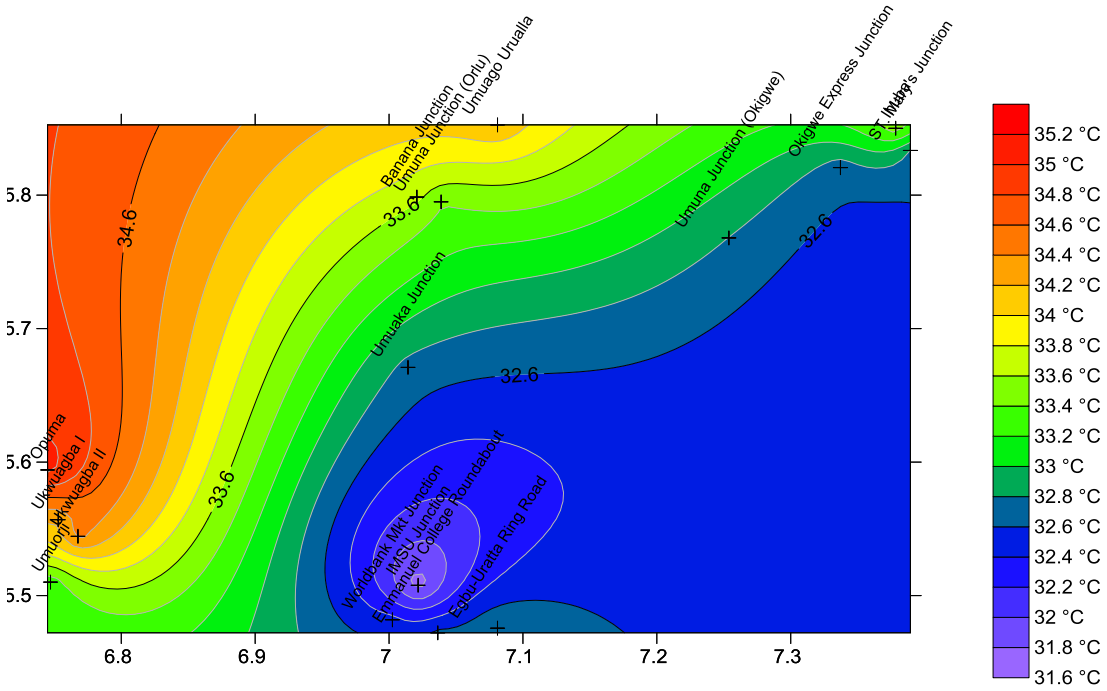



Fig. 4.11: Contour plot of ambient temperature (dry season)

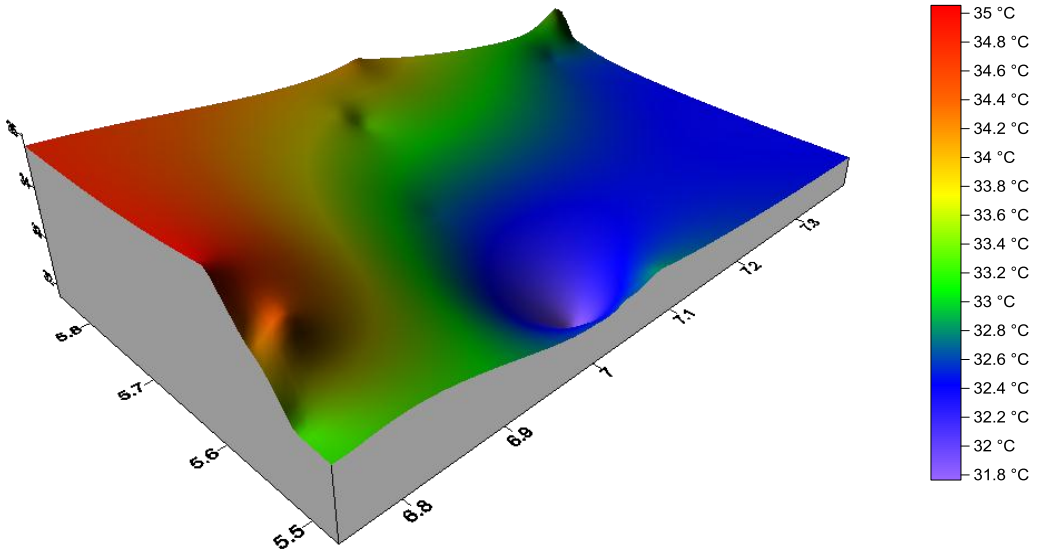



Fig. 4.12: 3-D surface plot of ambient temperature (dry season)

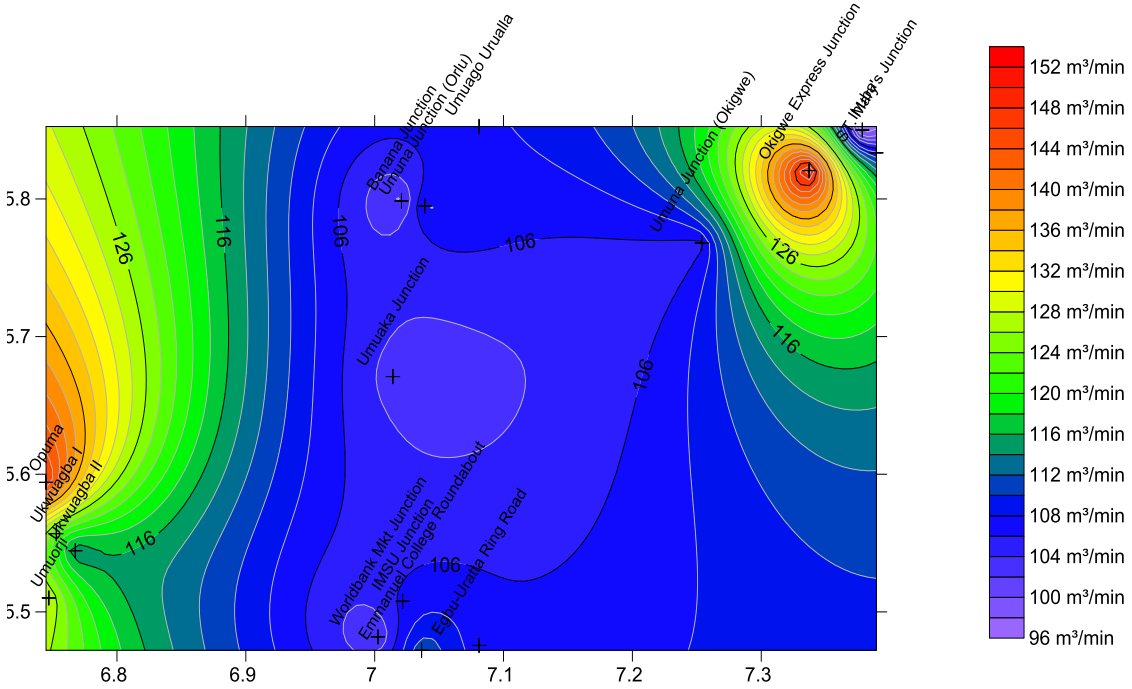



Fig. 4.13: Contour plot of air flow (dry season)

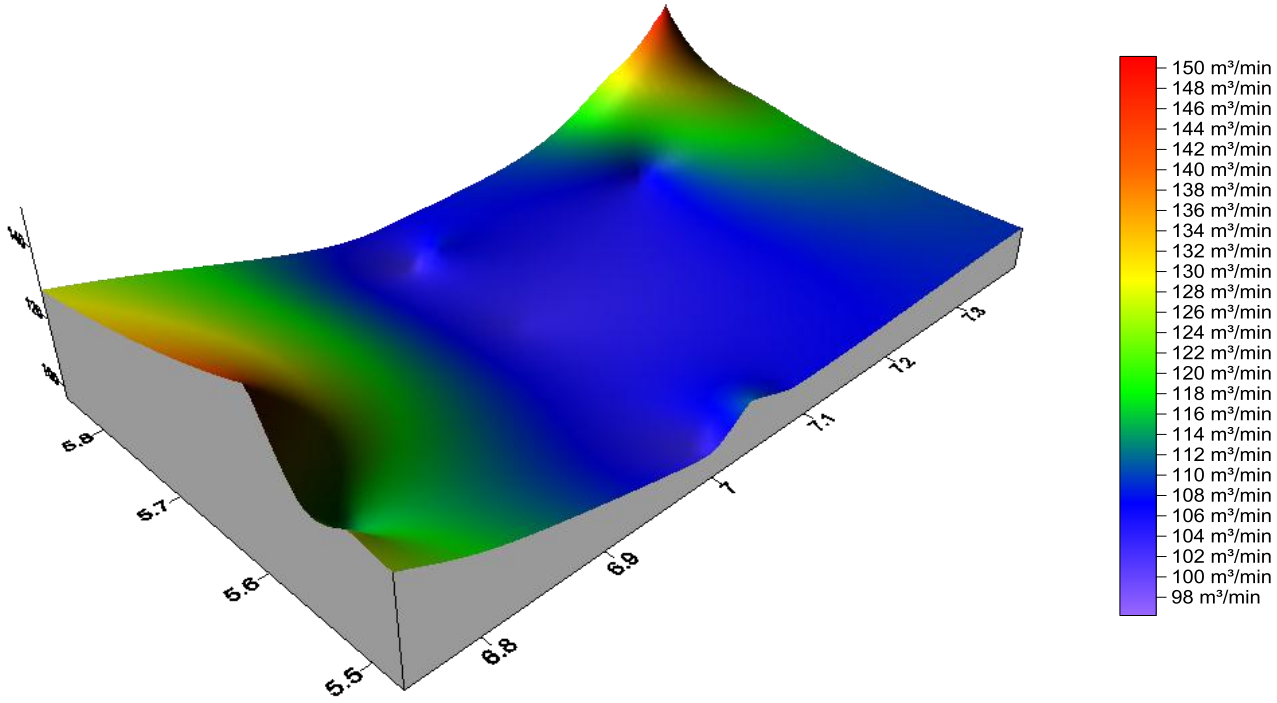



Fig. 4.14: 3-D surface plot of air flow (dry season)

### 4.3.2 Wet Season Contour and 3-D Surface Plots of Meteorological Parameters

The wet season contour and 3-D surface plots of the measured meteorological parameters including; wind speed, wind direction, ambient temperature, relative humidity wave height, elevation, and air flow are presented in Fig. 4.15 to 4.28. Also the observed level of each meteorological parameter is shown in colours. Values of the colours are also clearly indicated in units of the meteorological parameters.

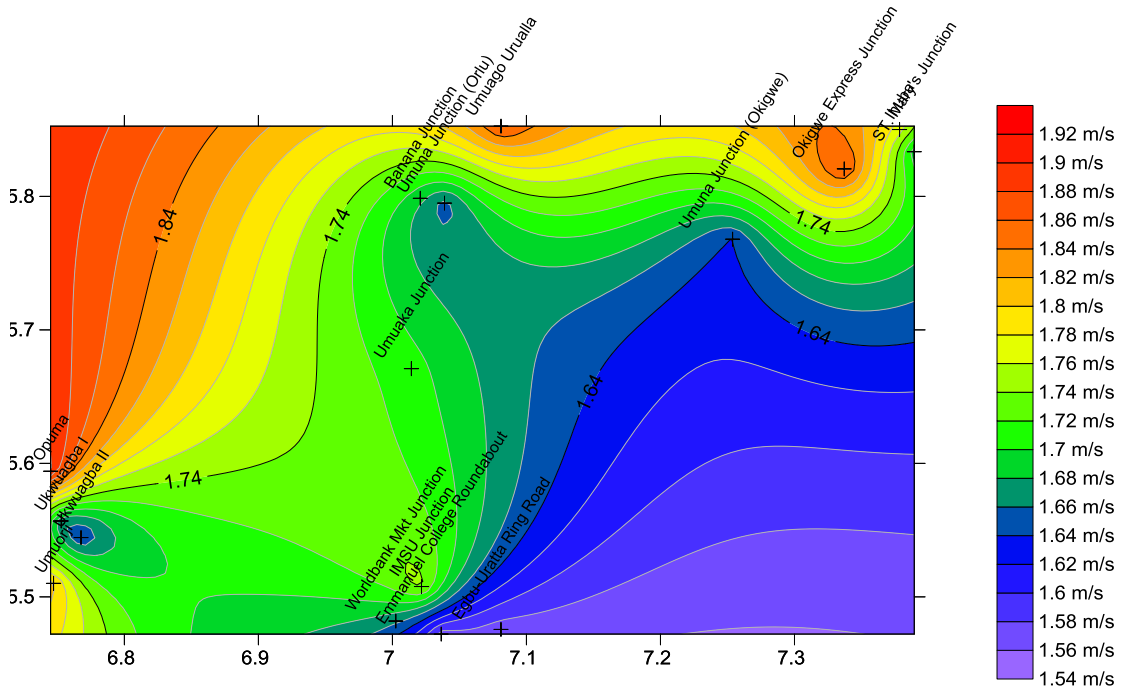



Fig. 4.15: Contour plot of Wind speed (wet season)

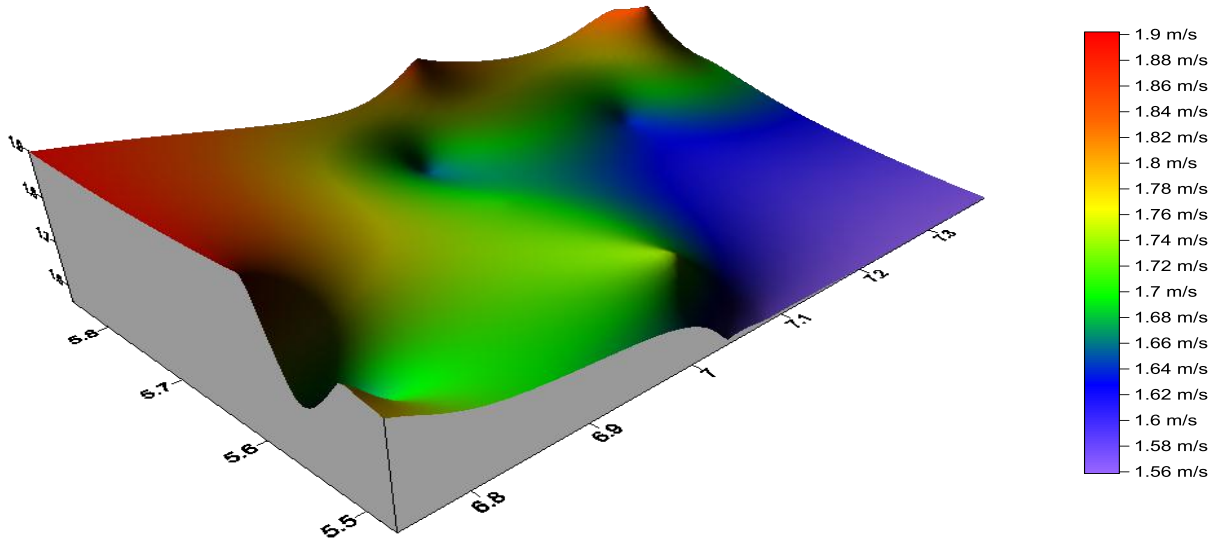



Fig. 4.16: 3-D Surface plot of Wind speed (wet season)

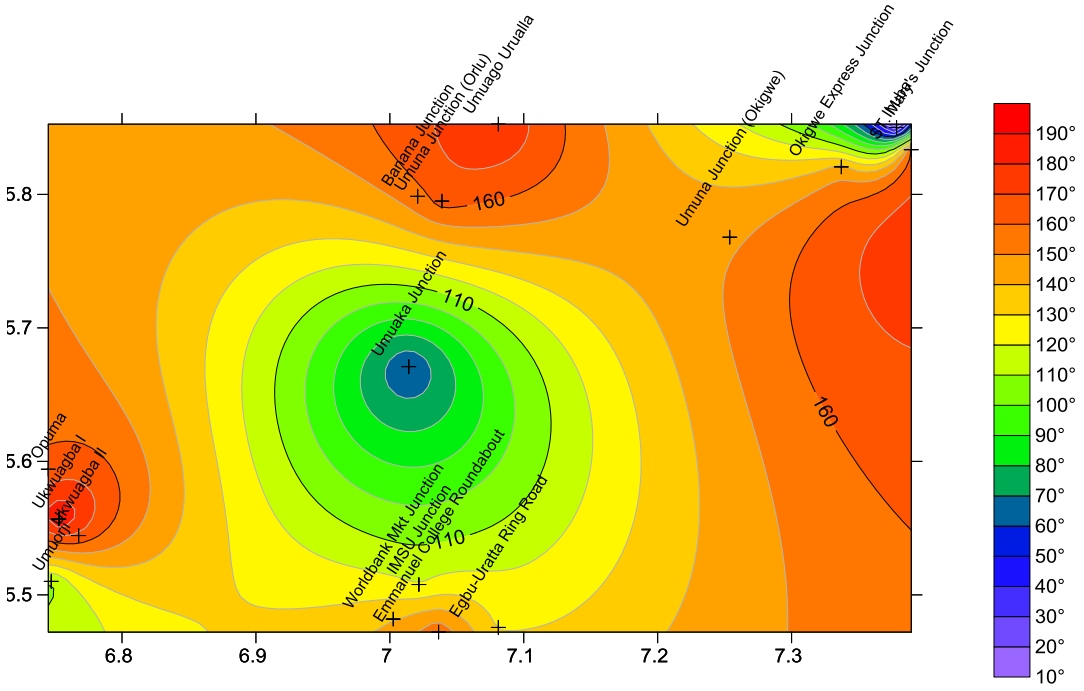



Fig. 4.17: Contour plot of Wind direction (wet season)

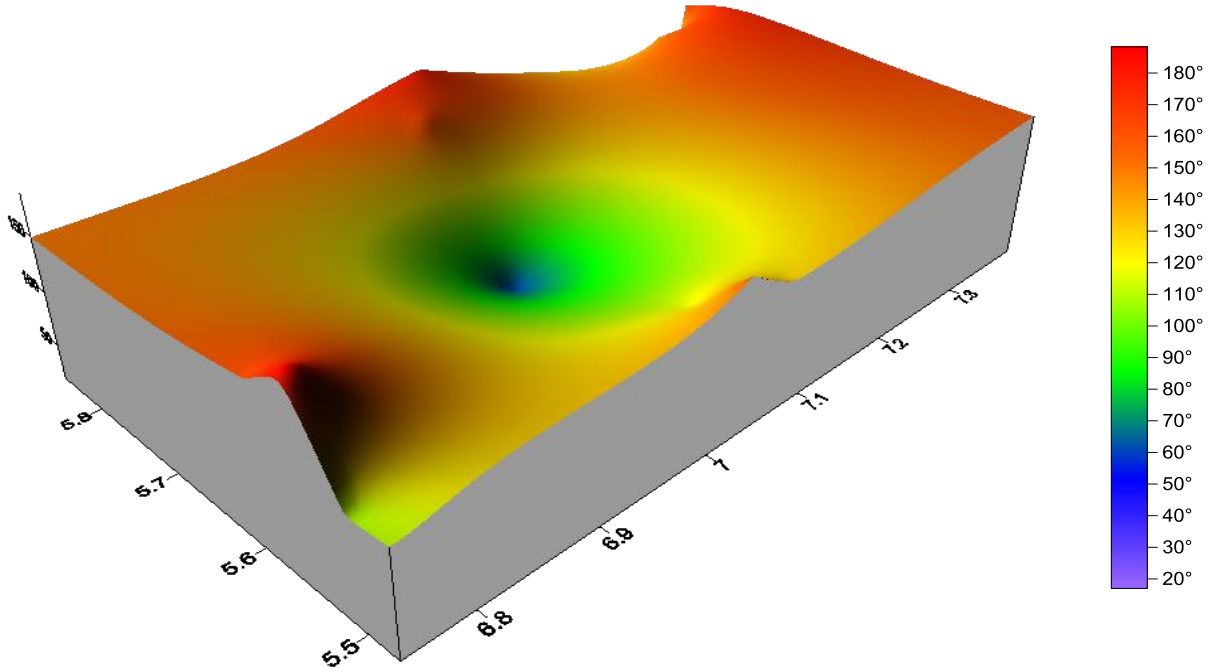



Fig. 4.18: 3-D Surface plot of Wind direction (wet season)

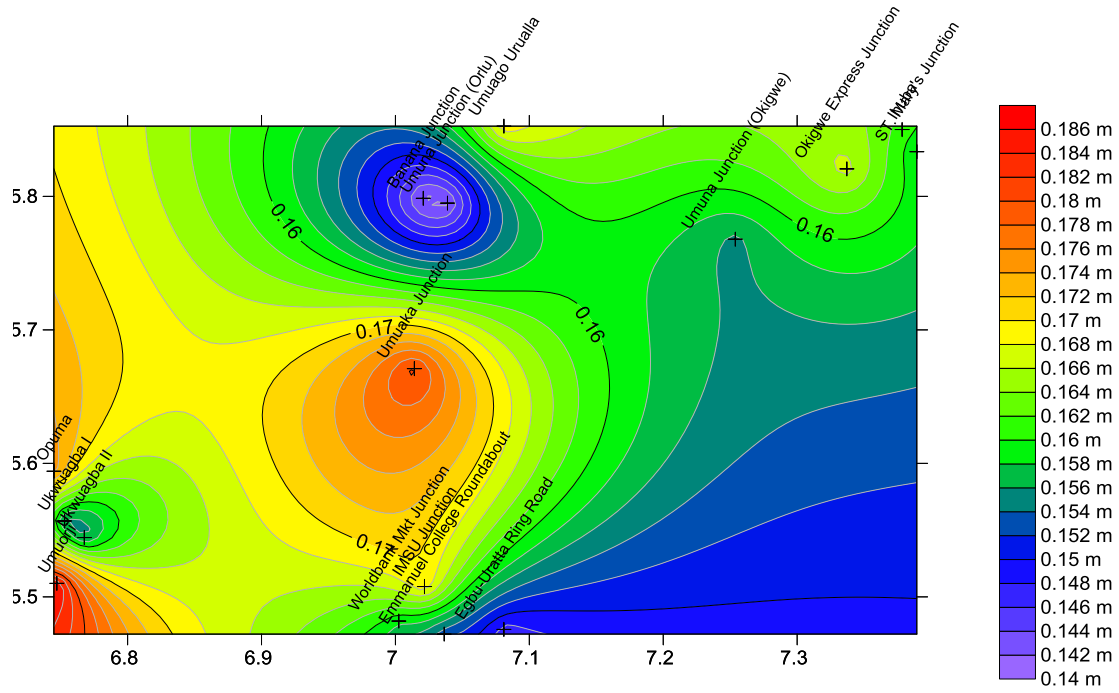



Fig. 4.19: Contour plot of Wave height (wet season)

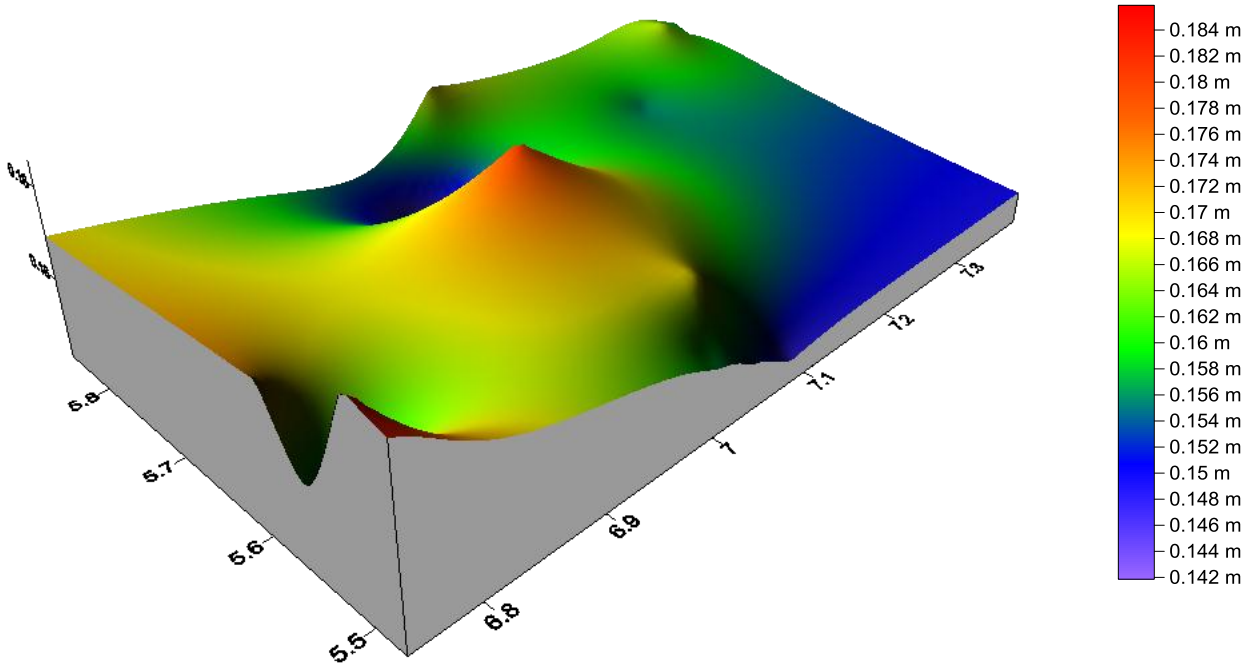



Fig. 4.20: 3-D Surface plot of Wave Height (wet season)

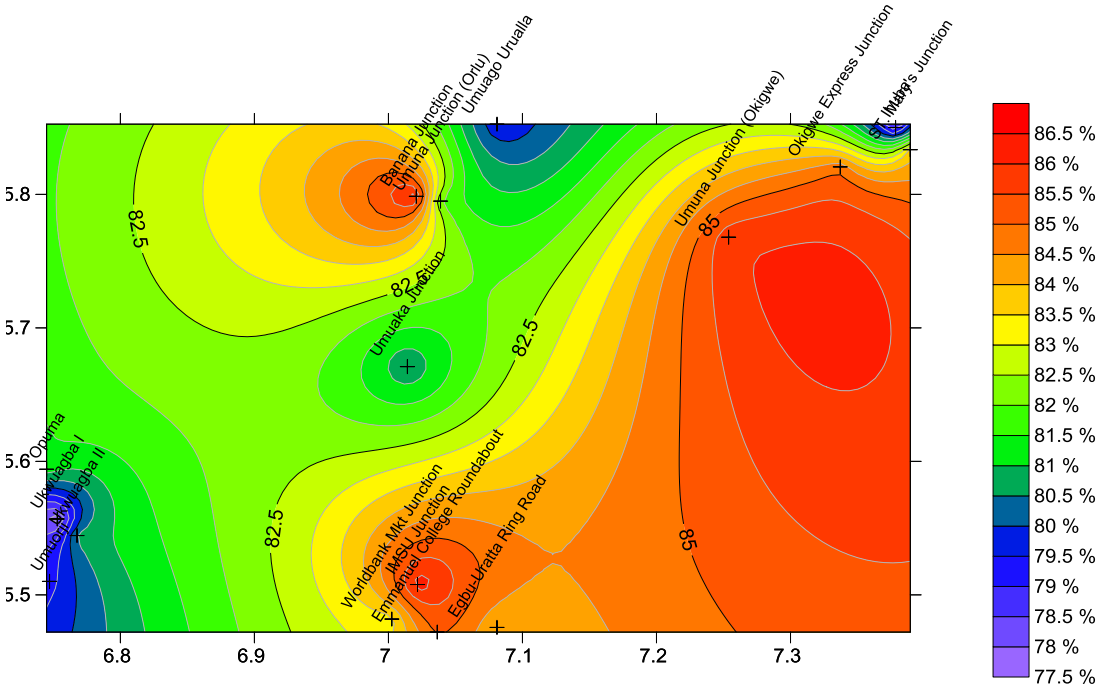



Fig. 4.21: Contour plot of Relative humidity

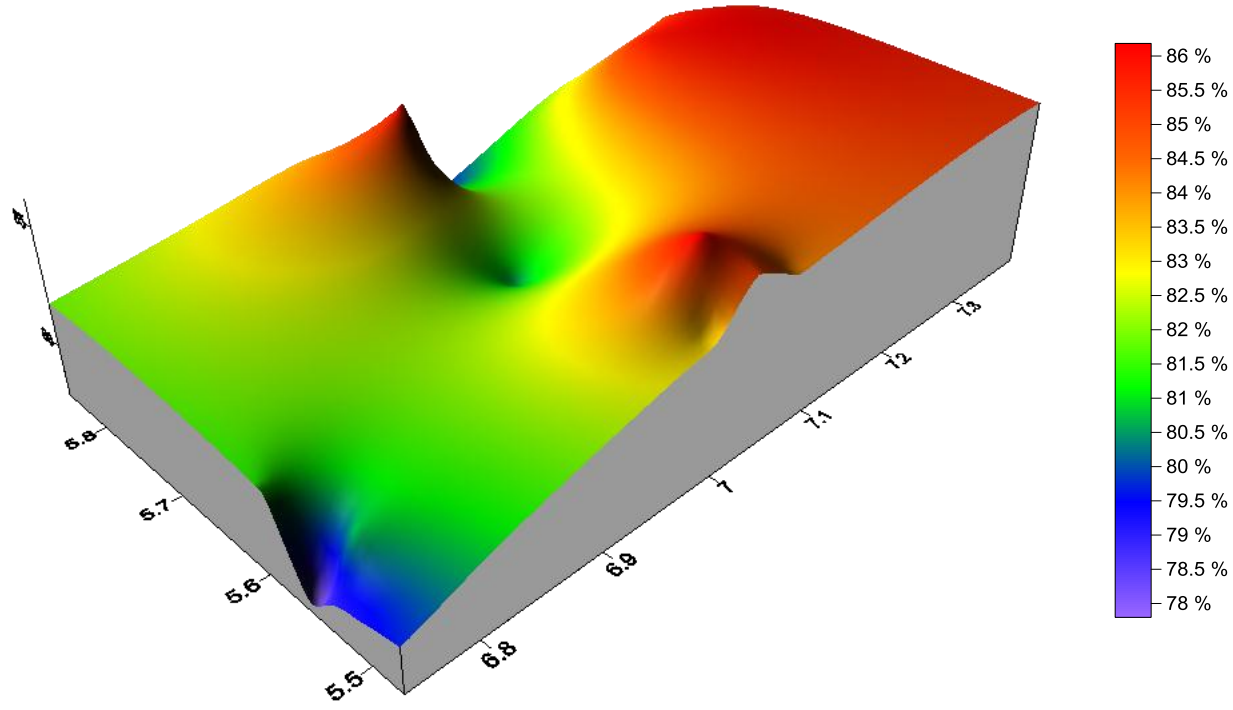



Fig. 4.22: 3-D Surface plot of Relative Humidity (wet season)

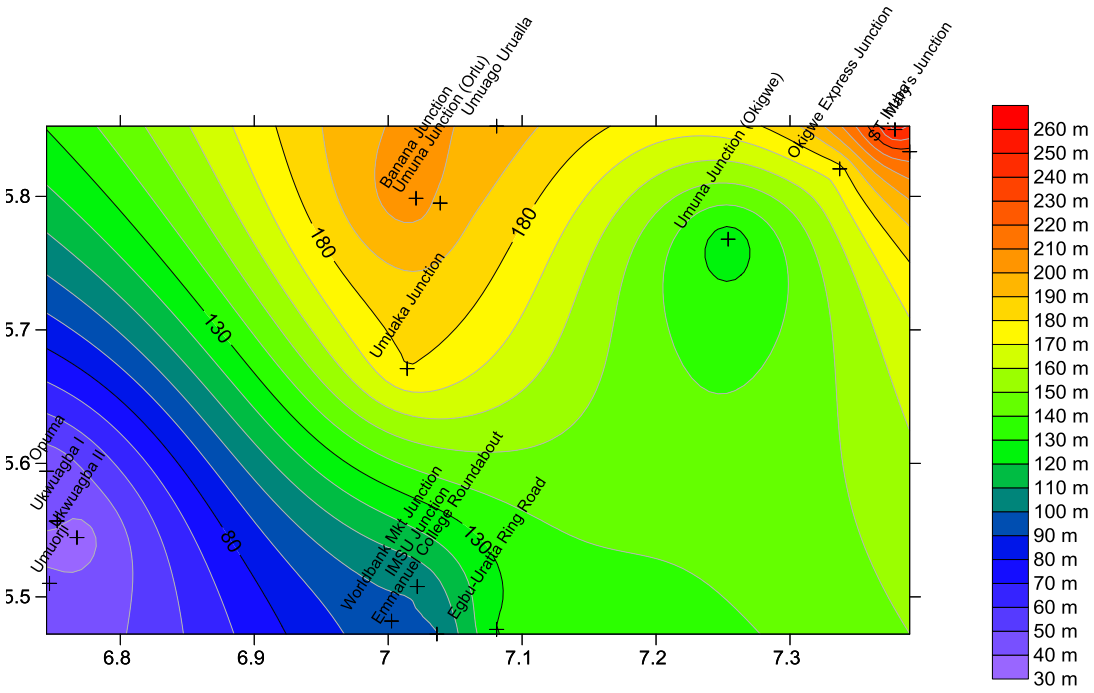



Fig. 4.23: Contour plot of Elevation (wet season)

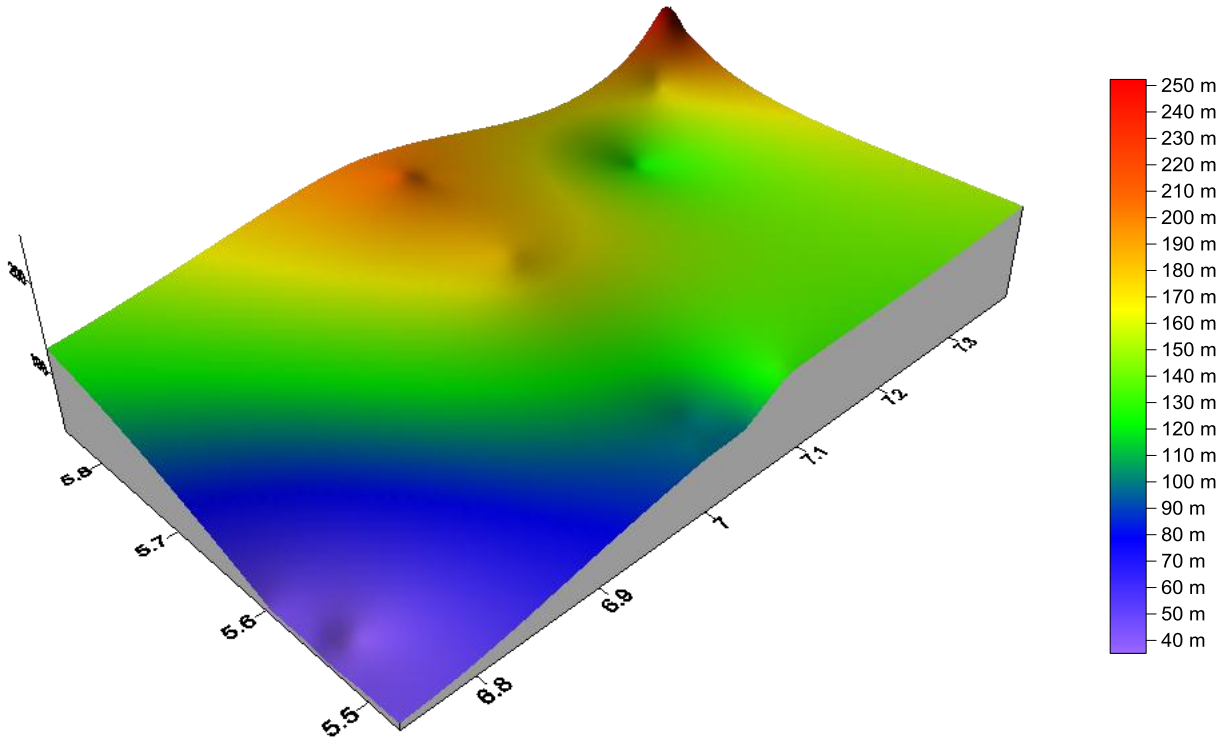



Fig. 4.24 3-Surface plot of Elevation (wet season)

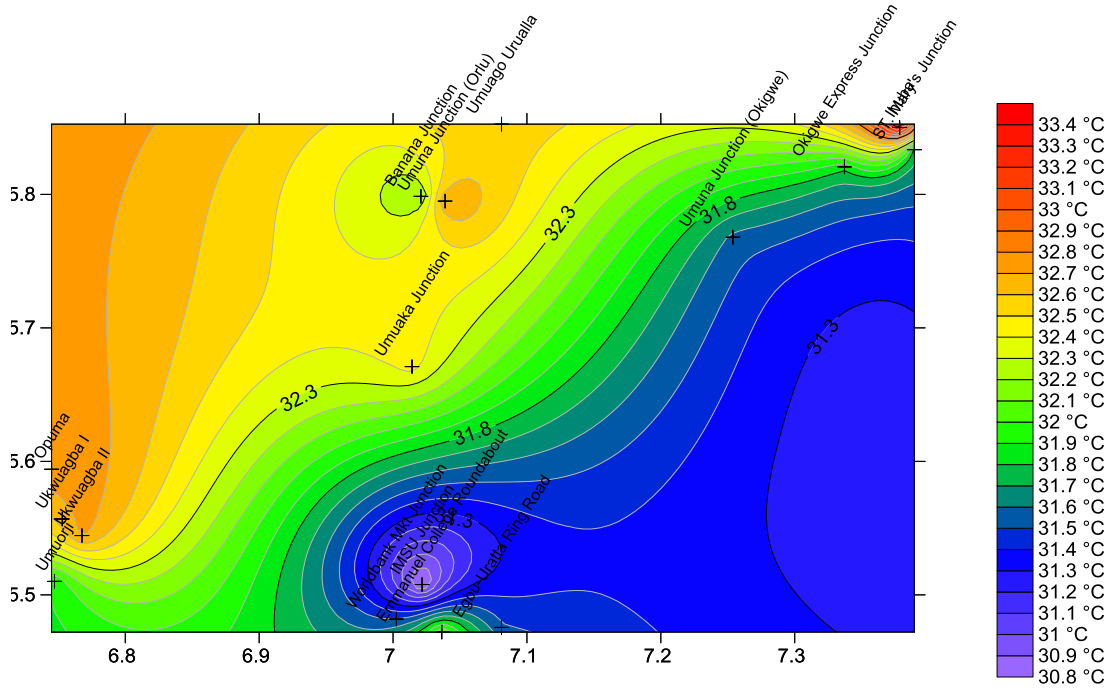



Fig. 4.25: Contour plot of ambient temperature (wet season)

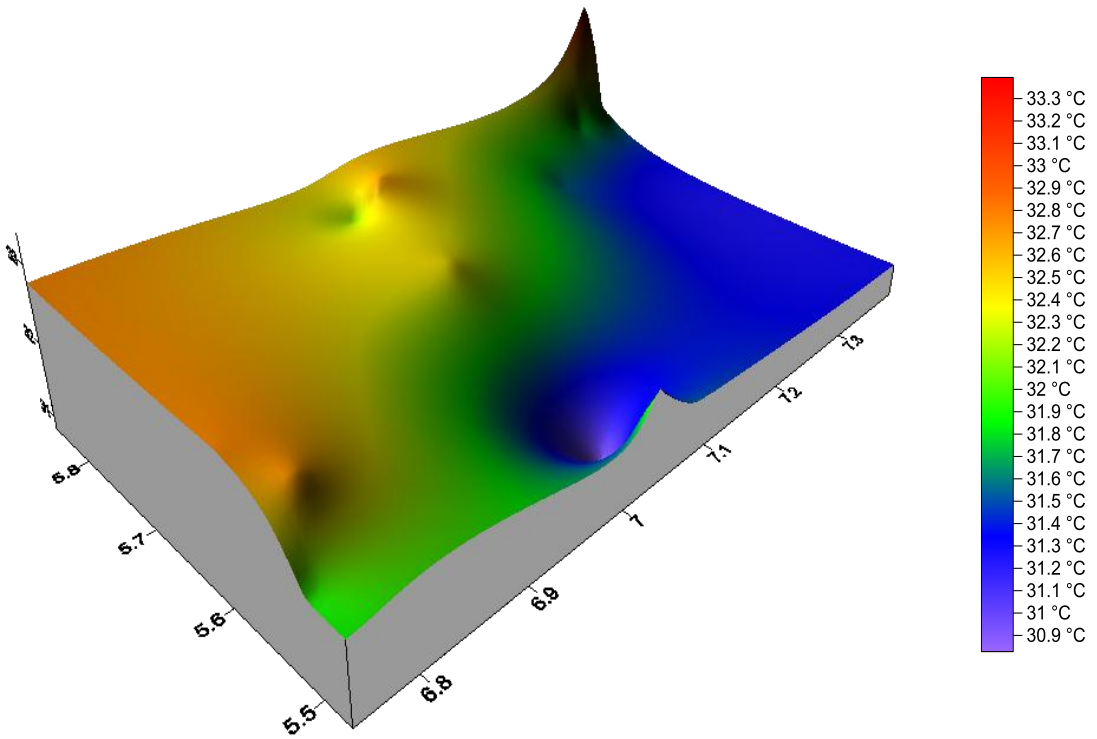



Fig. 4.26: 3-D Surface plot of ambient temperature (wet season)

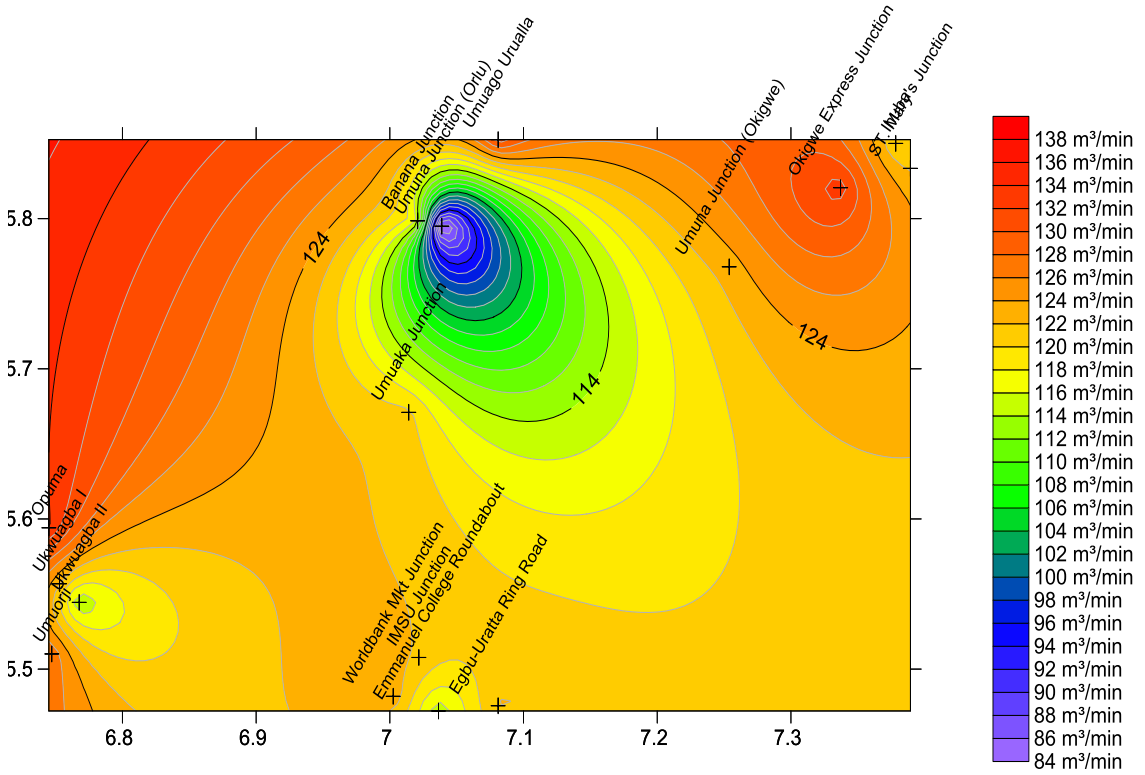



Fig. 4.27: Contour plot of air flow (wet season)

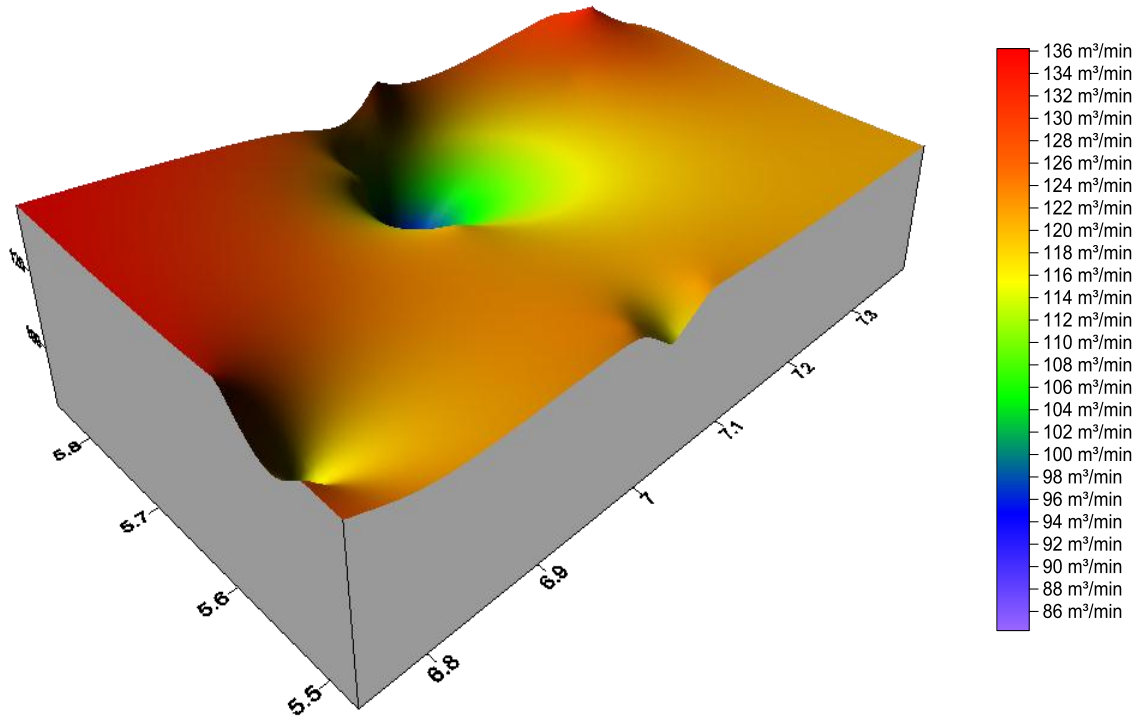



Fig. 4.28: 3-D Surface plot of air flow

## 4.4 The Dynamic Equation forAtmospheric Dispersion of Air Pollutants

The concentration of atmospheric pollutants could be influenced by meteorological elements like; ambient temperature, relative humidity, wind speed, wave height, air flow, wind direction, previous day concentration of the air pollutant, etc. Therefore, there is a need to establish an appropriate method that can be used to evaluate the influence of these variables on the observed level of air pollution in an area. Multiple linear regressions have proven to be a veritable tool in this regard. Regression analysis has been used to study the relationship between variables in atmospheric pollution studies (Ocak & Turalioglu 2008; Szyda et al., 2009; de Souza et al., 2014).

Regression models could be useful for prediction of air pollutant concentrations. This is achieved by using regression equation in which an unknown or dependent variable is expressed as a function of known or independent variables (Goyal & Kumar, 2011).

The general dynamic equation for the model is;

$$y = b + b_1x_1 + b_2x_2 \ldots\ldots b_nx_n \quad (4.1)$$

where b is the regression constant, y is the dependent variable, $x_1, x_2 \ldots x_n$ are the independent variable while $b_1$, $b_2$ .. $b_n$ are the coefficients of regression as earlier explained in equation 3.3 and 3.4 . Therefore, relating Eq. 3.2, 3.3 and 4.1 for $PM_{10}$ as an example for the model;

$$PM_{10} = b + b_1WS + b_2AT + b_3RH + b_4AF + b_5WH \quad (4.2)$$

$$PM_{10} = b + b_1WS + b_2AT + b_3RH + b_4AF + b_5WH + b_6PDC \quad (4.3)$$

The mean values of the air pollutant concentrations and the meteorological parameters were used to generate 12 x 6 matrices without PDC and 12 x 7 matrices with PDC. If the 12 x 6 or 12 x 7 matrix = X, concentration of air pollutant = V and constant parameters = b. So we no have,

$$V = Xb \quad (4.4)$$

This was simulated in Matlab7.9 with the code b = regress (V, X).

Multiple linear regressions can be used for prediction, estimation, hypothesis testing and modeling casual relationships. If the coefficient of determination ($R^2$) of the relationship is 1 or 100 %, then there is a perfect relationship, when there is no linear relationship between the dependent and independent variables, the coefficients of determination ($R^2$) is 0.

### 4.4.1 Dynamic Equations for Dry Season

After solving Eq 4.2 and 4.3 by the least square method with Matlab 7.9, the dynamic model for $PM_{10}$ at Owerri for IMSU junction (dry season) becomes Eq. (4.5) without PDC and (4.6) with PDC using the regression values shown in Tables 4.13 and 4.14, while the regression values of b for other locations in dry season are presented in appendix 1.

The dynamic equations for predicting air pollution concentrations are expressed below for IMSU junction, Owerri, in dry season as shown below;

$PM_{10} = 18.008 - 2.0605WS - 0.3279AT - 0.0073RH + 0.0173AF + 16.7290WH$ $R^2 = 0.2409$ (4.5)

$PM_{10} = 14.0644 - 2.1819WS + 0.2719AT - 0.0181RH + 0.0098AF + 17.8114WH + 0.1335PDC$ $R^2 = 0.2572$ (4.6)

The dynamic equations for other measured air pollutants are stated below for IMSU junction (dry season)

$NO_2 = 0.1381 - 0.0398WS + 0.0012AT + 0.0046RH - 0.0004AF + 0.1602WH$

$R^2 = 0.4577$ (4.7)

$NO_2 = -0.3265 + 0.0348WS + 0.0157AT + 0.0095RH - 0.0014AF + 0.0991WH - 0.8831PDC$ $R^2 = 0.8701$ (4.8)

$SO_2 = 4.1772 + 0.0203WS - 0.0564AT - 0.0153RH - 0.0006AF - 3.7963WH$

$R^2 = 0.564$ (4.9)

$SO_2 = 3.1654 + 0.1497WS - 0.0350AT - 0.0191RH - 0.0001AF - 32398WH + 0.3779PDC$ $R^2 = 0.4903$ (4.10)

$CO = 24.7590 - 16.109WS - 0.4255AT + 0.3852RH + 0.1282AF + 105.2155WH$ $R^2 = 0.6310$ (4.11)

$CO = 17.1899 - 15.975WS - 0.2862AT + 0.4335\ RH + 0.1296AF + 110.21WH - 0.0442PDC$ $R^2 = 0.6341$ (4.12)

Table 4.13: b -Values for IMSU Junction without PDC (Dry season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 18.0083 | 0.1381 | 4.1772 | 24.7590 | 3.1790 |
| b1 | -2.0605 | -0.0398 | 0.0203 | -16.109 | -0.1324 |
| b2 | -0.3279 | 0.0012 | -0.0564 | -0.4255 | -0.0175 |
| b3 | -0.0073 | 0.0046 | -0.0153 | 0.3852 | -0.0335 |
| b4 | 0.0173 | -0.0004 | -0.0006 | 0.1282 | -0.0018 |
| b5 | 16.7290 | 0.1602 | -3.7963 | 105.2155 | 5.4649 |
| $R^2$ | 0.2409 | 0.4577 | 0.5647 | 0.6310 | 0.7088 |

VOC = 3.1790 -0.1324WS -0.0175AT -0.0335RH -0.0018AF + 5.4649WH

$R^2$ = 0.7088 (4.13)

VOC = -0.0000 -0.0000WS - 0.0000AT +0.0000RH + 0.0000AF+ 0.0000WH + 1.0000PDC)

$R^2$ = 1.0000 (4.14)

The dynamic equation for $PM_{10}$ in dry season, Eq. (4.5) with $R^{2,}$ 0.2409, indicates that increased air flow and wave height contributed to increase in concentration of $PM_{10}$, while decreased wind speed, ambient temperature and relative humidity lowered the concentration of $PM_{10}$. In Eq. 4.6, $R^2$ is 0.2572, ambient temperature, air flow, wave height and PDC contribute to increase in the concentration of $PM_{10}$, while reduced wind speed and relative humidity decreased its concentration. Eq. (4.5) showed slightly higher coefficient of determination ($R^2$), 0.2572, which is 25.72 %, suggesting that it is a better model than Eq. 4.5.

Table 4.14: b -Values for IMSU junction with PDC (Dry season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 14.0644 | -0.3265 | 3.1654 | 17.1899 | -0.000 |
| b1 | -2.1819 | 0.0348 | 0.1497 | -15.975 | -0.000 |
| b2 | 0.2719 | 0.0157 | -0.0350 | -0.2862 | -0.000 |
| b3 | -0.0181 | 0.0095 | -0.0191 | 0.4335 | 0.000 |
| b4 | 0.0098 | -0.0014 | -0.0001 | 0.1296 | 0.000 |
| b5 | 17.8114 | 0.0991 | -3.2398 | 110.2100 | 0.000 |
| b6 | 0.1335 | -0.8831 | 0.3779 | -0.0442 | 1.000 |
| $R^2$ | 0.2572 | 0.8701 | 0.5384 | 0.6341 | 1.000 |

The model for dry season, Eq. 4.7 ($R^2$ =0.4577) shows that the concentration of $NO_2$ increased with higher ambient temperature, relative humidity and wave height, while decreased wind speed and air flow reduced concentration of the air pollutant. Eq. 4.8 indicates that apart from air flow and previous day concentration other variable contributed to elevated $NO_2$ level. This suggests that themodel showed a better relationship with $R^2$ = 0.8701 (87.01 %).

Dry season $SO_2$ model (Eq. 4.9) ($R^2$ = 0.5647) shows that with the exception of wind speed other variables decreased the concentration of $SO_2$. Also Eq. 4.10 for $SO_2$ model with PDC ($R^2$ = 0.4903) indicates that except wind speed and previous day concentration other variables decreased the concentration of $SO_2$. A slightly lower $R^2$ (0.4903) (49.03 %) was obtained in Eq.(4.10) than in Eq. 4.9 ($R^2$ = 0.5647) (56.47 %) which indicates that there is a more linear relationship without PDC for $SO_2$.

The dynamic equation for CO in dry season (Eq. 4.11) ($R^2$ = 0.6310) shows that decreased wind speed and ambient temperature decreased CO level, while air flow, relative humidity and wave height increased the CO level. According to the CO model in Eq. (4.12) with $R^2$ (0.6341), decreased wind speed, ambient temperature and previous day concentrations decreased the CO level while increased relative humidity, air flow and wave height contributed to the elevation of CO level. The coefficient of determination, $R^2$, of Eq. 4.11 and 4.12 only differ by 0.0031 (0.31%) which means that the model is good with or without PDC.

The model for VOC in dry season, Eq. 4.13 ($R^2$ = 0.7088) shows that apart from wave height other meteorological variables, wind speed, ambient temperature, relative humidity and air flow decreased the concentration of VOC. While in Eq.4.14 ($R^2$ = 1.0000), only PDC of VOC had significant influence on the concentration of VOC in this model. The $R^2$ of Eq.4.14 shows a very perfect relationship which means that the model is ideal for VOC.

### 4.4.2 Dynamic Equations for Wet Season

The wet season dynamic equations for IMSU junction are presented with and without the previous day concentration of air pollutants under consideration. The regression models for $H_2S$ could not be established because concentrations of the air pollutant were below detection limit in most of the sampling sites. Tables 4.15 and 4.16 are the regression values of b for IMSU junction in wet season. The regression values of b in wet season for other locations are presented in appendix 2. The dynamic models for predicting air pollutant concentrations are presented below for IMSU junction, Owerri, in wet season

Table 4.15: b-Values for IMSU Junction without PDC (Wet season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 41.1120 | -4.6272 | 0.3347 | 50.9003 | -3.2496 |
| b1 | 0.9278 | 0.0126 | -0.1370 | -5.7165 | 0.3532 |
| b2 | -0.5232 | 0.0868 | 0.0150 | 0.3865 | 0.0719 |
| b3 | -0.2232 | 0.0282 | 0.0027 | -0.1879 | 0.0129 |
| b4 | -0.0120 | -0.0043 | 0.0009 | -0.0167 | -0.0011 |
| b5 | 2.2883 | 3.6066 | -1.6849 | 18.9296 | -0.8302 |
| $R^2$ | 0.7220 | 0.5983 | 0.1172 | 0.8187 | 0.5187 |

$PM_{10}$ = 41.1120 + 0.9278WS -0.5232AT -0.2232RH -0.0120AF +2.2883WH
$R^2$ = 0.7220 (4.15)

$PM_{10}$ = 34.3211 + 2.2852WS -0.6253AT -0.1829RH -0.0067AF-0.6027 WH+ 0.6114PDC
$R^2$ = 0.7920. (4.16)

$NO_2$ = -4.6272 + 0.0126WS + 0.0868AT +0.0282RH -0.0043AF + 3.6066WH
$R^2$ = 0.5983 (4.17)

$NO_2$ = 0.5305 + 0.0537WS + 0.0122AT - 0.0013RH - 0.0004AF -0.8064WH- 0.5870 PDC $R^2$ = 0.6485. (4.18)

$SO_2$ = 0.3347 -0.1370WS +0.0150AT + 0.0027RH + 0.0009AF -1.6849WH $R^2$ = 0.1172 (4.19)

$SO_2$ = 1.6898 -0.0357WS -0.0176AT -0.0117RH + 0.0017AF + 0.8311WH + 0.1400PDC $R^2$ = 0.3370 (4.20)

Table 4.16: b-Values for IMSU Junction without PDC (Wet season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 34.3211 | 0.5305 | 1.6898 | -18.6691 | -0.0002 |
| b1 | 2.2852 | 0.0537 | -0.0357 | -0.0776 | -0.0000 |
| b2 | -0.6253 | 0.0122 | -0.0176 | 2.0291 | 0.0001 |
| b3 | -0.1829 | -0.0013 | -0.0117 | 0.0860 | 0.0003 |
| b4 | -0.0067 | -0.0004 | 0.0017 | -0.0962 | 0.0005 |
| b5 | -0.6027 | -0.8064 | 0.8311 | 28.0529 | 0.0012 |
| b6 | 0.6114 | -0.5870 | 0.1400 | -0.0162 | 1.0030 |
| $R^2$ | 0.7920 | 0.6485 | 0.3370 | 0.3993 | 0.9310 |

CO = 50.9003 - 5.7165WS + 0.3865AT -0.1879RH - 0.0167AF +18.929WH $R^2$ = 0.8187 (4.21)

CO = -18.6691 - 0.0776WS + 2.0291AT + 0.0860RH - 0.0962AF + 28.0529WH - 0.0162PDC
$R^2$ = 0.3993. (4.22)

VOC = - 3.2496 + 0.3532WS + 0.0719AT + 0.0129RH - 0.0011AF - 0.8302WH
$R^2$ = 0.5187 (4.23)

VOC = -0.0002 -0.0001WS + 0.0003AT + 0.0005RH +0.00012AF +1.0000WH +1.0030PDC
$R^2$ = 0.9310. (4.24)

In wet season, the dynamic equation for $PM_{10}$ (Eq. 4.15) $R^2$ = 0.7220, indicates that higher wind speed and wave height increased the concentration of $PM_{10}$, while decreased relative humidity, ambient temperature and air flow decreased its concentration. Eq. 4.16, $R^2$ = 0.7920 shows that while wind speed and PDC elevated the level of $PM_{10}$, decreased ambient temperature, air flow,

relative humidity and wave height lowered the level of the air pollutant. Eq. 4.15 with $R^2$ of 0.7920 (79.20 %) with PDC is a good model for $PM_{10}$.

$NO_2$ model shown in Eq. 4.17, $R^2 = 0.5983$, indicates that apart from decreased air flow, other meteorological variables elevated the level of $NO_2$. In Eq. 4.18 ($R^2 = 0.6485$), decreased relative humidity, air flow, wave height and PDC lowered the concentration of $NO_2$, while increase in wind speed and ambient temperature increases the concentration of $NO_2$. Eq. 4.18 with PDC having a $R^2$ of 0.6485 (64.85 %) indicates a better model than Eq 4.17.

The model for $SO_2$, Eq. (4.19) $R^2 = 0.1172$, shows that decreased wind speed and wave height lowered the level of $SO_2$, while increase in the temperature, air flow and relative humidity resulted in higher level of $SO_2$ concentrations. In Eq. (4.20), the model with $R^2 = 0.3370$ indicates that lower wind speed, ambient temperature and relative humidity decreased the level of $SO_2$, while increase in wave height and PDC increased the concentration of $SO_2$. The model in Eq.4.19 with $R^2 = 0.3370$ (33.70 %) showed a better relationship than Eq. 4.19 ($R^2 = 0.1172$) without PDC. of $SO_2$.

Eq. 4.21 ($R^2 = 0.8187$) is the model equation for CO in wet season without PDC. It indicates that the concentration of CO is lowered by decreased wind speed, air flow and relative humidity while elevated ambient temperature and wave height increased the concentration of the air pollutant. In Eq. 4.22 with $R^2 = 0.3993$ indicates that decreased wind speed, air flow and PDC lowered the concentration of CO, while ambient temperature, relative humidity and wave height increases the concentration of CO. Eq. 4.22 with $R^2 = 0.8187$ (81.87 %) indicates that the model is good for CO in wet season.

The model for VOC in wet season shown in Eq.4.23 with $R^2 = 0.5187$ indicates that decreased air flow and wave height lowered the concentration of VOC, while wind speed, ambient temperature and relative humidity increased the concentration of VOC. In the case of Eq 4.24 ($R^2 = 0.9010$), apart from decreased wind speed which lowered the concentration, other meteorological variables increased the concentration of VOC. So, the model in Eq. 4.24 with $R^2 = 0.9310$ (93.10 %) is a more perfect relationship and previous day concentration of the air pollutants played significant role in heightening the pollution level of VOC.

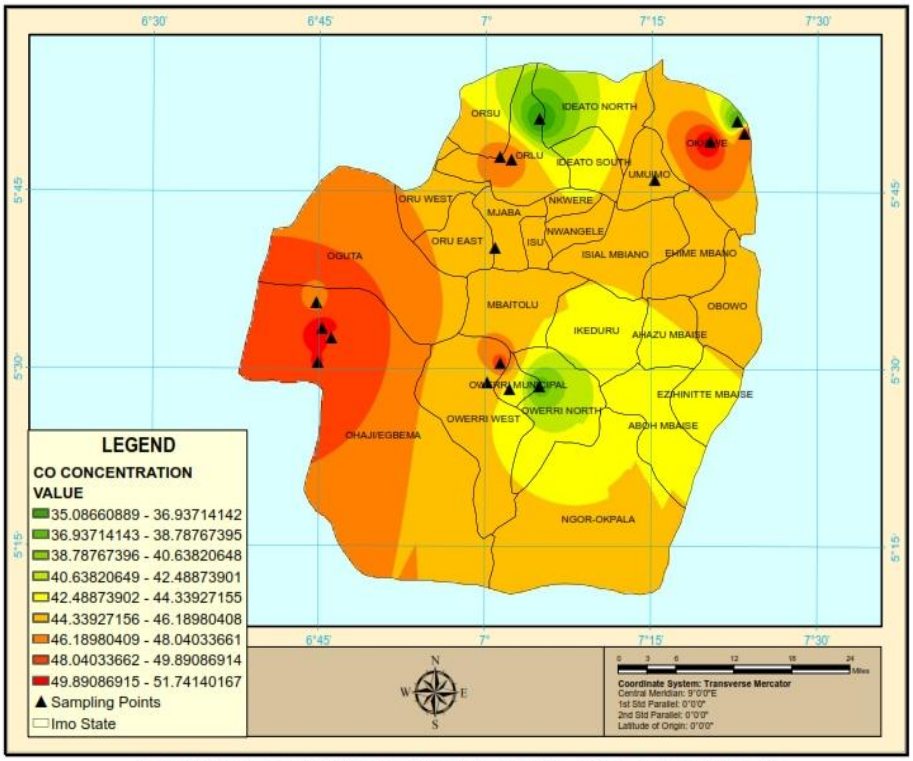
## 4.5 Presentation of Spatial Distribution Map Results

The results of spatial variation model were presented as choropleth maps to visualize the spatial distribution of the atmospheric pollutant concentrations associated with the geographical

location of the areas sampled. Choropleth mapping is a common technique for representing data. These are maps where enumeration units are shaded with a particular colour depending on that unit's data value. The choropleth map provides an easy way to visualize how a measurement varies across a geographical area or it shows the level of variability within a region (www.wikipedia.org). Subrata et al., (2010) used chloropleth maps for the study of spatial and temporal variation of urban air quality in Burdwan, India. Tawari and Abowei (2010) used chloropleth map to depict the position of their study locations in 'Air pollution in the Niger Delta Area of Nigeria'. Also Ibe et al. (2016) used chloropleth maps to elucidate the spatial variation of $SO_2$ and $NO_2$ in the ambient environment of Imo State, Nigeria.

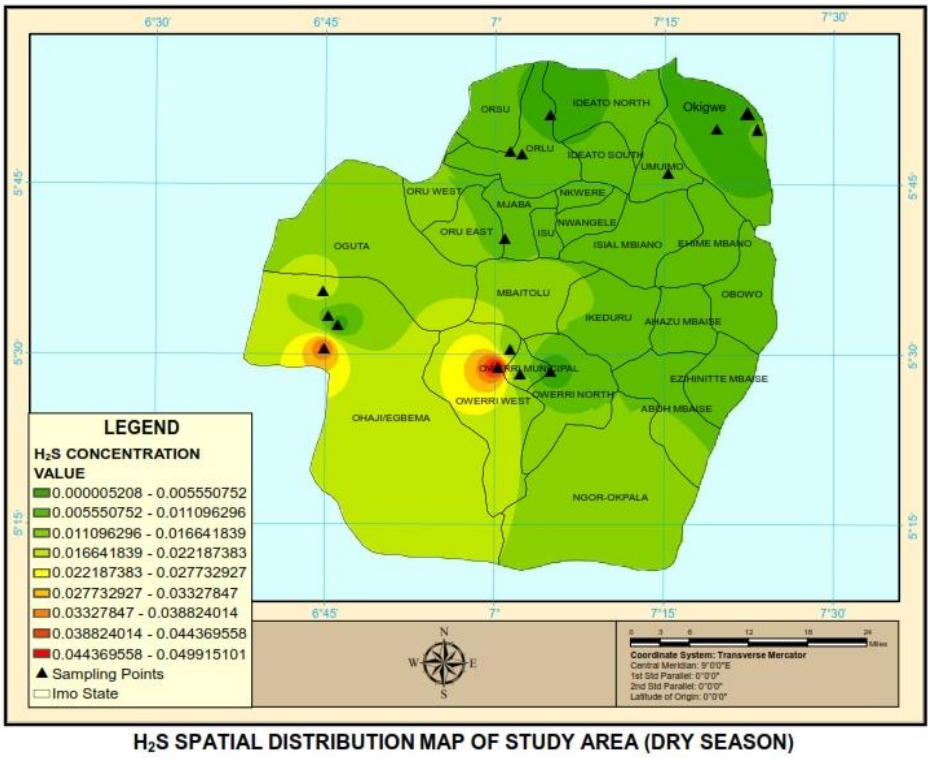
### 4.5.1 Presentation of Spatial Distribution Maps of Dry Season Results of Air Pollutant Concentrations

Dry season spatial distribution map of CO and $H_2S$ is presented in Fig. 4.29 and 4.30 respectively, while others are in appendix 3. The result presented in Fig. 4.29 is the dry season spatial distribution map of CO in the study location. Values of the concentration are shown in the legend, indicating the colour range in each area. The result indicates that elevated values of CO were observed in Egbema followed by Okigwe. The other of variation is Egbema > Okigwe > Owerri > Orlu. The elevated value of CO in Egbema could be attributed to gas flaring within and around the area (Egwurugwu et al, 2013; Audu, 2013). Figure 4.30 is the dry season spatial distribution map of $H_2S$ in the study location. The result as presented in Fig. 4.30 shows that the highest value of $H_2S$ recorded ranged from 0.044 - 0.049 ppm. The highest value of $H_2S$ was observed at Owerri and Egbema as indicated with red colouration in the chloropleth map. The order of $H_2S$ variation in the study area is Owerri > Egbema > Orlu and Okigwe.




**CO SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Fig. 4.29 Spatial distribution map of CO in dry season




**$H_2S$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Fig. 4.30 Spatial distribution map of $H_2S$ in dry season

### 4.5.2 Presentation of Spatial Distribution Maps of Wet Season Results of Air Pollutant Concentrations

The results of some wet season spatial distribution maps of the study air pollutant concentrations are presented in Fig. 4.31 and 4.32, while the remainder is in Appendix 4. Figure 4.31 is the spatial distribution map of CO in wet season. It indicates that higher value of CO was observed at Okigwe followed by Orlu. The order of CO variation in wet season is Okigwe > Orlu > Egbema > Owerri. Higher concentration of CO in Okigwe area could be attributed to increased vehicular traffic, especially heavy duty trucks that evacuate quarry product within and around the area (Njoku, Ibe, Alinnor & Opara, 2016) and combustion of biomass (Piotrowska, Kordylewski, Ciolek & Moscicki, 2010).

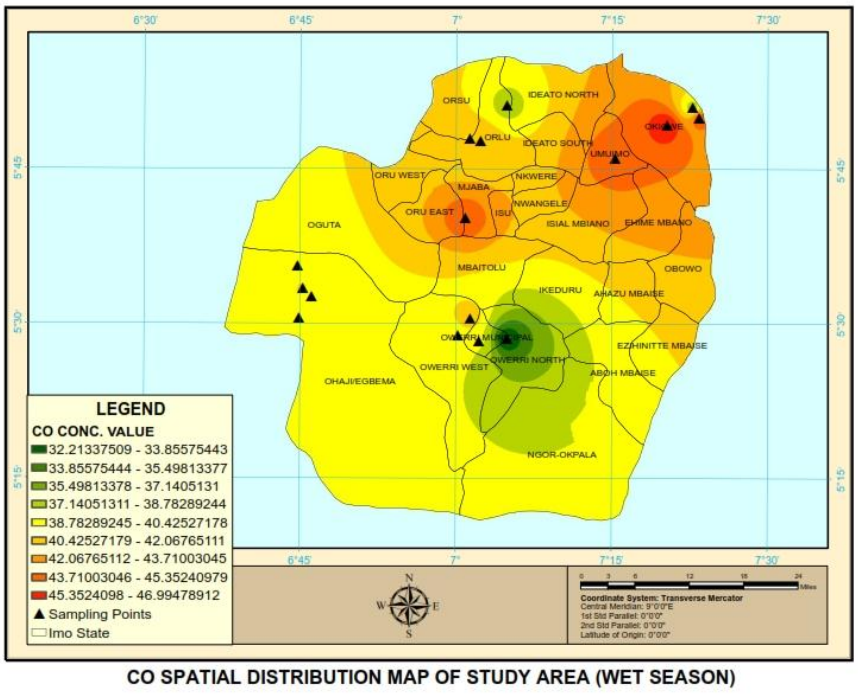
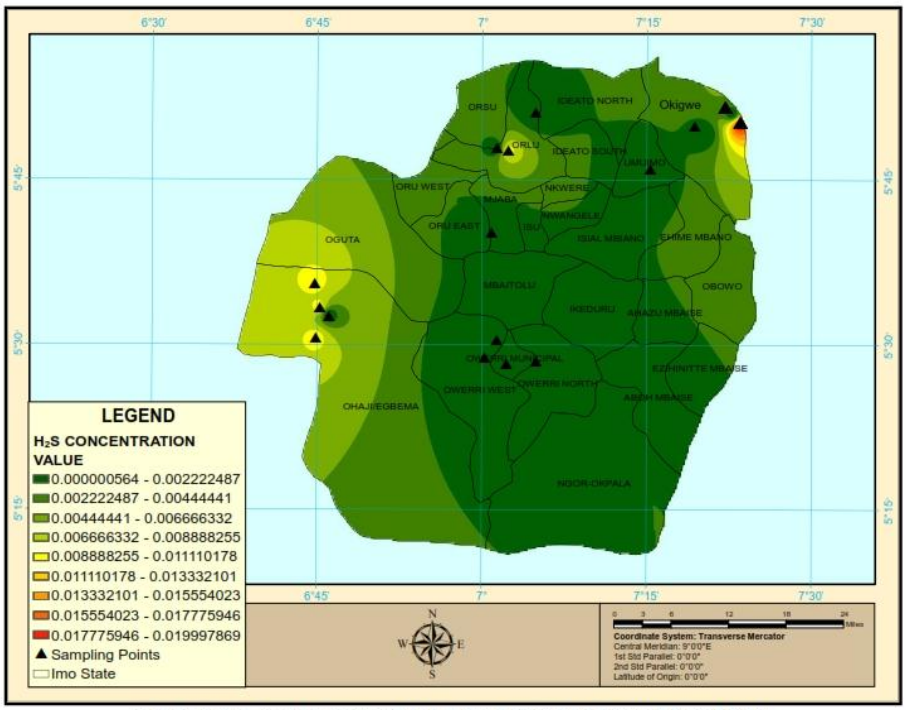



Fig. 4.31 Spatial distribution map of CO in wet season

Fig. 4.32 is the spatial distribution map of $H_2S$ in wet season. The result as shown indicates lower concentration of $H_2S$ in wet season, even though generally $H_2S$ was not detected in most of the sampled site due to its presence below the detection limit. The order $H_2S$ variation in wet season as indicated in the chloropleth map is; Okigwe > Egbema > > Orlu > Owerri.




**$H_2S$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)**

Fig. 4.32 Spatial distribution map of $H_2S$ in wet season

## 4.6 Presentation of Contour and 3-D Surface Plots of the Air Pollutant Concentrations

In order to further elucidate the variation in concentrations of the air pollutants, results were analyzed and presented using contour and 3-D surface plots as shown in Fig. 4.33 to 4.40. The rest of the contour and 3-D surface plots are in appendix 5. Contour and 3-D surface plots have been used in the study of variation of air pollutant concentration (Padma, Rao, Mhaisalkar, Kumar, Shrivastava, & Devotta 2009; Fisher, Wilson, Zeng, Williams, Emmons, Langenfelds, Krummel & Steele, 2015). Fig. 4.33 to 4.36 are the dry and wet season contour and 3-D surface plots of VOC, while Figures 4.37 to 4.40 are the dry and wet contour and 3 – D surface plots of CO. The results indicate that elevated level of VOC was recorded at Egbema in both dry and wet season. The elevated value could easily be visualized in the 3 – D surface plots (Fig. 4.34 and 4.36) with red peak. Also, Fig. 4.37 shows that higher CO values were recorded at Okigwe and Egbema in dry season, with Okigwe showing more prominent peak as illustrated by the 3-D surface plot. In wet season (Fig. 4.40), the red colour with upwards peak shows okigwe area with higher CO values.

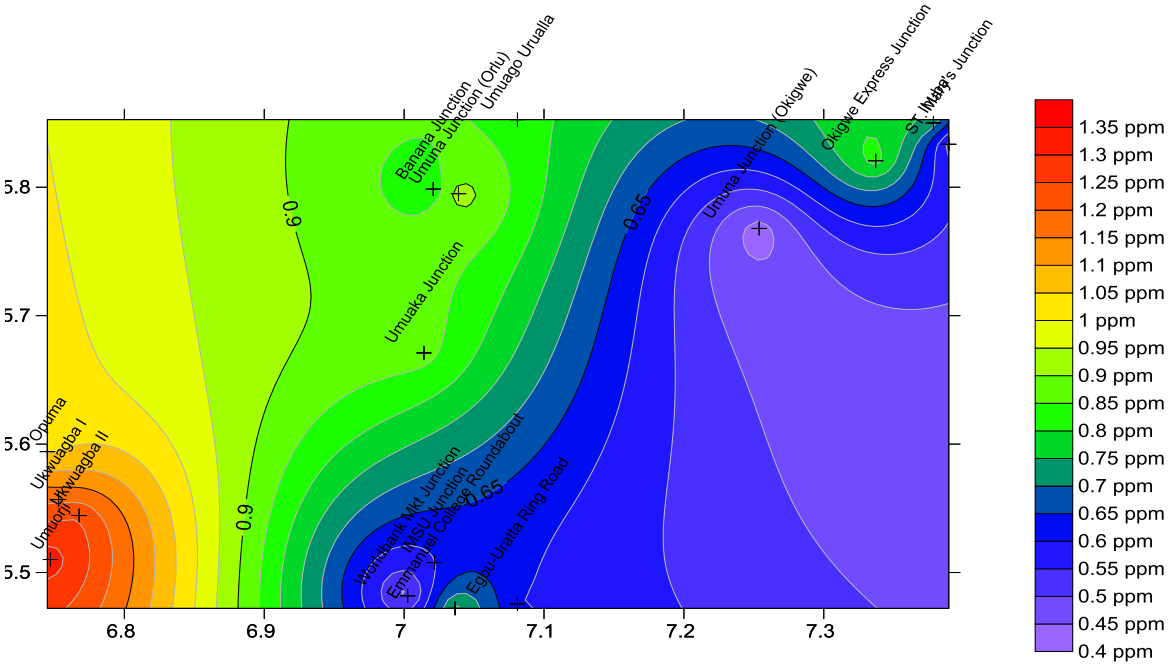



Fig. 4.33: Dry season contour plot of VOC

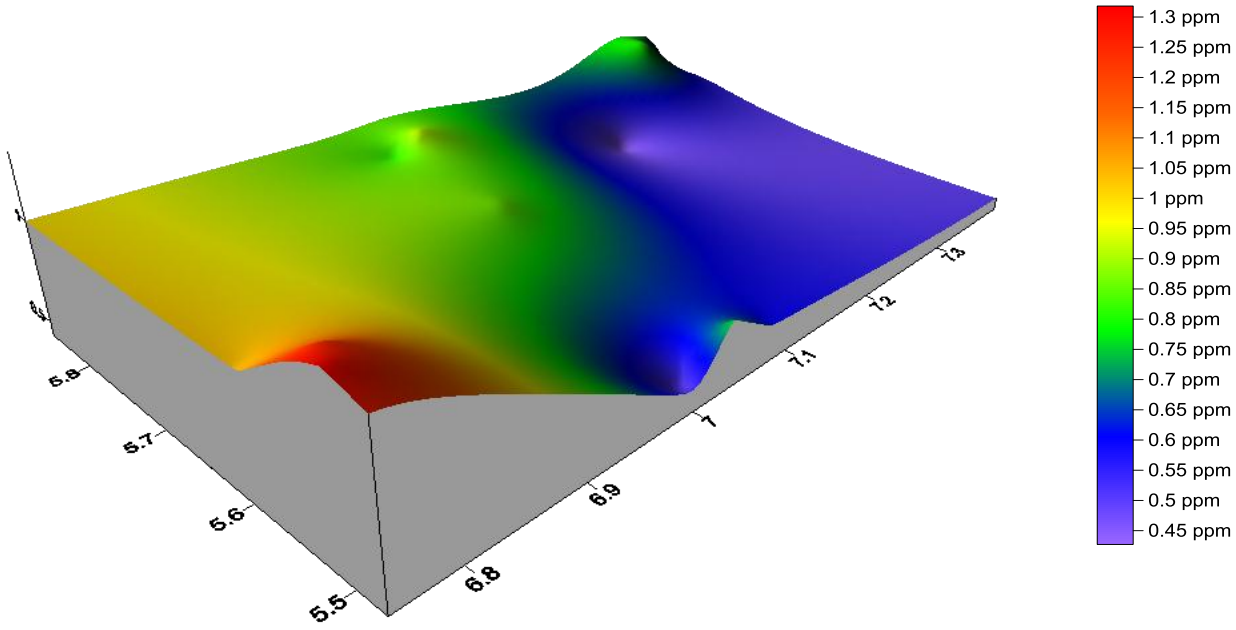



Fig. 4.34: Dry season 3 – D surface plot of VOC

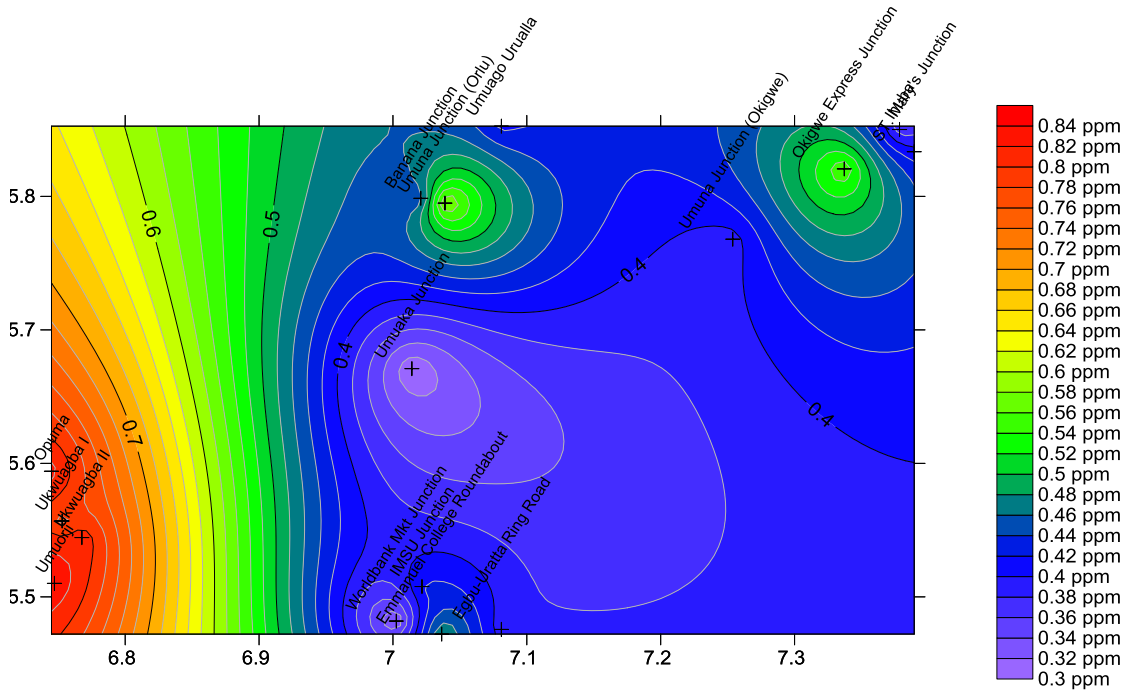



Fig.4.35: Wet season contour plot of VOC

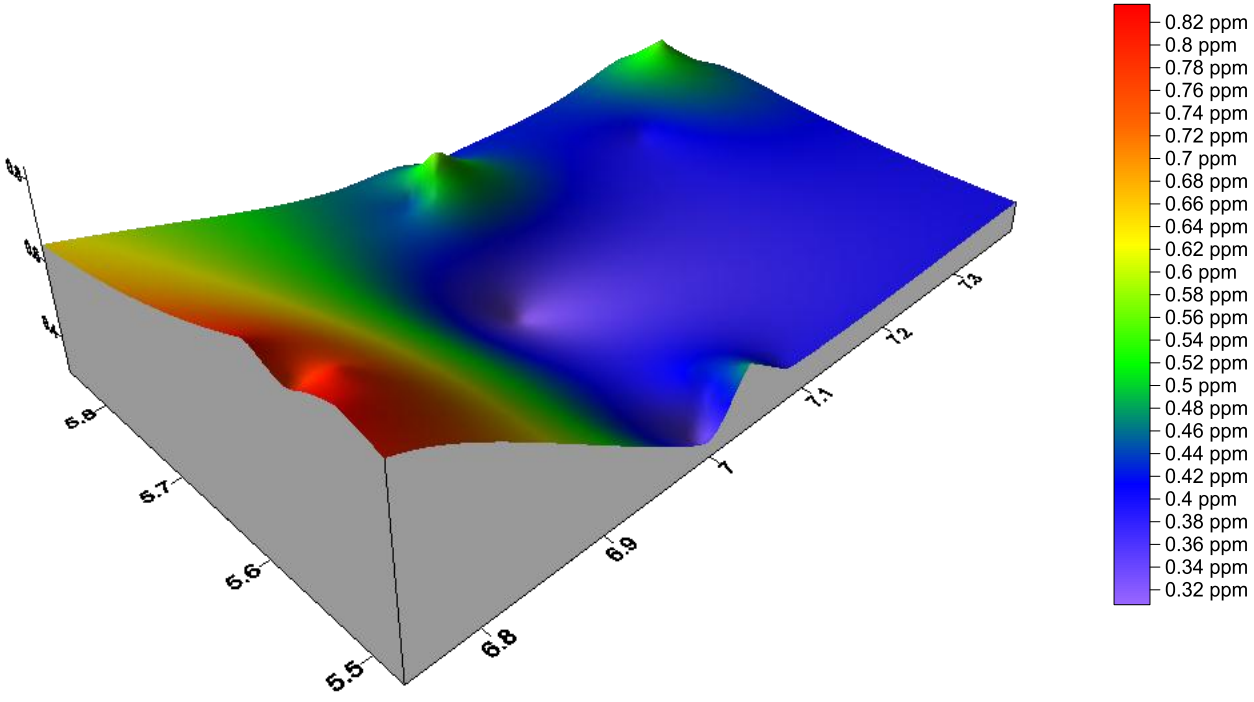



Fig.4.36: Wet season 3 – D surface plot of VOC

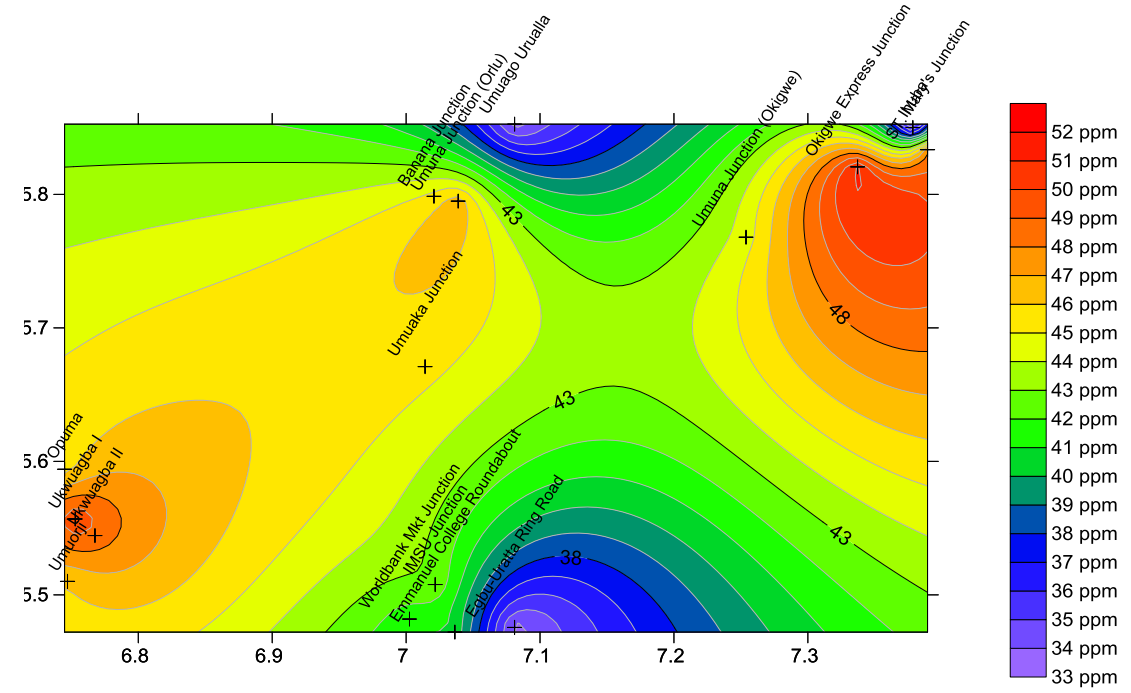



Fig.4.37: Dry season contour plot of CO

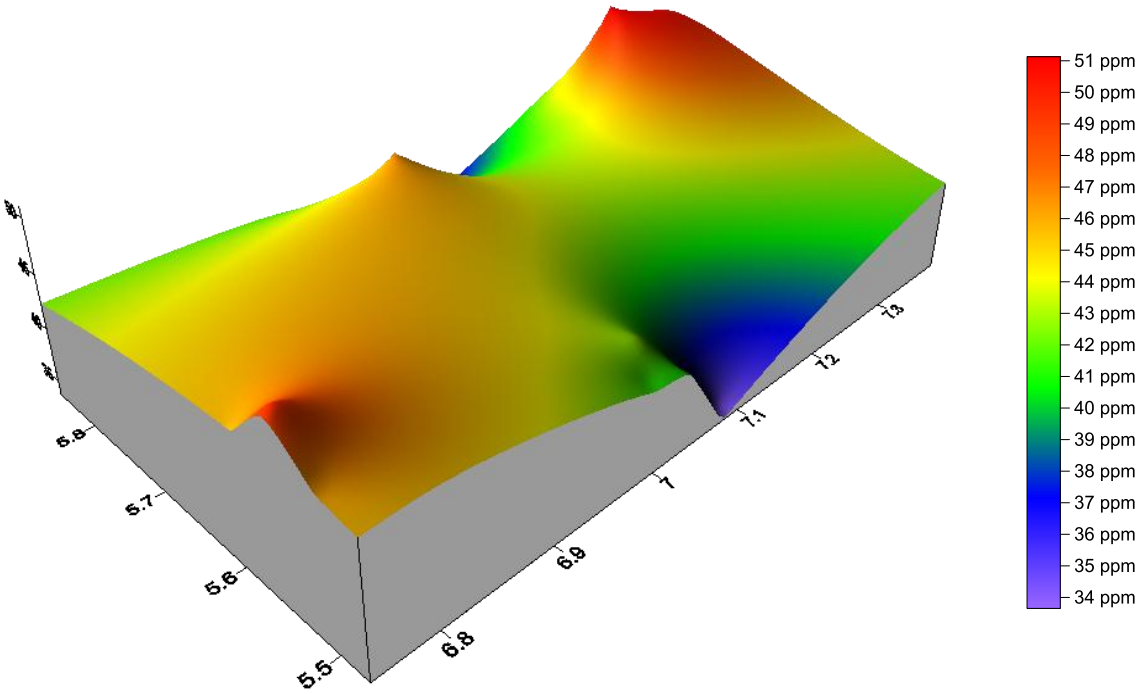



Fig.4.38: Dry season 3 - D surface plot of CO

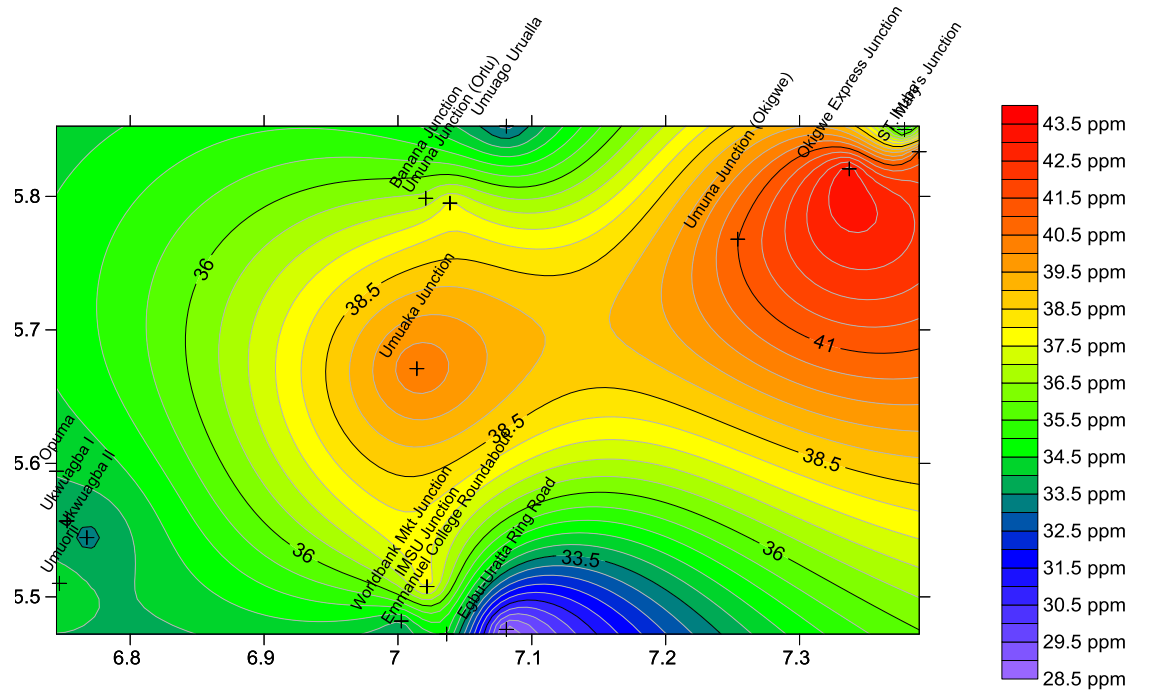



Fig.4.39: Wet season contour plot of CO

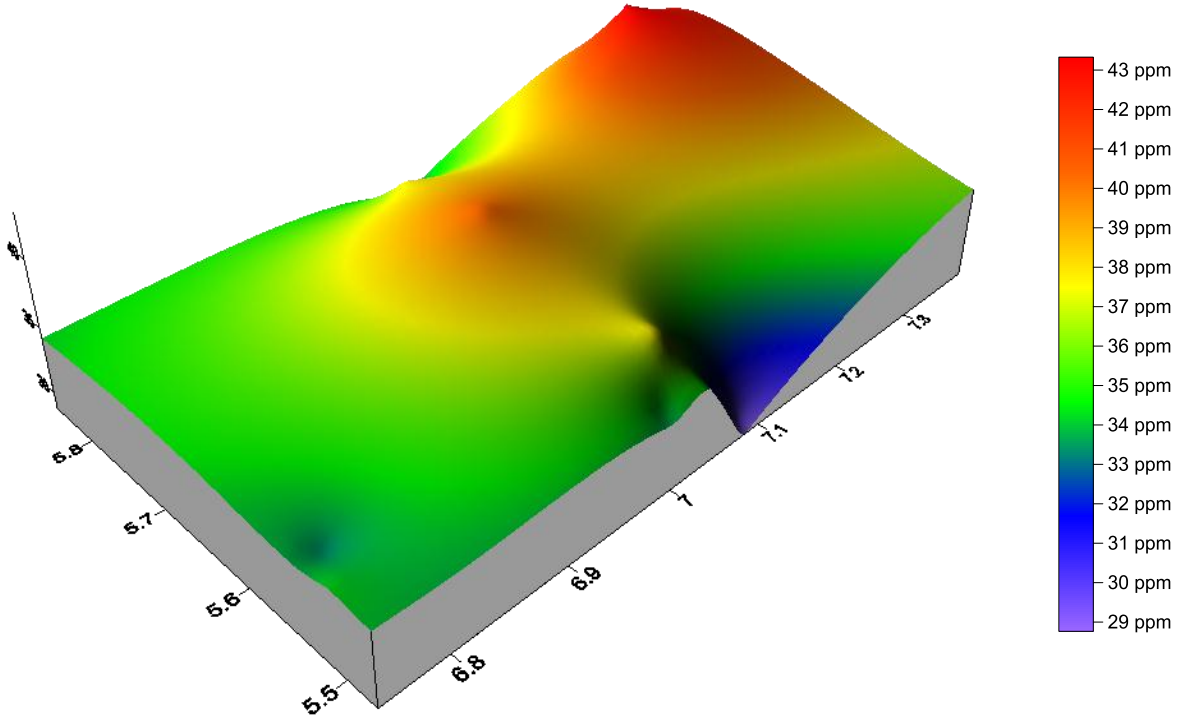



Fig.4.40: Wet season 3 – D surface plot of CO

## 4.7 Presentation of Time Series Models of the Air Pollutant Concentrations

Time series models were developed in order to analyze and characterize the nature of temporal relationship that exist during the air quality sampling which was three times a day (morning, afternoon and evening) 4 times a month for a period of six months (3 months each for dry and wet seasons which sums up to a total of 24 weeks. Therefore, the time series models for each of the air pollutants at the 16 air sampling points were modeled based on weeks and time (morning, afternoon and evening). Week 1 to 12 represents dry season while wet season is week 13 to 24 as shown in Fig. 4.41 to 4.45. The time series models of air pollutants for the remaining locations are in appendix 6. Norrimi et al., (2013) used time series models to evaluate ozone concentrations in Malaysia. Time series has been used in many air pollution studies to study changes in concentration of atmospheric pollutants (Diem & Comrie, 2002; Nunnari, Dorling, Schlink, Cawley, Foxall & Chatterton, 2004; Saffarini & Odat, 2008; Wu & Kuo, 2012; Zachary, Chiera & Boland, 2013). Fig. 4.41 is the time series model of $PM_{10}$ at Banana Junction, Orlu. The time series model indicates that the highest values of $PM_{10}$ was observed in the afternoon and evening in week 9, while the lowest value was recorded in the morning in week 23. Fig. 4.42 is the time series model of $PM_{10}$ at IMSU Junction, Owerri. The model shows that the highest value of $PM_{10}$ recorded at IMSU junction was in the afternoon in week 8, while in week 23 lowest value of $PM_{10}$ was observed. Also Figure 4.43 is time Series model of $SO_2$ at IMSU Junction, Owerri.

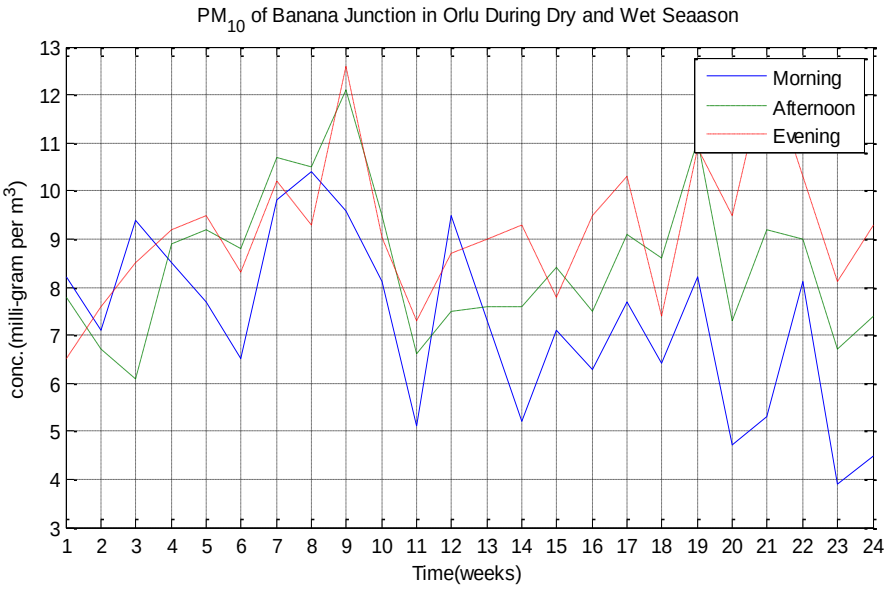



Fig.4.41: Time Series model of $PM_{10}$ at Banana Junction, Orlu

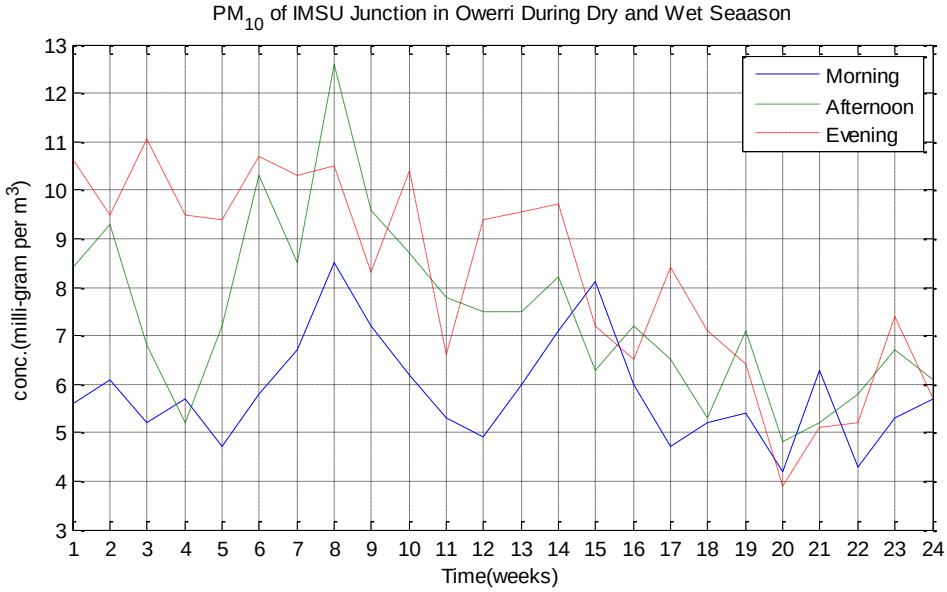



Fig.4.42: Time Series model of $PM_{10}$ at IMSU Junction, Owerri

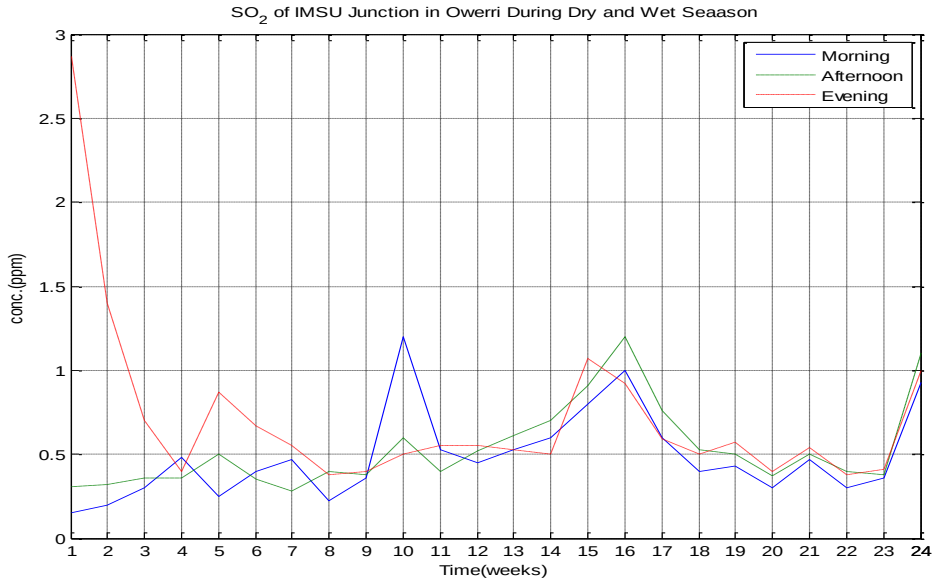



Fig.4.43: Time Series model of $SO_2$ at IMSU Junction, Owerri

It reveals that the highest and lowest value of $SO_2$ was observed in week 1 for both evening and morning. The model almost followed a similar trend. Fig. 4.44 is the time series model of $SO_2$ at Ukwugba 1, Egbema. The $SO_2$ time series did not follow any regular trend, rather the peaks were moving up and down at intervals. The model showed three prominent peaks in week 3, 8 and 10 respectively for evening, afternoon and evening again. Also a very low peak was observed in week 10 in the afternoon. The time Series model of $SO_2$ at Ihube, Okigwe in Fig. 4.45 indicates that the model has two outstanding peaks in week 9, 10, 17, 19 and 22. These peaks show significant variation in concentration of $SO_2$ recorded at Ihube in Okigwe.

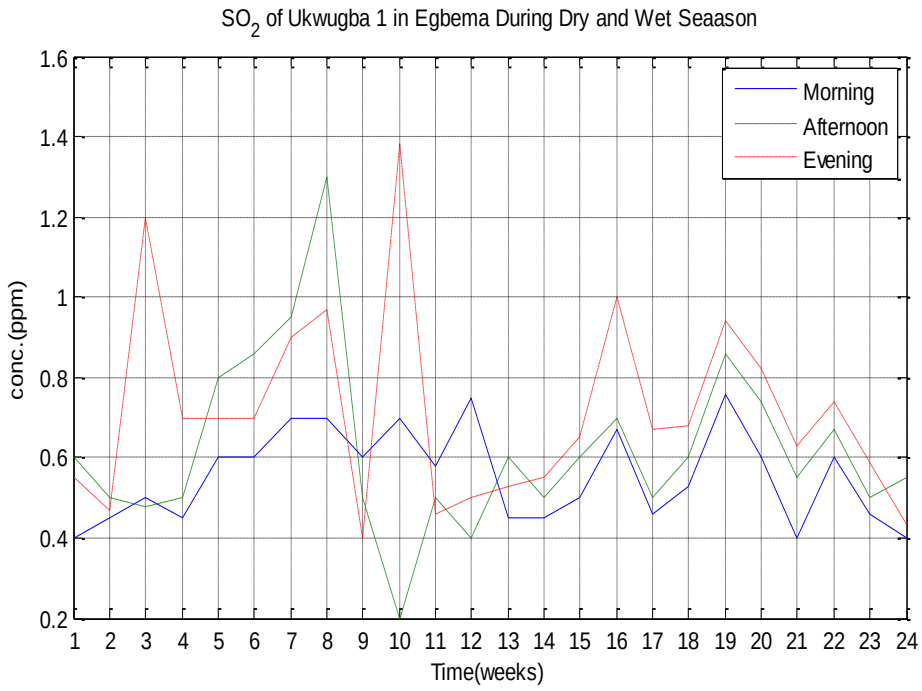



Fig.4.44: Time Series model of $SO_2$ at Ukwugba 1, Egbema

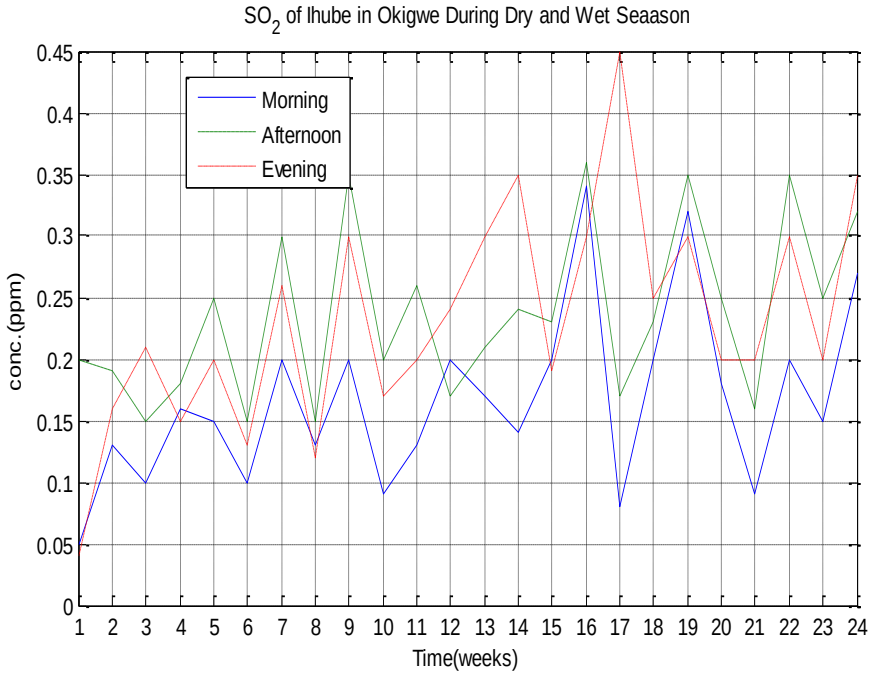



Fig.4.45: Time Series model of $SO_2$ at Ihube, Okigwe

## 4.8 Box and Whisker Plots of the Air Pollutant Concentration

Box and Whisker plots were used to show the distribution of the data in terms of the lower quartile, upper quartile, median, minimum and maximum values in the study locations. This was done to illustrate the distribution of the air pollutant concentrations in the morning, afternoon and evening. The Box plot essentially presents a quick sketch of the distribution of the underlying data using these five measures. The Box and Whisker plots are also the summary of air pollutant concentration in each zone ie Owerri, Okigwe, Orlu and Egbema. The results are presented with Box and Whisker plots as shown below, while the rest of the results are in appendix 7. Box and Whisker plots have been used in air quality studies (Agunbiade, Olu-Owolabi & Adebowale, 2010; Kramer, Helmig, Burkhart, Stoh, Oltmans, & Honrath, 2015; Lorga, Raicu & Stefan, 2015).

### 4.8.1 Dry Season Box and Whisker Plots of Air Pollutant concentration

Fig. 4.46 to 4.49 are the Box and Whisker plots of some air pollutants measured in dry season while the rest are in appendix.7. Fig. 4.46 is the Box and Whisker plot of $PM_{10}$ in Owerri. The plot indicates that in Owerri, 25 % of the results are within 5.00 – 6.50 mg/m$^3$, while 75 % of the results are within 5.09– 8.02 mg/m$^3$ for morning, afternoon and evening. On the other hand Fig. 4.47 is the Box plot of $PM_{10}$ for Okigwe in dry season. It shows that 6.03 – 6.07 mg/m$^3$ and 8.90 – 10.00 mg/m$^3$ of the results obtained in the morning, afternoon and evening are respectively the 25 % and 75 % of the data. Fig. 4.48 is the Box and whisker plot of $NO_2$ for Orlu in dry season. The plot indicates that in the morning, afternoon and evening, 0.43 – 0.47 ppm and 0.51 – 0.53 ppm, are respectively the 25% and 75% of the

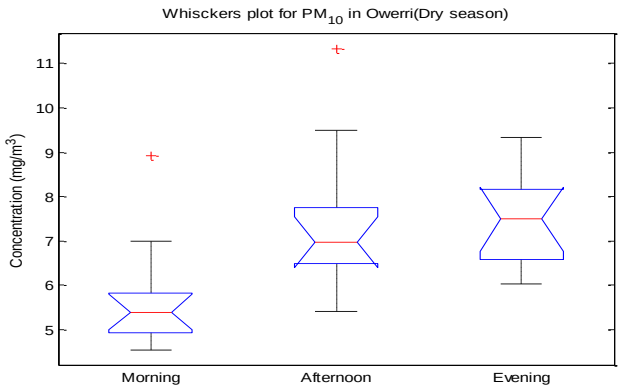


Fig. 4.46: Box and whisker plot of $PM_{10}$ for Owerri (dry season)

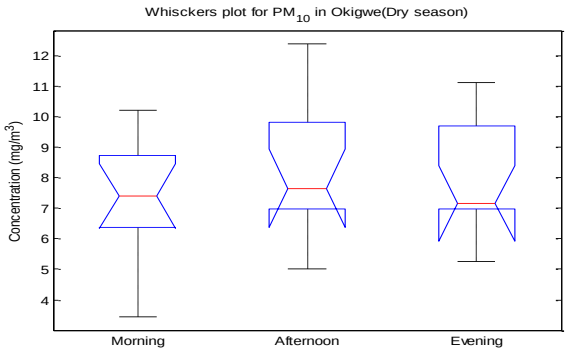



Fig. 4.47: Box and whisker plot of $PM_{10}$ for Okigwe (dry season)

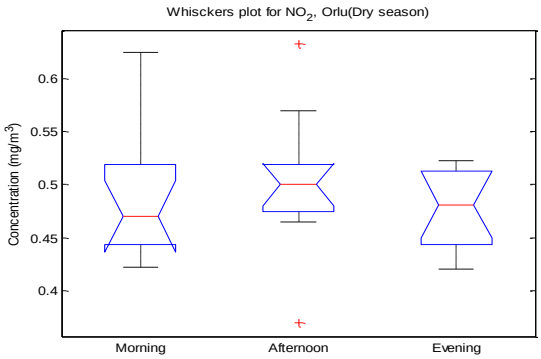



Fig. 4.48: Box and whisker plot of $NO_2$ for Orlu (dry season)

data. Also the Box and Whisker plot of $NO_2$ for Egbema in dry season as shown in Fig. 4.49 indicates that 25 % and 75 % of the data respectively lie within 0.43 – 0.47 ppm and 0.53 – 0.58 ppm in the morning, afternoon and evening.

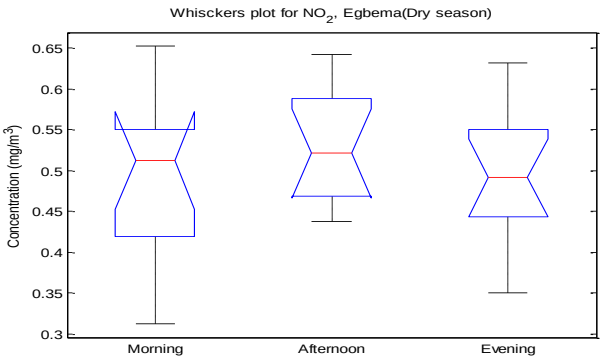


Fig. 4.49: Box and whisker plot of $NO_2$ for Egbema (dry season)

### 4.8.2 Wet Season Box and Whisker Plots of Air Pollutant concentration

The wet season Box and Whisker plots of the measured air pollutant concentration are presented in Fig. 4.50 to 4.53. Fig. 4.50 is the Box and Whisker plot of $PM_{10}$ for Orlu in wet season. The plot reveals that 25 % of results are within 4.5 - 7.3 mg/m$^3$, while 75 % of the results are within 6.2 - 8.3 mg/m$^3$ in the morning, afternoon and evening. Fig. 4.51 is the Box and whisker plot of $PM_{10}$ for Egbema in wet season. It shows that in the morning afternoon and evening, 25 % and 75 % of the results are respectively within 4.5 - 6.7 mg/m$^3$

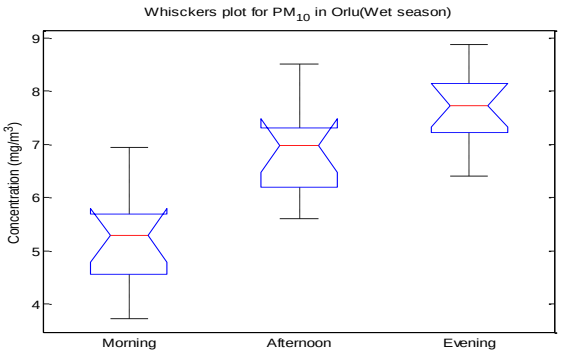



Fig. 4.50: Box and whisker plot of $PM_{10}$ for Orlu (wet season)

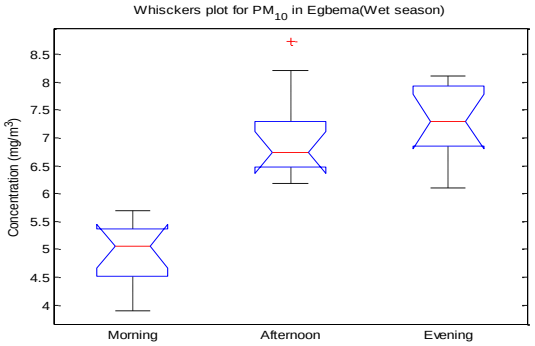



Fig. 4.51: Box and whisker plot of $PM_{10}$ for Egbema (wet season)

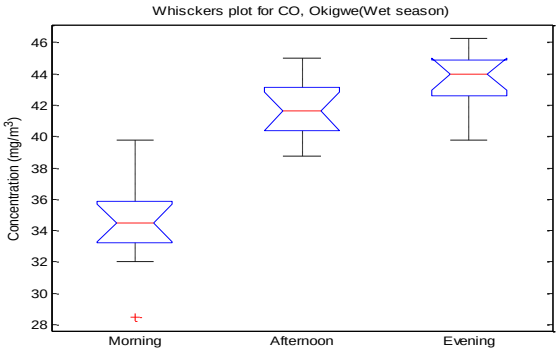



Fig. 4.52: Box and whisker plot of CO for Okigwe (wet season)

and 5.4 - 8.2 mg/m$^3$. Also, Fig. 4.52 is the Box and whisker plot of CO for Okigwe in wet season. The plot indicates that 25% and 75 % of the results in the morning, afternoon and evening are within 33.00 - 42.00 ppm and 36.00 ppm respectively. Again, Fig. 4.53 is the Box and whisker plot of VOC for Egbema in wet season. It could be observed from the plot that 0.68 - 0.95 ppm are respectively for 25 % and 75 % of the results in the morning, afternoon and evening.

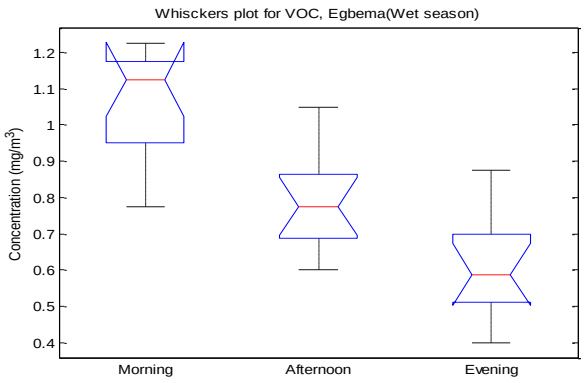



Fig. 4.53: Box and whisker plot of VOC for Egbema (wet season)

## 4.9 Analysis of Variance

One-way ANOVA was carried out to compare the effect of season, meteorological factors, location and time of measurement on the concentrations of of the atmospheric pollutants; $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$. The results were used to ascertain if the averages of the air pollutants were statistically significant. Table 4.17 is the One-way ANOVA which was conducted to compare the effect of season, meteorological factors, location and time of

measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at Egbema in dry season. It was used to determine if the averages of the pollutants are statistically significant. The sig. value of $PM_{10}$ 0.647 is greater than the F. value 0.556, indicating that there is no statistical significant difference in the mean mean of $PM_{10}$. The differences observed in their averages are likely due to chance. On the other hand the sig. values of $NO_2$, $SO_2$, CO VOC and $H_2S$ at 0.030, 0.000, 0.000, 0.647, 0.335 and 0.413 respectively are all greater than their *F* values in Table 4.17. This indicates that there is a statistical significant difference in their means. This observaton implies that the differences observed in their averages are affected by the season, meteorological factors, location and time of measurement.

Table 4.17: ANOVA Table for Pollutant Concentration at Egbema in Dry Season

| | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 3.227 | 3 | 1.076 | .556 | 0.647 |
| | Within Groups | 85.108 | 44 | 1.934 | | |
| | Total | 88.335 | 47 | | | |
| $NO_2$ | Between Groups | 0.076 | 3 | 0.025 | 3.261 | 0.030 |
| | Within Groups | 0.344 | 44 | .008 | | |
| | Total | 0.420 | 47 | | | |
| $SO_2$ | Between Groups | 0.632 | 3 | 0.211 | 8.845 | 0.000 |
| | Within Groups | 1.048 | 44 | 0.024 | | |
| | Total | 1.680 | 47 | | | |
| CO | Between Groups | 147.124 | 3 | 49.041 | 12.202 | 0.000 |
| | Within Groups | 176.837 | 44 | 4.019 | | |
| | Total | 323.962 | 47 | | | |
| VOC | Between Groups | 0.512 | 3 | 0.171 | 1.162 | 0.335 |
| | Within Groups | 6.462 | 44 | 0.147 | | |
| | Total | 6.974 | 47 | | | |
| $H_2S$ | Between Groups | 0.001 | 3 | 0.000 | 0.975 | 0.413 |
| | Within Groups | 0.015 | 44 | 0.000 | | |
| | Total | 0.016 | 47 | | | |

Table 4.18 shows the one-way between subjects ANOVA conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Egbema in dry season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically different. The significant values of wind speed and wave height at 0.693 and 0.905 are higher than the *F* value, which indicates that there is no statistical significant difference in their averages. The sig. values of temperature, relative humidity, air flow and at

Table 4.18: ANOVA table for Meteorological Parameters at Egbema in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.682 | 3 | 0.227 | 0.486 | 0.693 |
| | Within Groups | 20.555 | 44 | 0.467 | | |
| | Total | 21.237 | 47 | | | |
| Temperature | Between Groups | 19.178 | 3 | 6.393 | 1.070 | 0.372 |
| | Within Groups | 262.876 | 44 | 5.974 | | |
| | Total | 282.054 | 47 | | | |
| R.Humidity | Between Groups | 72.244 | 3 | 24.081 | 0.842 | 0.478 |
| | Within Groups | 1258.557 | 44 | 28.604 | | |
| | Total | 1330.800 | 47 | | | |
| Airflow | Between Groups | 6291.236 | 3 | 2097.079 | 1.593 | 0.205 |
| | Within Groups | 57913.939 | 44 | 1316.226 | | |
| | Total | 64205.175 | 47 | | | |
| W.Height | Between Groups | 0.011 | 3 | 0.004 | 0.186 | 0.905 |
| | Within Groups | 0.888 | 44 | 0.020 | | |
| | Total | 0.899 | 47 | | | |

0.372, 0.478 and 0.205 are respectively higher than their *F* values. This means that there is a statistical significant difference in their averages, which may be due to location, season or time of measurement.

Table 4.19 is the one-way ANOVA to compare the effects of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at Egbema in wet season. It was used to determine if the differences in mean values of the pollutants are statistically different. The sig. values of $PM_{10}$, $NO_2$, $SO_2$ CO, VOC and $H_2S$ in the table at 0.000, 0.000, 0.05, 0.004, 0.003 and 0.035 respectively are all less than their *F* values. This indicates that the differences in their mean values are statistically significant. The differences observed in their mean concentrations are affected by type of season, meteorological factors, location and time of measurement.

Table 4.19: ANOVA Table for Pollutant Concentration at Egbema in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 93.906 | 3 | 31.302 | 22.843 | 0.000 |
| | Within Groups | 60.293 | 44 | 1.370 | | |
| | Total | 154.199 | 47 | | | |
| $NO_2$ | Between Groups | 0.260 | 3 | 0.087 | 8.504 | 0.000 |
| | Within Groups | 0.448 | 44 | 0.010 | | |
| | Total | 0.708 | 47 | | | |
| $SO_2$ | Between Groups | 0.351 | 3 | 0.117 | 4.840 | 0.005 |
| | Within Groups | 1.064 | 44 | 0.024 | | |
| | Total | 1.415 | 47 | | | |
| CO | Between Groups | 363.938 | 3 | 121.313 | 5.238 | 0.004 |
| | Within Groups | 1019.002 | 44 | 23.159 | | |
| | Total | 1382.941 | 47 | | | |
| VOC | Between Groups | 0.493 | 3 | 0.164 | 5.266 | 0.003 |
| | Within Groups | 1.372 | 44 | 0.031 | | |
| | Total | 1.865 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | 3.143 | 0.035 |
| | Within Groups | 0.000 | 44 | 0.000 | | |
| | Total | 0.001 | 47 | | | |

Table 4.20 is the one-way between subjects ANOVA conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Egbema in wet season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically significant. The significant values of wind speed, temperature, relative humidity, air flow and wave height are 0.592, 0.366, 0.247, 0.558 and 0.313 respectively are all less than their *F* values. This indicates that there is statistical significant difference in the mean values of these meteorological parameters. The differences observed in their mean values are likely due to the effect of location, season and time o measurement.

Table 4.20: ANOVA table for Meteorological Parameters at Egbema in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.451 | 3 | 0.150 | 0.642 | 0.592 |
| | Within Groups | 10.289 | 44 | 0.234 | | |
| | Total | 10.740 | 47 | | | |
| Temperature | Between Groups | 8.800 | 3 | 2.933 | 1.083 | 0.366 |
| | Within Groups | 119.132 | 44 | 2.708 | | |
| | Total | 127.932 | 47 | | | |
| R.Humidity | Between Groups | 106.335 | 3 | 35.445 | 1.429 | 0.247 |
| | Within Groups | 1091.700 | 44 | 24.811 | | |
| | Total | 1198.035 | 47 | | | |
| Airflow | Between Groups | 1829.735 | 3 | 609.912 | 0.699 | 0.558 |
| | Within Groups | 38412.192 | 44 | 873.004 | | |
| | Total | 40241.926 | 47 | | | |
| W.Height | Between Groups | 0.011 | 3 | 0.004 | 1.221 | 0.313 |
| | Within Groups | 0.133 | 44 | 0.003 | | |
| | Total | 0.144 | 47 | | | |

Table 4.21: ANOVA Table for Pollutant Concentration at Okigwe in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 283.753 | 3 | 94.584 | 21.666 | 0.000 |
| | Within Groups | 192.085 | 44 | 4.366 | | |
| | Total | 475.838 | 47 | | | |
| $NO_2$ | Between Groups | 0.723 | 3 | 0.241 | 21.556 | 0.000 |
| | Within Groups | 0.492 | 44 | 0.011 | | |
| | Total | 1.215 | 47 | | | |
| $SO_2$ | Between Groups | 0.554 | 3 | 0.185 | 20.839 | 0.000 |
| | Within Groups | 0.390 | 44 | 0.009 | | |
| | Total | 0.943 | 47 | | | |
| CO | Between Groups | 2056.514 | 3 | 685.505 | 38.007 | 0.000 |
| | Within Groups | 793.591 | 44 | 18.036 | | |
| | Total | 2850.105 | 47 | | | |
| VOC | Between Groups | 1.156 | 3 | 0.385 | 11.541 | 0.000 |
| | Within Groups | 1.470 | 44 | 0.033 | | |
| | Total | 2.626 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | 2.106 | 0.113 |
| | Within Groups | 0.000 | 44 | 0.000 | | |
| | Total | 0.000 | 47 | | | |

Table 4.21 shows one-way ANOVA conducted to compare the effect of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at okigwe in dry season The result showed the sig. values of $PM_{10}$, $NO_2$,

$SO_2$, CO and VOC at 0.000, 0.000, 0.000, 0.000 and 0.000 respectively, are all less than their *F* values indicating that there is a significant statistical difference in their mean concentrations. This implies that the differences observed in their mean concentrations may have been affected by the season, meteorological factors, location and time of measurement. However, the significant value of $H_2S$ which is greater than the *p* value of 0.05 indicates that there is no statistically significant difference in the mean concentration of these pollutants. This also means that the differences observed in their mean values are likely due to chance.

Table 4.22: ANOVA table for Meteorological Parameters at Okigwe in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 1.320 | 3 | 0.440 | 1.279 | 0.293 |
| | Within Groups | 15.136 | 44 | 0.344 | | |
| | Total | 16.456 | 47 | | | |
| Temperature | Between Groups | 5.340 | 3 | 1.780 | 0.237 | 0.870 |
| | Within Groups | 330.412 | 44 | 7.509 | | |
| | Total | 335.753 | 47 | | | |
| R.Humidity | Between Groups | 118.506 | 3 | 39.502 | 1.514 | 0.224 |
| | Within Groups | 1147.995 | 44 | 26.091 | | |
| | Total | 1266.501 | 47 | | | |
| Airflow | Between Groups | 22188.949 | 3 | 7396.316 | 1.511 | 0.225 |
| | Within Groups | 215365.869 | 44 | 4894.679 | | |
| | Total | 237554.817 | 47 | | | |
| W.Height | Between Groups | 0.065 | 3 | 0.022 | 1.195 | 0.323 |
| | Within Groups | 0.798 | 44 | 0.018 | | |
| | Total | 0.863 | 47 | | | |

Table 4.22 shows the One-way between subjects ANOVA conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height okigwe in dry season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically significant. The significant values of wind speed, temperature, relative humidity, air flow and wave height are 0.293, 0.224, 0.225 and 0.323 respectively are all less than their *F* values except for temperature. This indicates that there is statistical significant difference in the mean values which may be due season, location and time of measurement

Table 4.23 is one-way between subjects ANOVA conducted to compare the effects of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at okigwe in wet season. The significant values of $PM_{10}$, $NO_2$, $SO_2$ CO, $H_2S$ and VOC in the table at 0.000, 0.000, 0.000, 0.000, 0.402 and 0.021 respectively are all

less than the *F* value. This indicates that the differences in their mean concentrations are statistically significant. The differences observed in their mean concentrations are affected by type of season, meteorological factors, location and time of measurement.

Table 4.23: ANOVA Table for Pollutant Concentration at Okigwe in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 207.168 | 3 | 69.056 | 60.583 | 0.000 |
| | Within Groups | 50.154 | 44 | 1.140 | | |
| | Total | 257.322 | 47 | | | |
| $NO_2$ | Between Groups | 0.268 | 3 | 0.089 | 7.567 | 0.000 |
| | Within Groups | 0.520 | 44 | 0.012 | | |
| | Total | 0.788 | 47 | | | |
| $SO_2$ | Between Groups | 1.496 | 3 | 0.499 | 58.302 | 0.000 |
| | Within Groups | .376 | 44 | 0.009 | | |
| | Total | 1.872 | 47 | | | |
| CO | Between Groups | 12976.775 | 3 | 4325.592 | 497.577 | 0.000 |
| | Within Groups | 382.506 | 44 | 8.693 | | |
| | Total | 13359.280 | 47 | | | |
| VOC | Between Groups | 0.268 | 3 | 0.089 | 3.583 | 0.021 |
| | Within Groups | 1.097 | 44 | 0.025 | | |
| | Total | 1.365 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | 1.000 | 0.402 |
| | Within Groups | 0.000 | 44 | 0.000 | | |
| | **Total** | 0.000 | 47 | | | |

Table 4.24 is one-way ANOVA was conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at okigwe in wet season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically significant. The significant values of wind speed and air flow at, 0.578 and 0.592 respectively are higher than the *p* value of 0.05. This indicates that there is no statistically significant difference in the mean values of these meteorological parameters. The differences observed in their mean values are likely due to chance. A different trend is observed as the significant values of temperature, relative humidity and wave height at 0.000, 0.000 and 0.000 are all less than the *p* value of 0.05. This shows that the differences in their mean values are statistically significant. Their values are affected by the type of season, location of measurement and time of measurement.

Table 4.24: ANOVA table for Meteorological Parameters at Okigwe in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.349 | 3 | 0.116 | 0.665 | 0.578 |
| | Within Groups | 7.689 | 44 | 0.175 | | |
| | Total | 8.038 | 47 | | | |
| Temperature | Between Groups | 26.428 | 3 | 8.809 | 17.578 | 0.000 |
| | Within Groups | 22.051 | 44 | 0.501 | | |
| | Total | 48.479 | 47 | | | |
| R.Humidity | Between Groups | 402.947 | 3 | 134.316 | 14.567 | 0.000 |
| | Within Groups | 405.717 | 44 | 9.221 | | |
| | Total | 808.664 | 47 | | | |
| Airflow | Between Groups | 1228.127 | 3 | 409.376 | .642 | 0.592 |
| | Within Groups | 28053.554 | 44 | 637.581 | | |
| | Total | 29281.681 | 47 | | | |
| W.Height | Between Groups | 56027.680 | 3 | 18675.893 | 1154.807 | 0.000 |
| | Within Groups | 711.581 | 44 | 16.172 | | |
| | Total | 56739.261 | 47 | | | |

Table 4.25: ANOVA Table for Pollutant Concentration at Orlu in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 225.494 | 3 | 75.165 | 46.416 | 0.000 |
| | Within Groups | 71.253 | 44 | 1.619 | | |
| | Total | 296.746 | 47 | | | |
| $NO_2$ | Between Groups | 1.151 | 3 | .384 | 164.769 | 0.000 |
| | Within Groups | .102 | 44 | .002 | | |
| | Total | 1.253 | 47 | | | |
| $SO_2$ | Between Groups | 1.185 | 3 | 0.395 | 37.423 | 0.000 |
| | Within Groups | .465 | 44 | 0.011 | | |
| | Total | 1.650 | 47 | | | |
| CO | Between Groups | 1366.024 | 3 | 455.341 | 30.519 | 0.000 |
| | Within Groups | 656.481 | 44 | 14.920 | | |
| | Total | 2022.505 | 47 | | | |
| VOC | Between Groups | .086 | 3 | 0.029 | 0.918 | 0.440 |
| | Within Groups | 1.381 | 44 | 0.031 | | |
| | Total | 1.468 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | 0.112 | 0.952 |
| | Within Groups | 0.001 | 44 | 0.000 | | |
| | Total | 0.001 | 47 | | | |

Table 4.25 is the one-way between subjects ANOVA conducted to compare the effect of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at Orlu in wet season. It was used to determine if the mean

concentrations of the pollutants are statistically significant. The sig. value of $H_2S$ at 0.952 is greater than the F value of 0.112. This indicates that there is no statistical significant difference in the mean values. Any difference observed in the mean values is likely due to chance. On the other hand, the sig. values of $PM_{10}$, $NO_2$, $SO_2$, VOC and CO at 0.000, 0.000, 0.000, 0.440 and 0.000 respectively which are less than their F values, indicating that there is a statistical significant difference in their mean values. This implies that the differences observed in their mean values mayhave been affected by the meteorological factors, season, location and time of measurement.

Table 4.26: ANOVA table for Meteorological Parameters at Orlu in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 105.159 | 3 | 35.053 | 17.810 | 0.000 |
| | Within Groups | 86.601 | 44 | 1.968 | | |
| | Total | 191.760 | 47 | | | |
| Temperature | Between Groups | 15.280 | 3 | 5.093 | 0.538 | 0.659 |
| | Within Groups | 416.573 | 44 | 9.468 | | |
| | Total | 431.853 | 47 | | | |
| R.Humidity | Between Groups | 202.220 | 3 | 67.407 | 2.038 | .122 |
| | Within Groups | 1455.211 | 44 | 33.073 | | |
| | Total | 1657.431 | 47 | | | |
| Airflow | Between Groups | 371.418 | 3 | 123.806 | 0.160 | 0.923 |
| | Within Groups | 34021.029 | 44 | 773.205 | | |
| | Total | 34392.447 | 47 | | | |
| W.Height | Between Groups | .061 | 3 | 0.020 | 0.487 | 0.693 |
| | Within Groups | 1.851 | 44 | 0.042 | | |
| | Total | 1.912 | 47 | | | |

Table 4.26 is ANOVA to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Orlu in dry season. It was observed that only the significant values of wind speed and relative humidity at 0.000 and 0.122 are less than their F values indicating that the difference observed in the mean values are statistically significant. The wind speed is influenced by the season, metrology, location and time of measurement. On the other hand, the significant values of temperature, air flow and wave height at 0.659, 0.923 and 0.693 respectively are all higher than their *F* value. This indicates that there is no statistical significant difference in the mean values. The differences observed in their mean values are likely due to chance.

Table 4.27 is a one-way between subjects ANOVA was conducted to compare the effects of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at Orlu in wet season. The result showed that the significant

values of $PM_{10}$, $NO_2$, $SO_2$ CO, VOC and $H_2S$ in the table at 0.000, 0.000, 0.005, 0.004, 0.003 and 0.035 respectively are all less than their *F* values. This indicates that the differences in their mean values are statistically significant. The differences observed in their mean concentrations are affected by type of season, meteorological factors, location and time of measurement.

Table 4.27: ANOVA Table for Pollutant Concentration at Orlu in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 93.906 | 3 | 31.302 | 22.843 | 0.000 |
| | Within Groups | 60.293 | 44 | 1.370 | | |
| | Total | 154.199 | 47 | | | |
| $NO_2$ | Between Groups | .260 | 3 | 0.087 | 8.504 | 0.000 |
| | Within Groups | .448 | 44 | 0.010 | | |
| | Total | .708 | 47 | | | |
| $SO_2$ | Between Groups | .351 | 3 | 0.117 | 4.840 | 0.005 |
| | Within Groups | 1.064 | 44 | 0.024 | | |
| | Total | 1.415 | 47 | | | |
| CO | Between Groups | 363.938 | 3 | 121.313 | 5.238 | 0.004 |
| | Within Groups | 1019.002 | 44 | 23.159 | | |
| | Total | 1382.941 | 47 | | | |
| VOC | Between Groups | .493 | 3 | 0.164 | 5.266 | 0.003 |
| | Within Groups | 1.372 | 44 | 0.031 | | |
| | Total | 1.865 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | 3.143 | 0.035 |
| | Within Groups | 0.000 | 44 | 0.000 | | |
| | Total | 0.001 | 47 | | | |

Table 4.28 is the one-way between subjects ANOVA was conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Orlu in wet season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically significant. The significant values of wind speed and temperature at 0.659 and 0.713 are higher than the *F* value of 0.537 and 0.459 respectively. These indicate that there is no statistically significant difference in the mean values of these meteorological parameters. Any differences observed in their mean values are likely due to chance. However, the significant values of relative humidity, air flow and wave height at 0.03, 0.002 and 0.108 which are less than their *F* values show that the difference in their mean values are statistically significant. The interpretation is that these parameters are influenced by season, location and time of measurement.

Table 4.28: ANOVA table for Meteorological Parameters at Orlu in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.368 | 3 | 0.123 | 0.537 | 0.659 |
| | Within Groups | 10.055 | 44 | 0.229 | | |
| | Total | 10.424 | 47 | | | |
| Temperature | Between Groups | 2.394 | 3 | 0.798 | 0.459 | 0.713 |
| | Within Groups | 76.546 | 44 | 1.740 | | |
| | Total | 78.940 | 47 | | | |
| R.Humidity | Between Groups | 251.412 | 3 | 83.804 | 3.278 | 0.030 |
| | Within Groups | 1124.869 | 44 | 25.565 | | |
| | Total | 1376.280 | 47 | | | |
| Airflow | Between Groups | 15111.588 | 3 | 5037.196 | 5.799 | 0.002 |
| | Within Groups | 38219.709 | 44 | 868.630 | | |
| | Total | 53331.297 | 47 | | | |
| W.Height | Between Groups | 0.015 | 3 | 0.005 | 2.145 | 0.108 |
| | Within Groups | 0.101 | 44 | 0.002 | | |
| | Total | 0.116 | 47 | | | |

Table 4.29: ANOVA Table for Pollutant Concentration at Owerri in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 115.658 | 3 | 38.553 | 19.852 | 0.000 |
| | Within Groups | 85.447 | 44 | 1.942 | | |
| | Total | 201.106 | 47 | | | |
| $NO_2$ | Between Groups | 0.510 | 3 | 0.170 | 44.086 | 0.000 |
| | Within Groups | 0.170 | 44 | 0.004 | | |
| | Total | 0.680 | 47 | | | |
| $SO_2$ | Between Groups | 0.977 | 3 | 0.326 | 11.348 | 0.000 |
| | Within Groups | 1.263 | 44 | 0.029 | | |
| | Total | 2.240 | 47 | | | |
| CO | Between Groups | 595.757 | 3 | 198.586 | 7.775 | 0.000 |
| | Within Groups | 1123.833 | 44 | 25.542 | | |
| | Total | 1719.590 | 47 | | | |
| VOC | Between Groups | 0.245 | 3 | 0.082 | 2.079 | 0.117 |
| | Within Groups | 1.729 | 44 | 0.039 | | |
| | Total | 1.974 | 47 | | | |
| $H_2S$ | Between Groups | 0.001 | 3 | 0.000 | 1.943 | 0.137 |
| | Within Groups | 0.009 | 44 | 0.000 | | |
| | Total | 0.010 | 47 | | | |

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Table 4.29 is a one - way ANOVA which was used to determine if the means of the air pollutants across the locations and measured at different time intervals are statistically different at Owerri in dry season. It was observed that the significant values of the pollutants $PM_{10}$, $NO_2$, $SO_2$ and CO were all less than their *F* values. This shows that the differences observed in the mean values of these parameters are statistically significant. This implies that the difference is not due to chance but is probably affected by the location, time and the season of measurement.

Table 4.30: ANOVA table for Meteorological Parameters at Owerri in Dry Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.210 | 3 | 0.070 | 0.182 | 0.908 |
| | Within Groups | 16.929 | 44 | 0.385 | | |
| | Total | 17.139 | 47 | | | |
| Temperature | Between Groups | 8.464 | 3 | 2.821 | 0.431 | 0.732 |
| | Within Groups | 288.171 | 44 | 6.549 | | |
| | Total | 296.635 | 47 | | | |
| R.Humidity | Between Groups | 181.159 | 3 | 60.386 | 3.355 | 0.027 |
| | Within Groups | 792.015 | 44 | 18.000 | | |
| | Total | 973.174 | 47 | | | |
| Airflow | Between Groups | 544.699 | 3 | 181.566 | 0.219 | 0.883 |
| | Within Groups | 36524.703 | 44 | 830.107 | | |
| | Total | 37069.402 | 47 | | | |
| W.Height | Between Groups | 0.012 | 3 | 0.004 | 0.419 | 0.740 |
| | Within Groups | 0.435 | 44 | 0.010 | | |
| | Total | 0.448 | 47 | | | |

Table 4.30 is a one-way between subjects ANOVA conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Owerri in dry season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically different. The significant values of wind speed, temperature, air flow and wave height at 0.908, 0.732, 0.883 and 0.740 arerespectively all higher than their *F* values. This indicates that there is no statistical significant difference in their mean values. The differences observed in their mean values are likely due to chance. The significant value of relative humidity at 0.027 being less than *F* value shows that the difference in the mean value is statistically significant. This parameter is influenced by season, location and time of measurement.

Table 4.31 is the one-way between subjects ANOVA conducted to compare the effects of season, meteorological factors, location and time of measurement on the concentrations of $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ at Owerri in wet season. It was used to determine if the differences in mean values of the pollutants are statistically different. The significant values of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC in the table at 0.000, 0.000, 0.000, 0.000 and 0.079 respectively are all less than their *F* values. This indicates that the differences in their mean values are statistically significant. The differences observed in their mean concentrations may have been affected by type of season, meteorological factors, location and time of measurement.

Table 4.31: ANOVA Table for Pollutant Concentration at Owerri in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| $PM_{10}$ | Between Groups | 82.731 | 3 | 27.577 | 33.803 | 0.000 |
| | Within Groups | 35.896 | 44 | 0.816 | | |
| | Total | 118.627 | 47 | | | |
| $NO_2$ | Between Groups | 0.684 | 3 | 0.228 | 22.565 | 0.000 |
| | Within Groups | 0.445 | 44 | 0.010 | | |
| | Total | 1.129 | 47 | | | |
| $SO_2$ | Between Groups | 2.093 | 3 | 0.698 | 30.234 | 0.000 |
| | Within Groups | 1.015 | 44 | 0.023 | | |
| | Total | 3.108 | 47 | | | |
| CO | Between Groups | 516.742 | 3 | 172.247 | 17.641 | 0.000 |
| | Within Groups | 429.630 | 44 | 9.764 | | |
| | Total | 946.372 | 47 | | | |
| VOC | Between Groups | 0.174 | 3 | 0.058 | 2.422 | 0.079 |
| | Within Groups | 1.051 | 44 | 0.024 | | |
| | Total | 1.224 | 47 | | | |
| $H_2S$ | Between Groups | 0.000 | 3 | 0.000 | . | . |
| | Within Groups | 0.000 | 44 | 0.000 | | |
| | Total | 0.000 | 47 | | | |

Table 4.32 is the one-way between subjects ANOVA was conducted to compare the influence of season, location and time of measurement on the mean values of wind speed, temperature, relative humidity, air flow and wave height at Owerri in wet season. It was used to determine if the difference in the mean values of these meteorological parameters are statistically significant. The significant values of wind speed and relative humidity height are 0.857 and 0.700 respectively are all higher than their *F* value of 0.255 and 0.477. These indicate that there is no statistically significant difference in the mean values of these meteorological parameters. The differences observed in their mean values are likely due to chance. The significant value of temperature, air flow and wave height at 0.098, 0.000 and 0.464 is statistically significant

meaning that this metrological parameters are influenced by the season, location and time of measurement.

Table 4.32: ANOVA table for Meteorological Parameters at Owerri in Wet Season

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| W.Speed | Between Groups | 0.149 | 3 | 0.050 | 0.255 | 0.857 |
| | Within Groups | 8.585 | 44 | 0.195 | | |
| | Total | 8.735 | 47 | | | |
| Temperature | Between Groups | 8.289 | 3 | 2.763 | 2.231 | 0.098 |
| | Within Groups | 54.484 | 44 | 1.238 | | |
| | Total | 62.773 | 47 | | | |
| R.Humidity | Between Groups | 27.356 | 3 | 9.119 | 0.477 | 0.700 |
| | Within Groups | 841.412 | 44 | 19.123 | | |
| | Total | 868.768 | 47 | | | |
| Airflow | Between Groups | 12643.913 | 3 | 4214.638 | 7.339 | 0.000 |
| | Within Groups | 25268.105 | 44 | 574.275 | | |
| | Total | 37912.018 | 47 | | | |
| W.Height | Between Groups | 0.004 | 3 | 0.001 | 0.870 | 0.464 |
| | Within Groups | 0.066 | 44 | 0.002 | | |
| | Total | 0.070 | 47 | | | |

## 4.10 Correlation Analysis

In order to determine the strength and direction of the linear relationships that exist between the atmospheric pollutants or between the meteorological parameters the Pearson product-moment correlation co-efficient, r, was computed to assess this relationships. Table 4.33 is the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between one pollutant and the other at Egbema in dry season. Weak positive correlations were observed between $PM_{10}$ and $SO_2$, r = 0.425, N = 48, $p$ = 0.003, $NO_2$ and CO and VOC, r = 0.397, N = 48, $p$ = 0.05 and r = 0.393, N = 48, $p$ = 0.006, respectively. CO also has a weak positive correlation with $SO_2$, r = 0.450, N = 48, $p$ = 0.05. The other correlations observed are not significant.

Table 4.34 is the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the meteorological parameters in dry season at Egbema. Weak negative significant correlation was observed between wind speed and temperature, r = - 0.505, N = 48, $p$ = 0.000. The correlation of this

parameter with relative humidity is weak and positive, r = 0.470, N= 48, $p$ = 0.001. High positive correlations were observed between wind speed and air flow and wave height, r = 0.781, N= 48, $p$ = 0.000 and r = 0.793, N= 48, $p$ = 0.000, respectively. Temperature has a high negative correlation with relative humidity, r = 0.000, N = 48, $p$ = 0.000 but a weak negative correlation with airflow. Air flow also has a weak correlation with wave height, r = 0.559, N = 48, $p$ = 0.000. Wave height has a high negative correlation with temperature, r = - 0.728, N = 48, $p$ = 0.000.

Table 4.33: Correlation Table for Pollutant Concentration at Egbema in Dry Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| $PM_{10}$ | Pearson Correlation | 1.000 | 0.044 | 0.425** | 0.258 | 0.067 | 0.281 |
| | Sig. (2-tailed) | | 0.769 | 0.003 | 0.076 | 0.649 | 0.053 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $NO_2$ | Pearson Correlation | 0.044 | 1.000 | 0.225 | 0.397** | 0.393** | -0.034 |
| | Sig. (2-tailed) | 0.769 | | 0.123 | 0.005 | 0.006 | 0.818 |
| | N | 48.00 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $SO_2$ | Pearson Correlation | 0.425** | 0.225 | 1.000 | 0.450** | 0.140 | 0.158 |
| | Sig. (2-tailed) | 0.003 | 0.123 | | 0.001 | 0.342 | 0.283 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| CO | Pearson Correlation | 0.258 | 0.397** | 0.450** | 1.000 | 0.046 | -0.018 |
| | Sig. (2-tailed) | 0.076 | 0.005 | 0.001 | | 0.754 | 0.905 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| VOC | Pearson Correlation | 0.067 | 0.393** | 0.140 | 0.046 | 1.000 | 0.127 |
| | Sig. (2-tailed) | 0.649 | 0.006 | 0.342 | 0.754 | | 0.391 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $H_2S$ | Pearson Correlation | 0.281 | -0.034 | 0.158 | -0.018 | 0.127 | 1.000 |
| | Sig. (2-tailed) | 0.053 | 0.818 | 0.283 | 0.905 | 0.391 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.34: Correlation Table for meteorological Parameters at Egbema in Dry Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | -0.505** | 0.470** | 0.781** | 0.793** |
| | Sig. (2-tailed) | | 0.000 | 0.001 | 0.000 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | -0.505** | 1.000 | -0.808** | -0.326* | -0.728** |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.024 | 0.000 |
| | N | 48.00 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | 0.470** | -0.808** | 1.000 | 0.235 | 0.613** |
| | Sig. (2-tailed) | 0.001 | 0.000 | | 0.108 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.781** | -0.326* | 0.235 | 1.000 | 0.559** |
| | Sig. (2-tailed) | 0.000 | 0.024 | 0.108 | | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.793** | -0.728** | 0.613** | 0.559** | 1.000 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.35 shows the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the air pollutants at Egbema in dry season. Weak positive correlations were observed between $PM_{10}$ and $SO_2$ and $H_2S$, r = 0.396, N = 48, $p$ = 0.005 and r = 0.380, N = 48, $p$ = 0.008, respectively. $PM_{10}$ however had a moderate positive correlation with $NO_2$, r = 0.520, N = 48, $p$ = 0.000. On the other hand, $NO_2$ had a moderately positive correlation with $SO_2$, r = 0.576, N = 48, $p$ = 0.000. VOC had a weak positive correlation with $SO_2$ as well as $H_2S$ which had a weak positive correlation with $PM_{10}$, r = 0.374, N = 48, $p$ = 0.009 and r = 0.380, N = 48, $p$ = 0.008 respectively.

Table 4.35: Correlation Table for Pollutant Concentration at Egbema in Wet Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| | Pearson Correlation | 1.000 | 0.520** | 0.396** | -0.042 | 0.184 | 0.380** |
| $PM_{10}$ | Sig. (2-tailed) | | 0.000 | 0.005 | 0.775 | 0.212 | 0.008 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.0000 |
| | Pearson Correlation | 0.520** | 1.000 | 0.576** | 0.324* | 0.177 | 0.171 |
| $NO_2$ | Sig. (2-tailed) | 0.000 | | 0.000 | 0.025 | 0.230 | 0.246 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.396** | 0.576** | 1.000 | 0.130 | 0.374** | 0.102 |
| $SO_2$ | Sig. (2-tailed) | 0.005 | 0.000 | | 0.380 | 0.009 | 0.492 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | -0.042 | 0.324* | 0.130 | 1.000 | 0.053 | -0.156 |
| CO | Sig. (2-tailed) | 0.775 | 0.025 | 0.380 | | 0.720 | 0.289 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.184 | 0.177 | 0.374** | 0.053 | 1.000 | 0.190 |
| VOC | Sig. (2-tailed) | 0.212 | 0.230 | 0.009 | 0.720 | | 0.195 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.380** | 0.171 | 0.102 | -0.156 | 0.190 | 1.000 |
| $H_2S$ | Sig. (2-tailed) | 0.008 | 0.246 | 0.492 | 0.289 | 0.195 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The result of Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between one meteorological parameter and the other at Egbema in wet season is shown in Table 4.36. Strong significant positive correlations was observed between wind speed and wave height, r = 0.627, N = 48, $p$ = 0.000 and very strong positive correlations with air flow, r = 0.916, N = 48, $p$ = 0.000. Temperature has a very strong negative correlation with relative humidity, r = - 0.805, N = 48, $p$ = 0.000. It was also

observed that wave height has a moderately positive correlation with wind speed and air flow, r = 0.627, N= 48, $p$ = 0.000 and r = 0.579, N = 48, $p$ = 0.000 respectively.

Table 4.36: Correlation Table for meteorological Parameters at Egbema in Wet Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | 0.004 | -0.028 | 0.916** | 0.627** |
| | Sig. (2-tailed) | | 0.979 | 0.852 | 0.000 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | 0.004 | 1.000 | -0.805** | -0.098 | 0.074 |
| | Sig. (2-tailed) | 0.979 | | 0.000 | 0.509 | 0.619 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | -0.028 | -0.805** | 1.000 | 0.060 | -0.126 |
| | Sig. (2-tailed) | 0.852 | 0.000 | | 0.686 | 0.395 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48 |
| Airflow | Pearson Correlation | 0.916** | -0.098 | 0.060 | 1.000 | 0.579** |
| | Sig. (2-tailed) | 0.000 | 0.509 | 0.686 | | 0.000 |
| | N | 48.0000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.627** | 0.074 | -0.126 | 0.579** | 1.000 |
| | Sig. (2-tailed) | 0.000 | 0.619 | 0.395 | 0.000 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.37: Correlation Table for Pollutant Concentration at Okigwe in Dry Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| $PM_{10}$ | Pearson Correlation | 1.000 | 0.564** | 0.503** | 0.647** | 0.063 | 0.018 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.670 | 0.906 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $NO_2$ | Pearson Correlation | 0.564** | 1.000 | 0.725** | 0.778** | -0.027 | -0.079 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.000 | 0.854 | 0.593 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $SO_2$ | Pearson Correlation | 0.503** | 0.725** | 1.000 | 0.703** | -0.103 | 0.109 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | .000 | 0.486 | 0.462 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| CO | Pearson Correlation | 0.647** | 0.778** | 0.703** | 1.000 | -0.061 | 0.022 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.681 | 0.880 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| VOC | Pearson Correlation | 0.063 | -0.027 | -0.103 | -0.061 | 1.000 | -0.125 |
| | Sig. (2-tailed) | 0.670 | 0.854 | 0.486 | 0.681 | | 0.396 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $H_2S$ | Pearson Correlation | 0.018 | -0.079 | 0.109 | 0.022 | -0.125 | 1.000 |
| | Sig. (2-tailed) | 0.906 | 0.593 | 0.462 | 0.880 | 0.396 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.37 shows the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the pollutants at Okigwe in dry season. Moderately positive correlations were observed between $PM_{10}$ and $NO_2$, $SO_2$ and CO, r = 0.564, N = 48, $p$ = 0.000, r = 0.503, N = 48, $p$ = 0.000 and r = 0.647, N = 48, $p$ = 0.000 respectively. CO also had a moderately positive correlation with $PM_{10}$, a very strong positive correlation with $NO_2$ and $SO_2$, r = 0.778, N = 48, $p$ = 0.000, r = 703, N = 48, $p$ = 0.000 respectively. The other correlations observed were not significant.

Table 4.38 is the Pearson product-moment correlation co-efficient, r, which was computed to assess the strength and direction of the linear relationships that exist between the meteorological parameters in dry season at Okigwe. A strong negative significant correlation was observed between wind speed and temperature, r = - 0.744, N = 48, $p$ = 0.000. However, moderate positive correlations was observed for wind speed and relative humidity and wave height, r = 0.595, N = 48, $p$ = 0.000 and r = 0.684, N = 48, $p$ = 0.684. Wind speed had a weak positive correlation with air flow, r = 0.399, N = 48, $p$ = 0.005. Temperature had a very strong negative correlation with wind speed and relative humidity, r = - 0.744, N = 48, $p$ = 0.000 and r = -0.879, N = 48, $p$ = 0.000. It also had a weak negative correlation with wave height, r = - 0.545, N = 48, $p$ = 0.000. Relative humidity also had a weak positive correlation with wave height and air flow, r = 0.455, N = 48, $p$ = 0.001 and r = 0.378, N = 48, p = 0.008.

Table 4.38: Correlation Table for meteorological Parameters at Okigwe in Dry Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | -0.744** | 0.595** | 0.399** | 0.684** |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.005 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | -0.744** | 1.000 | -0.879** | -0.351* | -0.545** |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.015 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | 0.595** | -0.879** | 1.000 | 0.378** | 0.455** |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.008 | 0.001 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.399** | -0.351* | 0.378** | 1.000 | 0.186 |
| | Sig. (2-tailed) | .005 | 0.015 | 0.008 | | 0.206 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.684** | -0.545** | 0.455** | 0.186 | 1.000 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.001 | 0.206 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.39 shows the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between one pollutant and the other in wet season at Okigwe. Moderately positive correlations were observed between $PM_{10}$ and $SO_2$ and CO, r = 0.628, N = 48, $p$ = 0.000, r = 0.506, N = 48, $p$ = 0.000 respectively. The other correlations observed are not significant.

Table 4.39: Correlation Table for Pollutant Concentration at Okigwe in Wet Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| $PM_{10}$ | Pearson Correlation | 1.000 | 0.362* | 0.628** | 0.506** | 0.347* | 0.073 |
| | Sig. (2-tailed) | | 0.011 | 0.000 | 0.000 | 0.016 | 0.622 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $NO_2$ | Pearson Correlation | 0.362* | 1.000 | 0.345* | 0.344* | 0.294* | 0.139 |
| | Sig. (2-tailed) | 0.011 | | 0.016 | 0.017 | 0.043 | 0.345 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $SO_2$ | Pearson Correlation | 0.628** | 0.345* | 1.000 | 0.158 | 0.318* | -0.060 |
| | Sig. (2-tailed) | 0.000 | 0.016 | | 0.283 | 0.028 | 0.685 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| CO | Pearson Correlation | 0.506** | 0.344* | 0.158 | 1.000 | 0.238 | 0.073 |
| | Sig. (2-tailed) | 0.000 | 0.017 | 0.283 | | 0.103 | 0.623 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| VOC | Pearson Correlation | 0.347* | 0.294* | 0.318* | 0.238 | 1.000 | -0.199 |
| | Sig. (2-tailed) | 0.016 | 0.043 | 0.028 | 0.103 | | 0.174 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $H_2S$ | Pearson Correlation | 0.073 | 0.139 | -0.060 | 0.073 | -0.199 | 1.000 |
| | Sig. (2-tailed) | 0.622 | 0.345 | 0.685 | 0.623 | 0.174 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.40: Correlation Table for meteorological Parameters at Okigwe in Wet Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | 0.105 | -0.110 | 0.910** | -0.027 |
| | Sig. (2-tailed) | | 0.478 | 0.455 | 0.000 | 0.856 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | 0.105 | 1.000 | -0.883** | -0.090 | -0.218 |
| | Sig. (2-tailed) | 0.478 | | 0.000 | 0.542 | 0.136 |
| | N | 48.000 | 48 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | -0.110 | -0.883** | 1.000 | 0.094 | 0.071 |
| | Sig. (2-tailed) | 0.455 | 0.000 | | 0.524 | 0.630 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.910** | -0.090 | 0.094 | 1.000 | -0.009 |
| | Sig. (2-tailed) | 0.000 | 0.542 | 0.524 | | 0.950 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | -0.027 | -0.218 | 0.071 | -0.009 | 1.000 |
| | Sig. (2-tailed) | 0.856 | 0.136 | 0.630 | 0.950 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.40 is the Pearson product-moment correlation co-efficient, r, estimated to assess the strength and direction of the linear relationships between the meteorological parameters in wet season at Okigwe. A very strong positive significant correlation was observed between wind speed and airflow, r = 0.910, N = 48, $p$ = 0.000. Temperature however had a very strong negative correlation with relative humidity, r = - 0.883, N = 48, $p$ = 0.000. All the other correlations are not significant.

The Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the pollutants at Orlu in dry season is shown in Table 4.41. The parameter $PM_{10}$ had a very strong positive correlation with $NO_2$ and CO and a moderate correlation with $SO_2$, r = 0.815, N = 48, $p$ = 0.000, r = 0.751, N = 48, $p$ = 0.000 and r = 0.660, N = 48, $p$ = 0.000. Also very strong correlations existed between $NO_2$ and $SO_2$ and CO, r = 0.852, N = 48, $p$ = 0.000 and r = 0.805, N = 48, $p$ = 0.000 respectively. CO had a moderately positive correlation with $SO_2$, r = 0.662, N = 48, $p$ = 0.000.

Table 4.41: Correlation Table for Pollutant Concentration at Orlu in Dry Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| | Pearson Correlation | 1.000 | 0.815** | 0.660** | 0.751** | 0.071 | 0.180 |
| $PM_{10}$ | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.629 | 0.221 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.815** | 1.000 | 0.852** | 0.805** | 0.102 | 0.049 |
| $NO_2$ | Sig. (2-tailed) | 0.000 | | 0.000 | 0.000 | 0.488 | 0.738 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.660** | 0.852** | 1.000 | 0.662** | 0.197 | 0.098 |
| $SO_2$ | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.179 | 0.506 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.00 | 48.000 |
| | Pearson Correlation | 0.751** | 0.805** | 0.662** | 1.000 | 0.298* | 0.070 |
| CO | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.040 | 0.636 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.071 | 0.102 | 0.197 | 0.298* | 1.000 | 0.086 |
| VOC | Sig. (2-tailed) | 0.629 | 0.488 | 0.179 | 0.040 | | 0.559 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.180 | 0.049 | 0.098 | 0.070 | 0.086 | 1.000 |
| $H_2S$ | Sig. (2-tailed) | 0.221 | 0.738 | 0.506 | 0.636 | 0.559 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.42 is the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the meteorological parameters at Orlu in dry season. Weak negative significant correlations was observed between wind speed and temperature, r = - 0.383, N = 48, $p$ = 0.007. Moderate positive correlations were

observed between wind speed and air flow and wave height, r = 0.534, N = 48, $p$ = 0.007 and r = 0.554, N = 48, $p$ = 0.000 respectively. A very strong negative correlation existed between temperature and relative humidity, r = - 0.910, N = 48, $p$ = 0.000. The correlation between temperature and air flow and wave height were moderately negative, r = - 0.638, N = 48, $p$ = 0.000 and r = - 0.581. N = 48, $p$ = 0.000. The correlation of air flow with relative humiditywas moderate and positive, r = 0.558, N= 48, $p$ = 0.000. Air flow and wave height had a moderate positive correlation, r = 0.606, N= 48, $p$ = 0.000. Wave height had a weak correlation with relative humidity, r = 0.490, N = 48, $p$ = 0.000.

Table 4.42: Correlation Table for meteorological Parameters at Orlu in Dry Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | -0.383** | 0.221 | 0.534** | 0.554** |
| | Sig. (2-tailed) | | 0.007 | 0.131 | 0.000 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | -0.383** | 1.000 | -.910** | -0.638** | -0.581** |
| | Sig. (2-tailed) | 0.007 | | 0.000 | 0.000 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | 0.221 | -0.910** | 1.000 | 0.558** | 0.490** |
| | Sig. (2-tailed) | 0.131 | 0.000 | | 0.000 | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.534** | -0.638** | 0.558** | 1.00 | 0.606** |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.554** | -0.581** | 0.490** | 0.606** | 1.000 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

The Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships between the pollutants at Orlu in wet season is presented in Table 4.43. Weak positive correlations were observed between $PM_{10}$ and $SO_2$ and $H_2S$, r = 0.396, N = 48, $p$ = 0.005 and r = 0.380, N = 48, $p$ = 0.008 respectively. There was however a moderate positive correlation between $PM_{10}$ and $NO_2$, r = 0.576, N = 48, $p$ = 0.000 and r = 0.374, N = 48, $p$ = 0.009. The other correlations observed were not significant.

Presented in Table 4.44 is the Pearson product-moment correlation co-efficient, r, estimated to assess the strength and direction of the linear relationships between the meteorological parameters in wet season at Orlu. The correlation existing between wind speed and air flow was a very strong and positive one, r = 0.826, N = 48, $p$ = 0.000 and a weak positive correlation with wave height, r = 0.467, N = 48, $p$ = 0.001. Temperature has a moderate negative correlation with relative humidity, r = - 0.640, N = 48, $p$ = 0.000. It was also observed that wave

height has a weak positive correlation with wind speed and air flow, r = 0.467, N= 48, $p$ = 0.001 and r = 0.405, N = 48, $p$ = 0.004, respectively.

Table 4.43: Correlation Table for Pollutant Concentration at Orlu in Wet Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| PM10 | Pearson Correlation | 1.000 | 0.520** | 0.396** | -0.042 | 0.184 | 0.380** |
| | Sig. (2-tailed) | | 0.000 | 0.005 | 0.775 | 0.212 | 0.008 |
| | N | 48.000 | 48.000 | 48.000 | 48.00 | 48.000 | 48.000 |
| NO2 | Pearson Correlation | 0.520** | 1.000 | 0.576** | 0.324* | 0.177 | 0.171 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.025 | 0.230 | 0.246 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| SO2 | Pearson Correlation | 0.396** | 0.576** | 1.000 | 0.130 | 0.374** | 0.102 |
| | Sig. (2-tailed) | 0.005 | 0.000 | | 0.380 | 0.009 | 0.492 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| CO | Pearson Correlation | -0.042 | 0.324* | 0.130 | 1.000 | 0.053 | -0.156 |
| | Sig. (2-tailed) | 0.775 | 0.025 | 0.380 | | 0.720 | 0.289 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| VOC | Pearson Correlation | 0.184 | 0.177 | 0.374** | 0.053 | 1.000 | 0.190 |
| | Sig. (2-tailed) | 0.212 | 0.230 | 0.009 | 0.720 | | 0.195 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| H2S | Pearson Correlation | 0.380** | 0.171 | 0.102 | -0.156 | 0.190 | 1.000 |
| | Sig. (2-tailed) | 0.008 | 0.246 | 0.492 | 0.289 | 0.195 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.44: Correlation Table for meteorological Parameters at Orlu in Wet Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | -0.160 | 0.008 | 0.826** | 0.467** |
| | Sig. (2-tailed) | | 0.276 | 0.959 | 0.000 | 0.001 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | -0.160 | 1.000 | -0.640** | -0.276 | -0.039 |
| | Sig. (2-tailed) | 0.276 | | 0.000 | 0.058 | 0.792 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | 0.008 | -0.640** | 1.000 | -0.003 | -0.202 |
| | Sig. (2-tailed) | 0.959 | 0.000 | | 0.983 | 0.168 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.826** | -0.276 | -0.003 | 1.000 | 0.405** |
| | Sig. (2-tailed) | 0.000 | 0.058 | 0.983 | | 0.004 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.467** | -0.039 | -0.202 | 0.405** | 1.000 |
| | Sig. (2-tailed) | 0.001 | 0.792 | 0.168 | 0.004 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.45 shows the linear relationships and associations among the atmospheric variables measured using the Pearson's Correlation co-efficient, *r*, at Owerri in dry season. There were moderate positive correlations between $PM_{10}$ and $NO_2$ at 0.638, $SO_2$ at 0.439 and CO at 0.533. These correlations were significant at the 0.01 significance level (2-tailed). $PM_{10}$ has weak non-significant correlations with VOC and $H_2S$ at 0.109 and 0.124.

Table 4.45: Correlation Table for Pollutant Concentration at Owerri in Dry Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| $PM_{10}$ | Pearson Correlation | 1.000 | 0.638** | 0.439** | 0.533** | 0.109 | 0.124 |
| | Sig. (2-tailed) | | 0.000 | 0.002 | 0.000 | 0.460 | 0.402 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $NO_2$ | Pearson Correlation | 0.638** | 1.000 | 0.377** | 0.590** | 0.064 | 0.205 |
| | Sig. (2-tailed) | 0.000 | | 0.008 | 0.000 | 0.665 | 0.163 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $SO_2$ | Pearson Correlation | 0.439** | 0.377** | 1.000 | 0.106 | -0.177 | 0.129 |
| | Sig. (2-tailed) | 0.002 | 0.008 | | 0.474 | 0.228 | 0.382 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| CO | Pearson Correlation | 0.533** | 0.590** | 0.106 | 1.000 | -0.054 | 0.337* |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.474 | | 0.718 | 0.019 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.00 |
| VOC | Pearson Correlation | 0.109 | 0.064 | -0.177 | -0.054 | 1.000 | -0.031 |
| | Sig. (2-tailed) | 0.460 | 0.665 | 0.228 | 0.718 | | 0.836 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| $H_2S$ | Pearson Correlation | 0.124 | 0.205 | 0.129 | 0.337* | -0.031 | 1.000 |
| | Sig. (2-tailed) | 0.402 | 0.163 | 0.382 | 0.019 | 0.836 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.46 shows the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the meteorological parameters at Owerri in dry season. A very weak negative significant correlation was observed between wind speed and temperature, r = - 0.713, N = 48, $p$ = 0.000. There was however a very strong positive correlation between wind speed and airflow, r = 0.768, N= 48, $p$ = 0.000. Also a moderate negative correlation existed between temperature and relative humidity, r = -0.617, N= 48, $p$ = 0.000.

Table 4.47 shows the Pearson product-moment correlation co-efficient, r, was computed to assess the strength and direction of the linear relationships that exist between the air pollutants in wet season at Owerri. Weak positive correlations were observed between $PM_{10}$ and $SO_2$ and

Table 4.46: Correlation Table for meteorological Parameters at Owerri in Dry Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| W.Speed | Pearson Correlation | 1.000 | -0.713** | 0.356* | 0.768** | 0.347* |
| | Sig. (2-tailed) | | 0.000 | 0.013 | 0.000 | 0.016 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Temperature | Pearson Correlation | -0.713** | 1.000 | -0.617** | -0.323* | -0.302* |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.025 | 0.037 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| R.Humidity | Pearson Correlation | 0.356* | -0.617** | 1.000 | 0.112 | 0.220 |
| | Sig. (2-tailed) | 0.013 | 0.000 | | 0.448 | 0.133 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| Airflow | Pearson Correlation | 0.768** | -0.323* | 0.112 | 1.000 | 0.225 |
| | Sig. (2-tailed) | 0.000 | 0.025 | 0.448 | | 0.125 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| W.Height | Pearson Correlation | 0.347* | -0.302* | 0.220 | 0.225 | 1.000 |
| | Sig. (2-tailed) | 0.016 | 0.037 | 0.133 | 0.125 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

$NO_2$, r = 0.497, N = 48, $p$ = 0.000 and r = 0.422, N = 48, $p$ = 0.003 respectively. $PM_{10}$ however had a moderate positive correlation with CO, r = 0.514, N = 48, $p$ = 0.00. On the other hand, $SO_2$ had a weak positive correlation with CO, r = 0.388, N = 48, $p$ = 0.006. Table 4.48 is the Pearson product-moment correlation co-efficient, r, computed to assess the strength and direction of the linear relationships that exist between the meteorological parameters at Owerri in wet season. A very strong significant positive correlations was observed between wind speed and wave height, r = 0.794, N = 48, $p$ = 0.000 and a weak positive correlation with air flow, r = 0.393, N = 48, $p$ = 0.006. Temperature had a moderate negative correlation with relative humidity, r = - 0.691, N = 48, $p$ = 0.000. All other correlations are not significant.

Table 4.47: Correlation Table for Pollutant Concentration at Owerri in Wet Season

| | | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC | $H_2S$ |
|---|---|---|---|---|---|---|---|
| | Pearson Correlation | 1.000 | 0.497** | 0.422** | 0.514** | 0.263 | .b |
| $PM_{10}$ | Sig. (2-tailed) | | 0.000 | 0.003 | 0.000 | 0.071 | . |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.00 | 48.000 |
| | Pearson Correlation | 0.497** | 1.000 | 0.432** | 0.480** | 0.099 | .b |
| $NO_2$ | Sig. (2-tailed) | 0.000 | | 0.002 | 0.001 | 0.503 | . |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48 |
| | Pearson Correlation | 0.422** | 0.432** | 1.000 | 0.388** | -0.086 | .b |
| $SO_2$ | Sig. (2-tailed) | 0.003 | 0.002 | | 0.006 | 0.560 | . |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.514** | 0.480** | 0.388** | 1.000 | 0.183 | .b |
| CO | Sig. (2-tailed) | 0.000 | 0.001 | 0.006 | | 0.214 | . |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.263 | 0.099 | -0.086 | 0.183 | 1.000 | .b |
| VOC | Sig. (2-tailed) | 0.071 | 0.503 | 0.560 | 0.214 | | . |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | .b | .b | .b | .b | .b | .b. |
| $H_2S$ | Sig. (2-tailed) | . | . | . | . | . | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).
b. Cannot be computed because at least one of the variables is constant.

Table 4.48: Correlation Table for meteorological Parameters at Owerri in Wet Season

| | | W.Speed | Temperature | R.Humidity | Airflow | W.Height |
|---|---|---|---|---|---|---|
| | Pearson Correlation | 1.000 | 0.001 | 0.071 | 0.393** | 0.794** |
| W.Speed | Sig. (2-tailed) | | 0.993 | 0.631 | 0.006 | 0.000 |
| | N | 48.000 | 48.000 | 48.00 | 48.000 | 48.000 |
| | Pearson Correlation | 0.001 | 1.000 | -0.691** | 0.166 | 0.097 |
| Temperature | Sig. (2-tailed) | 0.993 | | 0.000 | 0.259 | 0.514 |
| | N | 48.000 | 48.000 | 48.000 | 48.00 | 48.000 |
| | Pearson Correlation | 0.071 | -0.691** | 1.000 | 0.170 | 0.035 |
| R.Humidity | Sig. (2-tailed) | 0.631 | 0.000 | | 0.249 | 0.813 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.393** | 0.166 | 0.170 | 1.000 | 0.250 |
| Airflow | Sig. (2-tailed) | 0.006 | 0.259 | 0.249 | | 0.087 |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |
| | Pearson Correlation | 0.794** | 0.097 | 0.035 | 0.250 | 1.000 |
| W.Height | Sig. (2-tailed) | 0.000 | 0.514 | 0.813 | 0.087 | |
| | N | 48.000 | 48.000 | 48.000 | 48.000 | 48.000 |

**. Correlation is significant at the 0.01 level (2-tailed).

## 4.11 Hierarchical Cluster Analysis

Hierarchical cluster analysis (HCA) was conducted to show the similarities and disimilarities in the source or occurrence of the air pollutants and meteorological parameters. The results obtained from this analysis were presented in a dendrogram. The dendrogram is a branch diagram that represents the level of relationships or similarity among parameters arranged like

the branches of a tree. In the present study the air pollutants and the meteorological parameters were arranged in a tree like cluster. Mapoma et al (2014) employed HCA in air quality assessment of CO, $NO_2$ and $SO_2$ levels in Blantyre, Malawi.

Fig. 4.54 is a dendrogram of HCA to show the similarities in the source or occurrence of the air pollutants at Egbema in dry season. Cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity with each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

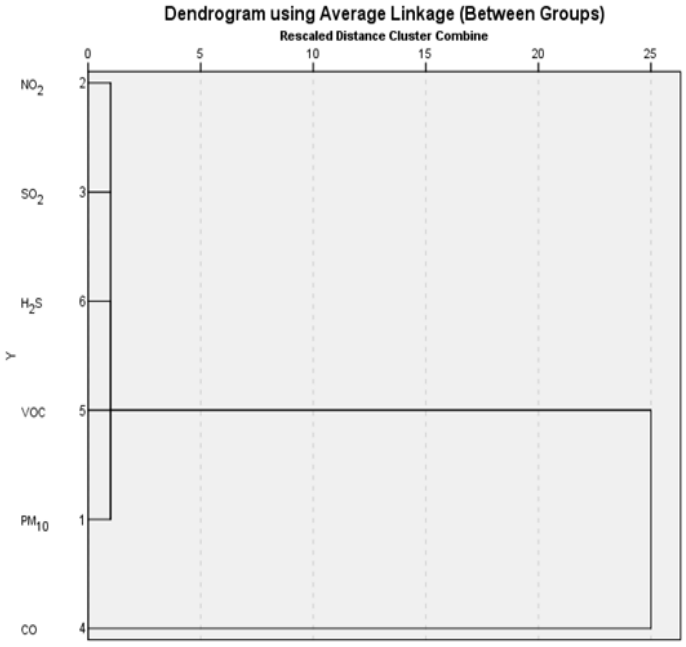


Fig. 4.54: A Dendrogram from HCA for Pollutant Concentration at Egbema in Dry Season

Fig. 4.55 is the Hierarchical cluster analysis conducted to show similarities in the source or occurrence of the meteorological parameters in dry season at Egbema. Its result is represented in the dendrogram. The dendrogram is a branch diagram that represents the relationships of similarity among the pollutants. Cluster 1 is the meteorological parameters, air flow and relative humidity. The parameters showing similarity within each other in cluster 2 are temperature, wave height and wind speed.

Fig. 4.56 is the HCA to showing the similarities in the source or occurrence of the air pollutants in wet season at Egbema. The dendrogram is a branch diagram that represents the

relationships of similarity among the pollutants. Cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

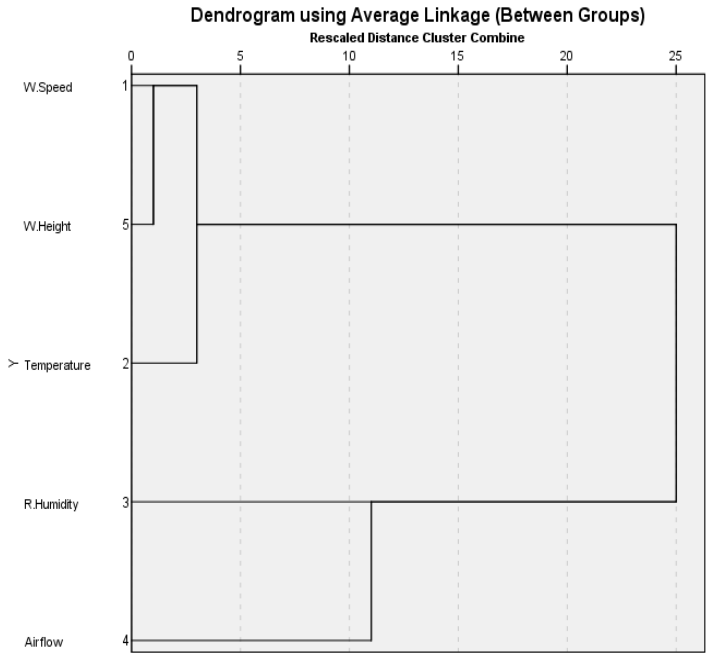


Fig. 4.55: A Dendrogram from HCA for Meteorological Parameters at Egbema in Dry Season

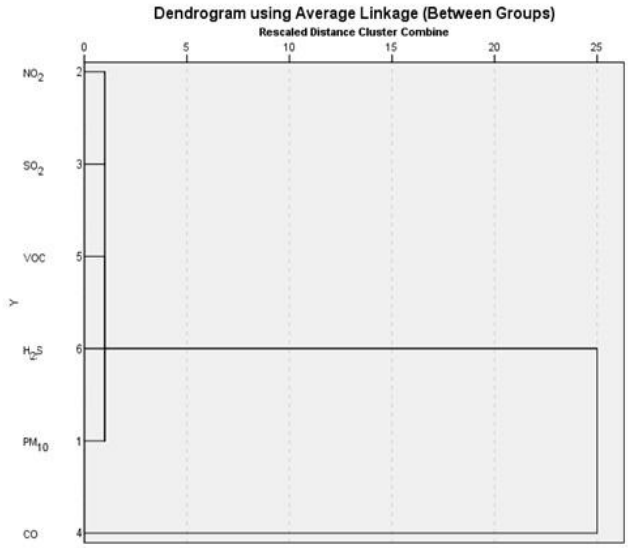

Fig. 4.56: A Dendrogram from HCA for Pollutant Concentration at Egbema in Wet Season

Fig. 4.57 is a dendrogram showing the result of HCA which was conducted to show the similarities in the source or occurrence of the meteorological parameters at Egbema in wet season. The dendrogram is a branch diagram that represents the relationships of similarity among the pollutants. Cluster 1 is the meteorological parameters, air flow and relative humidity. The parameters showing similarity within each other in cluster 2 are temperature, wave height and wind speed.

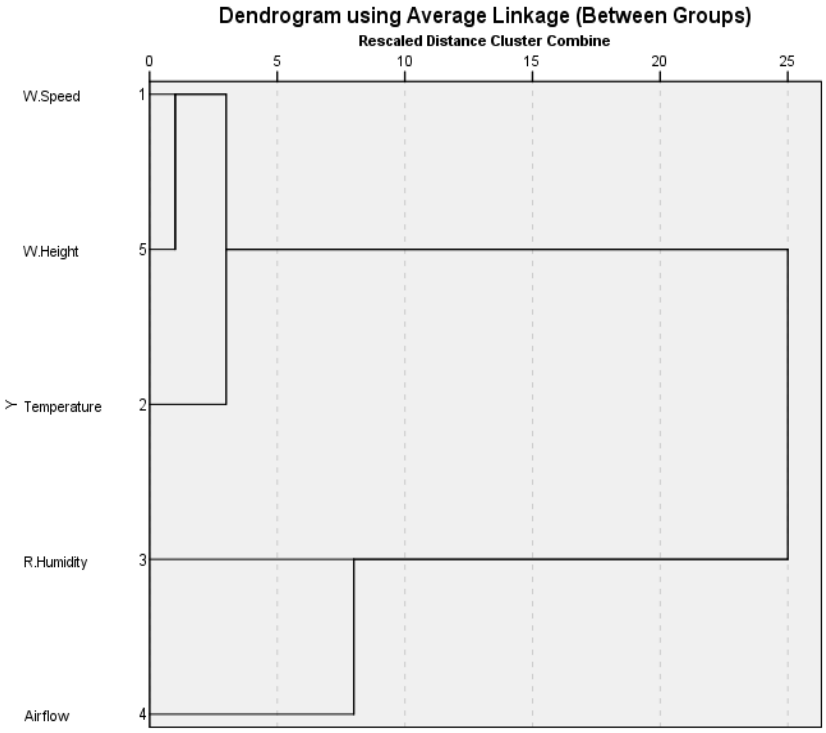


Fig.4.57: A Dendrogram from HCA for Meteorological Parameters at Egbema in Wet Season

Fig.4.58 shows the dendrogram of HCA indicating the similarities in the source or occurrence of the air pollutants in dry season at Okigwe. The Dendrogram is a branch diagram that represents the relationships among the pollutants. Cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

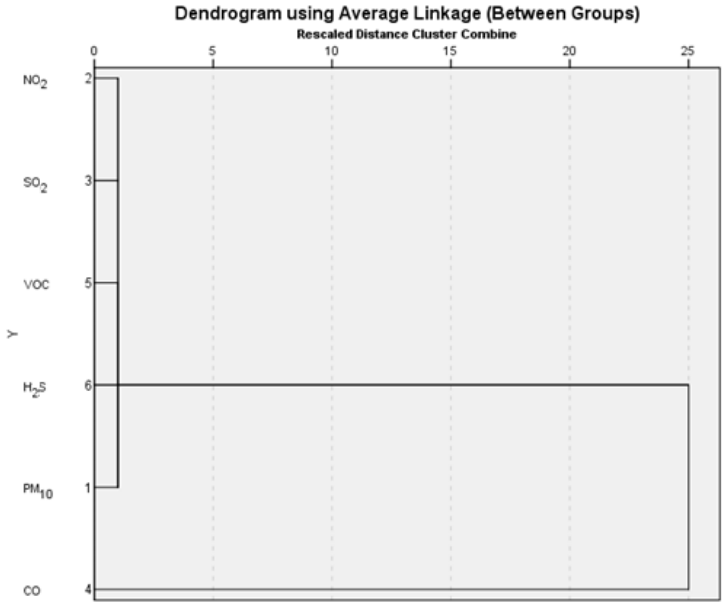


Fig.4.58: A Dendrogram from HCA for Pollutant Concentration at Okigwe in Dry Season

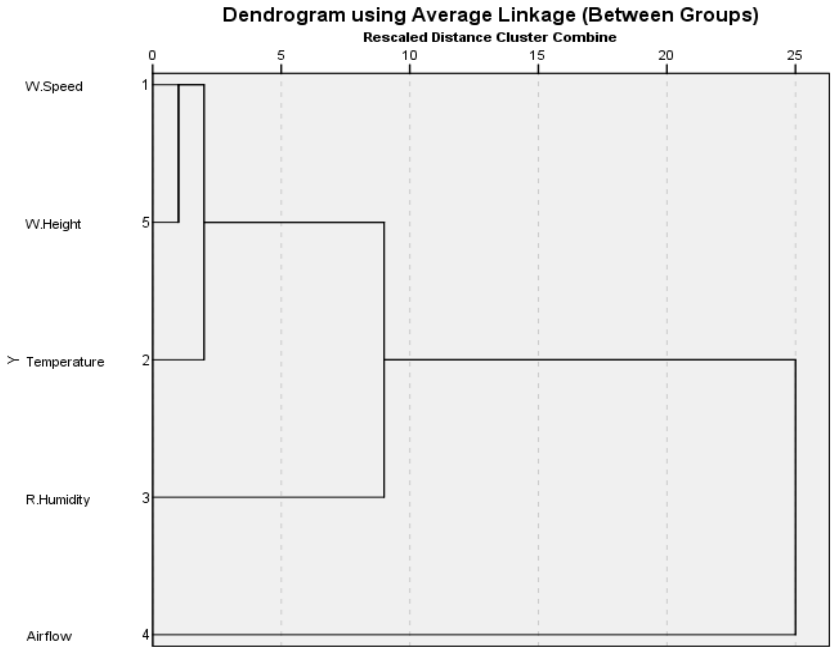


Fig.4.59: A Dendrogram from HCA for Meteorological Parameters at Okigwe in Dry Season

Fig.4.59 shows the dendrogram of HCA for the meteorological variables indicating the similarities in the source or occurrence of the parameters. The result indicates that clusters 1 and 2 are the meteorological parameters; air flow and relative humidity. The parameters showing similarity within each other as shown in cluster 3 are temperature, wave height and wind speed.

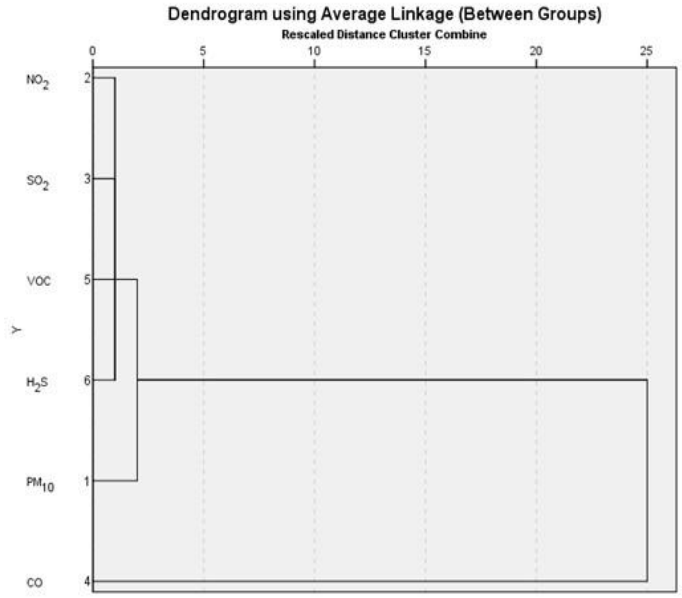


Fig.4.60: A Dendrogram from HCA for Pollutant Concentration at Okigwe in wet Season

Fig.4.60: is a dendrogram from HCA conducted to show the similarities in the source or occurrence of the air pollutants in wet season at Okigwe. The result reveals that Cluster 1 is the air pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

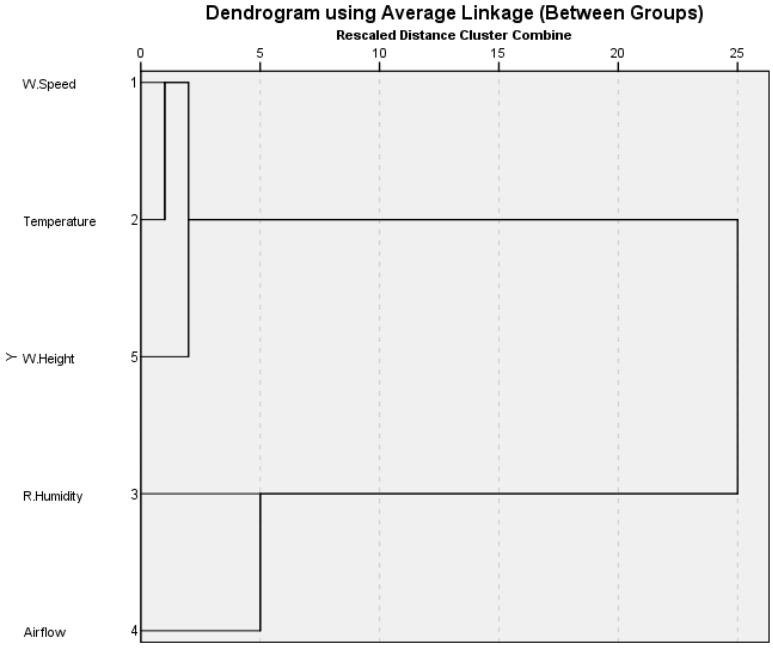


Fig.4.61: A Dendrogram from HCA for Meteorological Parameters at Okigwe in Wet Season

The dendrogram in Fig.4.61 is the HCA of the meteorological parameters conducted to show the similarities in the source or occurrence of the variables. Cluster 1 contains the meteorological parameters, air flow and relative humidity while cluster 2 represents temperature, wave height and wind speed.

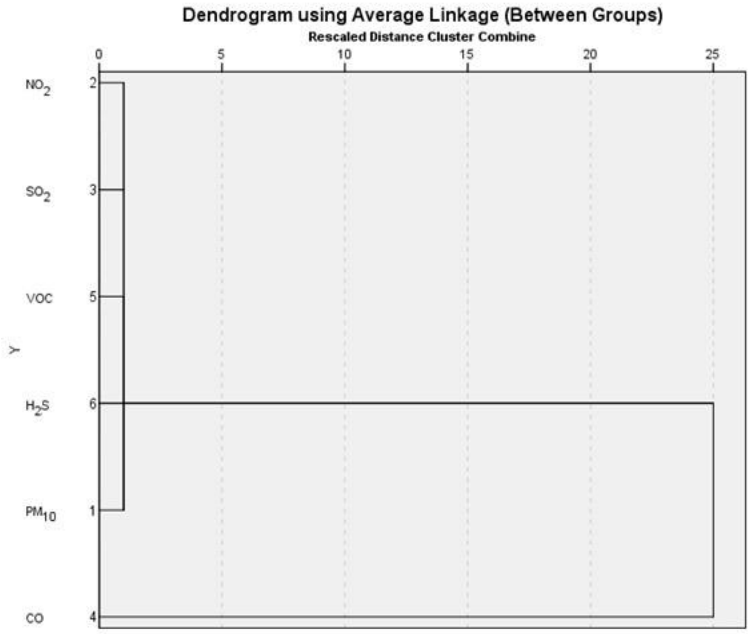


Fig.4.62: A Dendrogram from HCA for Pollutant Concentration at Orlu in Dry Season

Fig.4.62 is the HCA of the air pollutants at Orlu in dry season; this was conducted to show the similarities in the source or occurrence of the pollutants. The dendrogram reveals that cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

The dendrogram presented in Fig.4.63 is the result of HCA for the meteorological parameters conducted to show the similarities in the source or occurrence of the variables in dry season. The Dendrogram shows that clusters 1 contain the meteorological parameters, air flow and relative humidity, while cluster 2 contains temperature, wave height and wind speed.

Fig.4.64 shows the dendrogram of HCA conducted to show the similarities in the source or occurrence of the pollutants in wet season at Orlu. The dendrogram shows that cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it

does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

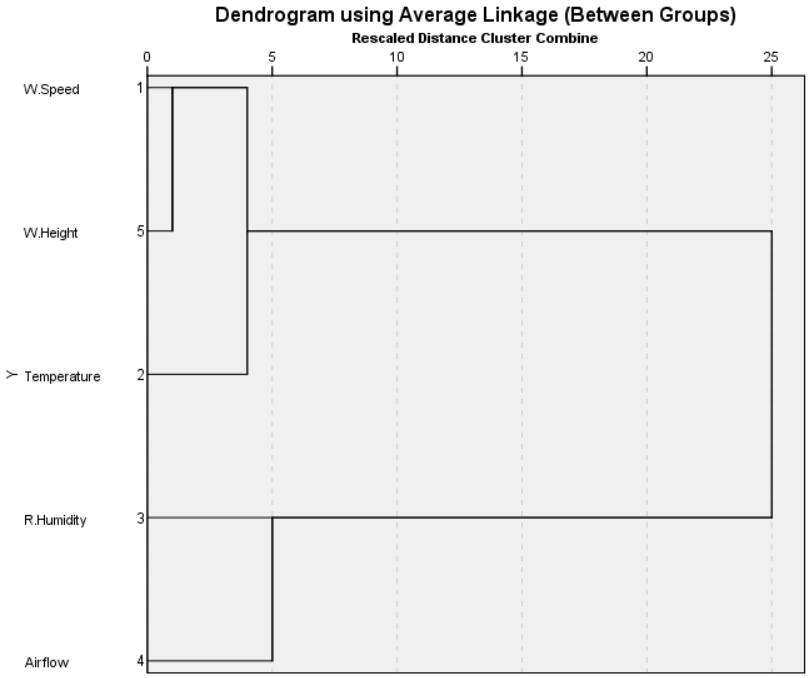


Fig.4.63: A Dendrogram from HCA for Meteorological Parameters at Orlu in Dry Season

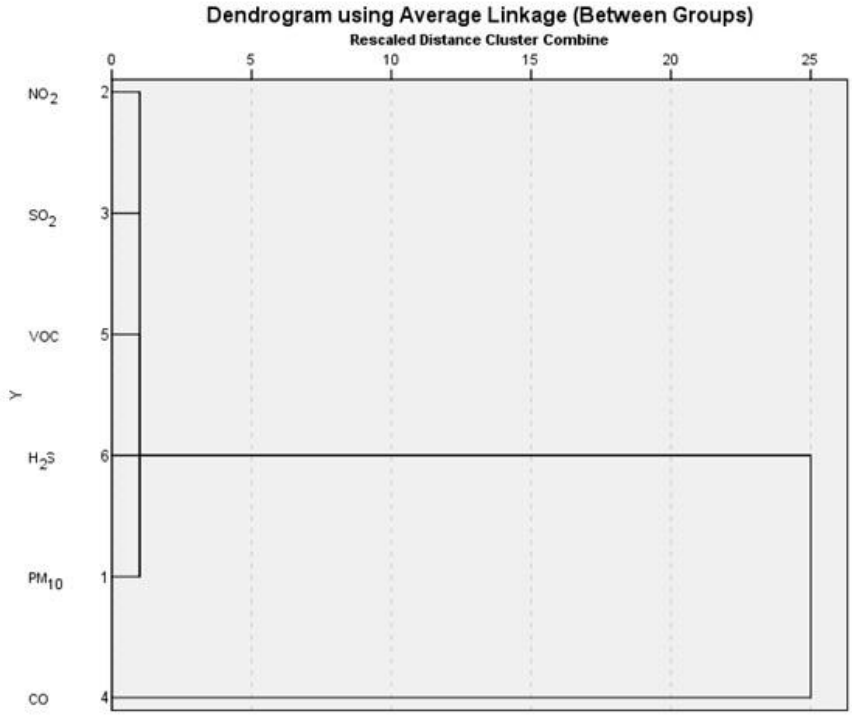

Fig.4.64: A Dendrogram from HCA for Pollutant Concentration at Orlu in Wet Season

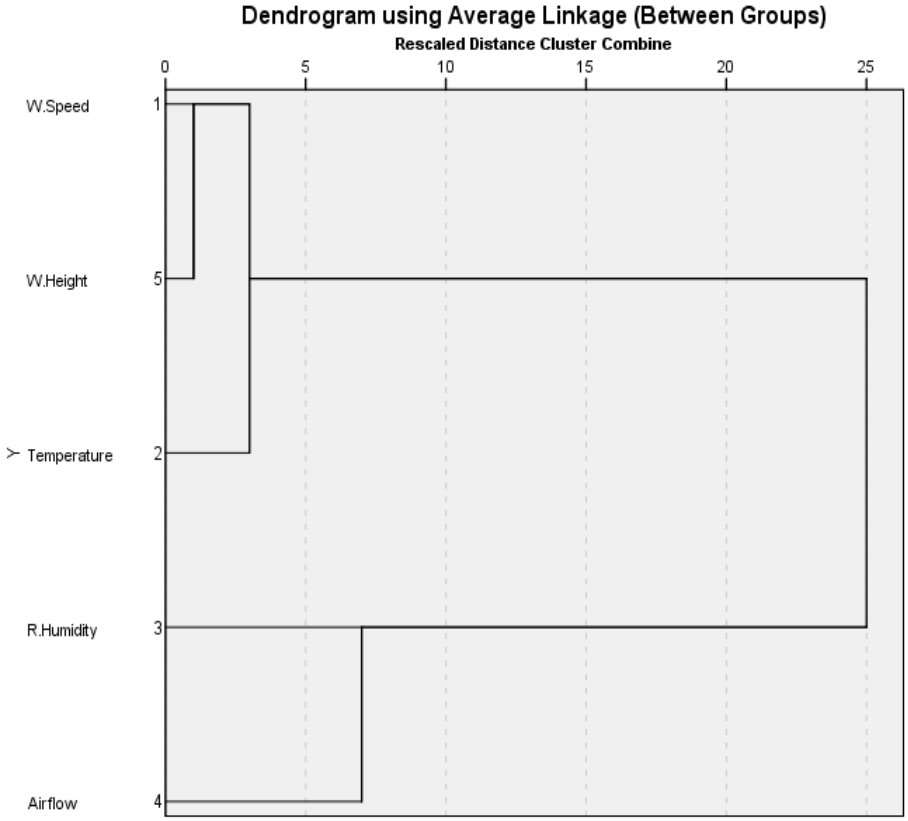


Fig.4.65: A Dendrogram from HCA for Meteorological Parameters at Orlu in Wet Season

The HCA of the meteorological parameters in wet season at Orlu was conducted to show similarities in the source or occurrence of the variables. The Dendrogram as presented in Fig. 4.65 indicates that cluster 1 contains the meteorological parameters, air flow and relative humidity, while cluster 2 contains temperature, wave height and wind speed.

Fig.4.66 is a dendrogram of the HCA conducted to show the similarities in the source or occurrence of the atmospheric pollutants in dry season at Owerri. The result of the dendrogram reveals that cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

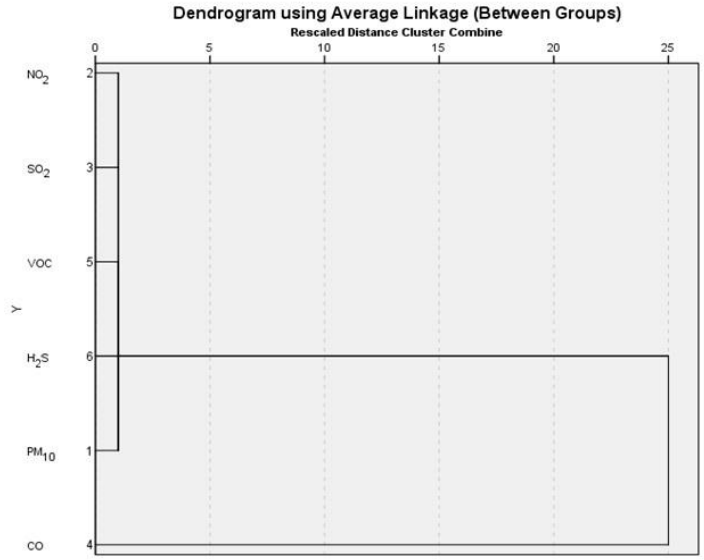


Fig.4.66: A A Dendrogram from HCA for Pollutant Concentration at Owerri in Dry Season

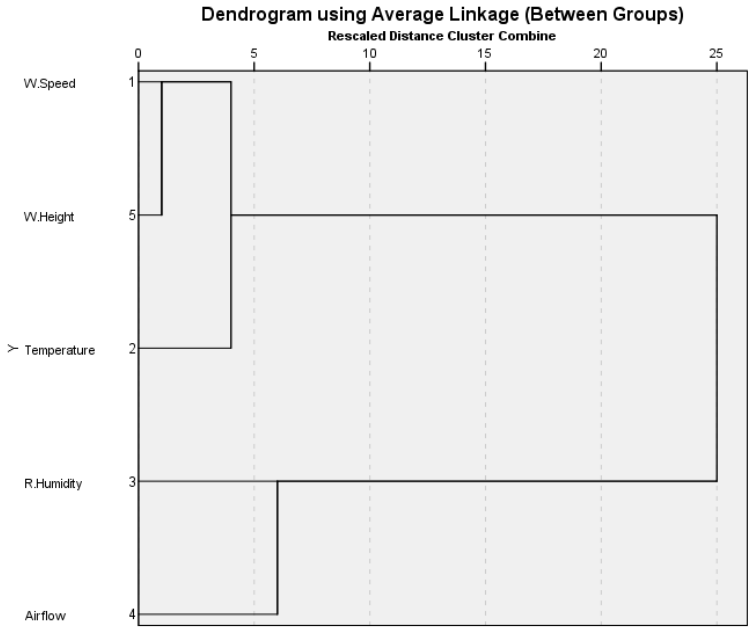


Fig.4.67: A Dendrogram from HCA for Meteorological Parameters at Owerri in Dry Season

The dendrogram presented in Fig.4.67 is the HCA which was conducted to show the similarities in the source or occurrence of the meteorological variables in dry season at Owerri. The dendrogram which is a branch diagram that represents the relationships of similarity among

the pollutants indicates that cluster 1 contain the meteorological parameters, air flow and relative humidity. Cluster 2 contains temperature, wave height and wind speed.

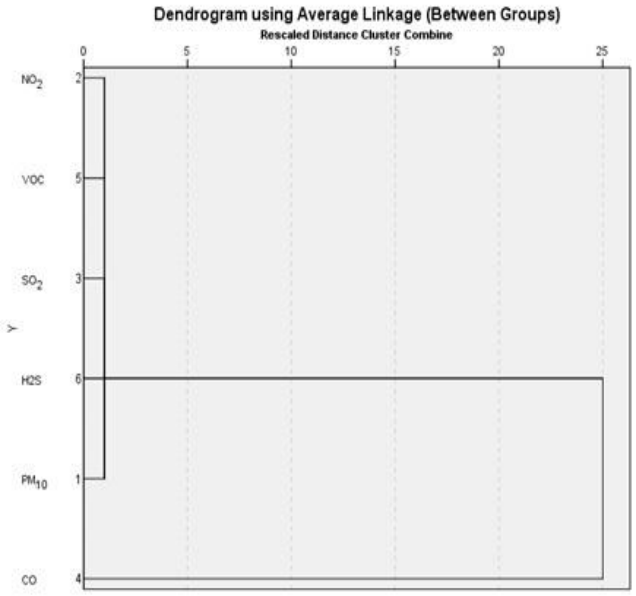


Fig.4.68: A Dendrogram from HCA for Pollutant Concentration at Owerri in Wet Season

Fig.4.68 shows the dendrogram of HCA conducted to show the similarities in the source or occurrence of the atmospheric pollutants in wet season at Owerri. The dendrogram which is a branch diagram that represents the relationships of similarity among the pollutants indicate that cluster 1 is the pollutant CO, according to this classification; it is an outlier and is not really a cluster since it does not seem to have any association with the other pollutants. However, the pollutants showing similarity within each other are in cluster 2. These include $NO_2$, $SO_2$, $H_2S$ and $PM_{10}$.

Fig. 4.69 shows the dendrogram of HCA conducted to show the similarities in the source or occurrence of the meteorological variables in wet season at Owerri. The dendrogram Cluster 1 contains the meteorological parameters, air flow and relative humidity, while cluster 2 contains temperature, wave height and wind speed.

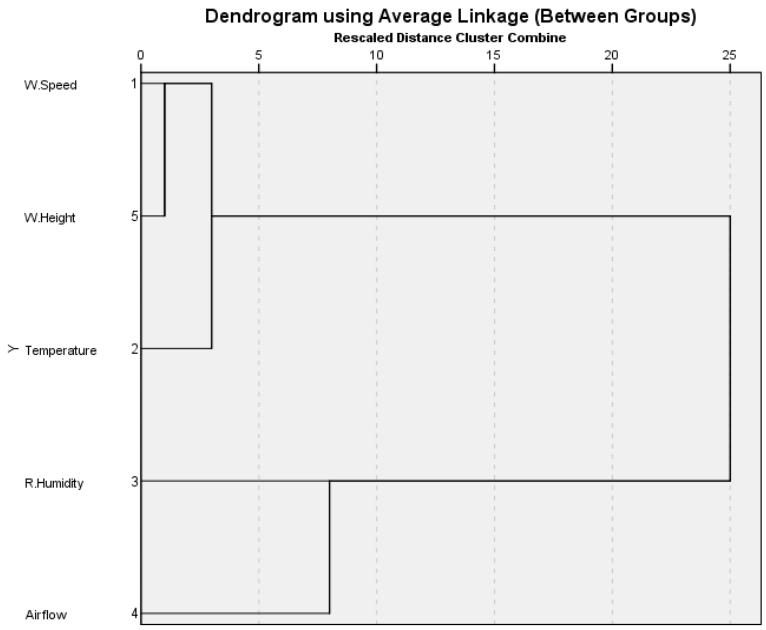


Fig.4.69: A Dendrogram from HCA for Meteorological Parameters at Owerri in Wet Season

## 4.12 Principal Components Analysis

The most widely used multivariate statistical technique in the atmospheric sciences is principal component analysis, usually denoted as PCA. PCA reduces a data set containing a large number of variables to a data set containing fewer new variables (Wilks, 2006). The PCA with varimax rotation was conducted to assess how the air pollutants or the meteorological parameters are clustered, that is to determine the level of variation between thre variables.

Table 4.49: Total Variance Explained Table for Pollutant Concentration at Egbema in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.066 | 34.425 | 34.425 | 2.066 | 34.425 | 34.425 | 1.762 | 29.367 | 29.367 |
| 2 | 1.277 | 21.287 | 55.712 | 1.277 | 21.287 | 55.712 | 1.385 | 23.080 | 52.447 |
| 3 | 1.086 | 18.107 | 73.818 | 1.086 | 18.107 | 73.818 | 1.282 | 21.371 | 73.818 |
| 4 | 0.637 | 10.612 | 84.430 | | | | | | |
| 5 | 0.521 | 8.682 | 93.112 | | | | | | |
| 6 | 0.413 | 6.888 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.50: Component Matrix[a]

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| $PM_{10}$ | 0.604 | 0.555 | -0.028 |
| $NO_2$ | 0.596 | -0.629 | 0.102 |
| $SO_2$ | 0.764 | 0.206 | -0.214 |
| CO | 0.705 | -0.156 | -0.480 |
| VOC | 0.424 | -0.416 | 0.683 |
| $H_2S$ | 0.292 | 0.577 | 0.577 |

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Table 4.51: Rotated Component Matrix[a]

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| $PM_{10}$ | 0.573 | -0.103 | 0.579 |
| $NO_2$ | 0.374 | 0.756 | -0.223 |
| $SO_2$ | 0.772 | 0.096 | 0.258 |
| CO | 0.832 | 0.153 | -0.188 |
| VOC | -0.066 | 0.873 | 0.230 |
| $H_2S$ | -0.015 | 0.089 | 0.862 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 8 iterations.

Table 4.49, 4.50 and 4.51 are respectively the total variance explained table, component matrix and rotated component matrix for the air pollutants in dry season at Egbema. Table 4.50 shows that three components were extracted. The total variance explained (Table 4.49) shows that there are three components with initial eigenvalues more than 1.0, although the eigenvalue for the third component is barely over 1 at 1.086. These three components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 29.367 % of the variance, the second principal component (PC2), accounted for 23.080 % of the variance while the third principal component (PC3) accounted for 21.371 % of the variance. The Rotated Component Matrix (Table 4.51) displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$ and CO have high positive loadings in the first principal component with correlation co-efficients of 0.573, 0.374, 0.772 and 0.832. VOC has a high loading in the second principal component with correlation co-efficient of 0.873, while $H_2S$ has high loadings in the third principal component with correlation co-efficient of 0.862. VOC and $H_2S$ are not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component. This is in

agreement with the result of Hierarchical Cluster Analysis which grouped these pollutants into one major cluster.

Table 4.52:Total Variance Explained Table for Meteorological Parameters at Egbema in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.354 | 67.078 | 67.078 | 3.354 | 67.078 | 67.078 | 2.265 | 45.291 | 45.291 |
| 2 | 1.054 | 21.082 | 88.160 | 1.054 | 21.082 | 88.160 | 2.143 | 42.869 | 88.160 |
| 3 | 0.284 | 5.676 | 93.836 | | | | | | |
| 4 | 0.209 | 4.175 | 98.011 | | | | | | |
| 5 | 0.099 | 1.989 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.53:Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.870 | 0.389 |
| Temperature | -0.829 | 0.456 |
| R.Humidity | 0.766 | -0.540 |
| Airflow | 0.698 | 0.635 |
| W.Height | 0.915 | 0.011 |

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 4.54: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.364 | 0.881 |
| Temperature | -0.915 | -0.240 |
| R.Humidity | 0.927 | 0.135 |
| Airflow | 0.069 | 0.941 |
| W.Height | 0.656 | 0.638 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 4.52, 4.53 and 4.54 are respectively the total variance explained table, component matrix and rotated component matrix for the meteorological parameters in dry season at Egbema.

Table 4.53 indicates that two components were extracted. The total variance explained (Table 4.52) shows that there are two components with initial eigenvalues more than 1.0, although the eigenvalues for the second component is barely over 1 at 1.054. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 45.291 % of the variance, the second principal component (PC2), accounted for 42.869 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that wind speed, temperature, relative humidity and wave height have high loadings in the first principal component with correlation co-efficients of 0.364, - 0.915, 0.927 and 0.656. Air flow has a high loading in the second principal component with correlation co-efficient of 0.941. Air flow is not substantially related to the other meteorological parameters and should not be aggregated with them but that the other meteorological parameters form a coherent component.

Table 4.55, 4.56 and 4.57 are the total variance explained table, component matrix and rotated component matrix respectively for the air pollutants in wet season at Egbema. Two component matrixes were extracted (Table 4.56), while Table 4.55, the total variance explained table shows that there are two components with initial eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated (Table 4.57). After rotation, the first principal component (PC1), accounted for 38.471 % of the variance while the second principal component (PC2), accounted for 21.485 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated

Table 4.55: Total Variance Explained Table for Pollutant Concentration at Egbema in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.315 | 38.581 | 38.581 | 2.315 | 38.581 | 38.581 | 2.308 | 38.471 | 38.471 |
| 2 | 1.282 | 21.374 | 59.955 | 1.282 | 21.374 | 59.955 | 1.289 | 21.485 | 59.955 |
| 3 | 0.911 | 15.190 | 75.145 | | | | | | |
| 4 | 0.733 | 12.218 | 87.363 | | | | | | |
| 5 | 0.451 | 7.519 | 94.881 | | | | | | |
| 6 | 0.307 | 5.119 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$, VOC and $H_2S$ have high loadings in the first principal component with correlation co-efficient values of 0.718, 0.834, 0.792,

Table 4.56:Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.744 | -0.298 |
| $NO_2$ | 0.814 | 0.280 |
| $SO_2$ | 0.780 | 0.178 |
| CO | 0.223 | 0.799 |
| VOC | 0.506 | -0.079 |
| $H_2S$ | 0.428 | -0.663 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.57: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.718 | 0.356 |
| $NO_2$ | 0.834 | -0.214 |
| $SO_2$ | 0.792 | -0.114 |
| CO | 0.286 | -0.779 |
| VOC | 0.498 | 0.120 |
| $H_2S$ | 0.373 | 0.695 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

0.498 and 0.373. CO has a high loading in the second principal component with correlation co-efficient of -0.799. CO is not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component. This is in

Table 4.58:Total Variance Explained Table for Meteorological Parameters at Egbema in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.428 | 48.555 | 48.555 | 2.428 | 48.555 | 48.555 | 2.427 | 48.547 | 48.547 |
| 2 | 1.827 | 36.549 | 85.104 | 1.827 | 36.549 | 85.104 | 1.828 | 36.557 | 85.104 |
| 3 | 0.474 | 9.484 | 94.588 | | | | | | |
| 4 | 0.194 | 3.876 | 98.464 | | | | | | |
| 5 | 0.077 | 1.536 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.59:Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.953 | 0.030 |
| Temperature | 0.012 | 0-.948 |
| R.Humidity | -0.057 | 0.948 |
| Airflow | 0.934 | 0.135 |
| W.Height | 0.803 | -0.111 |

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 4.60: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.953 | -0.005 |
| Temperature | -0.012 | 0.948 |
| R.Humidity | -0.033 | -0.949 |
| Airflow | 0.937 | -0.112 |
| W.Height | 0.800 | 0.132 |

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

agreement with the results of HCA which grouped these pollutants into one major cluster and showed CO as an outlier.

Table 4.58, 4.59 and 4.60 shows the total variance explained table, component matrix and rotated component matrix respectively for the meteorological parameters in wet season at Egbema. Table 4.58 shows that there are two components with initial eigenvalues more than 1.0. Table 4.59 shows the components matrix. These two components whose eigenvalues are above 1 where rotated. After rotation, the first principal component (PC1), accounted for 48.547 % of the variance, the second principal component (PC2), accounted for 36.557 % of the variance. Table 4.60 displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations,

that wind speed, air flow and wave height have high loadings in the first principal component with correlation co-efficient values of 0.953, 0.937 and 0.800. Temperature and relative humidity have high loadings in the second principal component with correlation co-efficient values of 0.948 and - 0.949. These meteorological parameters have substantial relationships in each of these components thereby forming two coherent components. This result tends to agree with the result of Hierarchical Cluster Analysis which groups them into two clusters.

Table 4.61: Total Variance Explained Table for Pollutant Concentration at Okigwe in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.973 | 49.547 | 49.547 | 2.973 | 49.547 | 49.547 | 2.968 | 49.473 | 49.473 |
| 2 | 1.152 | 19.201 | 68.748 | 1.152 | 19.201 | 68.748 | 1.157 | 19.275 | 68.748 |
| 3 | 0.894 | 14.901 | 83.649 | | | | | | |
| 4 | 0.506 | 8.438 | 92.087 | | | | | | |
| 5 | 0.273 | 4.551 | 96.638 | | | | | | |
| 6 | 0.202 | 3.362 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.62: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.772 | 0.131 |
| $NO_2$ | 0.896 | 0.096 |
| $SO_2$ | 0.856 | -0.138 |
| CO | 0.914 | 0.002 |
| VOC | -0.063 | 0.743 |
| $H_2S$ | 0.033 | -0.745 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.63:Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.778 | -0.093 |
| $NO_2$ | 0.899 | -0.051 |
| $SO_2$ | 0.849 | 0.180 |
| CO | 0.913 | 0.043 |
| VOC | -0.026 | -0.745 |
| $H_2S$ | -0.004 | 0.745 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 4.61, 4.62 and 4.63 shows the total variance explained table, component matrix and rotated component matrix respectively for the air pollutants in dry season at Okigwe. Table 4.61 shows that there are two components with initial eigenvalues more than 1.0. Also Table 4.62 indicates the component matrix extracted. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 49.473 % of the variance while the second principal component (PC2), accounted for 19.275 % of the variance. Table 4.63 displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$ and CO have high loadings in the first principal component with correlation co-efficient values of 0.778, 0.899, 0.849 and 0.913. VOC and $H_2S$ have high loadings in the second principal component with correlation co-efficient values of - 0.745 and 0.745. VOC and $H_2S$ are not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form coherent component since they are made up of four variables. This is in agreement with the result of HCA which grouped these pollutants into one major cluster.

Table 4.64 and 4.65 shows the total variance explained table and component matrix respectively for the meteorological parameters in dry season at Okigwe. The total variance explained table shows that there is only one component with an initial eigenvalue more than 1.0. This component explains 63.358 % of the total variance. Since this explains more than 50 % of the total variance, we do not have any more need to rotate this component. That means that all the variables form only one coherent component.

Table 4.64: Total Variance Explained Table for Meteorological Parameters at Okigwe in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.168 | 63.358 | 63.358 | 3.168 | 63.358 | 63.358 |
| 2 | 0.846 | 16.912 | 80.271 | | | |
| 3 | 0.626 | 12.517 | 92.788 | | | |
| 4 | 0.272 | 5.445 | 98.233 | | | |
| 5 | 0.088 | 1.767 | 100.000 | | | |

Extraction Method: Principal Component Analysis.

Table 4.65: Component Matrix[a]

| | Component |
|---|---|
| | 1 |
| W.Speed | 0.879 |
| Temperature | -0.919 |
| R.Humidity | 0.859 |
| Airflow | 0.523 |
| W.Height | 0.733 |

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

**Rotated Component Matrix[a]**

a. Only one component was extracted. The solution cannot be rotated.

Table 4.66: Total Variance Explained Table for Pollutant Concentration at Okigwe in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.445 | 40.757 | 40.757 | 2.445 | 40.757 | 40.757 | 2.394 | 39.901 | 39.901 |
| 2 | 1.177 | 19.618 | 60.375 | 1.177 | 19.618 | 60.375 | 1.228 | 20.473 | 60.375 |
| 3 | 0.822 | 13.706 | 74.081 | | | | | | |
| 4 | 0.722 | 12.034 | 86.115 | | | | | | |
| 5 | 0.581 | 9.682 | 95.797 | | | | | | |
| 6 | 0.252 | 4.203 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.67: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| PM10 | 0.848 | 0.068 |
| NO2 | 0.661 | 0.241 |
| SO2 | 0.726 | -0.181 |
| CO | 0.634 | 0.259 |
| VOC | 0.599 | -0.456 |
| H2S | 0.026 | 0.898 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

**Table 4.68: Rotated Component Matrix[a]**

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.845 | -0.104 |
| $NO_2$ | 0.696 | 0.103 |
| $SO_2$ | 0.675 | -0.323 |
| CO | 0.673 | 0.126 |
| VOC | 0.495 | -0.567 |
| $H_2S$ | 0.206 | 0.875 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Table 4.66, 4.67 and 4.68 shows the total variance explained table, component matrix and rotated component matrix respectively for the air pollutants in wet season at Okigwe. PCA with varimax rotation was conducted to assess how the air pollutants; $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ are clustered. Table 4.66 shows that there are two components with initial eigenvalues more than 1.0. Hence, two components were extracted (Table 4.4.67). These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 39.90100% of the variance while the second principal component (PC2), accounted for 20.4730% of the variance. The rotated component matrix (Table 4.68) displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$, CO and VOC have high loadings in the first principal component with correlation co-efficient values of 0.845, 0.696, 0.675, 0.673 and 0.495 respectively. $H_2S$ has a high loading in the second principal component with

Table 4.69: Total Variance Explained Table for Meteorological Parameters at Okigwe in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 1.958 | 39.164 | 39.164 | 1.958 | 39.164 | 39.164 | 1.950 | 39.005 | 39.005 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.901 | 38.029 | 77.193 | 1.901 | 38.029 | 77.193 | 1.909 | 38.188 | 77.193 |
| 3 | 0.968 | 19.350 | 96.543 | | | | | | |
| 4 | 0.105 | 2.098 | 98.641 | | | | | | |
| 5 | 0.068 | 1.359 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.70: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.481 | 0.856 |
| Temperature | 0.894 | -0.377 |
| R.Humidity | -0.873 | 0.369 |
| Airflow | 0.290 | 0.939 |
| W.Height | -0.285 | 0.085 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.71: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | -0.125 | 0.974 |
| Temperature | -0.971 | -0.014 |
| R.Humidity | 0.947 | 0.015 |
| Airflow | 0.084 | 0.979 |
| W.Height | 0.296 | -0.028 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

correlation co-efficient value of 0.875. $H_2S$ is not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component. This is in agreement with the result of HCA which grouped these pollutants into one major cluster.

Table 4.69, 4.70 and 4.71 are respectively the total variance explained table, component matrix and rotated component matrix for the meteorological parameters in wet season at Okigwe. PCA with varimax rotation was conducted to assess how the meteorological parameters; wind speed, temperature, relative humidity, air flow and wave height are clustered. Table 4.69 shows that there are two components with initial eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 39.005 % of the variance while the second principal component (PC2), accounted for 38.188 % of the variance. Table 4.69 displays the items and component loadings for the

rotated components, with loadings less than 0.30 omitted to improve clarity, while the extract component is in Table 4.70. Results suggest, in keeping with zero-order correlations, that temperature and relative humidity have high loadings in the first principal component with correlation co-efficient values of - 0.971 and 0.947. Wind speed and air flow have high loadings in the second principal component with correlation co-efficient values of 0.974 and 0.979. Wave height whose loadings in the components are below the guideline value of 0.3 is not substantially related to the other parameters and should not be aggregated with them but that the other parameters form two coherent components. This result tends to agree with the result of Hierarchical Cluster Analysis that groups them into two clusters.

Table 4.72: Total Variance Explained Table for Pollutant Concentration at Orlu in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.343 | 55.709 | 55.709 | 3.343 | 55.709 | 55.709 | 3.260 | 54.337 | 54.337 |
| 2 | 1.041 | 17.349 | 73.058 | 1.041 | 17.349 | 73.058 | 1.123 | 18.721 | 73.058 |
| 3 | 0.951 | 15.855 | 88.913 | | | | | | |
| 4 | 0.377 | 6.286 | 95.199 | | | | | | |
| 5 | 0.205 | 3.409 | 98.609 | | | | | | |
| 6 | 0.083 | 1.391 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.73: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.884 | -0.089 |
| $NO_2$ | 0.948 | -0.186 |
| $SO_2$ | 0.875 | -0.060 |
| CO | 0.895 | 0.012 |
| VOC | 0.262 | 0.692 |
| $H_2S$ | 0.161 | 0.719 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.74: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.885 | 0.080 |
| $NO_2$ | 0.966 | -0.003 |

| | | |
|---|---|---|
| $SO_2$ | 0.871 | 0.107 |
| CO | 0.877 | 0.181 |
| VOC | 0.127 | 0.729 |
| $H_2S$ | 0.022 | 0.736 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Table 4.72, 4.73 and 4.74 shows the total variance explained table, component matrix and rotated component matrix respectively for the air pollutants in dry season at Orlu. Table 4.72 indicates that there are two components with initial eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 54.337 % of the variance while the second principal component (PC2), accounted for 18.721 % of the variance. The rotated component matrix Table (4.74) displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$ and CO have high loadings in the first principal component with correlation co-efficient values of 0.885, 0.966, 0.875 and 0.895. VOC and $H_2S$ have high loadings in the second principal component with correlation co-efficient values of 0.729 and 0.736. VOC and $H_2S$ are not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component since it is made up of four variables. This is in agreement with the result of HCA which grouped these pollutants into one major cluster.

Table 4.75 and 4.76 shows the total variance explained table and component matrix and rotated component matrix respectively for the meteorological parameters in dry season at Orlu. The total variance explained (Table 4.75) shows that there is only one component with an initial eigenvalue more than 1.0. This component explains 64.386 % of the total variance. Therefore this having explained more than 50% of the total variance, we do not have any more need to rotate this component. This implies that the entire variables form one coherent component which agrees with HCAthat classified these parameters into one cluster.

Table 4.75: Total Variance Explained Table for Meteorological Parameters at Orlu in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 3.219 | 64.386 | 64.386 | 3.219 | 64.386 | 64.386 |
| 2 | 0.949 | 18.970 | 83.356 | | | |
| 3 | 0.395 | 7.904 | 91.260 | | | |
| 4 | 0.363 | 7.259 | 98.519 | | | |
| 5 | 0.074 | 1.481 | 100.000 | | | |

Extraction Method: Principal Component Analysis.

Table 4.76: Component Matrix[a]

| | Component |
|---|---|
| | 1 |
| W.Speed | 0.637 |
| Temperature | -0.896 |
| R.Humidity | 0.818 |
| Airflow | 0.836 |
| W.Height | 0.802 |

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

**Rotated Component Matrix[a]**

| |
|---|

a. Only one component was extracted. The solution cannot be rotated.

Table 4.77, 4.78 and 4.79 are the total variance explained table, component matrix and rotated component matrix respectively for the atmospheric pollutants in wet season at Orlu. The total variance explained table shows that there are two components with initial Eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 38.4710% of the variance while the second principal component (PC2), accounted for 21.4850% of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$, VOC and $H_2S$ have high loadings in the first principal component with correlation co-efficient values of 0.718, 0.834, 0.792, 0.498 and 0.373. CO has a high loading in the second principal component with correlation co-efficient of -00.799. CO is not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component. This is in agreement with the result of HCA which grouped these pollutants into one major cluster and showed CO as an outlier.

Table 4.77: Total Variance Explained Table for Pollutant Concentration at Orlu in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.315 | 38.581 | 38.581 | 2.315 | 38.581 | 38.581 | 2.308 | 38.471 | 38.471 |
| 2 | 1.282 | 21.374 | 59.955 | 1.282 | 21.374 | 59.955 | 1.289 | 21.485 | 59.955 |
| 3 | 0.911 | 15.190 | 75.145 | | | | | | |
| 4 | 0.733 | 12.218 | 87.363 | | | | | | |
| 5 | 0.451 | 7.519 | 94.881 | | | | | | |
| 6 | 0.307 | 5.119 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.78: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.744 | -0.298 |
| $NO_2$ | 0.814 | 0.280 |
| $SO_2$ | 0.780 | 0.178 |
| CO | 0.223 | 0.799 |
| VOC | 0.506 | -0.079 |
| $H_2S$ | 0.428 | -0.663 |

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Table 4.79: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| $PM_{10}$ | 0.718 | 0.356 |
| $NO_2$ | 0.834 | -0.214 |
| $SO_2$ | 0.792 | -0.114 |
| CO | 0.286 | -0.779 |
| VOC | 0.498 | 0.120 |
| H2S | 0.373 | 0.695 |

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 4.80, 4.81 and 4.82 are respectively the total variance explained table, component matrix and rotated component matrix for the meteorological variable in wet season at Orlu. The

total variance explained table indicates that there are two components with initial eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 43.813 % of the variance, the second principal component (PC2), accounted for 33.782 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that wind speed, air flow and wave height have high loadings in the first principal component with correlation co-efficient values of 0.912, 0.896,

Table 4.80: Total Variance Explained Table for Meteorological Parameters at Orlu in Wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.228 | 44.564 | 44.564 | 2.228 | 44.564 | 44.564 | 2.191 | 43.813 | 43.813 |
| 2 | 1.652 | 33.030 | 77.594 | 1.652 | 33.030 | 77.594 | 1.689 | 33.782 | 77.594 |
| 3 | 0.635 | 12.706 | 90.300 | | | | | | |
| 4 | 0.342 | 6.843 | 97.143 | | | | | | |
| 5 | 0.143 | 2.857 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.81:Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.907 | 0.136 |
| Temperature | -0.398 | 0.812 |
| R.Humidity | 0.105 | -0.912 |
| Airflow | 0.910 | 0.064 |
| W.Height | 0.640 | 0.372 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.82: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.912 | 0.100 |
| Temperature | -0.177 | -0.887 |
| R.Humidity | -0.131 | 0.908 |
| Airflow | 0.896 | 0.171 |
| W.Height | 0.713 | -0.196 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

and 0.713. Temperature and relative humidity have high loadings in the second PC with correlation co-efficient values of - 0.887 and 0.908. These meteorological parameters have substantial relationships in each of these components thereby forming two coherent components. This result tends to agree with HCA result that groups them into two clusters.

Table 4.83: Total Var`iance Explained Table for Pollutant Concentration at Owerri in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.492 | 41.535 | 41.535 | 2.492 | 41.535 | 41.535 | 2.207 | 36.778 | 36.778 |
| 2 | 1.115 | 18.584 | 60.119 | 1.115 | 18.584 | 60.119 | 1.290 | 21.498 | 58.276 |
| 3 | 1.008 | 16.802 | 76.921 | 1.008 | 16.802 | 76.921 | 1.119 | 18.645 | 76.921 |
| 4 | 0.759 | 12.645 | 89.567 | | | | | | |
| 5 | 0.352 | 5.866 | 95.433 | | | | | | |
| 6 | 0.274 | 4.567 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.84: Component Matrix[a]

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| $PM_{10}$ | 0.836 | 0.134 | -0.285 |
| $NO_2$ | 0.856 | 0.120 | -0.107 |
| $SO_2$ | 0.552 | -0.485 | -0.443 |
| CO | 0.768 | 0.118 | 0.343 |
| VOC | -0.004 | 0.909 | -0.154 |
| $H_2S$ | 0.408 | -0.084 | 0.760 |

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Table 4.85: Rotated Component Matrix[a]

| | Component | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| $PM_{10}$ | 0.882 | 0.111 | 0.093 |
| $NO_2$ | 0.821 | 0.280 | 0.076 |
| $SO_2$ | 0.668 | -0.172 | -0.510 |
| CO | 0.546 | 0.647 | 0.076 |
| VOC | 0.104 | -0.114 | 0.909 |
| $H_2S$ | 0.031 | 0.859 | -0.110 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Table 4.83, 4.84 and 4.85 are the total variance explained table, component matrix and rotated component matrix respectively for the air pollutants; $PM_{10}$, $NO_2$, $SO_2$, CO, VOC and $H_2S$ in dry season at Owerri. The rotal variance explained table shows that there are three components with initial eigenvalues more than 1.0, although the eigenvalue for the third component is barely over 1 at 1.008. These three components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 36.778 % of the variance, the second principal component (PC2), accounted for 21.498 % of the variance while the third principal component (PC3) accounted for 18.645 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that $PM_{10}$, $NO_2$, $SO_2$ and CO have high positive loadings in the first principal component with correlation co-efficient values of 0.882, 0.821, 0.668 and 0.546. $H_2S$ has a high loading in the second principal component with correlation co-efficient of 0.859 and lastly VOC had high loadings in the third principal component with correlation co-efficient of 0.909. VOC and $H_2S$ are not substantially related to the other pollutants and should not be aggregated with them but that the other pollutants form a coherent component. This is in agreement with the result of Hierarchical Cluster Analysis which grouped these pollutants into one major cluster.

Table 4.86: Total Variance Explained Table for Meteorological Parameters at Owerri in Dry Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.676 | 53.518 | 53.518 | 2.676 | 53.518 | 53.518 | 1.910 | 38.196 | 38.196 |
| 2 | 1.048 | 20.966 | 74.484 | 1.048 | 20.966 | 74.484 | 1.814 | 36.288 | 74.484 |
| 3 | 0.817 | 16.331 | 90.815 | | | | | | |
| 4 | 0.364 | 7.289 | 98.105 | | | | | | |
| 5 | 0.095 | 1.895 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.87: Component Matrix[a]

| | Component |
|---|---|

| | 1 | 2 |
|---|---|---|
| W.Speed | 0.915 | 0.283 |
| Temperature | -0.844 | 0.320 |
| R.Humidity | 0.619 | -0.672 |
| Airflow | 0.692 | 0.643 |
| W.Height | 0.515 | -0.036 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.88: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.860 | 0.421 |
| Temperature | -0.394 | -0.812 |
| R.Humidity | -0.010 | 0.913 |
| Airflow | 0.945 | 0.007 |
| W.Height | 0.350 | 0.380 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Table 4.86, 4.87 and 4.88 are respectively the total variance explained table, component matrix and rotated component matrix for the meteorological parameters in dry season at Owerri. The total variance explained table reveals that there are two components with initial eigenvalues more than 1.0, although the eigenvalue for the second component is barely over 1 at 1.048. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 38.196 % of the variance, the second principal component (PC2), accounted for 36.288 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, in keeping with zero-order correlations, that wind speed, temperature, air flow and wave height have high loadings in the first principal component with correlation co-efficient values of 0.860, -0.394, 0.945 and 0.350. Relative humidity has a high loading in the second principal component with correlation co-efficient of 0.913. Relative humidity is not substantially related to the other meteorological parameters and should not be aggregated with them but that the other meteorological parameters form a coherent component.

Table 4.89, 4.90 and 4.91 are respectively the total variance explained table, component matrix and rotated component matrix for the meteorological parameters in wet season at Owerri. The total variance explained table shows that there are two components with initial eigenvalues more than 1.0. These two components whose eigenvalues are above 1 were rotated. After rotation, the first principal component (PC1), accounted for 40.474 % of the variance, the second principal component (PC2), accounted for 33.878 % of the variance. The rotated component matrix table displays the items and component loadings for the rotated components, with loadings less than 0.30 omitted to improve clarity. Results suggest, that in keeping with zero-order correlations, that wind speed, air flow and wave height have high loadings in the first principal component with correlation co-efficient values of 0.924, 0.607 and 0.880. Temperature and relative humidity have high loadings in the second principal component with correlation co-efficient values of- 0.920 and 0.919. These meteorological parameters have substantial relationships in each of these components thereby forming two coherent components. This result tends to agree with the result of Hierarchical Cluster Analysis that grouped them into two clusters.

Table 4.89: Total Variance Explained Table for Meteorological parameters at Owerri in wet Season

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 2.024 | 40.476 | 40.476 | 2.024 | 40.476 | 40.476 | 2.024 | 40.474 | 40.474 |
| 2 | 1.694 | 33.876 | 74.352 | 1.694 | 33.876 | 74.352 | 1.694 | 33.878 | 74.352 |
| 3 | 0.856 | 17.113 | 91.465 | | | | | | |
| 4 | 0.276 | 5.521 | 96.986 | | | | | | |
| 5 | 0.151 | 3.014 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.

Table 4.90: Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.925 | -0.022 |
| Temperature | 0.094 | 0.922 |
| R.Humidity | 0.132 | -0.916 |
| Airflow | 0.607 | 0.005 |
| W.Height | 0.879 | 0.059 |

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Table 4.91: Rotated Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| W.Speed | 0.924 | 0.039 |
| Temperature | 0.111 | -0.920 |
| R.Humidity | 0.114 | 0.919 |
| Airflow | 0.607 | 0.006 |
| W.Height | 0.880 | -0.042 |

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

## 4.13 Presentation of Result of Wind Rose models

Furthermore, dispersion of atmospheric pollutants depends not only on the wind speed but also on the wind direction. Therefore the wind direction and wind speed obtained in each of the 16 air quality sampling points were modeled into wind rose diagram for the morning, afternoon and evening air pollution events. This was done in an attempt to elucidate the dispersion of air the pollutants. Giri, Krishna and Adhikary (2008) used wind rose diagram to evaluate dispersion of $PM_{10}$ in Kathmandu Valley, Nepal. The wind rose model for IMSU Junction, Owerri, is presented in Fig.4.70 to 4.72. The rest of the wind rose models are placed in appendix 8. Fig.4.70 is the windrose diagram at IMSU Junction in the morning; it indicates a dominant wind speed of > 3.5 m/s in the NE direction. Fig.4.71 is the wind rose diagram at IMSU Junction in the afternoon; there are three dominating wind speed in NE, SW and NW directions. These dominant wind speed and directions could contribute significantly to the dispersion of the atmospheric pollutants. Fig. 4.72 is the wind rose diagram at IMSU Junction in the evening. The wind rose model indicates the dominant wind speed of > 3.5 m/s in the NE direction.

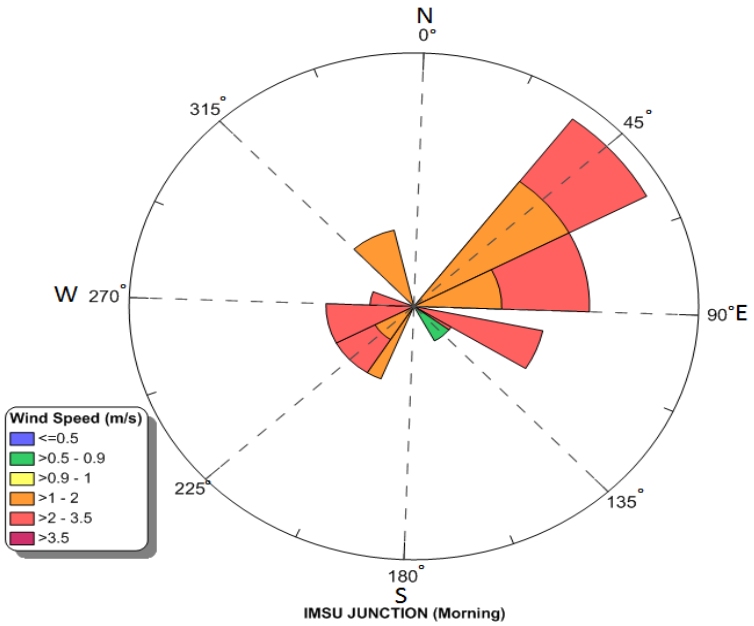


Fig.4.70: Wind rose Diagram at IMSU Junction (Morning)

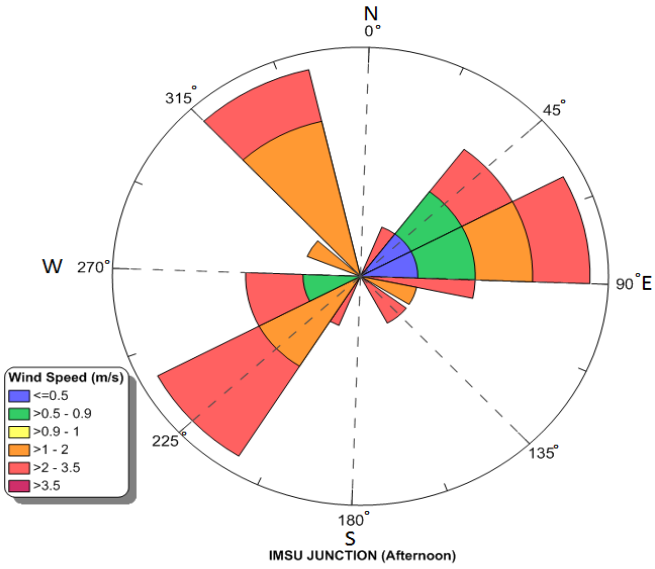


Fig.4.71: Wind rose Diagram at IMSU Junction (Afternoon)

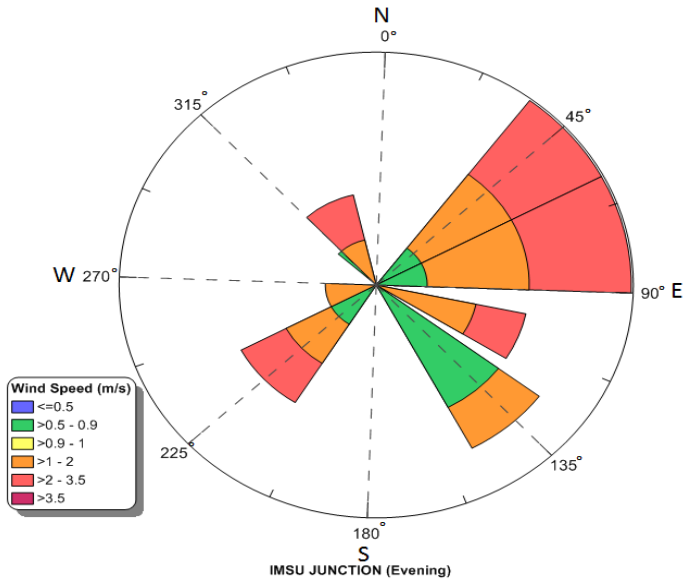


Fig.4.72: Wind rose Diagram at IMSU Junction (Evening)

## 4.14 Air Quality Index (AQI) of the Atmospheric Pollutants

The air quality of a particular locality affects how the people live and breathe. Air quality like weather could change daily or even hourly, hence the need to make available the information regarding the air quality of an area is imperative for air quality evaluation and forecast. An important tool in this regard is the Air Quality Index (AQI), which can be used to provide information about the local air quality, as it regards to effect of unhealthy air and how to protect once health. AQI lays emphasis on the probable health effects that people may experience on few hours or days of exposure to polluted atmosphere (EPA, 2014). Ravikumar et al (2014) used AQI to study air quality in the vicinity of dam sites of different irrigation projects in Karnataka State, India.

Therefore, the AQI of the pollutants were determined in order to evaluate the health risk which the public are exposed due to atmospheric pollution. The AQI values, risk message and associated colours are shown in Table 4.92. AQI of the individual air pollutants, the average AQI and the conditional air pollutant are presented in Table 4.91 to 4.98 for each location in wet and dry season. The risk or message of AQI is indicated with the respective colour as shown. Also in most of the AQI tables the value for $NO_2$ is 0.00. This is because in most of the areas monitored the concentration of $NO_2$ was less than 0.65 ppm which is the minimum value of the air pollutant required for calculating AQI using SIM-Air quality software. VOC and $H_2S$ were

not included in the AQI tables because they are not among the criteria air pollutants used for determining the AQI of an area (Wong et al, 2012; EPA, 2014), also the air pollutants (VOC and $H_2S$) are not included in the SIM – Air quality software for modeling AQI .

The AQI of the study locations were rated using EPA (2014) AQI rating for determining the ambient air quality is presented in Table 4.92. The result indicates that the AQI of the study locations range from moderate to very unhealthy (51 – 300). Again, AQI result in Tables 4.93 – 4.100 indicate that CO is the conditional air pollutant responsible for the observed AQI level in the study locations

Table 4.92: AQI Values and Level of Health Concern

| **Descriptor** | **AQI** | **Colour** | **Risk Message** |
|---|---|---|---|
| Good | 0-50 | Green | No Message |
| Moderate | 51-100 | Yellow | Unusually sensitive Individuals (ozone) |
| Unhealthy for Sensitive Groups | 101-150 | Orange | Identifible group at risk different groups for different pollutants |
| Unhealthy | 151-200 | Red | General public at risk; groups at greater risk |
| Very unhealthy | 201-300 | Purple | General public at greater risk; groups at greatest risk |

Table 4.93: AQI of Owerri in Dry Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| IMSU Junction | 0.007 | 0.00 | 274.70 | 409.67 | CO | 228.13 |
| Emmanuel College Roundabout | 0.007 | 0.00 | 221.49 | 390.06 | CO | 203.85 |
| World Bank Mkt Junction | 0.007 | 0.00 | 273.19 | 394.89 | CO | 222.70 |
| Egbu - Uratta Ring Road | 0.004 | 0.00 | 129.59 | 321.29 | CO | 150.30 |

Table 4.94: AQI of Owerri in Wet Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| IMSU Junction | 0.006 | 0.00 | 296.60 | 361.32 | CO | 219.31 |
| Emmanuel College Roundabout | 0.007 | 0.00 | 282.80 | 330.43 | CO | 204.41 |
| World Bank Mkt Junction | 0.005 | 0.00 | 389.92 | 323.44 | SO2 | 237.79 |
| Egbu - Uratta Ring Road | 0.004 | 0.00 | 148.93 | 282.02 | CO | 143.65 |

Table 4.95: AQI of Okigwe in Dry Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| Umuna Junction | 0.007 | 0.00 | 194.32 | 426.59 | CO | 206.97 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Okigwe Express Junction | 0.010 | 0.00 | 237.59 | 490.52 | CO | 242.71 |
| St. Mary's Junction | 0.008 | 0.00 | 240.80 | 457.75 | CO | 232.85 |
| Ihube | 0.004 | 0.00 | 117.26 | 323.17 | CO | 146.81 |

Table 4.96:AQI of Okigwe in Wet Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| Umuna Junction | 0.006 | 0.00 | 257.53 | 392.48 | CO | 216.67 |
| Okigwe Express Junction | 0.009 | 202.05 | 357.96 | 415.04 | CO | 243.77 |
| St. Mary's Junction | 0.009 | 0.00 | 255.30 | 393.55 | CO | 216.29 |
| Ihube | 0.005 | 0.00 | 158.98 | 329.89 | CO | 162.96 |

Table 4.97: AQI of Orlu in Dry Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| Umuaka Junction | 0.007 | 0.00 | 243.65 | 434.11 | CO | 225.92 |
| Banana Junction | 0.008 | 0.00 | 271.68 | 433.58 | CO | 235.09 |
| Umuna Junction | 0.009 | 0.00 | 298.73 | 447.28 | CO | 248.67 |
| Umuago Urualla | 0.004 | 0.00 | 131.26 | 319.95 | CO | 150.40 |

Table 4.98: AQI of Orlu in Wet Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| Umuaka Junction | 0.006 | 0.00 | 264.29 | 387.37 | CO | 217.22 |
| Banana Junction | 0.007 | 0.00 | 323.73 | 350.30 | CO | 224.68 |
| Umuna Junction | 0.007 | 0.00 | 292.68 | 359.71 | CO | 217.46 |
| Umuago Urualla | 0.004 | 0.00 | 243.02 | 312.97 | CO | 185.33 |

Table 4.99: AQI of Egbema in Dry Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| Umuorji | 0.007 | 0.00 | 282.36 | 441.63 | CO | 241.33 |
| Ukwugba I | 0.008 | 0.00 | 314.91 | 477.90 | CO | 264.27 |
| Ukwugba Ii | 0.007 | 0.00 | 292.50 | 466.62 | CO | 253.04 |
| Opuoma | 0.007 | 0.00 | 212.77 | 437.34 | CO | 216.70 |

Table 4.100: AQI of Egbema in Wet Season

| Location | Individual AQI | | | | Conditional Pollutant | Average AQI |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | | |
| UMUORJI | 0.01 | 0.00 | 286.54 | 328.28 | CO | 204.94 |

| | | | | | | |
|---|---|---|---|---|---|---|
| UKWUGBA I | 0.01 | 0.00 | 294.73 | 322.64 | CO | 205.79 |
| UKWUGBA II | 0.01 | 0.00 | 297.13 | 317.80 | CO | 204.98 |
| OPUOMA | 0.01 | 0.00 | 228.34 | 325.05 | CO | 184.47 |

## 4.15 Multivariate Plots of the Air Pollutants

Meteorological parameters such as ambient temperature, wind speed, wind direction, relative humidity, air flow, etc play a significant role in the dispersion of atmospheric pollutant (Manahan, 2001; Ocak & Turalioglu, 2008). Therefore, multivariate plots of each of the meteorological parameters and all the measured air pollutants except $H_2S$ were plotted in order to show the relationship between the air pollutants and the meteorological variables as it affects dispersion of the air pollutants and the observed air quality level.

The plots of the air pollutant concentration against each of the meteorological variables are presented in Fig. 4.73 to 4.76 while the rest of the multivariate plots are in appendix 9. Fig. 4.73 is the multivariate plot at Banana Junction in dry season; it indicates slight increase in the concentration of the pollutant in week 8 with higher wind speed. While in week 11 the observed low wind speed resulted in decreased concentration of the pollutants. Also, Fig. 4.74 showed lower pollutant concentration with elevated ambient temperature. Fig. 4.75 is the multivariate plot of air flow against the air pollutant at St. Mary's Junction, Okigwe in wet season. The plot indicates that there is corresponding high pollutant concentration with increase in air flow. It was observed that the concentrations of some air pollutants either decreased or increased with either increase or decrease in the value of the meteorological parameters. This is exemplified in the level of $PM_{10}$ which increases with increase in wind speed, temperature and air flow.

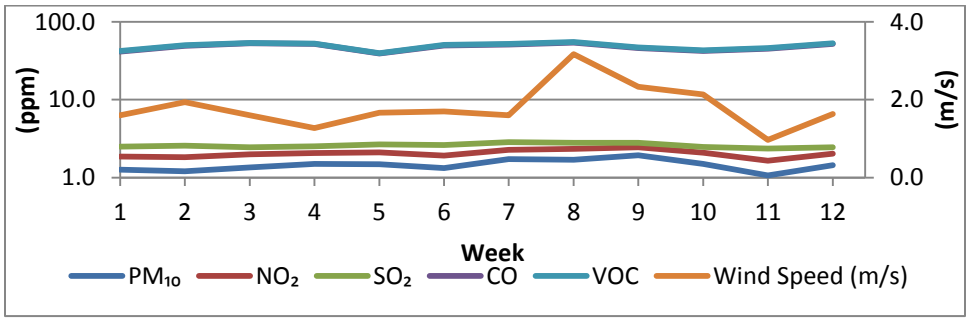


Fig.4.73: Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind speed at Banana Junction (dry season)

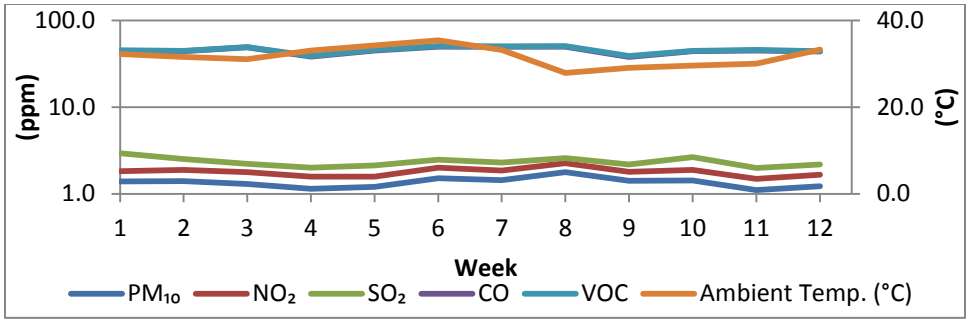


Fig.4.74: Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at IMSU Junction (dry season)

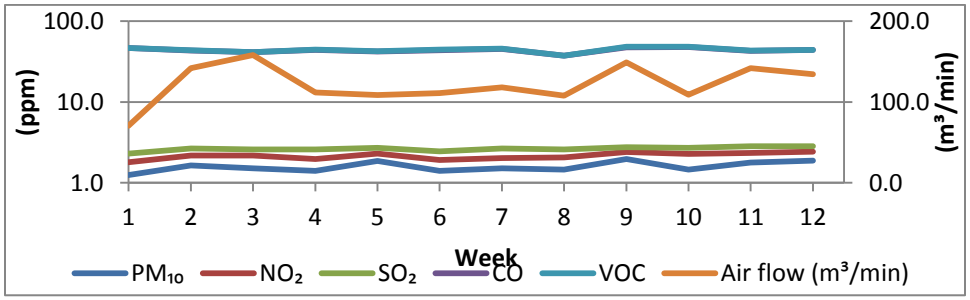


Fig.4.75: Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air Flow at St. Mary's Junction (wet season)

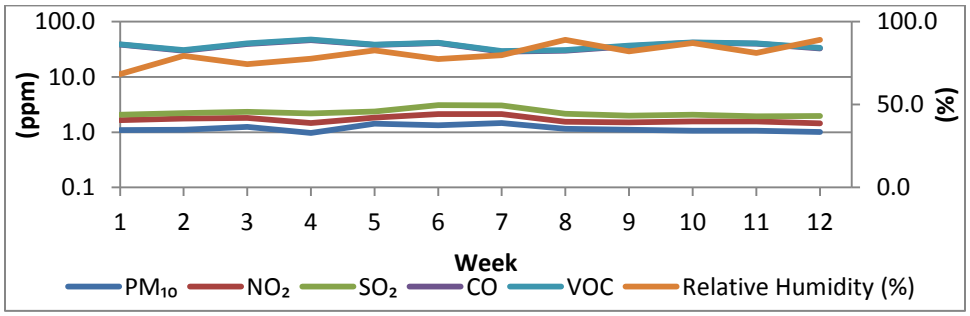


Fig.4.76: Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuorji (wet season)

# CHAPTER FIVE

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

Spatio – temporal characterization and dynamic modeling of ambient air quality in Imo State, Nigeria were studied with reference to $PM_{10}$, $SO_2$, $NO_2$, VOC, $H_2S$ and CO, as well as some meteorological parameters; wind speed, wind direction, relative humidity, ambient temperature, wave height, air flow and elevation that could influence the concentration of the

atmospheric pollutants. The study was conducted for a period of 3 months in wet season and 3 months in dry season from months of November, 2014 to June, 2015. The results indicate that elevated levels of $PM_{10}$, VOC, $H_2S$ and CO were recorded in dry season, while higher concentration of $SO_2$ and $NO_2$ were observed in wet season

The study has established the spatial and temporal attributes of the measured ambient air pollutants, the dynamics of atmospheric dispersion and prediction of air pollution events. Spatial attributes of the atmospheric pollutants were determined with the help of GIS data of the study areas which revealed areas with elevated values of the pollutants in a chloropleth map layer. The result indicates that higher concentration of CO and $\mathbf{PM_{10}}$ were observed at Okigwe and Egbema area. Owerri area showed higher mean values of $SO_2$ in wet season, while higher mean values were observed at Egbema in dry season. Higher values of VOC and $H_2S$ were observed at Egbema followed by Owerri. Also, elevated values of $PM_{10}$, $NO_2$, CO and $SO_2$ were observed at Egbema in bot dry and wet seasons. Infact, apart from gas flaring, little or no commercial and agricultural activites, there is no other visible activities in this location that could have contributed to the air pollution level. So, meteorological and topographical factors must have contributed significantly to this. For instance, Egbema area has the lowest elevation level recorded during the study (ie Umuorji, 42 m, Ukwugba 1, 42 m, Ukwugba 2, 32 m and Opuoma, 41 m. The low elevation level of this area could have contributed to the heightened air pollution level, since air pollutants concentrates more in low level plains; this is compounded by gas flaring within this area and the neigbouring towns like Omoku in River State.

Characterization and distribution of the ambient air pollutant in terms of; lower quartile, upper quartile, median, minimum and maximum values in the study locations was established with the Box and Whisker plots. This was done to illustrate the distribution of the air pollutant concentration in the morning, afternoon and evening. The result of this analysis showed higher concentration of VOC and $H_2S$ in the morning, while elevated values of $NO_2$ and $SO_2$ were observed in the morning and afternoon. The concentration of $PM_{10}$ was observed to be higher in the afternoon and evening, while significant level of CO was recored in either morning, afternoon or evening.

Temporal variations of the atmospheric pollutants were illustrated with time series models. This was accomplished to show the temporal correlation of the air pollutants with time, i.e morning, afternoon and evening, which could be useful for prediction of air pollution.

Dynamic models like regression and wind rose models together with multivariate plots were developed, which explained the dispersion and migration of the atmospheric pollutants.

One-way ANOVA ($p < 0.05$) was carried to compare the influence of season, location and time of measurement on the mean values of both the air pollutants and the meteorological variables. The result revealed that the difference in mean values of the air pollutants were not statistically significant in most of the locations due to the influence of season, meteorological factors, location and time of measurement, while that of the meteorological variables were significant in most of the area sampled. The observed differences in their mean values are likely due to chance. Pearson product-moment correlation co-efficient, r, was computed to assess the strength and direction of the linear relationships that exist between the air pollutants and among meteorological parameters. High correlation was observed between $NO_2$ and $SO_2$, wind speed, wave height and air flow, while weak correlation was observed between $PM_{10}$, $SO_2$, $NO_2$, VOC and CO, temperature and relative humidity.

Hierarchical cluster analysis (HCA) was conducted to show the similarities or otherwise the desimilarities in the source or occurrence of the pollutants and the meteorological parameters. The result which was represented in a dendogram grouped both the air pollutants and meteorological parameters into two clusters. Principal components analysis (PCA) with varimax rotation was conducted to assess variation of the air pollutants. The PCA result revealed two coherent components existing among the air pollutants and between the meteorological variables. Variability of atmospheric pollutants could be attributed to changes in meteorological and topographical conditions which could change the atmospheric pollution pattern with different locations and time.

Apart from higher vehicular traffic, presence of three stroke engine or tricycles known for incomplete combustion and combustion of biomass is observed as being responsible for the observed elevated concentration of the air pollutants. Poor environmental management practices resulting from anthropogenic emissions due to industrial activities such as gas flaring, use of power generating sets and other domestic activities could have impacted significantly to the observed air polluton level in the study areas. Also the influence of meteorological parameters could contribute significantly to space variation of the air pollution level which results in migration and transportation to areas outside the source of pollution.

The observed unhealthy AQI in most locations may pose severe health consequences for the general public and the environment. This therefore calls for adequate attention and best environmental management practices to reduce the level of air quality deterioration.

## 5.2 Recommendation

i. The observed AQI within the study area is of great concern and therefore requires serious attention by environmentalist, researches, regulatory bodies, and of course the government at the various levels.
ii. Government agencies should formulate appropriate environmental policies and measures for mitigation and reduction of air pollutant emission which most likely will help in guaranting a sustainable and eco-friendly environment.
iii. Efforts should be intensified by the government of Nigeria at all levels to enforce stringent environmental legislative measures that will eliminate or drastically reduce gas flaring.
iv. National regulatory agencies should as a matter of urgency procure containuous air quality monitoring devices to monitor the ambient air quality of our cities and towns. This is a critical activity in ambient air quality control and atmospheric management that enables continuous monitoring of criteria air pollutants such as CO, $NO_2$, $O_3$, $SO_2$, and $PM_{10}$.
v. The Federal and State governments, environmental regulatory agencies, and research institutions should as a matter of utmost importance carry out widespread awareness and sensitization of the populace on the issue of atmospheric pollution.

## 5.3 Contribution to Knowledge

i. The research has produced a generic predictive model capabale of predicting the dispersion of atmospheric pollutant concentration in time and space.

ii. This work has established the spatial and temporal trends of ambient air quality in the study area using statistical analysis.

iii. The work is the first atmospheric study in Imo State with integrated mulltidiciplinary approach including geology, meteorology, GIS, mathematics, physics and chemistry in the study of atmospheric pollution. Based on the aforementioned, the study therefore has established the relationship between meteorological parameters and dispersion of anthropogenically generated atmospheric contaminants

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## APPENDIX 1

## REGRESSION VALUES FOR DRY SEASON

### Owerri

b -Values for Imsu Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 14.0644 | -0.3265 | 3.1654 | 17.1899 | -0.0000 |
| b1 | -2.1819 | 0.0348 | 0.1497 | -15.9750 | -0.0000 |
| b2 | -0.2719 | 0.0157 | -0.0350 | -0.2862 | -0.0000 |
| b3 | -0.0181 | 0.0095 | -0.0191 | 0.4335 | 0.0000 |
| b4 | 0.0098 | -0.0014 | -0.0001 | 0.1296 | 0.0000 |
| b5 | 17.8114 | 0.0991 | -3.2398 | 110.2100 | 0.0000 |
| b6 | 0.1335 | -0.8831 | 0.3779 | -0.0442 | 1.0000 |
| $R^2$ | 0.2572 | 0.8701 | 0.5384 | 0.6341 | 1.0000 |

b -Values for Imsu Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 18.0083 | 0.1381 | 4.1772 | 24.7590 | 3.1790 |
| b1 | -2.0605 | -0.0398 | 0.0203 | -16.1090 | -0.1324 |
| b2 | 0.3279 | 0.0012 | -0.0564 | -0.4255 | -0.0175 |
| b3 | -0.0073 | 0.0046 | -0.0153 | 0.3852 | -0.0335 |
| b4 | 0.0173 | -0.0004 | -0.0006 | 0.1282 | -0.0018 |
| b5 | 16.7290 | 0.1602 | -3.7963 | 105.2155 | 5.4649 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.2409 | 0.4577 | 0.5647 | 0.6310 | 0.7088 |

b -Values for Emmanuel College Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 50.4270 | 2.8003 | -1.9907 | 49.1194 | -5.8056 |
| b1 | 0.4444 | 0.0676 | 0.3106 | 5.9445 | -0.0440 |
| b2 | -0.7666 | -0.0084 | 0.0444 | 0.9673 | 0.0510 |
| b3 | -0.1462 | -0.0282 | 0.0080 | -0.5175 | 0.0670 |
| b4 | -0.0039 | 0.0014 | -0.0039 | -0.0113 | 0.0020 |
| b5 | -0.4639 | -1.4292 | 0.1523 | -40.420 | -1.7850 |
| b6 | -0.7599 | 0.3718 | 0.3892 | -0.0251 | -0.5130 |
| $R^2$ | 0.8297 | 0.7936 | 0.4903 | 0.2162 | 0.7013 |

b – for Emmanuel College Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 32.8743 | 2.6440 | -0.1048 | 93.9953 | -12.3771 |
| b1 | 1.3973 | 0.0911 | 0.2125 | 2.7265 | 0.5131 |
| b2 | -0.3356 | -0.0004 | 0.0030 | -0.0830 | 0.1746 |
| b3 | 0.1719 | -0.0282 | 0.0050 | -0.5900 | 0.0863 |
| b4 | -0.0148 | 0.0014 | -0.0039 | 0.0107 | -0.0034 |
| b5 | -6.5989 | -1.0973 | 0.1981 | -59.5680 | -0.1276 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7067 | 0.6926 | 0.4233 | 0.1962 | 0.5847 |

b -Values for World Bank Mkt Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 159.200 | 0.2917 | -0.0000 | 139.5940 | 14.3593 |
| b1 | -4.4050 | 0.0697 | -0.0000 | -4.6341 | -0.2830 |
| b2 | -2.1782 | 0.0127 | 0.0000 | 0.0596 | -0.1850 |
| b3 | -1.0745 | -0.0040 | 0.0000 | -1.3510 | -0.0910 |
| b4 | 0.0485 | -0.0003 | 0.0000 | 0.0348 | 0.0020 |
| b5 | -11.229 | 0.1875 | -0.0000 | 38.0390 | -1.0990 |
| b6 | 1.1257 | -0.0353 | 1.0000 | 0.1236 | -0.3510 |
| $R^2$ | 0.8149 | 0.6669 | 1.0000 | 0.7422 | 0.5881 |

b -Values for World Bank Mkt Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 74.2563 | -0.1823 | -9.8365 | 163.6666 | 10.2012 |
| b1 | -0.5486 | 0.0722 | 0.3109 | -5.1034 | -0.2588 |
| b2 | -0.9722 | 0.0160 | 0.1040 | -0.3367 | -0.1379 |
| b3 | -0.4359 | 0.0005 | 0.0826 | -1.4073 | -0.0619 |
| b4 | 0.0057 | -0.0005 | 0.0003 | 0.0305 | 0.0019 |
| b5 | -3.9026 | 0.1819 | -0.6287 | 32.9297 | -0.5962 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5481 | 0.5238 | 0.6984 | 0.7129 | 0.4337 |

b -Values for Egbu-Uratta Ring Road without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 57.9088 | 2.4720 | -0.3005 | 134.9296 | -1.2847 |
| b1 | 0.0749 | 0.0528 | -0.1497 | 5.7727 | -0.0556 |
| b2 | -1.0398 | -0.0177 | -0.0148 | -0.8001 | 0.0181 |
| b3 | -0.2480 | -0.0200 | 0.0126 | -0.9975 | 0.0175 |
| b4 | 0.0027 | -0.0013 | 0.0020 | -0.0242 | 0.0003 |
| b5 | 0.1826 | 0.1500 | 0.0215 | -8.1977 | -0.3053 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.9597 | 0.5250 | 0.6125 | 0.5713 | 0.1288 |

b -Values for Egbu-Uratta Ring Road with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 56.4848 | 4.3107 | -0.3667 | 141.7890 | -1.7310 |
| b1 | 0.3511 | 0.1044 | -0.1377 | 4.9850 | -0.0080 |
| b2 | -1.0127 | -0.0326 | -0.0133 | -0.9623 | 0.0300 |
| b3 | -0.2409 | -0.0350 | 0.0133 | -0.9464 | 0.0220 |
| b4 | 0.0021 | -0.0019 | 0.0018 | -0.0079 | -0.0010 |
| b5 | 0.1354 | 0.2559 | 0.0160 | -7.1321 | -0.3950 |
| b6 | -0.0977 | -0.7593 | -0.1926 | -0.1946 | -0.4250 |
| $R^2$ | 0.9634 | 0.7738 | 0.5979 | 0.5487 | 0.3061 |

## OKIGWE

b -Values for Umuna Junction wthout PDC ( Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 39.0694 | -1.5331 | 0.2693 | -73.1101 | -13.0627 |
| b1 | 4.6901 | 0.1590 | -0.0116 | 11.3500 | 0.5520 |
| b2 | -0.7937 | 0.0278 | -0.0020 | 2.0961 | 0.2163 |
| b3 | -0.0983 | 0.0140 | 0.0004 | 0.5478 | 0.0808 |
| b4 | -0.0372 | -0.0024 | 0.0020 | -0.1292 | 0.0011 |
| b5 | -14.7952 | -0.3582 | -0.7307 | 0.2855 | -6.3383 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7341 | 0.4420 | 0.2682 | 0.3616 | 0.8923 |

b -Values for Umuna Junction wth PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -96.5959 | 0.7277 | -0.3819 | -109.646 | 0.0000 |
| b1 | 6.5076 | 0.1613 | 0.0608 | 14.889 | 0.0000 |
| b2 | 1.5754 | 0.0049 | 0.0085 | 2.7608 | 0.0600 |
| b3 | 0.4422 | -0.0015 | 0.0028 | 0.9172 | -0.0310 |
| b4 | -0.0503 | -0.0030 | 0.0008 | -0.1356 | 0.0090 |
| b5 | 8.1566 | -0.3398 | -0.7569 | -9.7111 | 0.0000 |

| | | | | | |
|---|---|---|---|---|---|
| b6 | 1.3520 | -0.5075 | 0.4486 | -0.4150 | 0.0000 |
| $R^2$ | 0.8913 | 0.5662 | 0.2805 | 0.5804 | 1.0000 |

b -Values for Okigwe Express Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -41.9415 | 0.4534 | 0.4769 | 98.7949 | 8.8333 |
| b1 | 3.5052 | -0.0224 | -0.0132 | 1.3103 | 0.0701 |
| b2 | 0.7330 | -0.0094 | -0.0036 | -0.3793 | -0.1147 |
| b3 | 0.2670 | 0.0088 | 0.0021 | -0.4804 | -0.0561 |
| b4 | 0.0053 | -0.0002 | 0.0002 | 0.0013 | 0.0000 |
| b5 | -1.1783 | -0.5489 | -0.3938 | -0.4044 | 0.1387 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7507 | 0.6788 | 0.4953 | 0.2837 | 0.2941 |

b -Values for Okigwe Express Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| | -39.0367 | 3.4550 | 0.5962 | 118.7320 | 18.0565 |
| b1 | 2.9633 | 0.0010 | -0.0064 | 2.4922 | 0.0340 |
| b2 | 0.6179 | -0.0422 | -0.0022 | -0.3486 | -0.2380 |
| b3 | 0.3380 | -0.0129 | -0.0004 | -0.6687 | -0.1240 |
| b4 | 0.0042 | 0.0002 | 0.0002 | 0.0024 | -0.0000 |
| b5 | -1.9634 | -0.5243 | -0.4026 | 0.1042 | -0.1740 |
| b6 | -0.2898 | -0.5527 | 0.0730 | -0.1642 | 0.4630 |
| $R^2$ | 0.7712 | 0.8001 | 0.5359 | 0.5013 | 0.6862 |

b -Values for St Mary's Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 24.2285 | -1.4961 | -0.0947 | 30.2894 | 10.8078 |
| b1 | 17.4089 | -1.8796 | -0.8820 | -8.2691 | 2.7849 |
| b2 | -1.9075 | 0.0811 | -0.1228 | -4.5651 | -0.7960 |
| b3 | -0.5505 | 0.0356 | 0.0087 | 0.2155 | -0.1404 |
| b4 | -0.0056 | 0.0093 | 0.0027 | -0.0473 | -0.0632 |
| b5 | 0.0351 | 0.0024 | 0.0035 | 0.2144 | 0.0035 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.6494 | 0.5009 | 0.7113 | 0.6670 | 0.5075 |

b -Values for St Mary's Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 22.0497 | -1.7923 | 0.8399 | 44.4943 | 0.0000 |
| b1 | 54.162 | -3.2887 | 0.9320 | -19.086 | 6.7213 |
| b2 | -5.3028 | 0.2477 | -0.2597 | 1.1520 | 1.2040 |
| b3 | -0.5606 | 0.0410 | 0.0005 | 0.4882 | 0.3349 |
| b4 | -0.0739 | 0.0131 | -0.0057 | -0.1516 | -0.1149 |
| b5 | 0.0650 | 0.0009 | 0.0043 | 0.1473 | -0.0127 |

| | | | | | |
|---|---|---|---|---|---|
| b6 | 0.5408 | -0.2088 | -0.2732 | -0.3352 | -3.8981 |
| $R^2$ | 0.7375 | 0.6748 | 0.8003 | 0.7081 | 1.0000 |

b -Values for Ihube without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 31.5246 | 0.1078 | -0.9536 | 73.2239 | 5.3666 |
| b1 | 2.0933 | 0.0698 | -0.0011 | 1.1919 | 0.2503 |
| b2 | -0.6358 | 0.0082 | 0.0105 | -0.3585 | -0.0377 |
| b3 | -0.0721 | -0.0008 | 0.0101 | -0.2922 | -0.0510 |
| b4 | -0.0406 | -0.0008 | 0.0008 | -0.1107 | 0.0004 |
| b5 | -0.1367 | -0.4927 | -0.3456 | 17.6070 | -0.1935 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.8953 | 0.5143 | 0.4603 | 0.2272 | 0.3596 |

b -Values for Ihube with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 20.6944 | -0.4728 | 0.0175 | 107.931 | -6.8946 |
| b1 | 0.5370 | -0.0241 | 0.0133 | -6.7093 | 0.3560 |
| b2 | -0.4885 | 0.0179 | 0.0013 | -1.2151 | 0.1080 |
| b3 | 0.0418 | -0.0020 | 0.0006 | -0.1384 | -0.0132 |
| b4 | -0.1029 | 0.0038 | 0.0018 | -0.2082 | 0.0564 |
| b5 | 0.0234 | 0.0012 | 0.0001 | 0.1735 | 0.0023 |
| b6 | 0.3518 | -0.3170 | -0.5911 | -0.4020 | -0.5036 |
| $R^2$ | 0.9765 | 0.5348 | 0.3367 | 0.8607 | 1.0000 |

## ORLU

b -Values for Umuaka Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 33.1454 | -1.3473 | -2.4638 | -22.9757 | -4.0603 |
| b1 | 0.4900 | -0.0004 | 0.1854 | 2.6748 | 0.4156 |
| b2 | -0.4574 | 0.0280 | 0.0527 | 1.2756 | 0.0923 |
| b3 | -0.1814 | 0.0115 | 0.0159 | 0.3000 | 0.0200 |
| b4 | 0.0229 | -0.0005 | -0.0013 | -0.0315 | -0.0013 |
| b5 | 4.0188 | 0.5152 | -1.9710 | 5.4607 | -2.2285 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.6541 | 0.4942 | 0.7201 | 0.7603 | 0.7125 |

b -Values for Umuaka Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |

| | | | | | |
|---|---|---|---|---|---|
| b | 3.1138 | -1.3560 | -2.6214 | -8.4486 | -4.8731 |
| b1 | 3.3171 | 0.0013 | 0.3038 | 4.3730 | 0.3311 |
| b2 | 0.2378 | 0.0296 | 0.0690 | 1.4896 | 0.0937 |
| b3 | -0.1943 | 0.0125 | 0.0114 | 0.2595 | 0.0265 |
| b4 | 0.0376 | -0.0005 | -0.0011 | -0.0411 | -0.0001 |
| b5 | -19.1410 | 0.4857 | -2.5620 | 1.0347 | -1.7020 |
| b6 | 0.6885 | -0.2275 | -0.3501 | -0.4359 | 0.2278 |
| $R^2$ | 0.8716 | 0.5356 | 0.8633 | 0.8552 | 0.6011 |

b -Values for Banana Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 9.8963 | 0.5482 | -0.0866 | -247.9905 | -2.7945 |
| b1 | 2.6242 | -0.0261 | 0.2042 | 17.7032 | 0.0347 |
| b2 | -0.1480 | 0.0049 | 0.0315 | 4.6201 | 0.0662 |
| b3 | 0.0247 | -0.0024 | -0.0053 | 1.7001 | 0.0160 |
| b4 | -0.0239 | 0.0008 | -0.0039 | -0.2436 | -0.0001 |
| b5 | -1.9775 | 0.0885 | -0.0122 | 1.0155 | 0.4327 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5211 | 0.5195 | 0.5509 | 0.6263 | 0.3923 |

b -Values for Banana Junction with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 45.5614 | 1.0186 | -3.6882 | -279.7310 | -6.7422 |
| b1 | 0.8065 | -0.0556 | 0.5814 | 19.0512 | 0.0998 |
| b2 | -0.7077 | -0.0019 | 0.1027 | 5.0464 | 0.1178 |
| b3 | -0.1395 | -0.0055 | 0.0110 | 1.8499 | 0.0419 |
| b4 | -0.0026 | 0.0012 | -0.0075 | -0.2560 | -0.0010 |
| b5 | -1.1467 | 0.1045 | -0.1391 | 0.1182 | 0.4219 |
| b6 | -0.3776 | 0.0249 | -0.6092 | 0.1092 | 0.2340 |
| $R^2$ | 0.5460 | 0.5363 | 0.7175 | 0.5662 | 0.4733 |

b -Values for Umuna Junction without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| | -14.9278 | 1.6558 | -0.6449 | -62.9885 | 0.3885 |
| b1 | -0.1258 | -0.0272 | 0.0933 | 2.2808 | -0.3894 |
| b2 | 0.2586 | -0.0124 | 0.0261 | 1.3721 | -0.0142 |
| b3 | 0.1548 | -0.0093 | 0.0017 | 0.8167 | 0.0082 |
| b4 | 0.0428 | 0.0018 | 0.0007 | -0.0435 | 0.0082 |
| b5 | -1.8680 | -0.2163 | 0.0666 | 6.3178 | 1.1445 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5456 | 0.5653 | 0.2534 | 0.5851 | 0.6071 |

b -Values for Umuna Junction with PDC (Dry Season)

| b-VALUES | With PDC |
|---|---|

| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
|---|---|---|---|---|---|
| b | -16.7661 | 0.9114 | -1.4225 | -35.7928 | 1.3930 |
| b1 | -0.8144 | -0.0191 | 0.0935 | 1.0162 | -0.4228 |
| b2 | 0.2720 | -0.0130 | 0.0287 | 1.1722 | -0.0193 |
| b3 | 0.0901 | -0.0061 | 0.0088 | 0.6456 | -0.0016 |
| b4 | 0.0459 | 0.0035 | 0.0018 | -0.0447 | 0.0070 |
| b5 | 0.5613 | -0.7304 | -0.3556 | 16.9518 | 1.7538 |
| b6 | 0.7093 | 0.6384 | 0.1193 | -0.1360 | 0.0372 |
| $R^2$ | 0.7337 | 0.7468 | 0.3498 | 0.6692 | 0.6808 |

b -Values for Umuago Urualla without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -22.8507 | 1.1394 | -2.0190 | -16.4061 | 2.7977 |
| b1 | 2.7578 | 0.0052 | -0.0702 | -1.0945 | -0.9516 |
| b2 | -1.3091 | 0.0219 | 0.0824 | 8.3027 | 0.1936 |
| b3 | 0.3899 | -0.0133 | 0.0362 | 1.2042 | -0.0332 |
| b4 | 0.1674 | -0.0060 | 0.0120 | -0.0100 | -0.0103 |
| b5 | 0.0273 | -0.0005 | -0.0003 | -0.0532 | -0.0022 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.1676 | 0.1477 | 0.7837 | 0.2283 | 0.4597 |

b -Values for Umuago Urualla with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 27.0355 | 0.5507 | -1.8088 | -38.6757 | 4.1038 |
| b1 | 0.2282 | -0.0332 | -0.0649 | 1.5281 | -0.8477 |
| b2 | -3.4764 | 0.0593 | 0.0711 | 10.7126 | 0.1588 |
| b3 | -0.4607 | -0.0031 | 0.0321 | 1.7885 | -0.0462 |
| b4 | -0.1341 | -0.0010 | 0.0110 | 0.1408 | -0.0197 |
| b5 | 0.0447 | -0.0012 | -0.0003 | -0.0939 | -0.0019 |
| b6 | 0.9801 | -0.4622 | 0.1627 | -0.2747 | -0.2028 |
| $R^2$ | 0.3301 | 0.1731 | 0.7914 | 0.2527 | 0.4894 |

## EGBEMA

b -Values for Umuorji without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 13.3448 | -3.3215 | -1.9196 | 67.5170 | -4.3548 |
| b1 | 0.2788 | 0.0373 | 0.2272 | 4.2509 | 0.1095 |
| b2 | -0.1126 | 0.0486 | 0.0231 | -0.8554 | 0.0623 |
| b3 | -0.0178 | 0.0243 | 0.0186 | 0.0758 | 0.0422 |
| b4 | -0.0021 | 0.0037 | 0.0012 | -0.0117 | 0.0047 |
| b5 | -4.7717 | -0.5011 | -1.0124 | -25.0780 | -1.4141 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.1088 | 0.8677 | 0.3027 | 0.3908 | 0.2684 |

b -Values for Umuorji with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -10.5702 | -3.4349 | -5.8856 | 83.9335 | -4.0403 |
| b1 | -1.4455 | 0.0119 | -0.5095 | 5.5316 | 0.1195 |
| b2 | -0.0338 | 0.0486 | 0.0643 | -0.9598 | 0.0582 |
| b3 | 0.1769 | 0.0249 | 0.0404 | 0.0439 | 0.0420 |
| b4 | 0.0304 | 0.0038 | 0.0123 | -0.0324 | 0.0045 |
| b5 | -12.645 | -0.3934 | -0.1034 | -27.0520 | -1.5520 |
| b6 | 1.0019 | 0.1723 | 1.3664 | -0.2164 | -0.0950 |
| $R^2$ | 0.5672 | 0.8759 | 0.5121 | 0.4114 | 0.2725 |

b -Values for Ukwugba 1 without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 33.6105 | 5.1710 | 3.3449 | 13.1931 | 15.2328 |
| b1 | 2.0144 | 0.1274 | 0.1026 | 0.0161 | 0.5342 |
| b2 | -0.5718 | -0.0800 | -0.0420 | 0.6022 | -0.2413 |
| b3 | -0.1171 | -0.0260 | -0.0205 | 0.1840 | -0.0812 |
| b4 | 0.0221 | 0.0004 | 0.0025 | 0.0146 | 0.0006 |
| b5 | 16.0566 | -1.0153 | -0.9900 | 2.8185 | -3.7925 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.8007 | 0.3685 | 0.4181 | 0.3613 | 0.6288 |

b -Values for Ukwugba 1 with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -73.2818 | 3.7467 | -2.4297 | -1.4528 | 4.1446 |
| b1 | -0.9645 | 0.0734 | -0.2532 | -1.1421 | 0.3078 |
| b2 | 1.2588 | -0.0388 | 0.0648 | 0.6882 | -0.0256 |
| b3 | 0.4039 | -0.0228 | 0.0044 | 0.2534 | -0.0332 |
| b4 | 0.0148 | 0.0014 | 0.0043 | 0.0165 | 0.0025 |
| b5 | 5.5677 | -0.9255 | 0.7168 | 8.9459 | -2.3422 |
| b6 | 0.8767 | -0.5102 | 0.5535 | 0.1470 | -0.0082 |
| $R^2$ | 0.9329 | 0.6034 | 0.4747 | 0.4497 | 0.6625 |

b -Values for Ukwugba 2 without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -0.6269 | -1.9990 | 3.7767 | 34.1096 | 0.4747 |
| b1 | 0.3941 | -0.2019 | 0.4617 | -2.2356 | -2.1019 |
| b2 | 0.1777 | 0.0379 | -0.0126 | -0.1346 | -0.0394 |
| b3 | 0.0421 | 0.0137 | -0.0377 | 0.2760 | 0.0197 |
| b4 | 0.0375 | 0.0039 | -0.0015 | 0.0490 | 0.0330 |
| b5 | -34.5380 | 0.3766 | -3.1622 | -18.6590 | 2.9028 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.8789 | 0.2841 | 0.4859 | 0.6629 | 0.5325 |

Values for Ukwugba 2 with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -0.8667 | -2.0394 | 3.8358 | 16.5011 | 3.4255 |
| b1 | -0.0832 | -0.1933 | 0.4864 | -3.8306 | -1.9126 |
| b2 | 0.1407 | 0.0400 | -0.0129 | -0.1127 | -0.0669 |
| b3 | 0.0404 | 0.0140 | -0.0387 | 0.3308 | 0.0031 |
| b4 | 0.0393 | 0.0038 | -0.0021 | 0.0675 | 0.0318 |
| b5 | -33.0650 | 0.2517 | -3.1204 | -17.1190 | -0.7371 |
| b6 | 0.2573 | -0.0625 | 0.0705 | 0.2693 | -0.2558 |
| $R^2$ | 0.9273 | 0.2856 | 0.4882 | 0.6944 | 0.5698 |

b-Values for Opuoma without PDC (Dry Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 65.3637 | -3.4313 | 2.2517 | 75.1958 | 8.2113 |
| b1 | 2.4635 | -0.2453 | 0.1160 | 6.3390 | -0.0257 |
| b2 | -1.0489 | 0.0528 | -0.0264 | -0.6270 | -0.0955 |
| b3 | -0.2942 | 0.0257 | -0.0140 | -0.0566 | -0.0479 |
| b4 | 0.0016 | 0.0024 | -0.0003 | -0.0862 | -0.0017 |
| b5 | -20.9970 | 1.6562 | -0.6718 | -19.9751 | -0.2254 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7561 | 0.3879 | 0.4358 | 0.6067 | 0.5669 |

b-Values for Opuoma with PDC (Dry Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 55.2918 | 0.2092 | 2.3033 | 80.3644 | 8.8733 |
| b1 | 2.1719 | 0.1005 | 0.1367 | 7.1634 | 0.0400 |
| b2 | -0.9115 | 0.0176 | -0.0264 | -0.5314 | -0.0935 |
| b3 | -0.2628 | -0.0000 | -0.0158 | -0.0967 | -0.0690 |
| b4 | 0.0068 | -0.0024 | -0.0005 | -0.0943 | -0.0024 |
| b5 | -20.0530 | 0.0164 | -0.6915 | -19.367 | 0.0540 |
| b6 | 0.3239 | -0.5592 | 0.2070 | -0.1398 | 0.6705 |
| $R^2$ | 0.8010 | 0.4622 | 0.4711 | 0.6135 | 0.7490 |

## APPENDIX 2
## REGRESSION VALUES FOR WET SEASON
### Owerri

b - Values for Imsu Junction without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 41.1120 | -4.6272 | 0.3347 | 50.9003 | -3.2496 |
| b1 | 0.9278 | 0.0126 | -0.1370 | -5.7165 | 0.3532 |
| b2 | -0.5232 | 0.0868 | 0.0150 | 0.3865 | 0.0719 |
| b3 | -0.2232 | 0.0282 | 0.0027 | -0.1879 | 0.0129 |

| | | | | | |
|---|---|---|---|---|---|
| b4 | -0.0120 | -0.0043 | 0.0009 | -0.0167 | -0.0011 |
| b5 | 2.2883 | 3.6066 | -1.6849 | 18.9296 | -0.8302 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7220 | 0.5983 | 0.1172 | 0.8187 | 0.5187 |

b - Values for Imsu Junction with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 34.3211 | 0.5305 | 1.6898 | -18.6691 | -0.0002 |
| b1 | 2.2852 | 0.0537 | -0.0357 | -0.0776 | -0.0000 |
| b2 | -0.6253 | 0.0122 | -0.0176 | 2.0291 | 0.0001 |
| b3 | -0.1829 | -0.0013 | -0.0117 | 0.0860 | 0.0003 |
| b4 | -0.0067 | -0.0004 | 0.0017 | -0.0962 | 0.0005 |
| b5 | -0.6027 | -0.8064 | 0.8311 | 28.0529 | 0.0012 |
| b6 | 0.6114 | -0.5870 | 0.1400 | -0.0162 | 1.0030 |
| $R^2$ | 0.7920 | 0.6485 | 0.3370 | 0.3993 | 0.9010 |

b - Values for Emmanuel College without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 56.1215 | -0.0946 | 1.8912 | 36.0669 | 2.0967 |
| b1 | -1.8091 | 0.1212 | -0.0135 | 3.3801 | -0.4597 |
| b2 | -1.2176 | 0.0153 | -0.0086 | -0.8491 | -0.0171 |
| b3 | -0.1279 | 0.0033 | -0.0141 | 0.3583 | -0.0152 |
| b4 | 0.0143 | -0.0013 | 0.0055 | -0.1520 | 0.0058 |
| b5 | 17.5922 | -0.9294 | -2.9866 | 48.5940 | 1.8776 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.3072 | 0.2919 | 0.7867 | 0.3401 | 0.4128 |

b - Values for Emmanuel College without PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 56.0604 | 0.5142 | 0.9745 | 17.0466 | -7.4797 |
| b1 | -2.3113 | -0.0289 | -0.1877 | -1.5890 | 0.8950 |
| b2 | -1.8057 | -0.0075 | 0.0065 | 1.8052 | 0.2455 |
| b3 | 0.0174 | 0.0021 | -0.0126 | -0.2332 | 0.0075 |
| b4 | 0.0347 | -0.0043 | 0.0018 | -0.0561 | 0.0018 |
| b5 | 20.8868 | 2.1162 | 0.9523 | 41.2653 | -9.8503 |
| b6 | 0.5441 | 0.5509 | 0.5953 | -0.2672 | -0.5498 |
| $R^2$ | 0.6525 | 0.8357 | 0.5278 | 0.3675 | 0.9040 |

b - Values for World Bank without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 18.2711 | -5.5232 | -9.2872 | -68.3198 | -1.1860 |
| b1 | -1.5164 | -0.1542 | -0.0241 | 4.3436 | 0.3294 |
| b2 | -0.1914 | 0.1087 | 0.1182 | 1.8294 | -0.0198 |
| b3 | -0.0609 | 0.0306 | 0.0765 | 0.6067 | 0.0290 |
| b4 | 0.0249 | 0.0032 | 0.0009 | -0.0655 | -0.0036 |
| b5 | -14.229 | -0.4438 | -0.5109 | -32.6578 | -2.5168 |
| b6 | - | - | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| $R^2$ | 0.4452 | 0.6745 | 0.7086 | 0.8329 | 0.5666 |

b - Values for World Bank with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 19.6042 | 1.0049 | 0.0000 | 308.9130 | 4.1337 |
| b1 | -1.1490 | -0.0279 | -0.0000 | 13.5206 | -0.2913 |
| b2 | -0.1892 | -0.0015 | -0.0000 | -5.3268 | 0.0416 |
| b3 | -0.0791 | -0.0063 | -0.0000 | -1.3465 | -0.0531 |
| b4 | 0.0185 | -0.0007 | 0.0000 | -0.2187 | 0.0032 |
| b5 | -15.496 | 0.9560 | 0.0000 | -73.904 | -0.2254 |
| b6 | 0.0944 | 0.0501 | 1.0000 | 0.6831 | -0.8184 |
| $R^2$ | 0.4377 | 0.1495 | 1.0000 | 0.5832 | 0.7144 |

b -Values for Egbu-Uratta Road without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 8.9748 | 1.1784 | 0.2800 | -86.7418 | -6.7666 |
| b1 | 1.1027 | 0.2959 | 0.1190 | -21.6674 | -0.2470 |
| b2 | -0.1879 | -0.0184 | -0.0172 | 1.5746 | 0.1370 |
| b3 | 0.0263 | -0.0014 | 0.0063 | 0.6313 | 0.0272 |
| b4 | -0.0220 | -0.0055 | -0.0022 | 0.3353 | 0.0084 |
| b5 | -1.3970 | 0.0599 | 0.4205 | 53.1386 | 0.0446 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.1463 | 0.5529 | 0.5225 | 0.6791 | 0.5910 |

b -Values for Egbu-Uratta Road with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -7.6472 | -0.2769 | 1.6101 | -101.026 | 0.1793 |
| b1 | 1.0241 | -0.5834 | 0.1227 | -12.289 | 0.7055 |
| b2 | 0.1948 | 0.0274 | -0.0595 | 3.5813 | 0.0218 |
| b3 | 0.1116 | -0.0052 | 0.0065 | -0.1052 | 0.0001 |
| b4 | -0.0187 | 0.0073 | -0.0009 | 0.1123 | -0.0120 |
| b5 | 0.4853 | 1.1149 | -0.2238 | 183.8010 | 2.0550 |
| b6 | -0.7010 | -0.2410 | -0.6832 | 0.2750 | -0.3110 |
| $R^2$ | 0.3402 | 0.6871 | 0.6824 | 0.7649 | 0.5062 |

## OKIGWE

b - Values for Umuna without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |

| | | | | | |
|---|---|---|---|---|---|
| b | 20.0510 | 6.2922 | -4.5250 | 86.4207 | 6.2548 |
| b1 | 1.9506 | 0.1086 | -0.2991 | 9.9978 | -0.4760 |
| b2 | -0.2078 | -0.0892 | 0.1028 | 0.0065 | -0.1339 |
| b3 | -0.0743 | -0.0355 | 0.0208 | -0.4467 | -0.0198 |
| b4 | 0.0108 | -0.0031 | 0.0071 | -0.1828 | -0.0002 |
| b5 | -34.3848 | 1.7731 | -2.5620 | -7.7526 | 5.6472 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5152 | 0.4373 | 0.7173 | 0.2566 | 0.4791 |

b - Values for Umuna with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 7.8420 | -2.9083 | 3.6456 | 74.1700 | 0.0000 |
| b1 | 2.4361 | 0.3557 | 0.1608 | 2.6839 | 0.0000 |
| b2 | 0.1478 | 0.1204 | -0.1158 | 2.4848 | 0.1990 |
| b3 | -0.0173 | 0.0040 | 0.0006 | -0.8830 | -0.0710 |
| b4 | 0.0042 | -0.0057 | -0.0021 | -0.1698 | 0.0050 |
| b5 | -43.805 | -2.6143 | 1.6809 | 59.9629 | 0.0000 |
| b6 | -0.3602 | -0.5441 | -0.0119 | -0.5595 | 0.0000 |
| $R^2$ | 0.7745 | 0.8210 | 0.6996 | 0.4249 | 1.0000 |

b - Values for Okigwe Express without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -54.6017 | -3.4149 | 11.1499 | -142.0599 | 5.1241 |
| b1 | 0.4077 | 0.0333 | -0.5832 | 1.8436 | 0.2947 |
| b2 | 1.0268 | 0.0336 | -0.1627 | 4.0378 | -0.0019 |
| b3 | 0.3379 | 0.0414 | -0.0626 | 0.6908 | -0.0613 |
| b4 | -0.0185 | -0.0084 | 0.0078 | -0.1109 | 0.0191 |
| b5 | 30.5317 | 3.3750 | 0.7898 | 57.5223 | -14.3649 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.6940 | 0.5485 | 0.7379 | 0.4730 | 0.5302 |

b - Values for Okigwe Express with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -53.1915 | 2.5019 | 7.0577 | 324.8010 | -5.0349 |
| b1 | -1.6978 | -0.6854 | 0.5336 | -7.0743 | 0.2571 |
| b2 | 0.8310 | -0.1109 | -0.1090 | -4.5297 | 0.1424 |
| b3 | 0.3681 | 0.0243 | -0.0360 | -1.7091 | 0.0243 |
| b4 | -0.0109 | -0.0089 | -0.0030 | 0.1702 | -0.0077 |
| b5 | 52.2357 | 13.3714 | -3.9657 | -62.851 | -0.9353 |
| b6 | 0.1427 | -0.3365 | -0.0018 | 0.3360 | 0.0301 |
| $R^2$ | 0.5925 | 0.5950 | 0.4997 | 0.8576 | 0.5307 |

b -Values for St Mary's Junction Okigwe without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |

| | | | | | |
|---|---|---|---|---|---|
| b | 69.8682 | -10.7086 | -1.0849 | -85.5587 | 0.5579 |
| b1 | 12.0898 | -0.4178 | -0.1703 | -5.0893 | -0.0878 |
| b2 | -8.2927 | 0.0091 | 0.5030 | -5.9394 | 0.1496 |
| b3 | -1.2028 | 0.2667 | -0.0138 | 3.7482 | -0.0136 |
| b4 | -0.3348 | 0.0337 | 0.0268 | 0.1140 | 0.0038 |
| b5 | 0.1470 | 0.0002 | -0.0087 | 0.0730 | -0.0022 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7577 | 0.7028 | 0.7447 | 0.2755 | 0.0075 |

b -Values for St Mary's Junction Okigwe with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 71.4712 | -5.1348 | 2.2499 | 374.0240 | 0.0000 |
| b1 | 10.2163 | 1.7841 | 1.7401 | 96.2324 | 10.2615 |
| b2 | -9.6628 | -0.5590 | -0.2404 | -29.008 | -0.9545 |
| b3 | -0.8922 | 0.1453 | -0.0255 | -4.2130 | -0.1082 |
| b4 | -0.4203 | 0.0056 | -0.0127 | -2.4056 | 0.0240 |
| b5 | 0.1490 | 0.0119 | 0.0027 | 0.3488 | 0.0106 |
| b6 | -0.1906 | -0.5137 | -0.3268 | 0.0014 | 1.1418 |
| $R^2$ | 0.7802 | 0.8365 | 0.3358 | 0.6873 | 1.0000 |

b -Values for Ihube without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 41.3133 | -9.2454 | -1.8865 | -64.2475 | -17.9855 |
| b1 | -2.4748 | 0.0577 | 0.0325 | 3.6359 | -0.2915 |
| b2 | -0.9236 | 0.2065 | -0.0394 | 2.4539 | 0.3430 |
| b3 | -0.0669 | 0.0398 | 0.0347 | 0.3876 | 0.0880 |
| b4 | 0.0547 | -0.0042 | 0.0131 | -0.1081 | 0.0048 |
| b5 | -13.624 | 0.7573 | 0.0000 | -43.8158 | -0.4580 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5614 | 0.6454 | 0.3168 | 0.3549 | 0.6280 |

b -Values for Ihube with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 33.6655 | -4.8651 | 1.8602 | -648.1230 | -37.3612 |
| b1 | -2.6538 | -0.3753 | -0.1276 | -18.7280 | -1.6779 |
| b2 | -0.7808 | 0.0857 | -0.0403 | 14.1980 | 0.5097 |
| b3 | -0.0409 | 0.0256 | -0.0038 | 3.0884 | 0.2529 |
| b4 | 0.0551 | 0.0008 | -0.0006 | 0.1687 | 0.0375 |
| b5 | -10.708 | 5.5252 | 1.7759 | 61.8452 | -4.2480 |
| b6 | 0.1259 | -0.2407 | -0.2131 | -0.9660 | 0.1943 |
| $R^2$ | 0.4313 | 0.7108 | 0.6867 | 0.6653 | 1.0000 |

b - Values for Umuaka Junction without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 1.9989 | 0.0587 | 0.5988 | 12.9235 | -1.3557 |
| b1 | 3.3266 | 0.1459 | -0.2297 | -13.0327 | 0.1203 |
| b2 | -0.0351 | 0.0122 | 0.0118 | 2.0566 | 0.0416 |
| b3 | 0.0632 | 0.0007 | -0.0053 | -0.5279 | 0.0020 |
| b4 | -0.0367 | -0.0014 | 0.0028 | 0.2320 | 0.0005 |
| b5 | -6.9468 | -0.4852 | 0.0567 | -12.8262 | -0.6534 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.2221 | 0.3365 | 0.1601 | 0.4775 | 0.6475 |

b - Values for Umuaka Junction with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 33.1497 | 5.0506 | 5.3688 | 14.5484 | -2.4604 |
| b1 | 4.8075 | 0.1932 | 0.1657 | -7.7121 | -0.4261 |
| b2 | -1.0561 | -0.0800 | -0.0850 | 0.7622 | 0.0951 |
| b3 | 0.0825 | -0.0155 | -0.0262 | -0.0219 | -0.0007 |
| b4 | -0.0594 | -0.0029 | -0.0028 | 0.1089 | 0.0042 |
| b5 | -8.8460 | -0.9487 | -0.0703 | 2.3918 | 0.8337 |
| b6 | 0.1051 | -1.0118 | -0.0212 | 0.1595 | 0.4094 |
| $R^2$ | 0.3994 | 0.4200 | 0.3303 | 0.1822 | 0.4823 |

b -Values for Banana Junction without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -13.7752 | -0.8104 | -2.8360 | -42.4362 | -2.7581 |
| b1 | -9.8761 | -0.5098 | 1.7656 | 53.2904 | 2.6303 |
| b2 | 0.5156 | 0.0472 | 0.0129 | 1.4118 | -0.0211 |
| b3 | 0.0256 | -0.0005 | 0.0441 | 0.6711 | 0.0530 |
| b4 | 0.1132 | 0.0046 | -0.0251 | -0.7193 | -0.0362 |
| b5 | 45.4310 | 1.3140 | -5.3999 | -213.3850 | -6.3368 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.1741 | 0.6950 | 0.3863 | 0.5308 | 0.7490 |

b -Values for Banana Junction with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -22.9440 | 0.5241 | 12.4844 | 179.9240 | 18.9651 |
| b1 | -9.3247 | -0.2109 | 1.3360 | -0.4088 | 1.7056 |
| b2 | 0.7914 | -0.0062 | -0.1886 | -3.3899 | -0.3922 |
| b3 | 0.0308 | 0.0021 | -0.0680 | -0.2549 | -0.0614 |
| b4 | 0.0996 | 0.0038 | -0.0105 | 0.1464 | -0.0116 |
| b5 | 49.6467 | 0.0214 | -7.6500 | -170.510 | -13.4010 |
| b6 | 0.0013 | -0.0271 | 0.0793 | 0.0803 | 0.0921 |
| $R^2$ | 0.1943 | 0.2999 | 0.8933 | 0.3710 | 0.6723 |

b -Values for Umuna Junction without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -10.0569 | -0.3206 | 0.4812 | 108.7637 | -1.2073 |
| b1 | 2.8815 | 0.2202 | 0.3056 | 12.4170 | 0.7210 |
| b2 | 0.7418 | 0.0289 | 0.0101 | -2.6777 | 0.0423 |
| b3 | -0.0835 | -0.0050 | -0.0065 | 0.0985 | 0.0004 |
| b4 | -0.0612 | -0.0062 | -0.0029 | 0.1750 | -0.0050 |
| b5 | 5.0948 | 3.2913 | 0.4399 | -187.2910 | -2.8621 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.7144 | 0.7953 | 0.5620 | 0.6704 | 0.4341 |

b -Values for Umuna Junction with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 1.2477 | 1.8566 | 3.0700 | 84.0667 | -6.7620 |
| b1 | 3.6185 | 0.0419 | 0.0339 | -1.7333 | -0.6507 |
| b2 | 0.4238 | -0.0203 | -0.0444 | -2.0594 | 0.1493 |
| b3 | -0.0985 | -0.0049 | -0.0094 | -0.0863 | 0.0293 |
| b4 | -0.0714 | -0.0016 | -0.0024 | -0.0534 | 0.0057 |
| b5 | -3.4430 | -1.2177 | -1.4946 | 113.7580 | 6.6976 |
| b6 | 0.1331 | 0.1084 | 0.1673 | 0.6095 | 0.1105 |
| $R^2$ | 0.7085 | 0.7482 | 0.7883 | 0.5727 | 0.7605 |

b -Values for Umuago Urualla without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 11.9625 | -1.3445 | -1.7397 | -43.9471 | -0.0189 |
| b1 | -9.7989 | -0.0343 | -1.4387 | -19.4383 | -0.9001 |
| b2 | 0.7168 | 0.3223 | 0.1915 | 15.0368 | -0.1527 |
| b3 | -0.0622 | 0.0209 | 0.0349 | 1.5973 | 0.0061 |
| b4 | -0.0810 | 0.0193 | 0.0248 | 0.3821 | 0.0091 |
| b5 | 0.0102 | -0.0087 | -0.0083 | -0.2378 | -0.0006 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.5137 | 0.8198 | 0.5747 | 0.4804 | 0.6115 |

b -Values for Umuago Urualla with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 0.4901 | 0.3773 | 2.4352 | 114.8840 | 2.8454 |
| b1 | -9.1658 | -1.0442 | -0.2823 | -91.5370 | 2.3270 |
| b2 | 0.5999 | 0.1367 | -0.0564 | 5.5352 | -0.2090 |
| b3 | 0.1530 | -0.0060 | -0.0365 | -1.6551 | -0.0206 |
| b4 | -0.0377 | 0.0030 | -0.0132 | -0.2762 | -0.0149 |
| b5 | 0.0134 | -0.0031 | 0.0017 | -0.1208 | 0.0014 |
| b6 | 0.1591 | 0.4520 | -0.2614 | 0.3790 | -0.3737 |
| $R^2$ | 0.4810 | 0.7505 | 0.8876 | 0.8979 | 0.6599 |

## EGBEMA

b -Values for Umuorji without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -14.0675 | 0.6476 | 0.3571 | -48.0017 | -0.3655 |
| b1 | -0.1769 | 0.2829 | -0.1357 | -20.3372 | -0.2944 |
| b2 | 0.2821 | -0.0017 | -0.0157 | 0.9169 | -0.0006 |
| b3 | 0.1199 | -0.0041 | -0.0026 | 0.4524 | 0.0152 |
| b4 | 0.0138 | -0.0015 | 0.0106 | 0.4787 | 0.0051 |
| b5 | 5.5447 | -0.3055 | -0.9686 | -38.2902 | -0.5711 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.6424 | 0.6395 | 0.6140 | 0.2123 | 0.3523 |

b -Values for Umuorji with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -4.2466 | -5.0788 | -0.7177 | 7.3369 | -2.4546 |
| b1 | 2.8704 | -0.2823 | -0.2099 | -8.7023 | 0.3455 |
| b2 | 0.0239 | 0.0770 | -0.0189 | 0.2990 | 0.0249 |
| b3 | 0.0650 | 0.0329 | 0.0137 | 0.3584 | 0.0327 |
| b4 | -0.0652 | 0.0056 | 0.0097 | 0.2746 | -0.0049 |
| b5 | 16.3655 | -0.0166 | -0.5070 | -24.666 | 0.6491 |
| b6 | 0.7488 | 0.5915 | 0.0400 | -0.3045 | 0.1832 |
| $R^2$ | 0.9625 | 0.5431 | 0.6997 | 0.9091 | 0.3548 |

b -Values for Ukwugba 1 without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 34.1897 | -1.4708 | -3.7611 | -22.1878 | -2.5014 |
| b1 | 0.1708 | -0.3522 | -0.2064 | 13.5291 | -0.4826 |
| b2 | -0.5218 | 0.0379 | 0.0722 | 0.6142 | 0.0286 |
| b3 | -0.1123 | 0.0106 | 0.0228 | 0.5354 | 0.0285 |
| b4 | -0.0140 | 0.0054 | 0.0049 | -0.1694 | 0.0088 |
| b5 | -6.5835 | -0.2242 | -0.1036 | -39.7073 | -0.7806 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.3469 | 0.4621 | 0.4004 | 0.6562 | 0.6635 |

b -Values for Ukwugba 1 with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 25.9793 | -0.1622 | -4.2144 | 70.0194 | -1.9502 |
| b1 | -0.9392 | 0.0072 | 0.0300 | 3.1894 | -0.2909 |
| b2 | -0.3300 | 0.0083 | 0.0910 | -0.3281 | 0.0706 |
| b3 | -0.0763 | 0.0067 | 0.0203 | 0.0651 | 0.0176 |
| b4 | 0.0048 | -0.0017 | 0.0021 | -0.0490 | 0.0044 |
| b5 | -2.8383 | -0.0845 | 0.0190 | 2.3284 | -0.9749 |

| | | | | | |
|---|---|---|---|---|---|
| b6 | -0.3515 | 0.2499 | 0.0422 | -0.2869 | -0.3201 |
| $R^2$ | 0.3947 | 0.6121 | 0.2585 | 0.6233 | 0.3465 |

b -Values for Ukwugba 2 without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 29.3819 | -1.9750 | -0.4983 | 10.2464 | 0.6380 |
| b1 | -0.3276 | 0.4155 | 0.2680 | 10.0533 | 0.0551 |
| b2 | -0.3497 | 0.0394 | 0.0264 | -0.2943 | -0.0104 |
| b3 | -0.1396 | 0.0226 | 0.0034 | 0.5716 | 0.0071 |
| b4 | 0.0026 | -0.0060 | -0.0020 | -0.1012 | 0.0013 |
| b5 | 0.5634 | -3.3324 | -1.5449 | -118.1550 | -1.9094 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.0713 | 0.5280 | 0.2026 | 0.5131 | 0.1205 |

b -Values for Ukwugba 2 with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | -47.5771 | 1.8806 | -5.8616 | 191.5710 | -15.6561 |
| b1 | -5.9232 | 0.2866 | -0.0069 | 6.9293 | 3.5646 |
| b2 | 1.0308 | 0.0009 | 0.1210 | -1.9312 | 0.2124 |
| b3 | 0.1719 | -0.0081 | 0.0316 | -0.5252 | 0.1827 |
| b4 | 0.0781 | -0.0023 | 0.0039 | -0.0766 | -0.0422 |
| b5 | -6.9456 | -4.5402 | -4.1378 | -16.8890 | -35.813 |
| b6 | 1.2791 | -0.5035 | 0.3082 | -0.7686 | -0.0864 |
| $R^2$ | 0.3687 | 0.4652 | 0.4407 | 0.3919 | 0.8661 |

b -Values for Opuoma without PDC (Wet Season)

| b-VALUES | Without PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 23.1180 | -1.0254 | -0.2885 | -55.6764 | 9.4330 |
| b1 | -0.0258 | 0.1963 | 0.3599 | -0.7911 | 0.1458 |
| b2 | -0.2112 | 0.0354 | 0.0323 | 2.8528 | -0.1264 |
| b3 | -0.0714 | 0.0072 | -0.0029 | 0.1189 | -0.0573 |
| b4 | -0.0253 | -0.0030 | -0.0034 | -0.1790 | 0.0049 |
| b5 | -2.9822 | -0.9626 | -2.0823 | 69.3526 | -4.2093 |
| b6 | - | - | - | - | - |
| $R^2$ | 0.4730 | 0.6054 | 0.2906 | 0.7168 | 0.5122 |

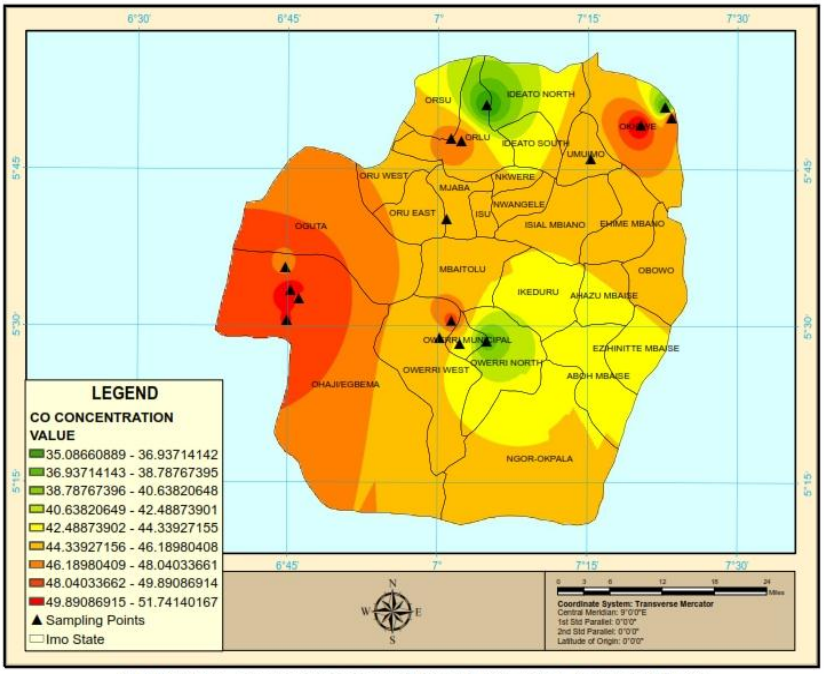
b -Values for Opuoma with PDC (Wet Season)

| b-VALUES | With PDC | | | | |
|---|---|---|---|---|---|
| | $PM_{10}$ | $NO_2$ | $SO_2$ | CO | VOC |
| b | 39.4301 | -3.5694 | 1.8960 | 11.0852 | 8.2082 |
| b1 | -1.4388 | 0.0107 | 0.3310 | -21.446 | -0.9502 |
| b2 | -0.4073 | 0.0409 | -0.0198 | -0.7858 | -0.1015 |
| b3 | -0.1846 | 0.0281 | -0.0080 | 0.3860 | -0.0439 |
| b4 | -0.0096 | 0.0015 | -0.0021 | 0.2872 | 0.0099 |
| b5 | -0.1901 | 0.5508 | -3.4628 | 112.6470 | 6.4224 |
| b6 | -0.0692 | 0.1207 | 0.0656 | 0.2410 | -0.8735 |

| | | | | | |
|---|---|---|---|---|---|
| $R^2$ | 0.5729 | 0.5410 | 0.3529 | 0.8122 | 0.4762 |

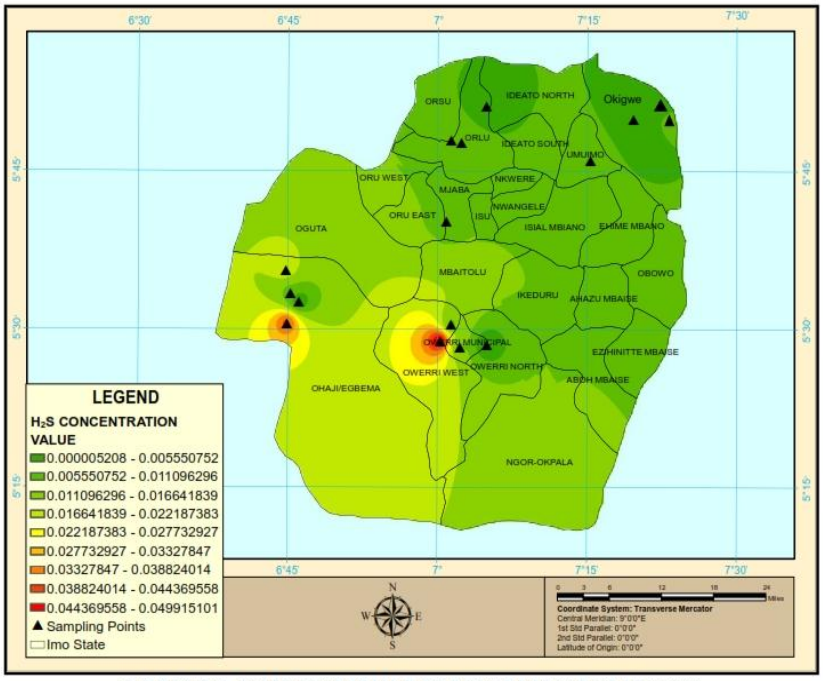
## APPENDIX 3

## PRESENTATION OF SPATIAL DISTRIBUTION MAPS OF DRY SEASON RESULTS OF AIR POLLUTANT CONCENTRATION



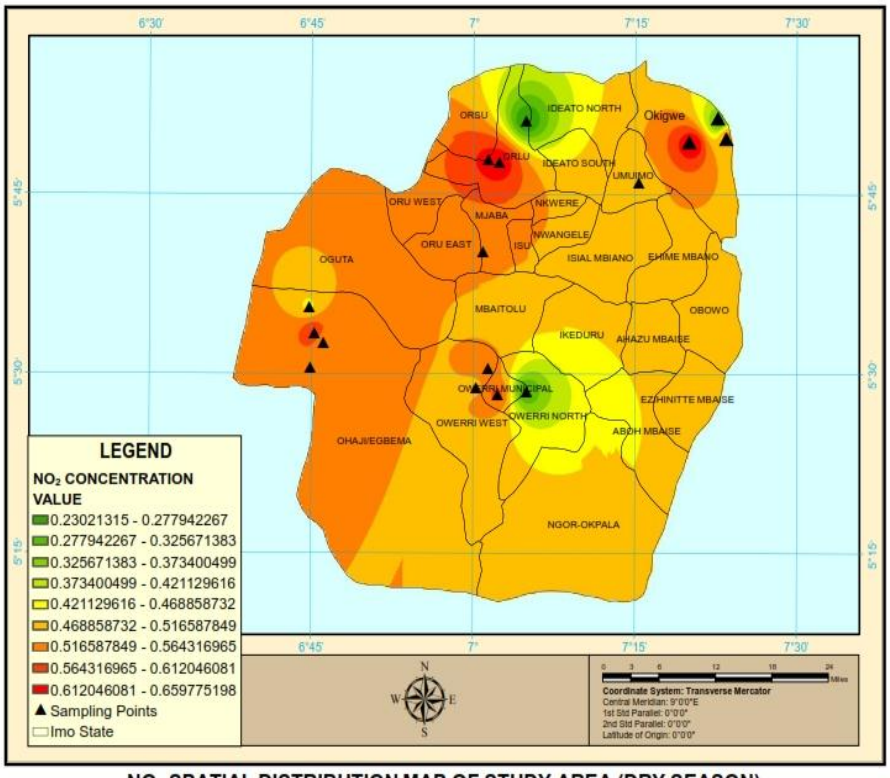

CO SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)

Spatial distribution map of CO in dry season



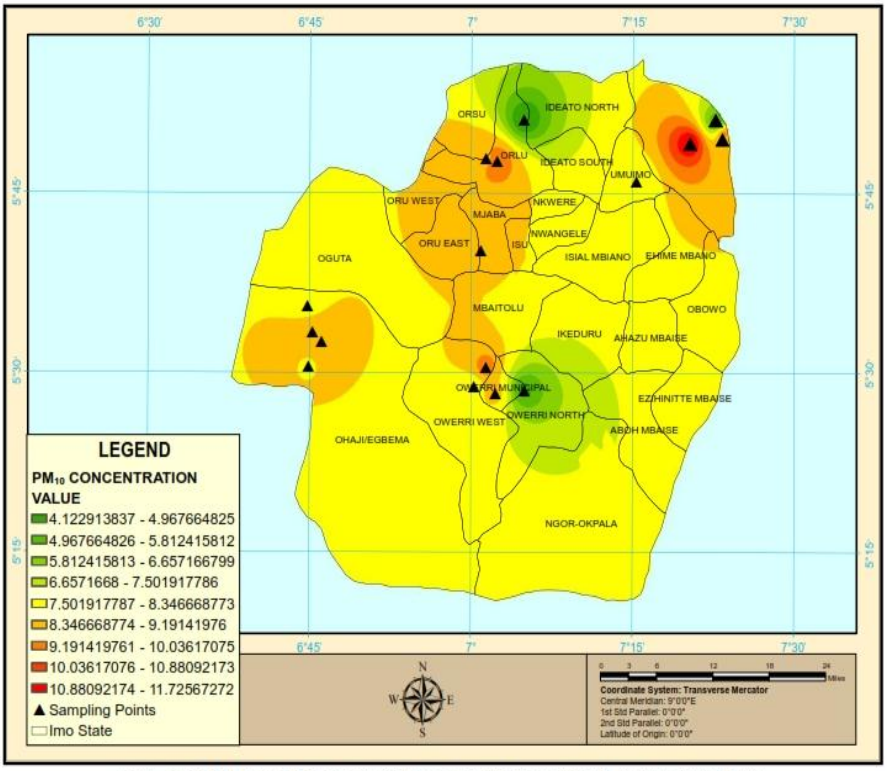

**$H_2S$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Spatial distribution map of $H_2S$ in dry season



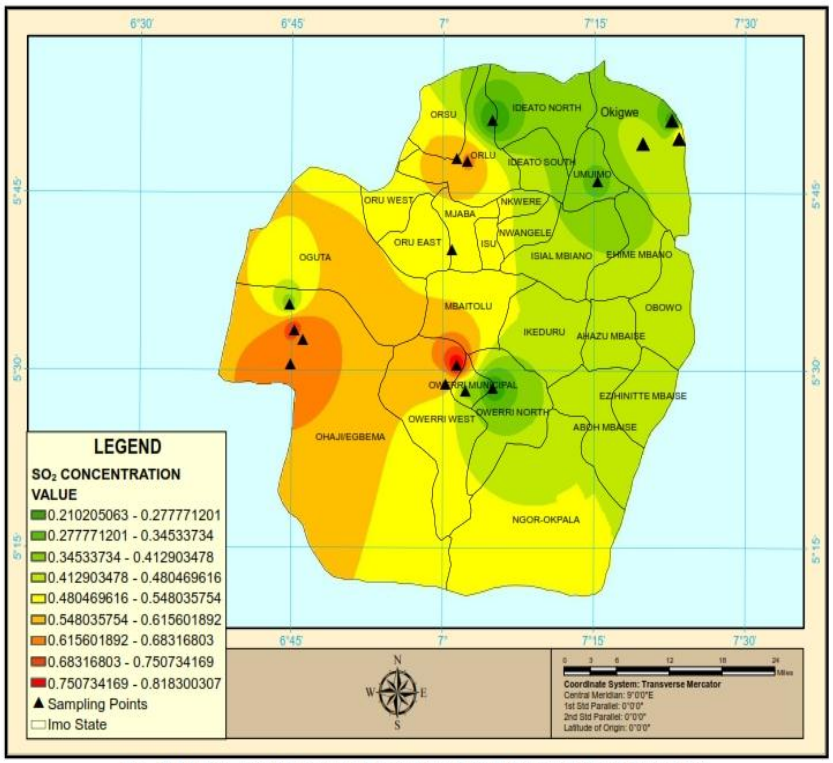

**$NO_2$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Spatial distribution map of $NO_2$ in dry season



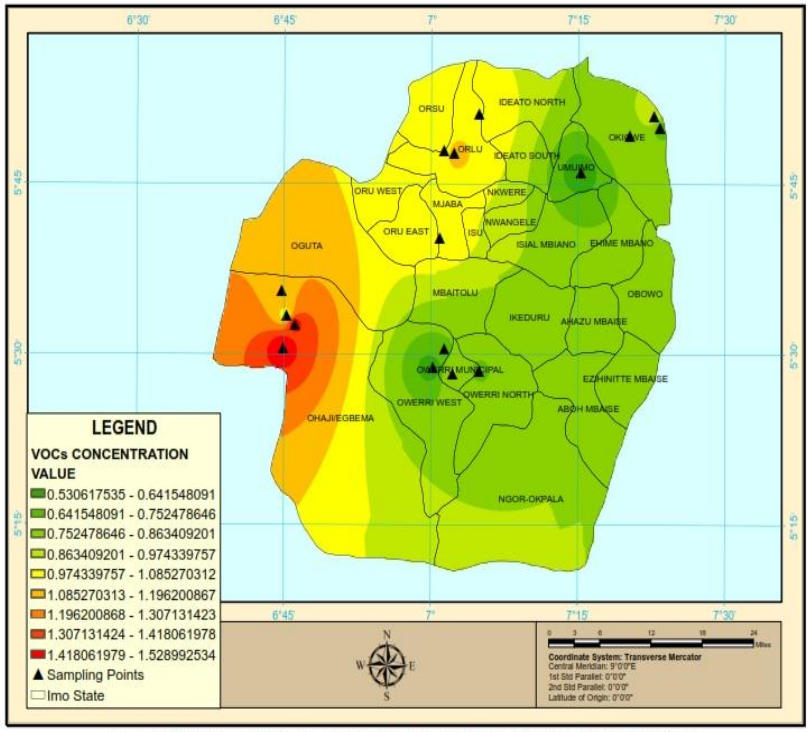

**$PM_{10}$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Spatial distribution map of $PM_{10}$ in dry season




**$SO_2$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)**

Spatial distribution map of $SO_2$ in dry season

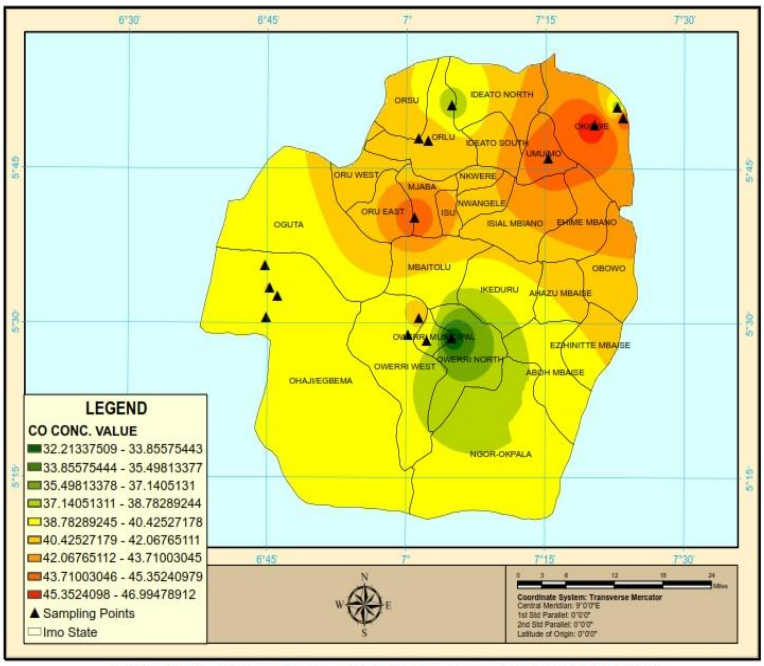


VOC SPATIAL DISTRIBUTION MAP OF STUDY AREA (DRY SEASON)

Spatial distribution map of VOC in dry season

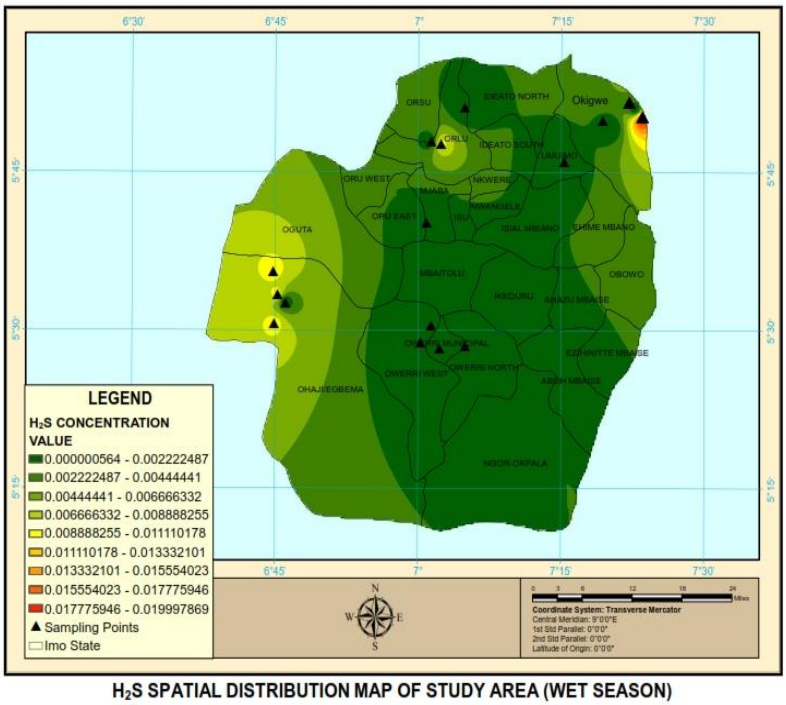
## APPENDIX 4

## Presentation of Spatial Distribution Maps of Wet Season Results of Air Pollutant Concentration



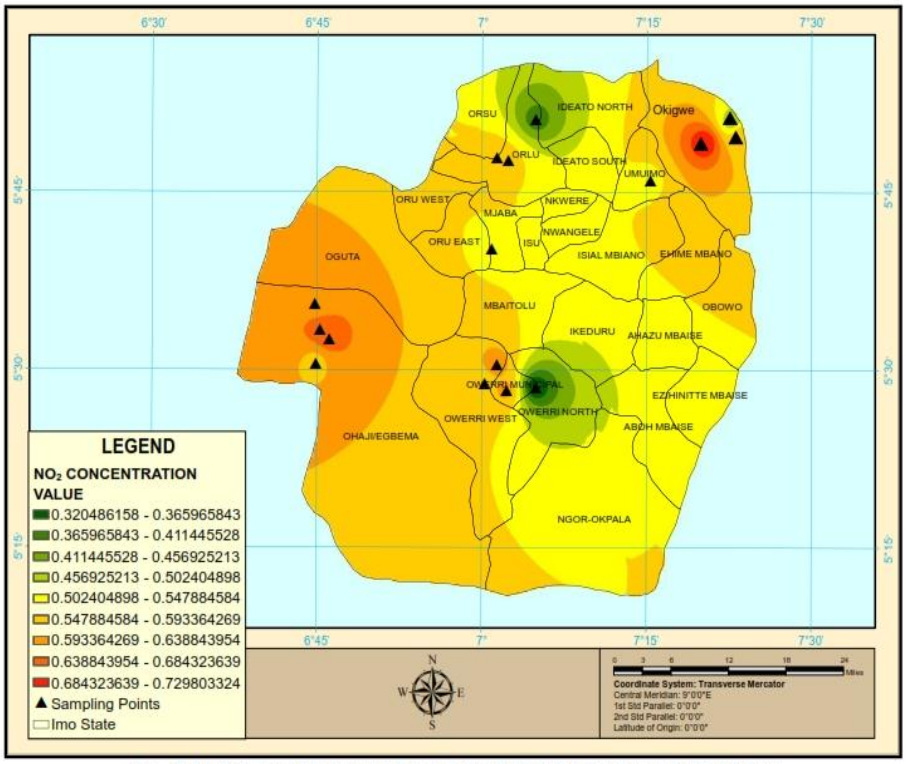

CO SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)

Spatial distribution map of CO in wet season



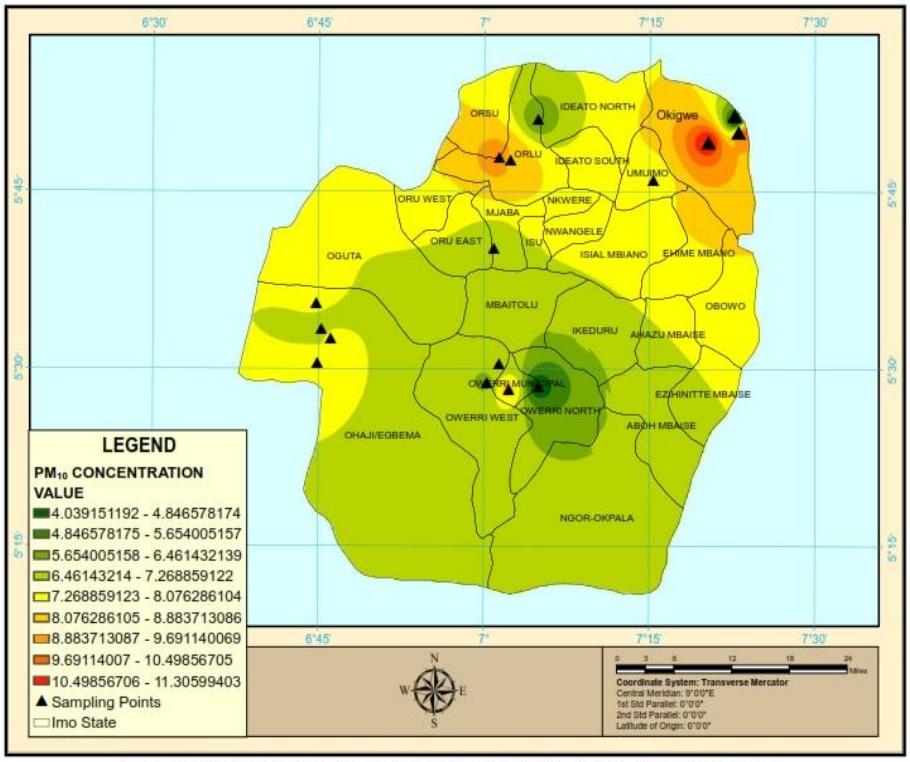

$H_2S$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)

Spatial distribution map of $H_2S$ in wet season



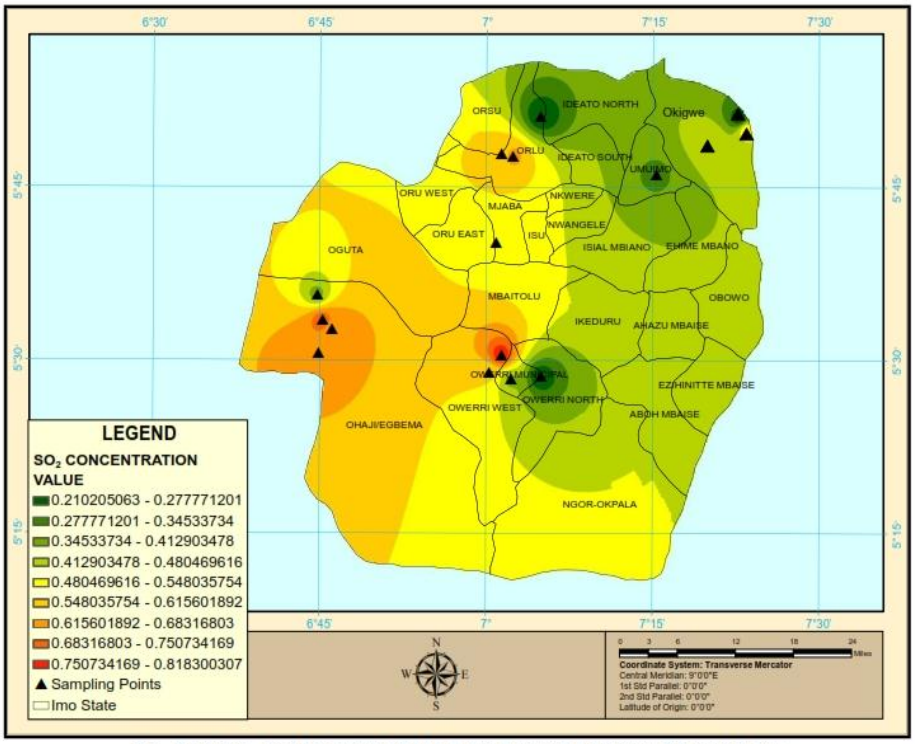

**$NO_2$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)**

Spatial distribution map of $NO_2$ in wet season



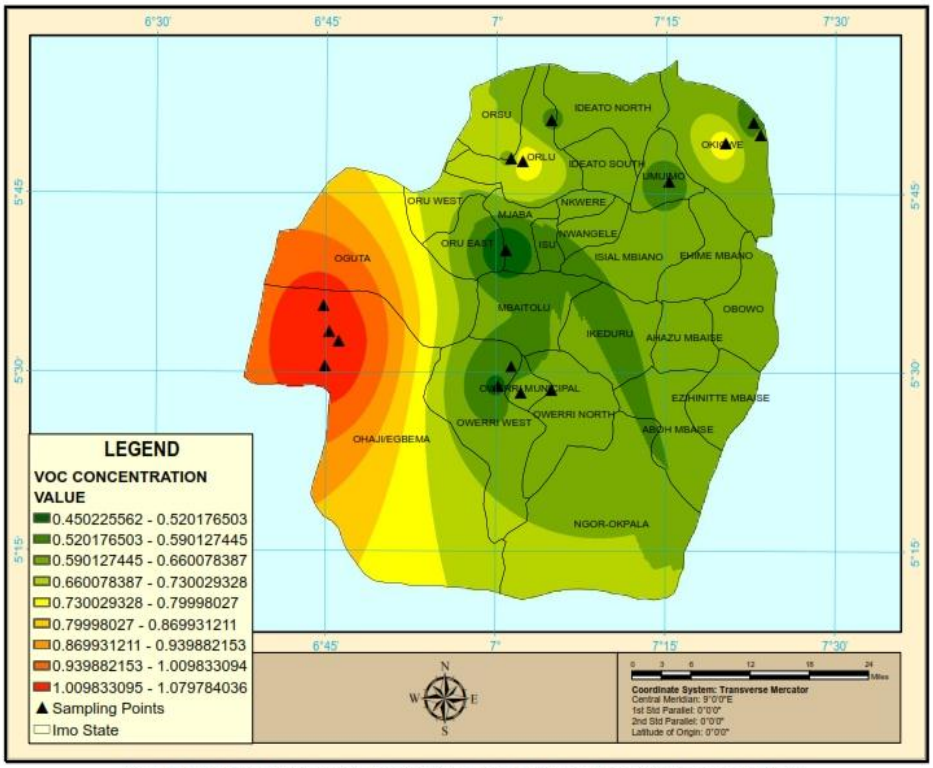

**$PM_{10}$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)**

Spatial distribution map of $PM_{10}$ in wet season




**$SO_2$ SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)**

Spatial distribution map of $SO_2$ in wet season

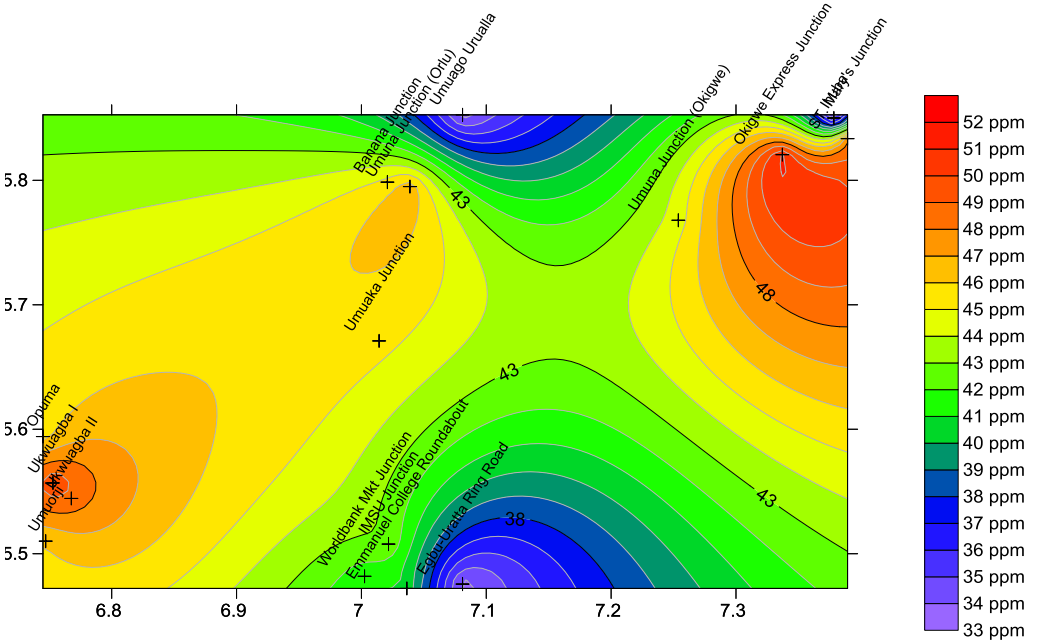



VOC SPATIAL DISTRIBUTION MAP OF STUDY AREA (WET SEASON)

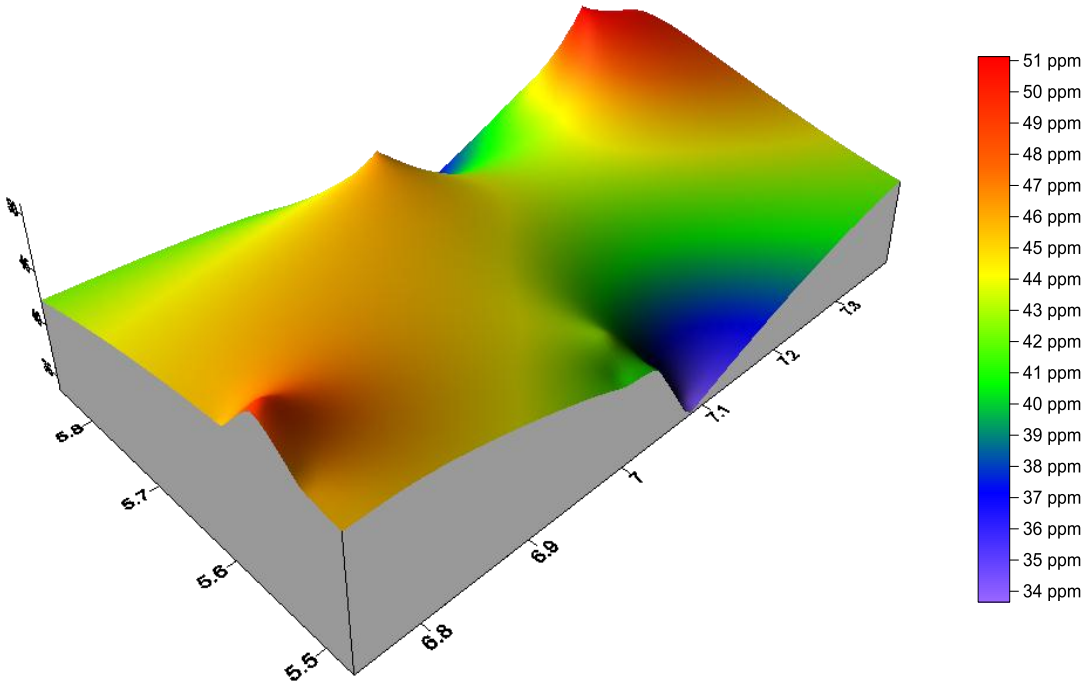
Spatial distribution map of VOC in wet season

## APPENDIX 5

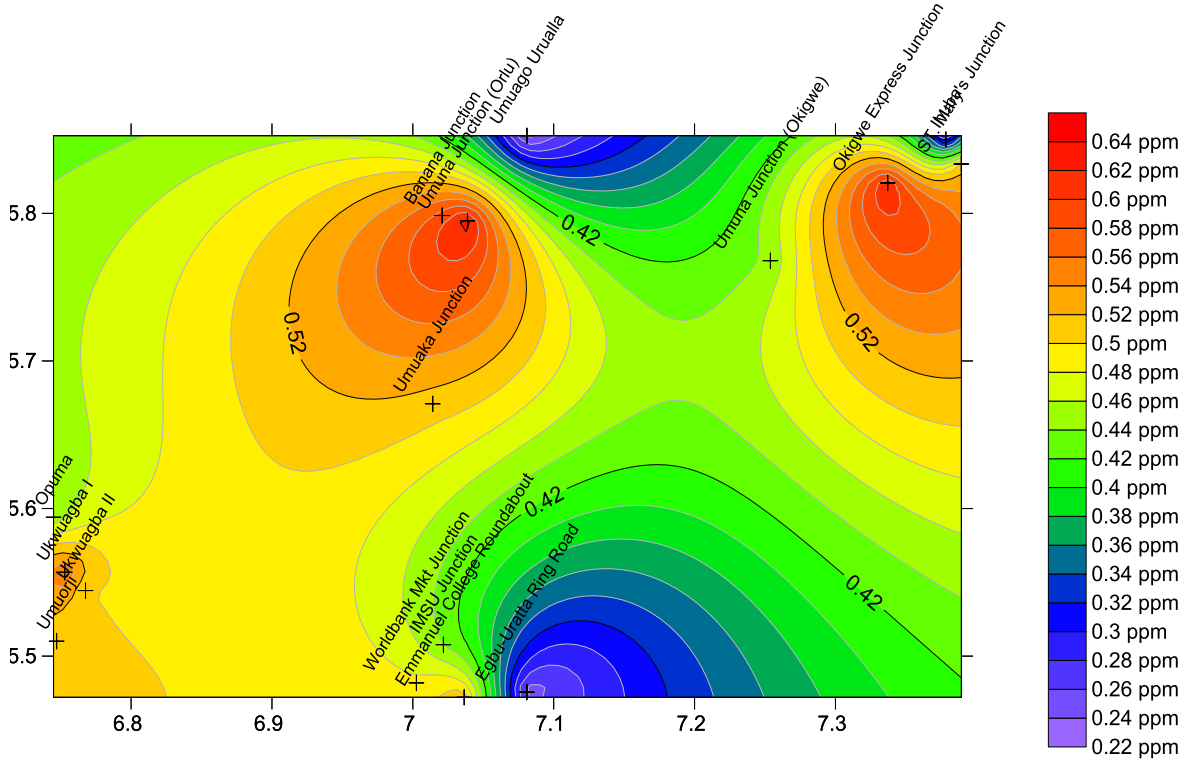
## Presentation of Dry Season Contour and 3-D Surface Plots of Air Pollutants Concentration



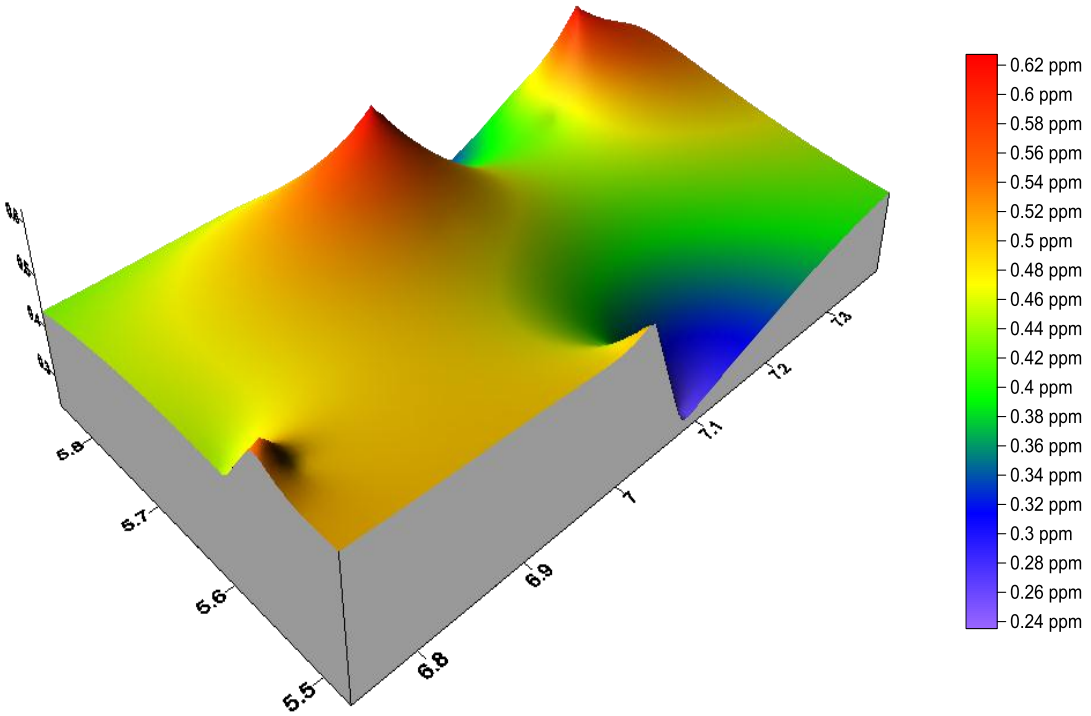
Dry season contour plot CO



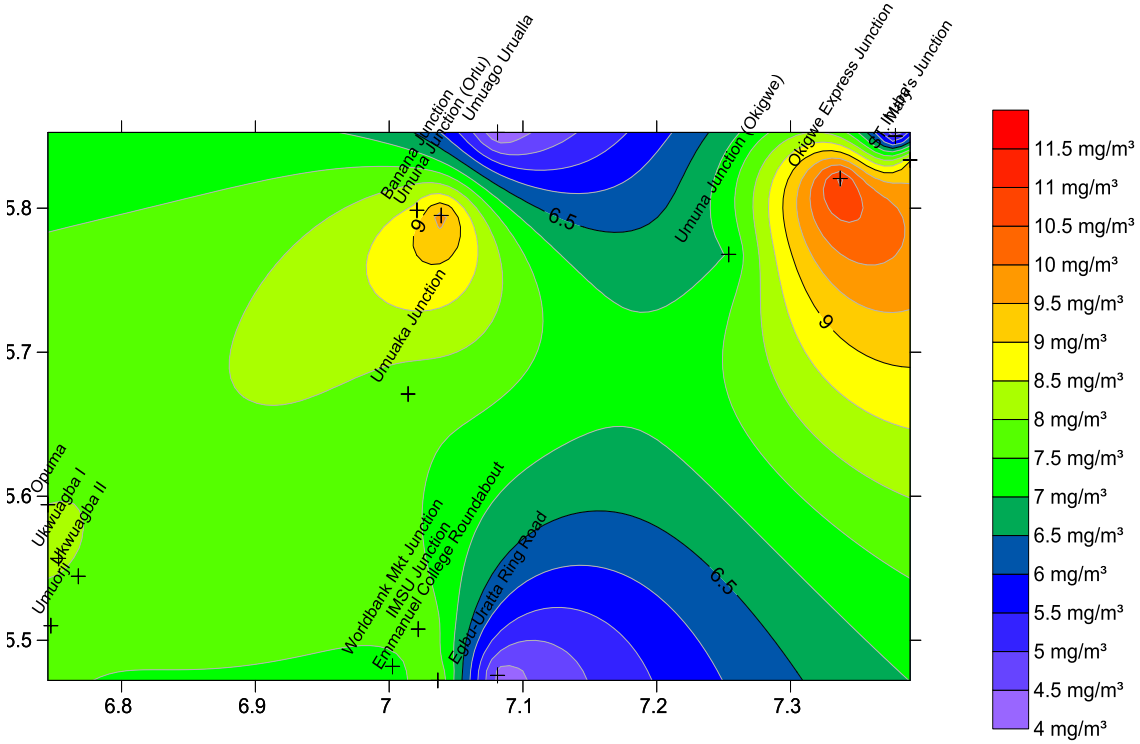

Dry season 3 - D surface plot of CO



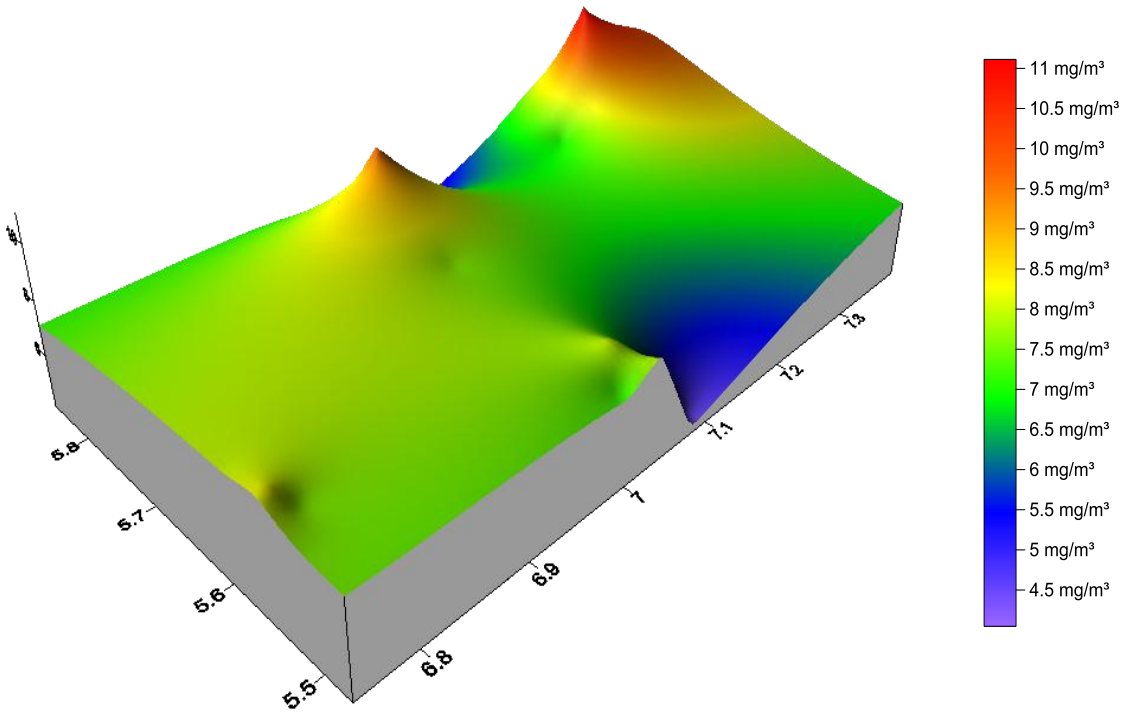

Dry season contour of plot of $NO_2$



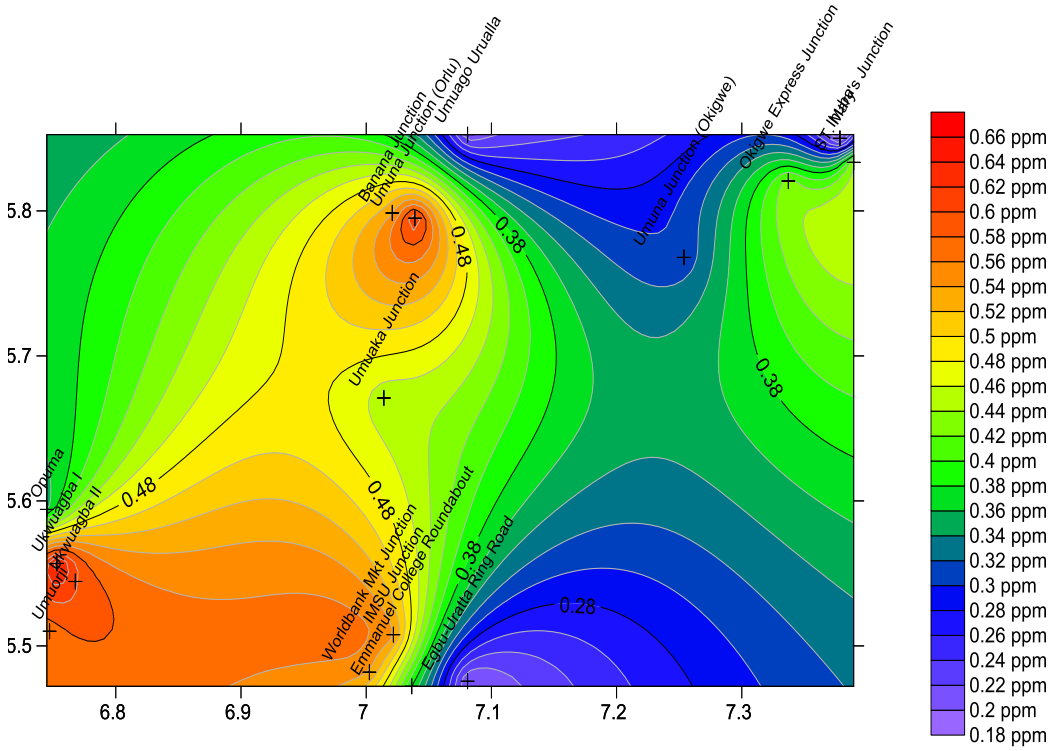

Dry season 3 - D surface plot of $NO_2$



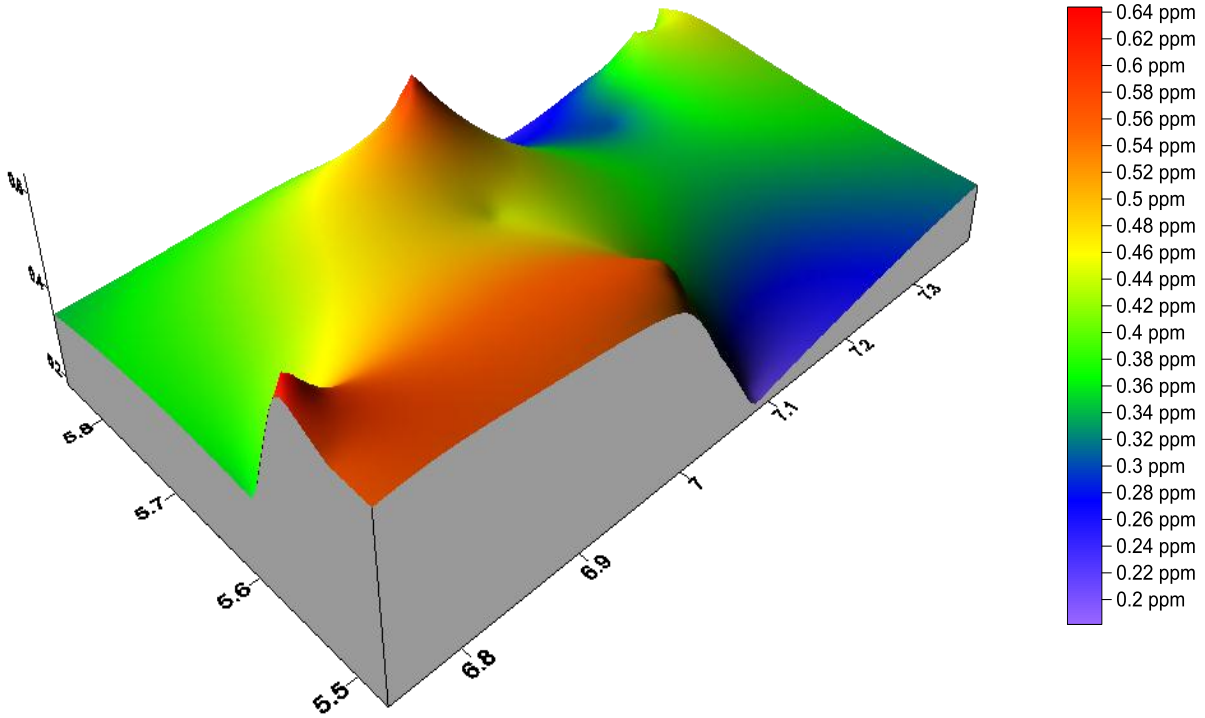

Dry season contour plot of $PM_{10}$



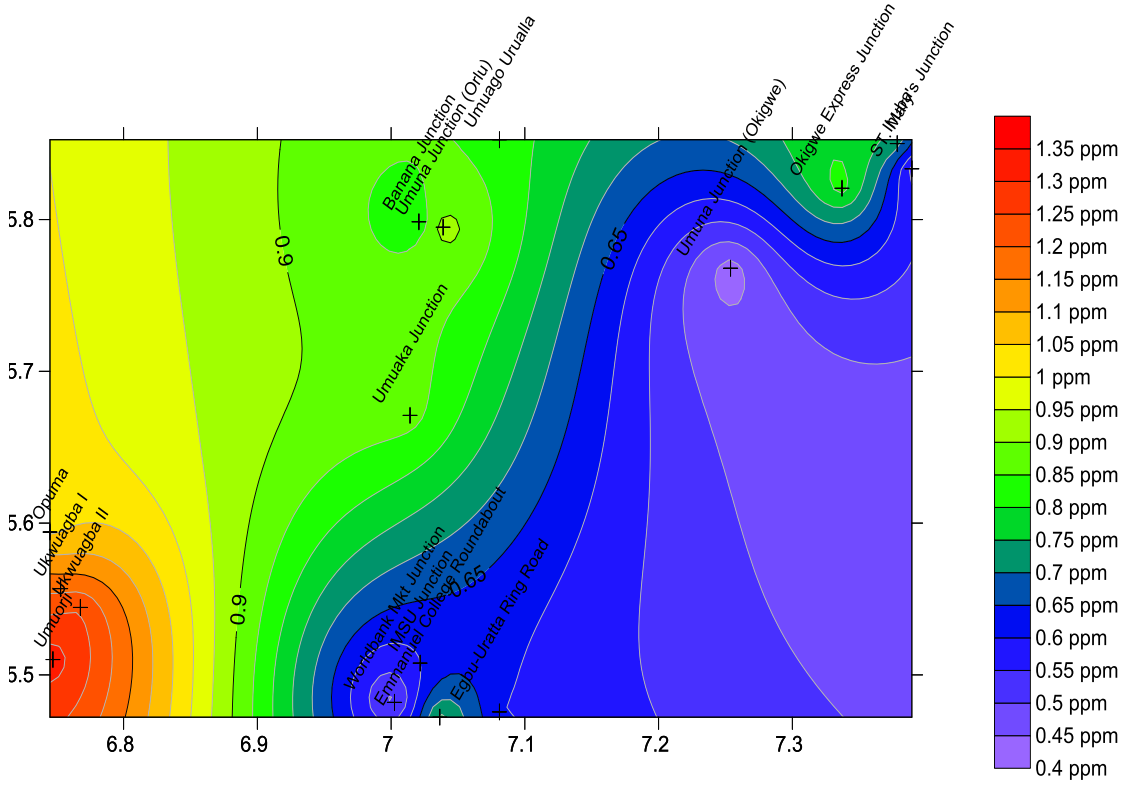

Dry season 3 – D surface plot of $PM_{10}$



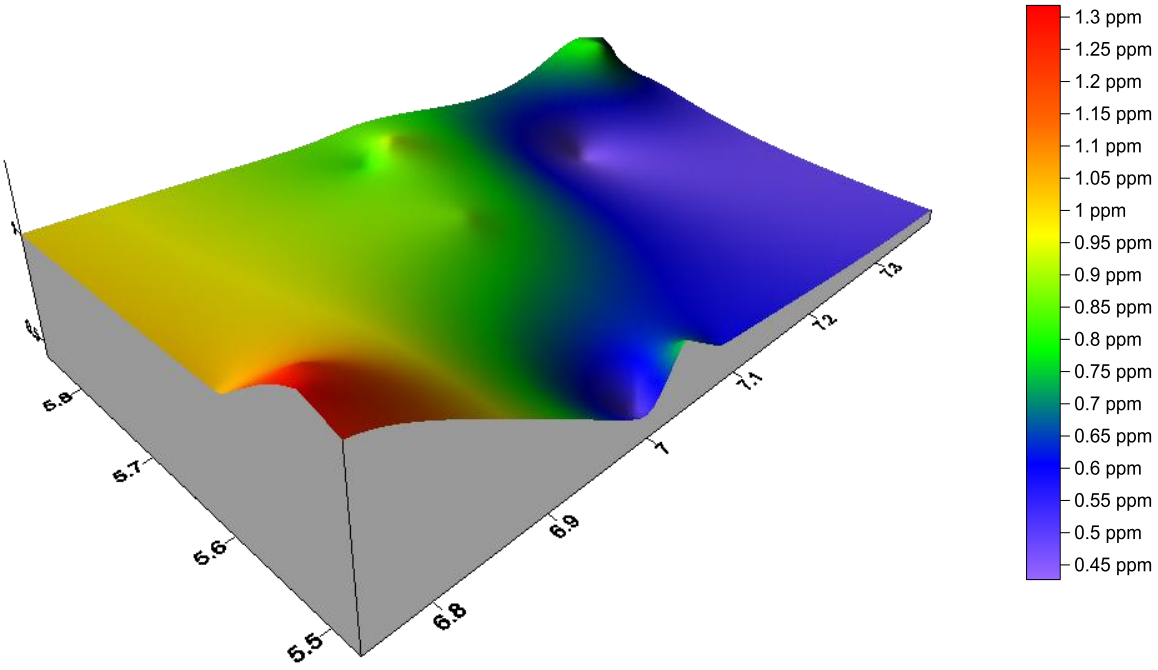

Dry season contour plot of $SO_2$



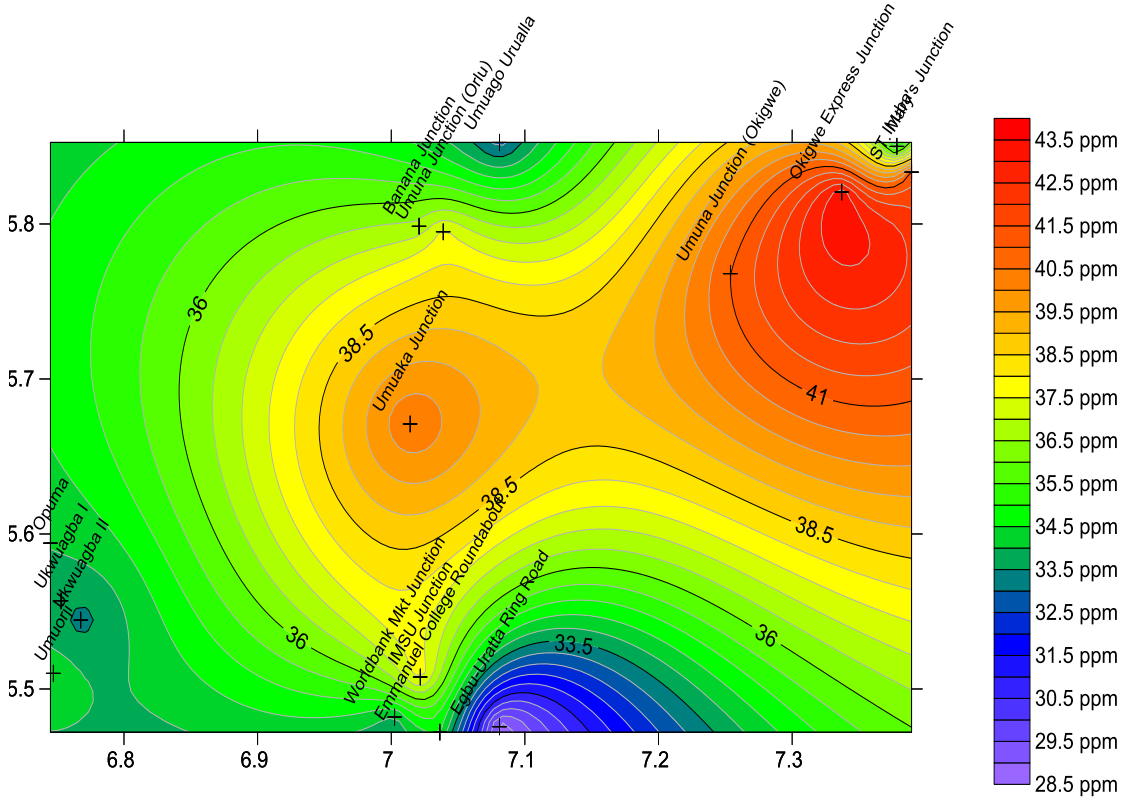

Dry season 3 – D surface plot of $SO_2$



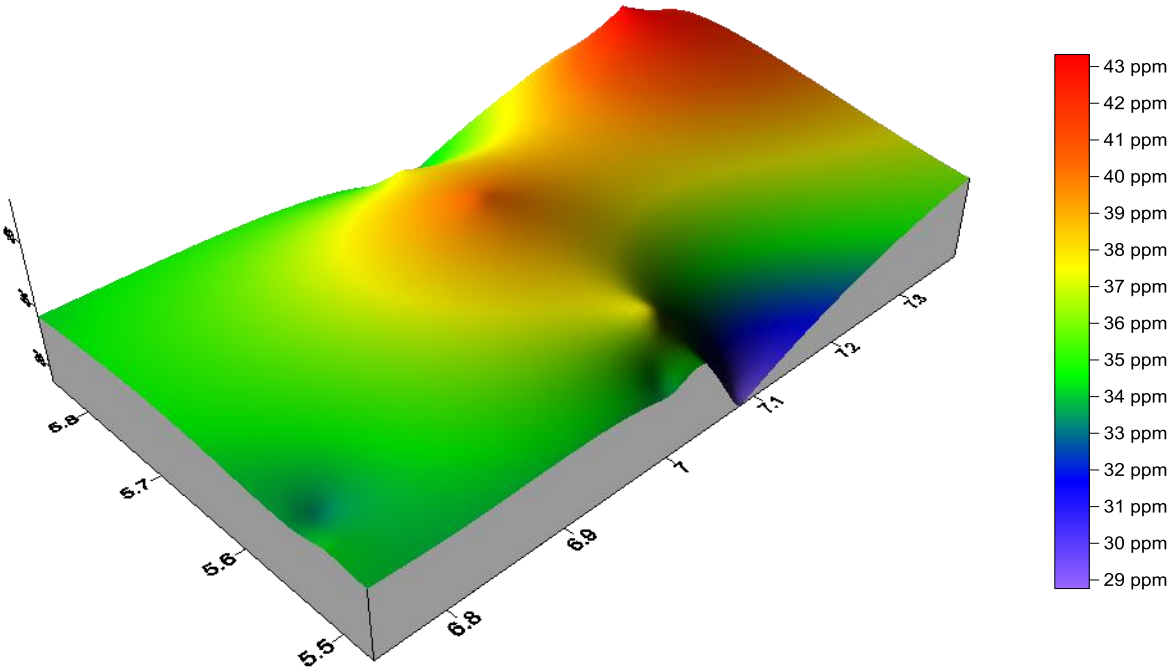

Dry season contour plot of VOC



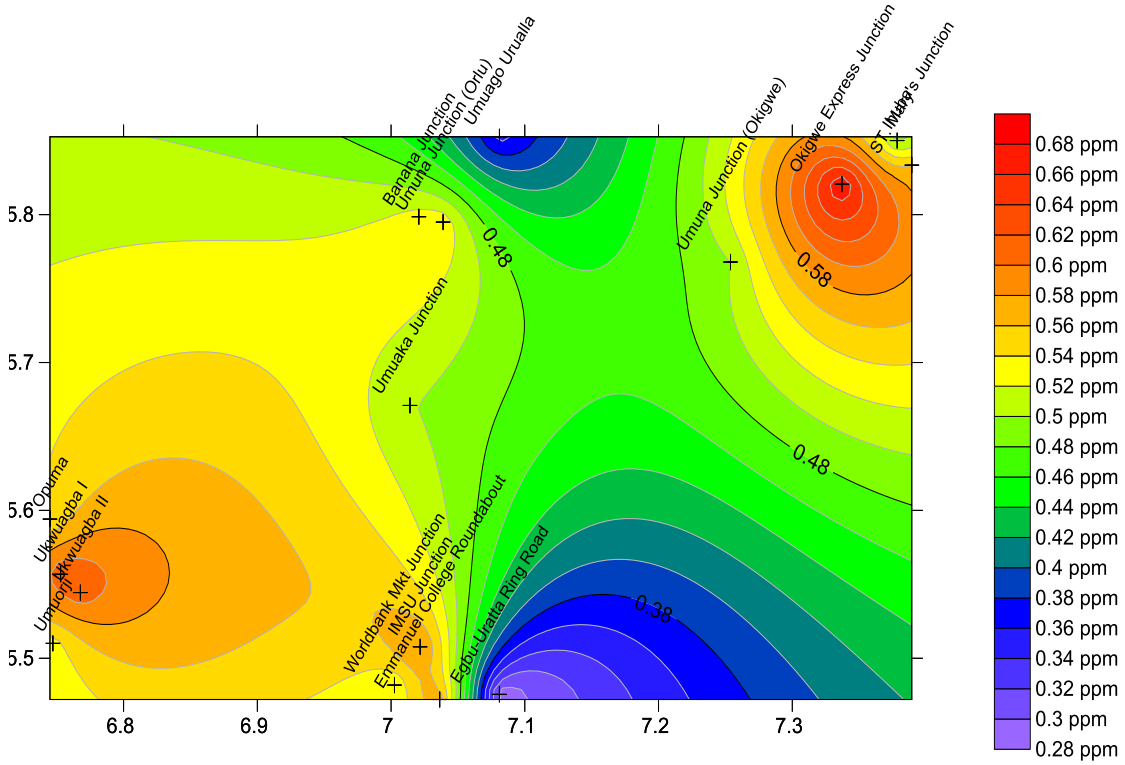

Dry season 3 – D surface plot of VOC



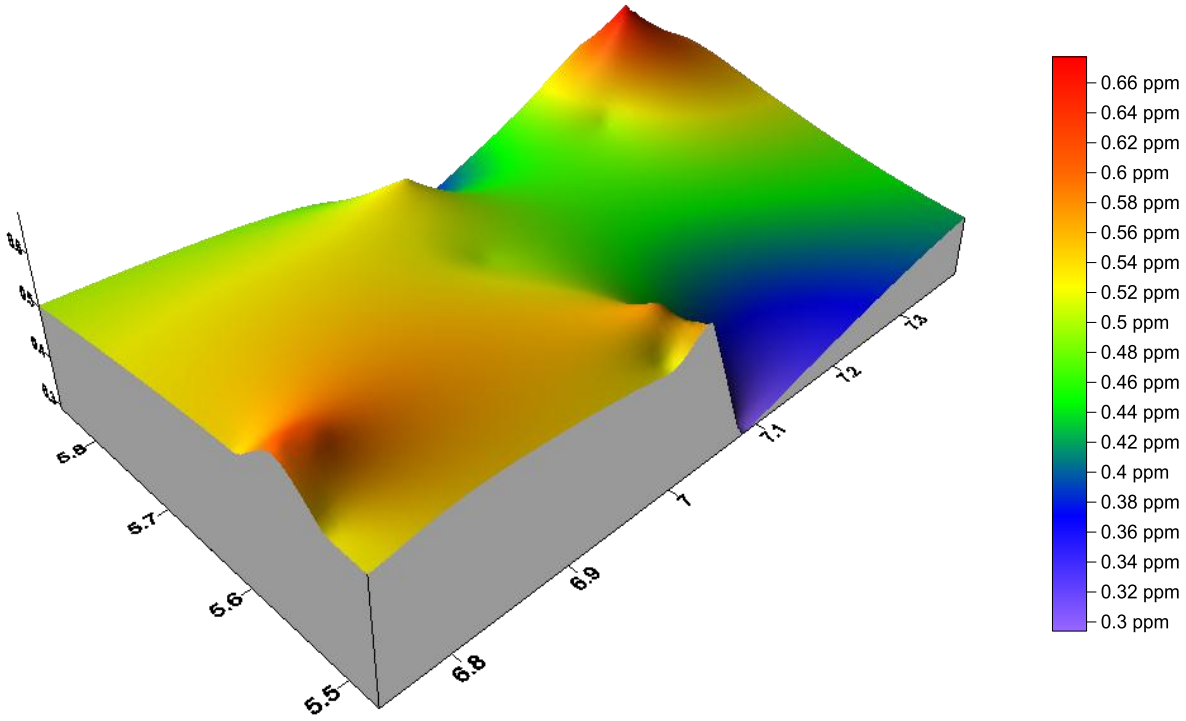
Wet season contour plot of CO



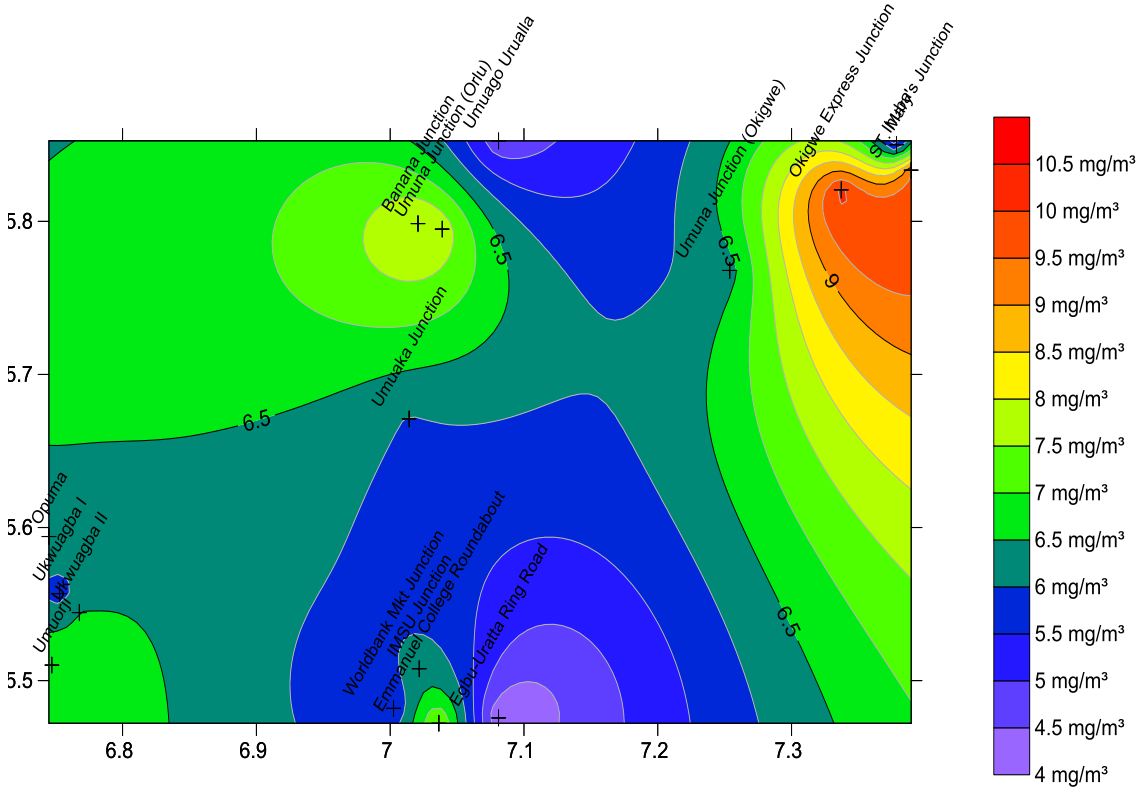

Wet season contour and 3 – D surface plot of CO



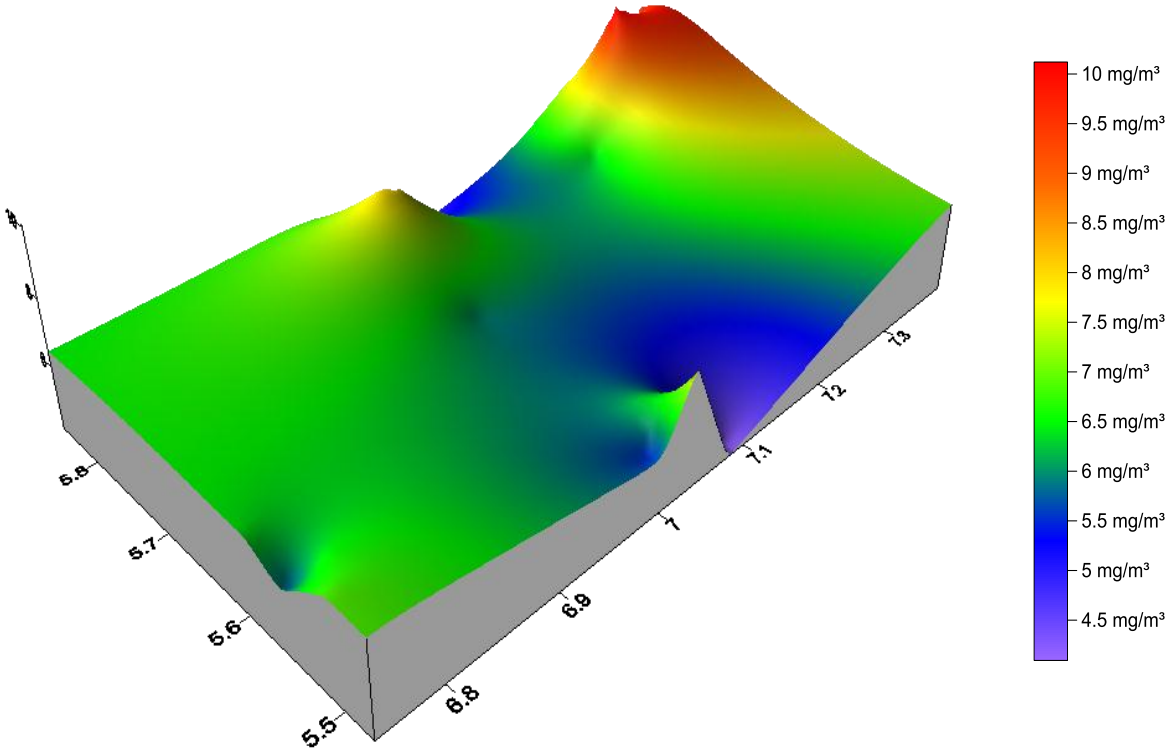

Wet season contour plot of $NO_2$



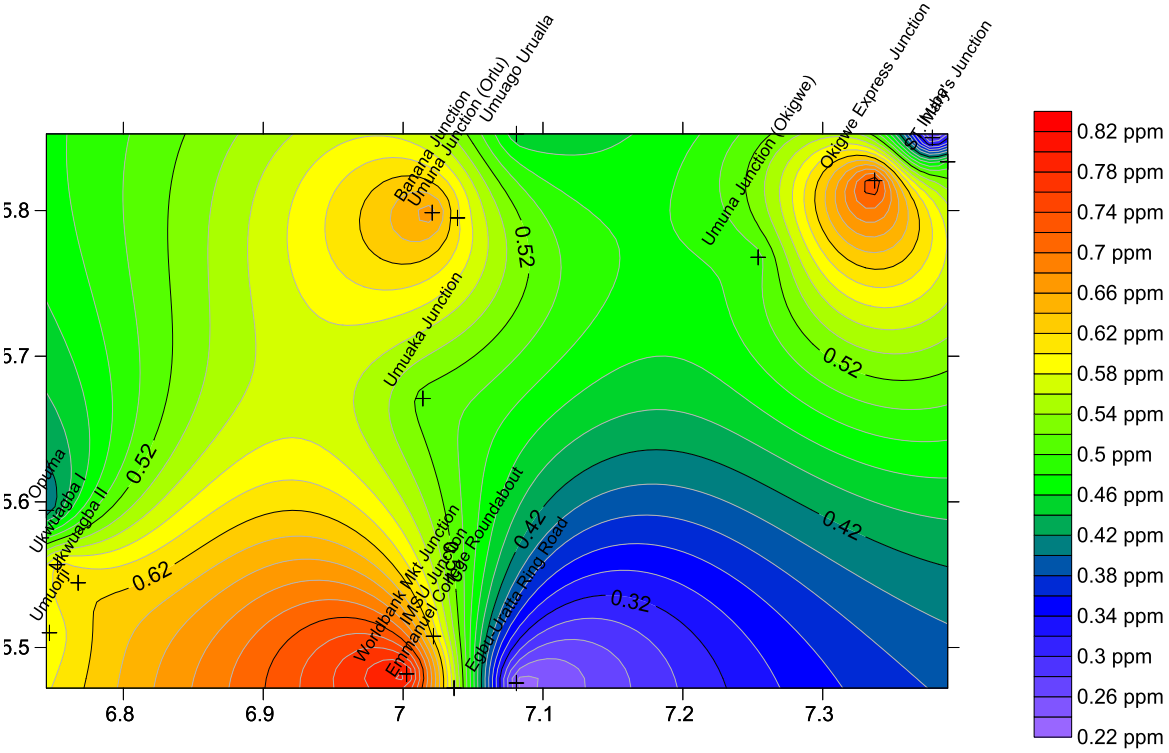

Wet season 3 – D surface plot of $NO_2$



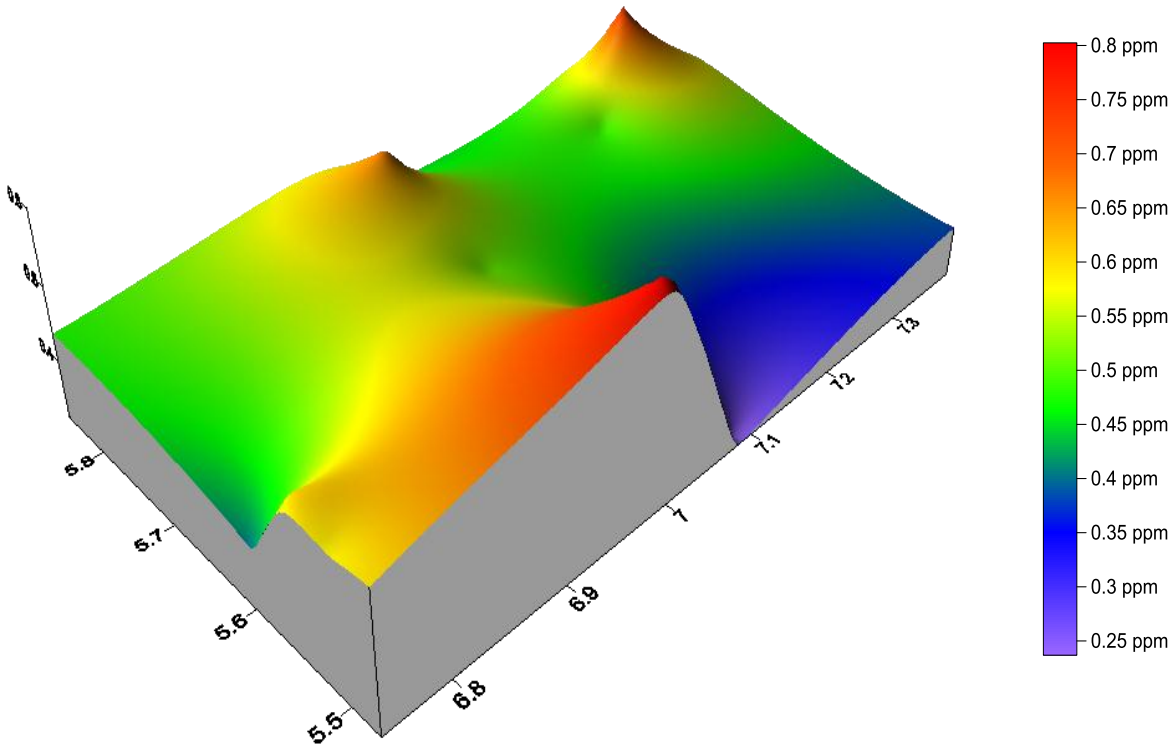

Wet season contour plot of $PM_{10}$



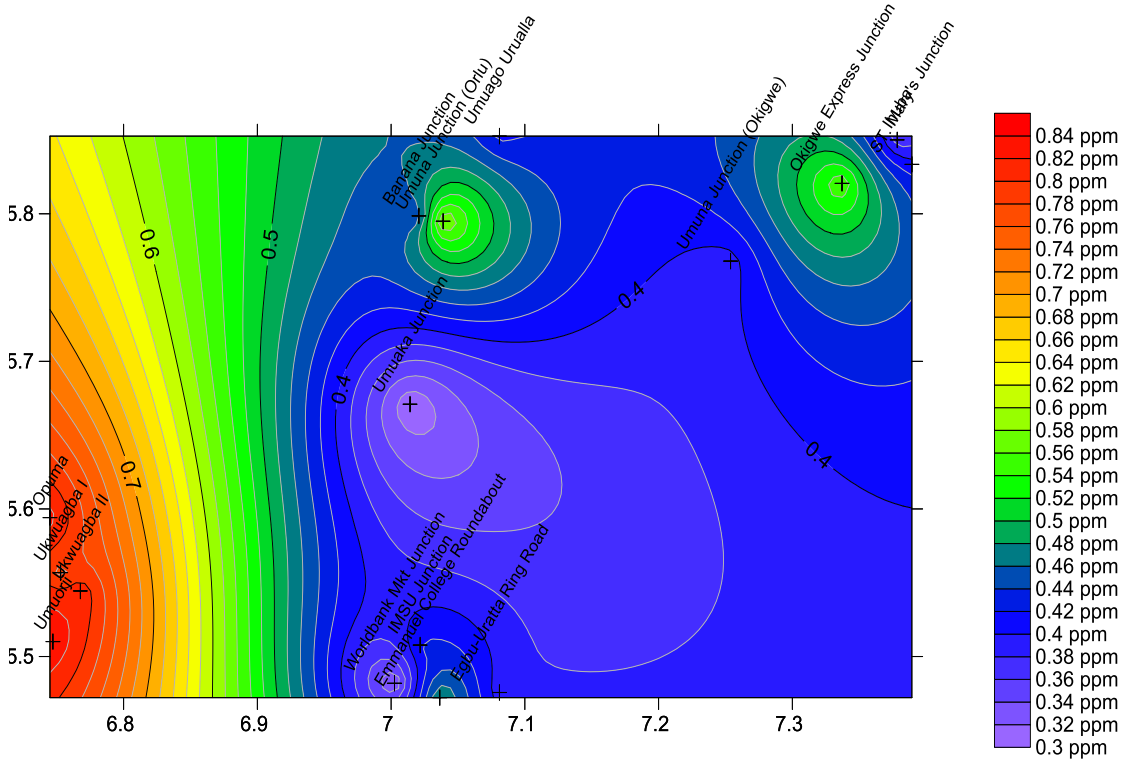

Wet season 3 – D surface plot of $PM_{10}$



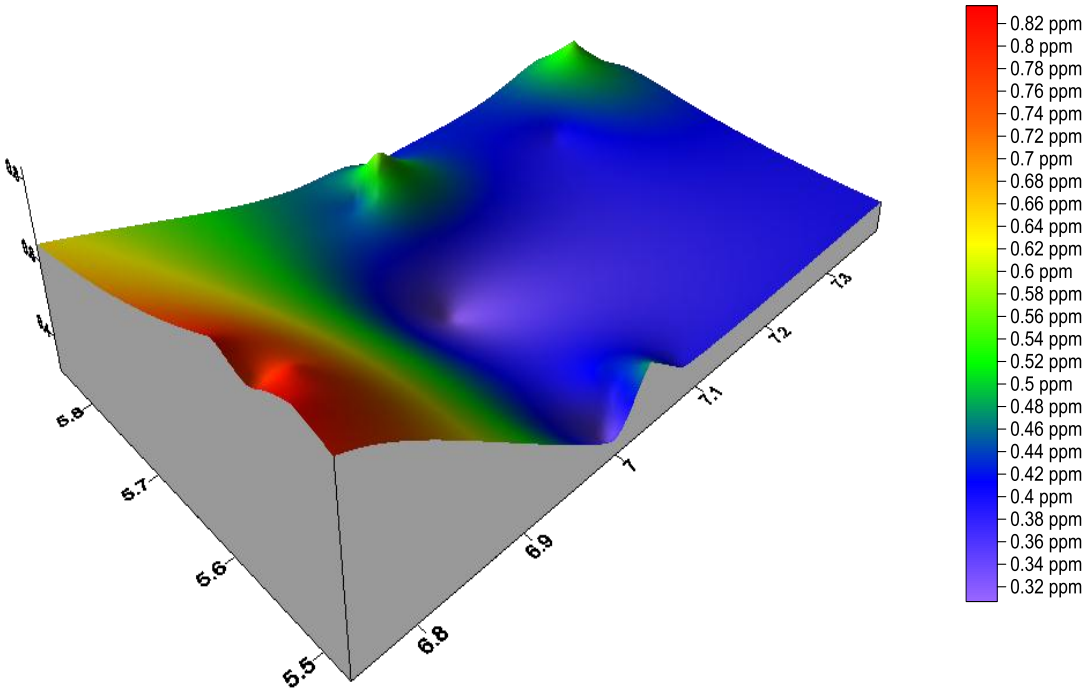

Wet season contour plot of $SO_2$




Wet season 3 – D surface plot of $SO_2$



Wet season contour and 3 – D surface plot of VOC

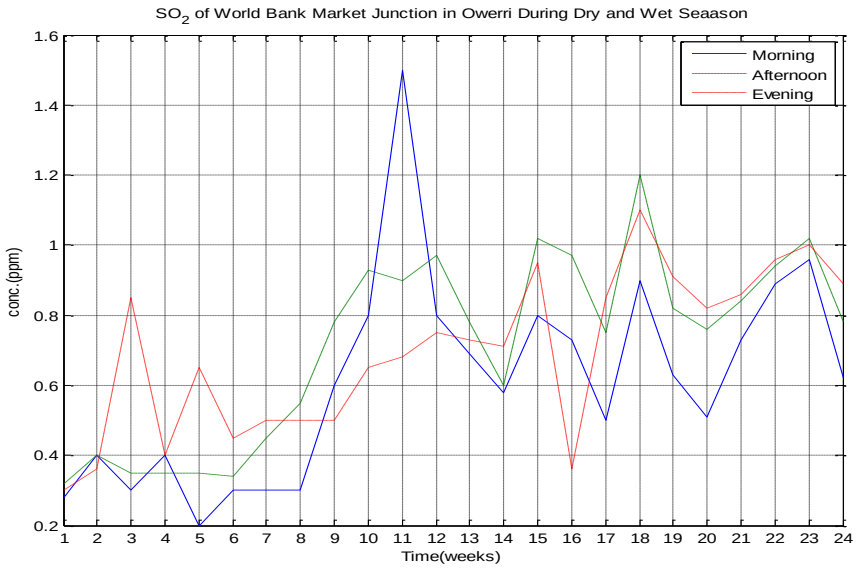



Wet season contour and 3 – D surface plot of VOC

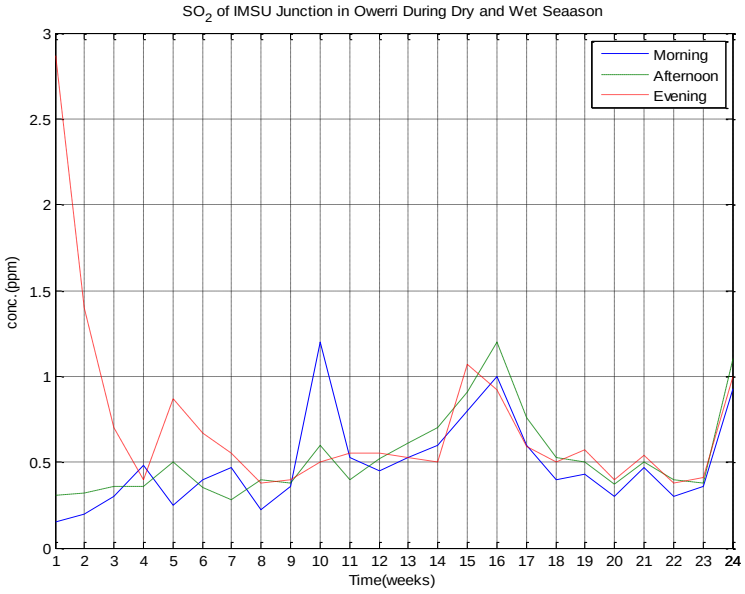
## APPENDIX 6

### Presentation of Time Series Models

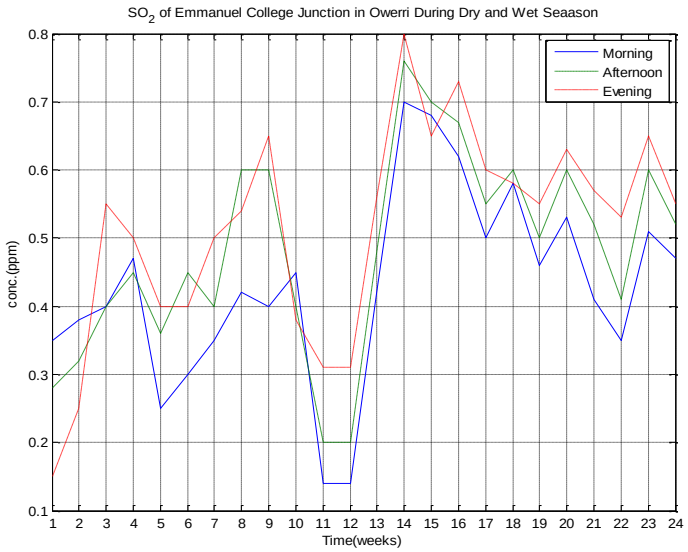
TIME SERIES MODEL FOR $SO_2$



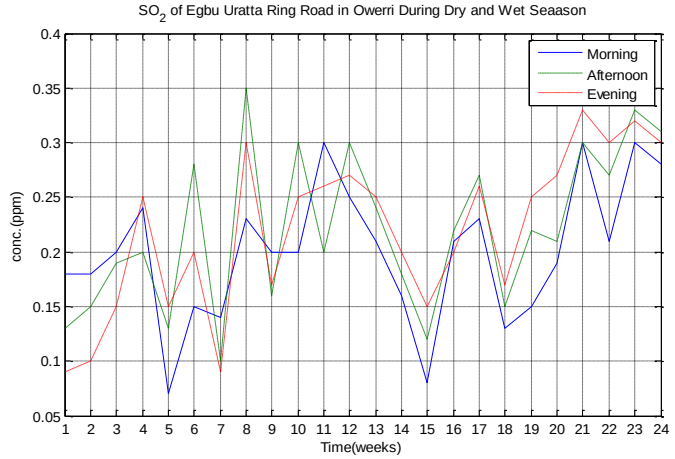

Time Series model of $SO_2$ at World Bank Market Junction, Owerri



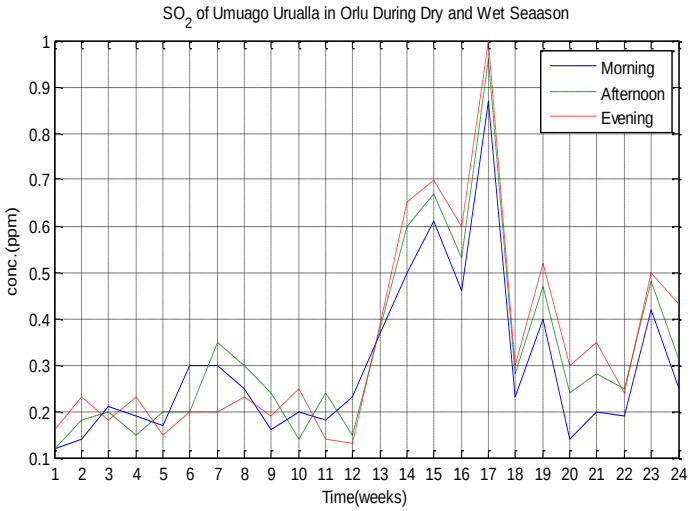

Time Series model of $SO_2$ at IMSU Junction, Owerri



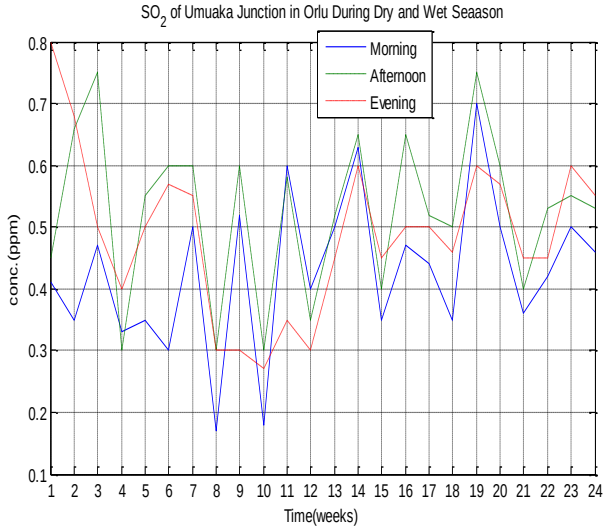

Time Series model of $SO_2$ at Emmanuel College Junction, Owerri



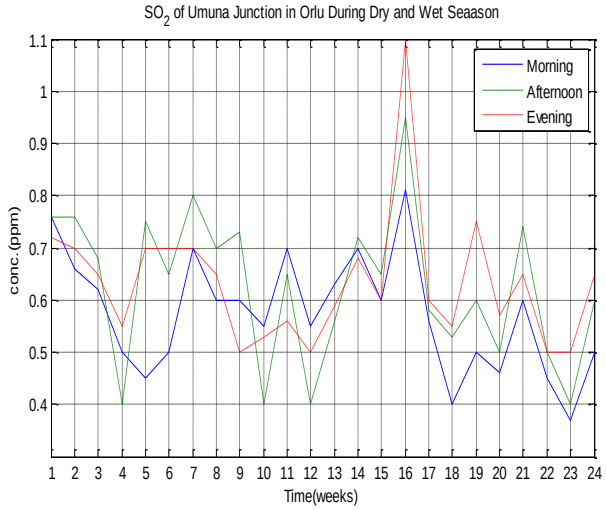

Time Series model of $SO_2$ at Ebgu - Uratta ring road, Owerri



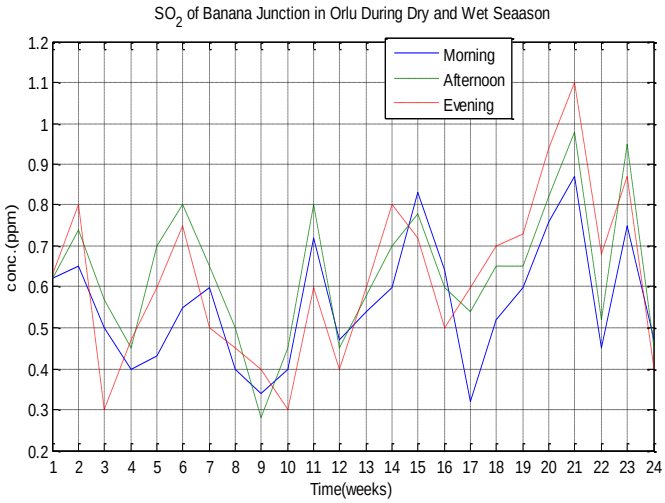
Time Series model of $SO_2$ at Umuago Urulla, Orlu



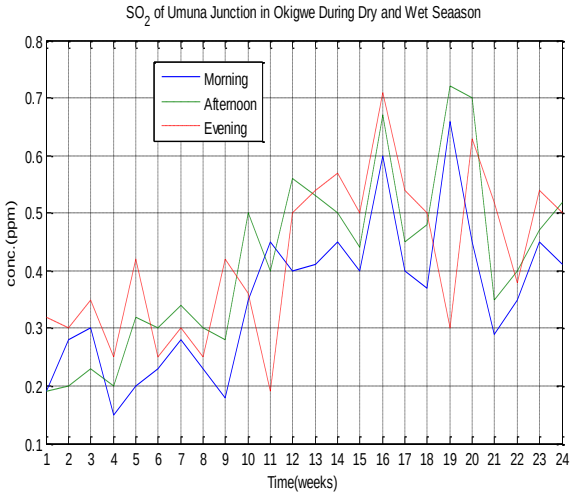

Time Series model of $SO_2$ at Umuaka Junction, Orlu



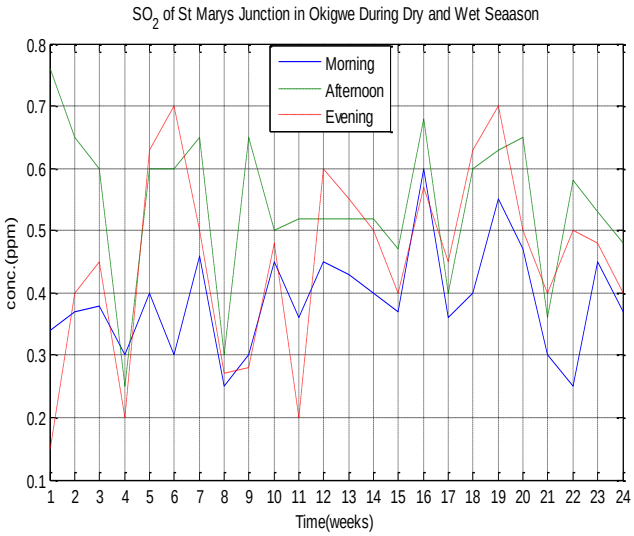

Time Series model of $SO_2$ at Umuna Junction, Orlu



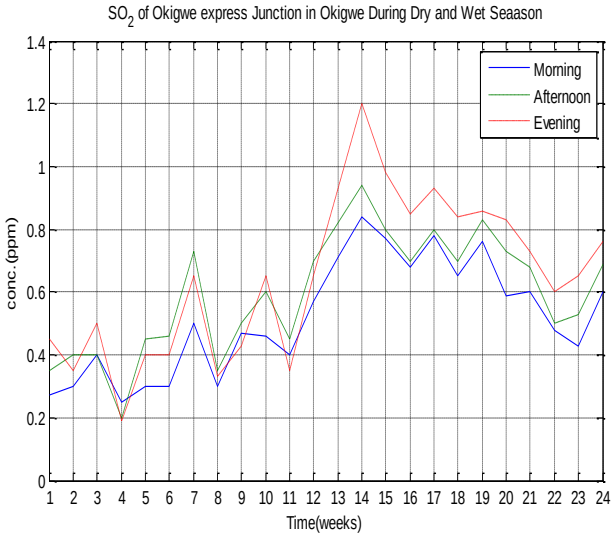

Time Series model of $SO_2$ at Banana Junction, Orlu



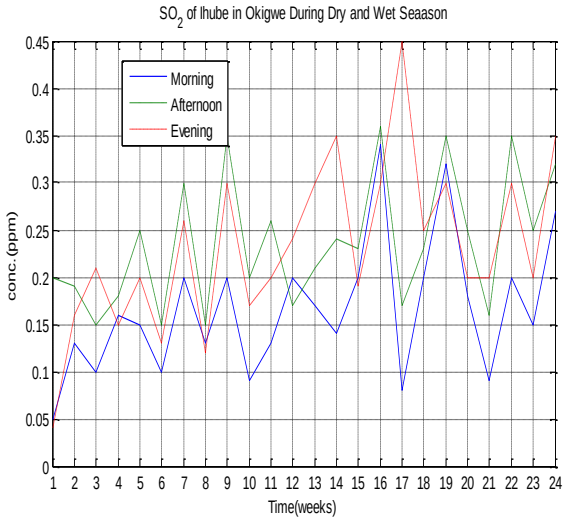

Time Series model of $SO_2$ at Umuna Junction, Okigwe.



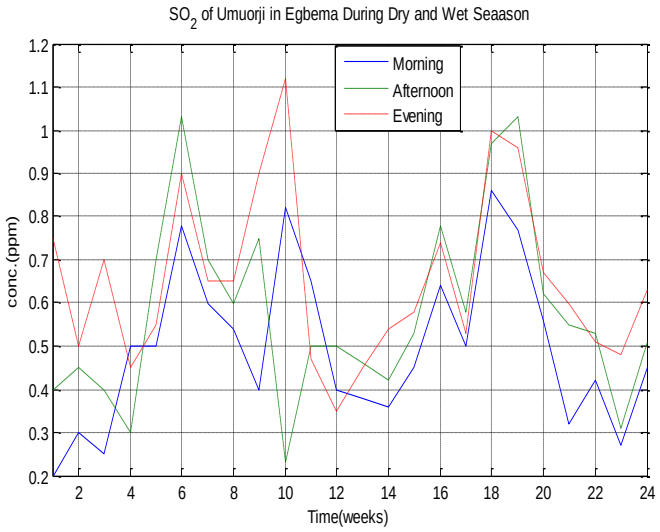
Time Series model of $SO_2$ at St. Mary's Junction, Okigwe



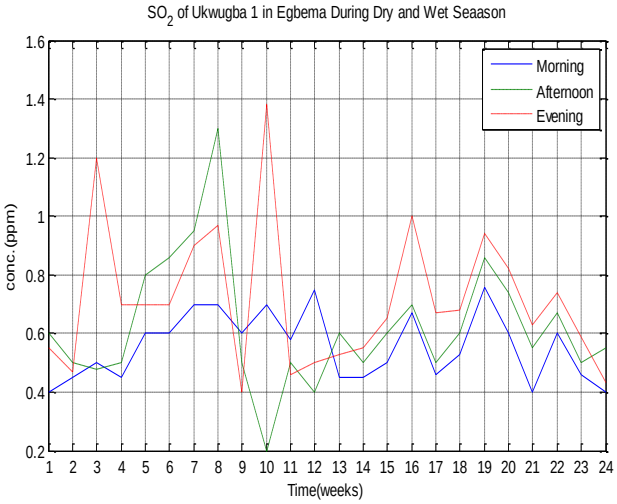

Time Series model of $SO_2$ at Okigwe Express Junction



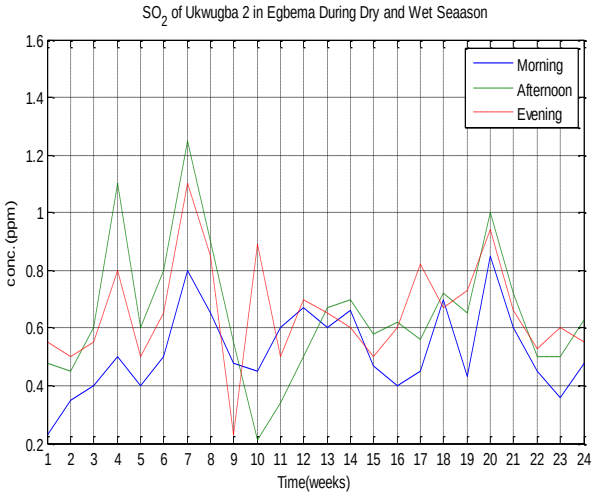

Time Series model of $SO_2$ at Ihube, Okigwe



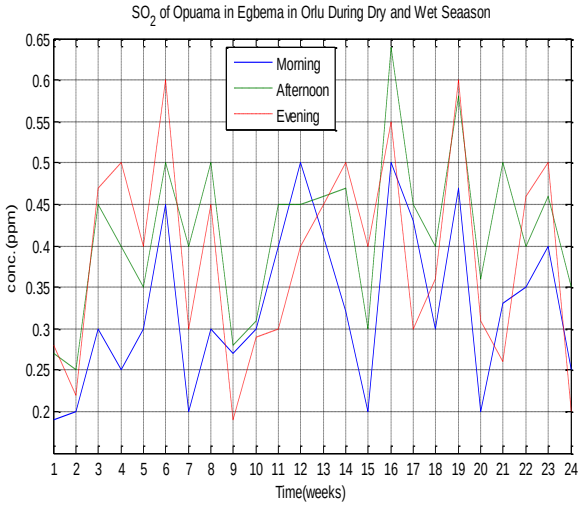

Time Series model of $SO_2$ at Umuorji, Egbema




Time Series model of $SO_2$ at Ukwugba 1, Egbema

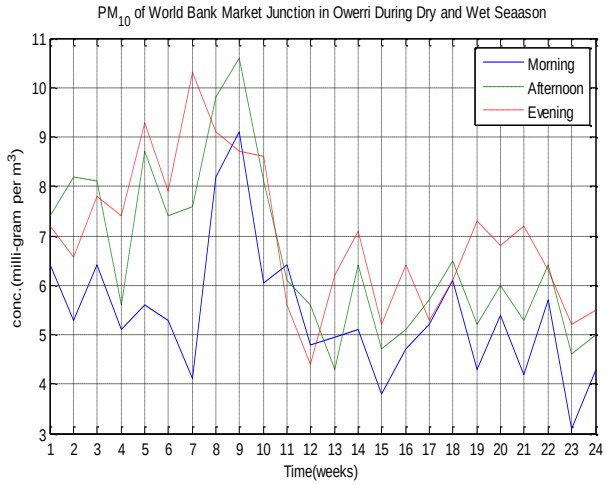


Time Series model of $SO_2$ at Ukwugba 2, Egbema

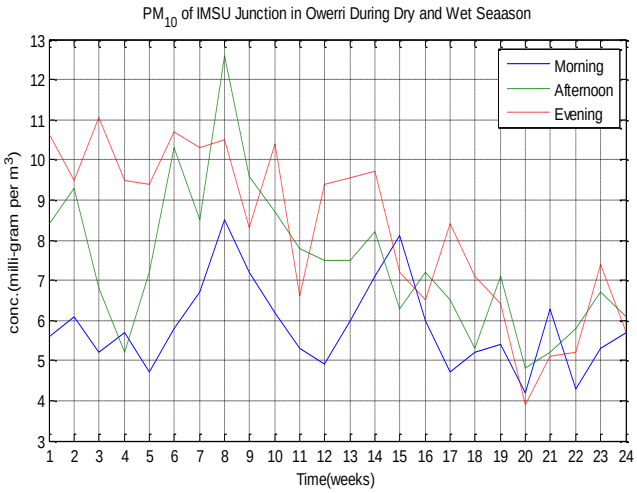



Time Series model of $SO_2$ at Opuoma, Egbema

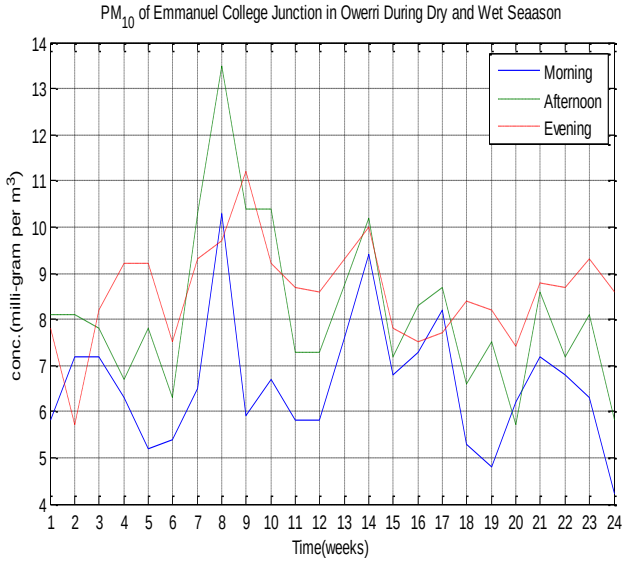
TIME SERIES MODEL FOR $PM_{10}$



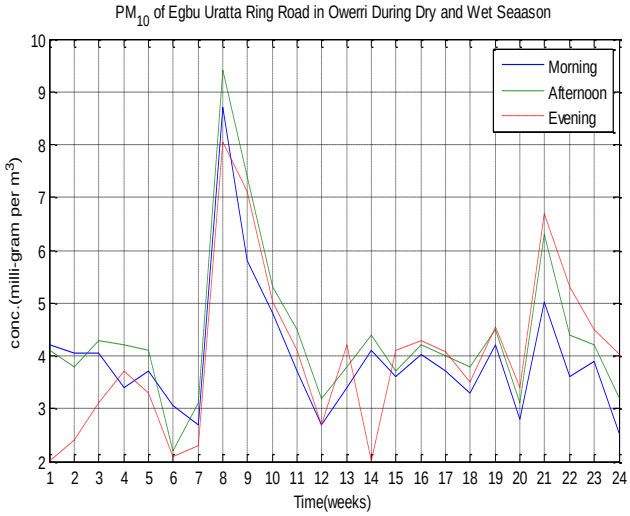

Time Series model of $PM_{10}$ at World Bank Market Junction, Owerri



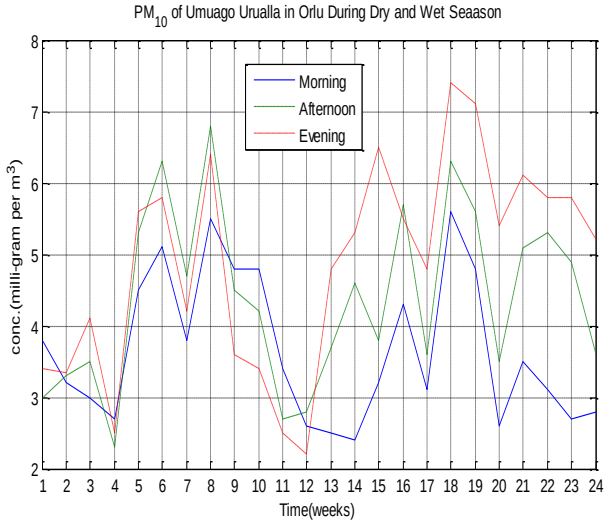

Time Series model of $PM_{10}$ at IMSU Junction, Owerri



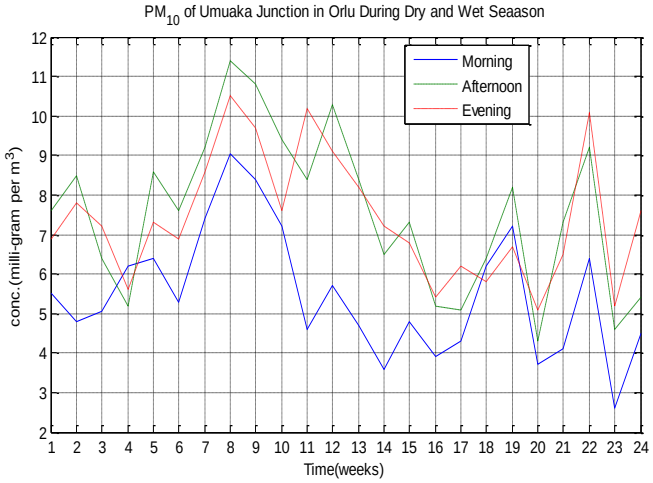

Time Series model of $PM_{10}$ at Emmanuel College Junction



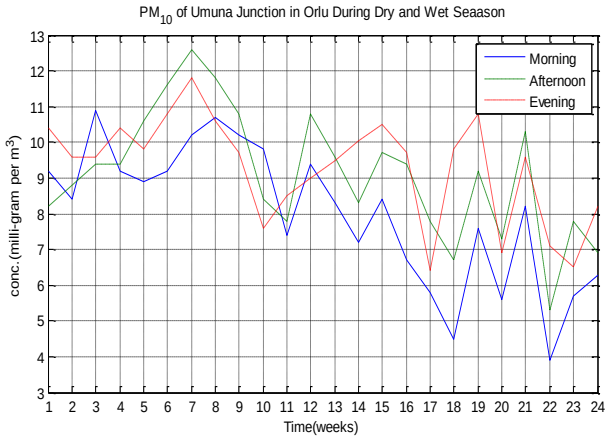
Time Series model of $PM_{10}$ at Egbu – Uratta Ring road, Owerri



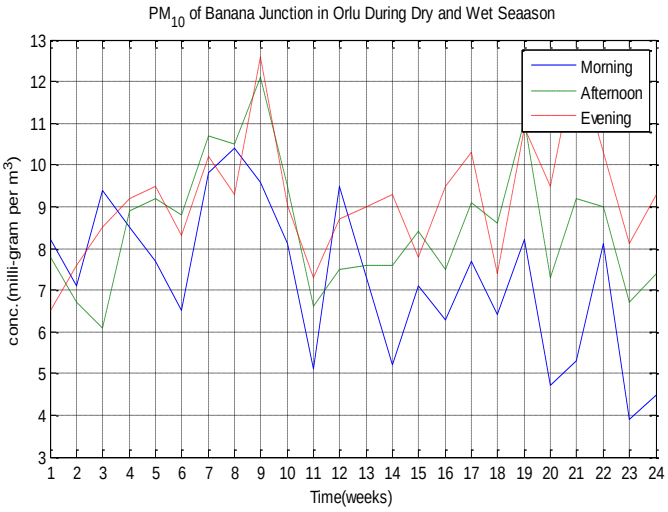

Time Series model of $PM_{10}$ at Umuago Urulla, Orlu



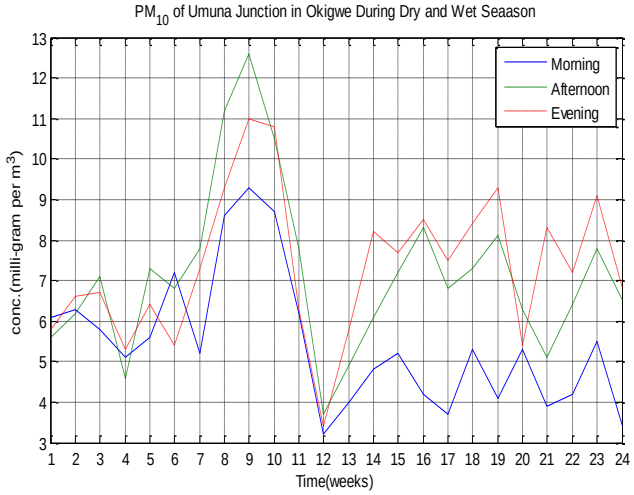

Time Series model of $PM_{10}$ at Umuaka Junction, Orlu



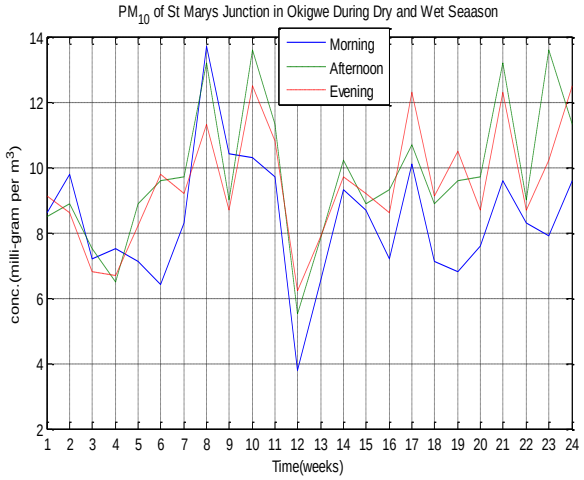
Time Series model of $PM_{10}$ at Umuna Junction, Orlu



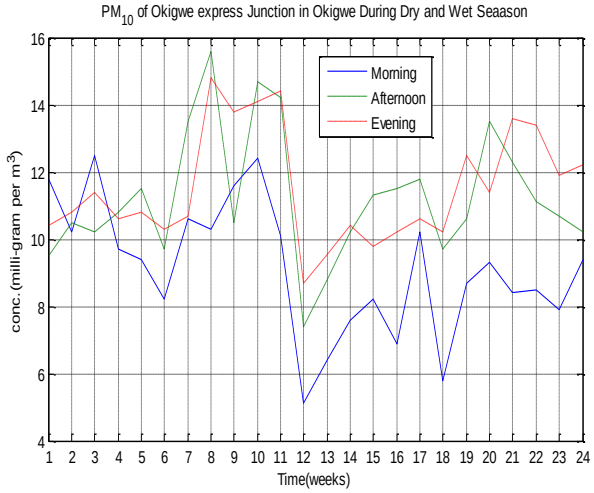

Time Series model of $PM_{10}$ at Banana Junction, Orlu



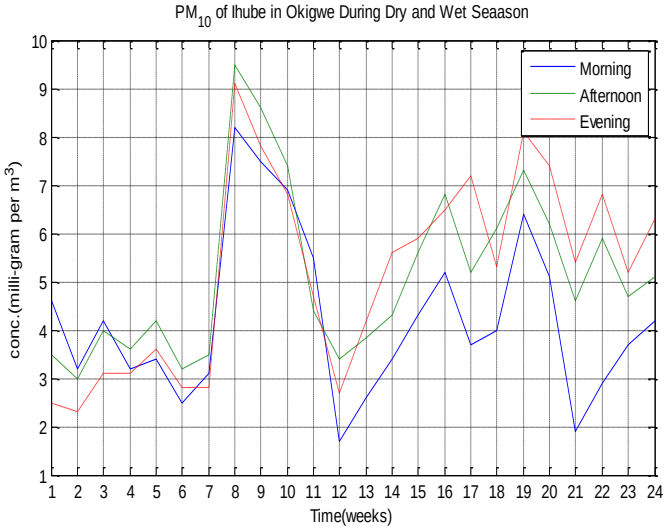

Time Series model of $PM_{10}$ at Umuna Junction, Okigwe



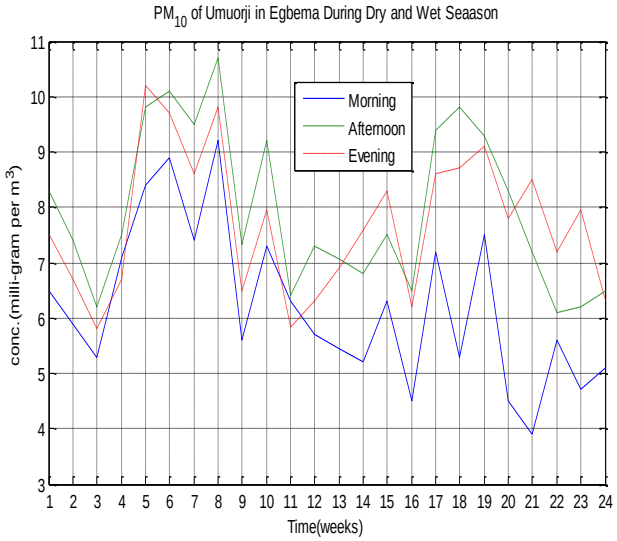

Time Series model of $PM_{10}$ at St. Mary's junction, Okigwe



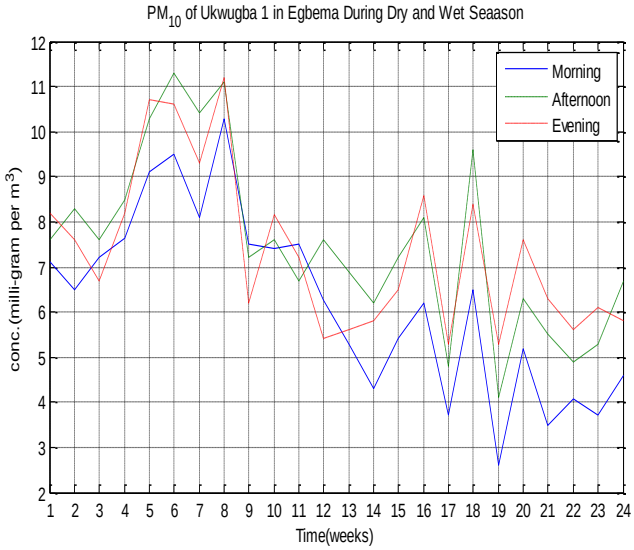

Time Series model of $PM_{10}$ at Okigwe Express Junction, Okigwe



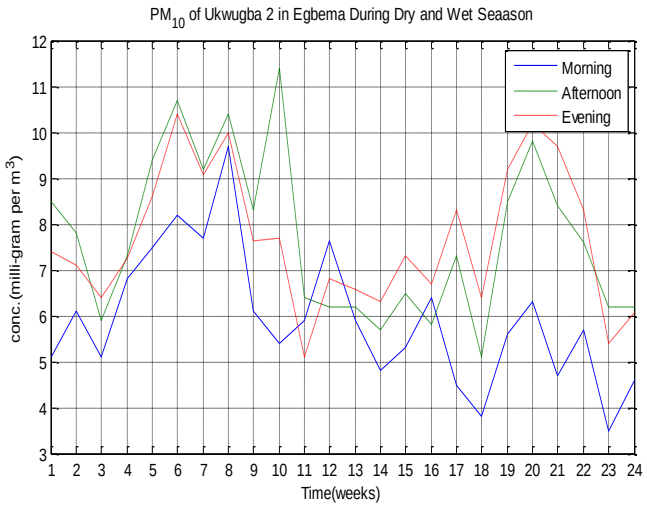

Time Series model of $PM_{10}$ at Ihube, Okigwe



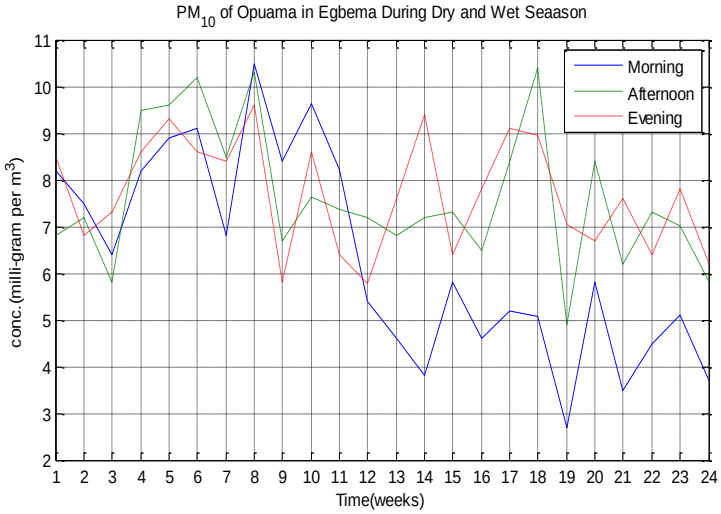

Time Series model of $PM_{10}$ at Umuorji, Egbema




Time Series model of $PM_{10}$ at Ukwugba 1, Egbema

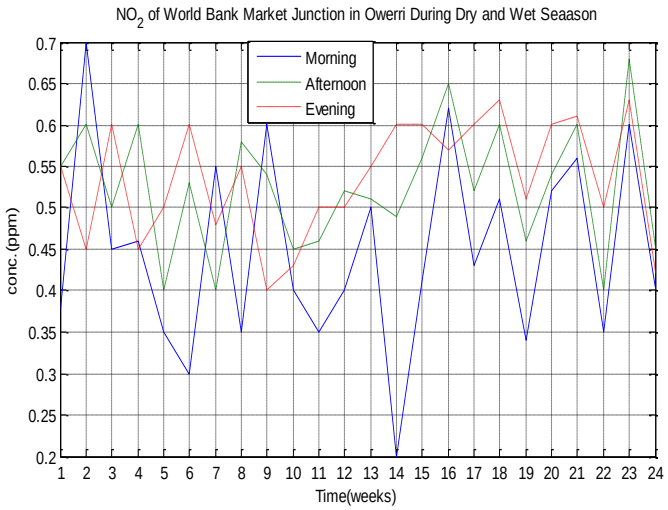



Time Series model of $PM_{10}$ at UKwugba 2, Egbema

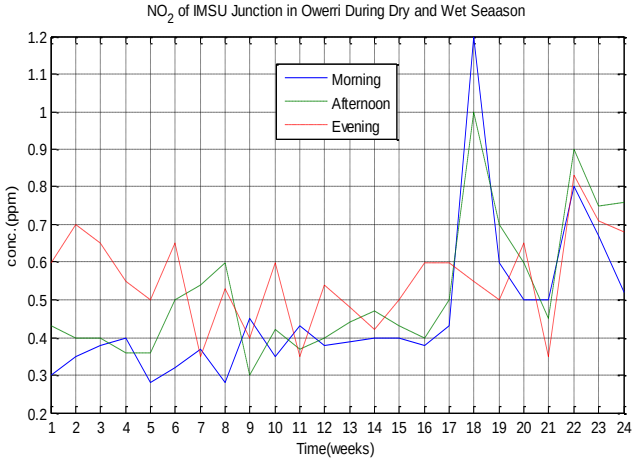



Time Series model of $PM_{10}$ at Opuoma, Egbema

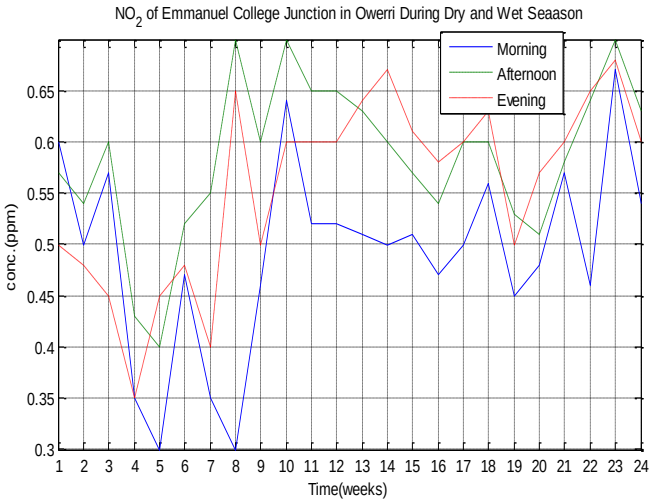
TIME SERIES MODEL FOR $NO_2$



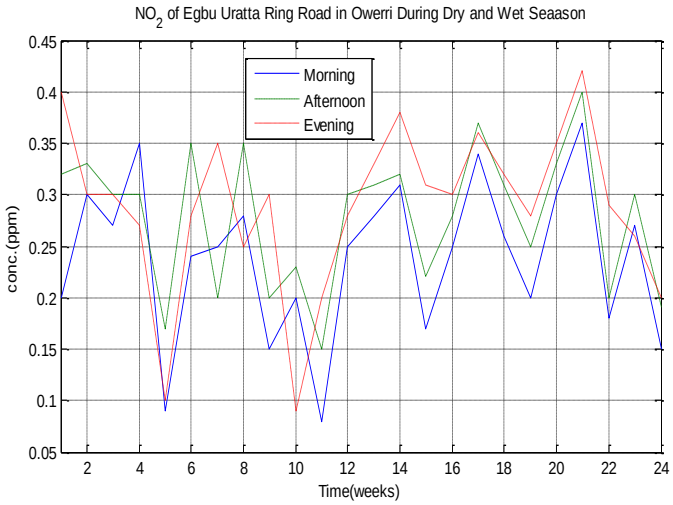

Time Series model of $NO_2$ at World Bank Market Junction, Owerri



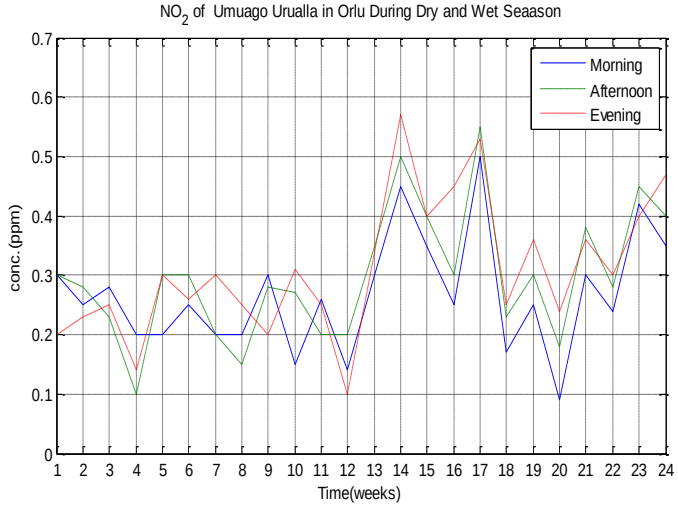

Time Series model of $NO_2$ at IMSU Junction



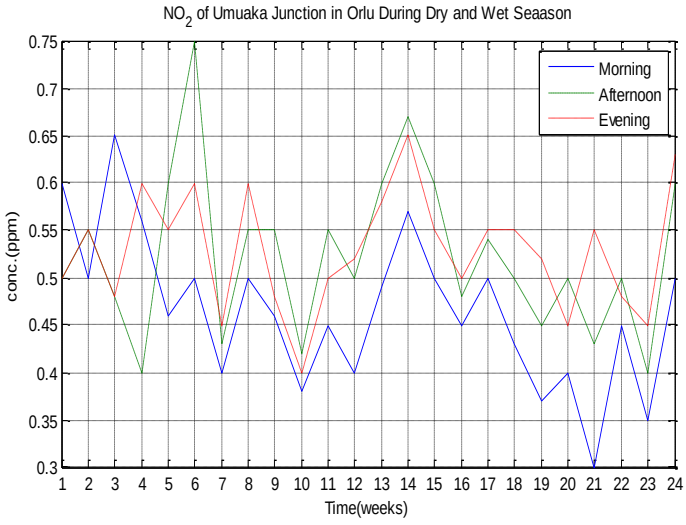

Time Series model of $NO_2$ at Emmanuel College Junction



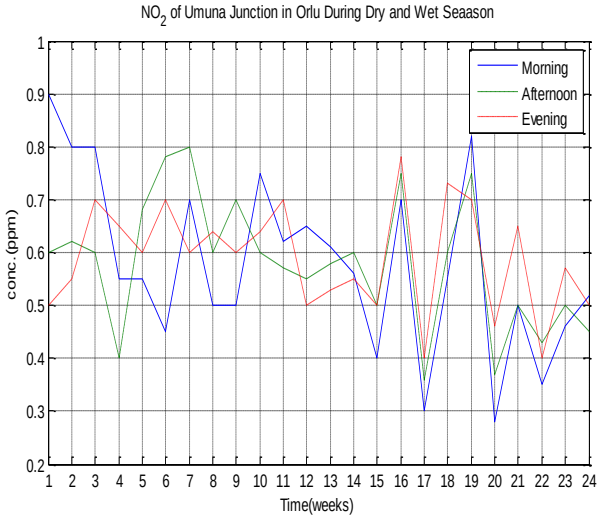

Time Series model of $NO_2$ at Egbe-Uratta Ring Road, Owerri



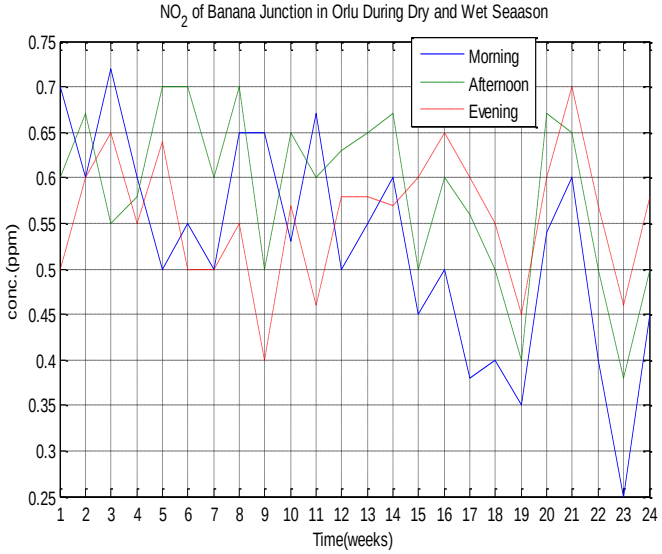

Time Series model of $NO_2$ at Umuago Urualla, Orlu



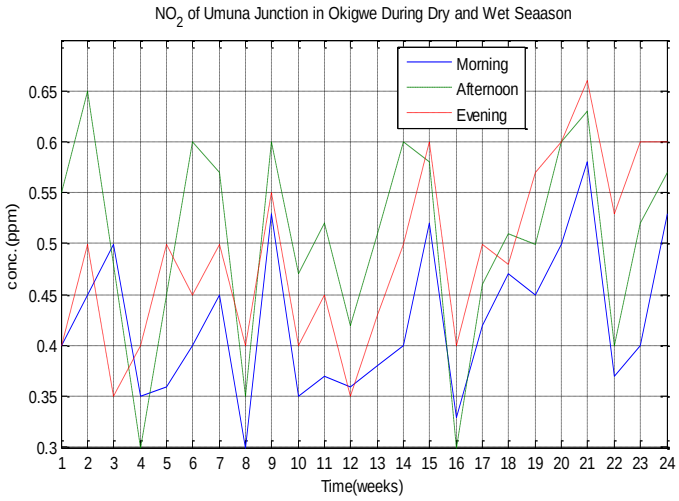
Time Series model of $NO_2$ at Umuaka Junction, Orlu



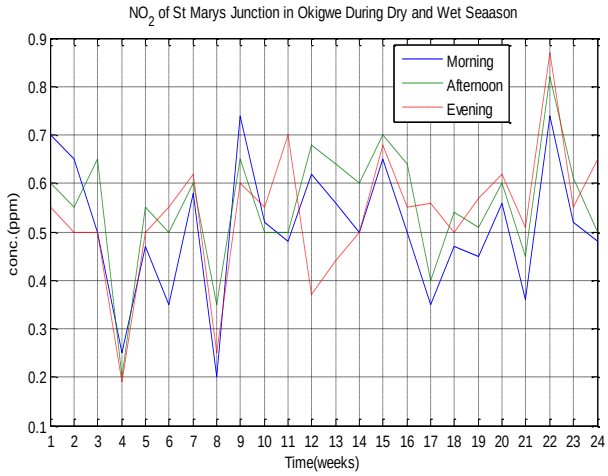

Time Series model of $NO_2$ at Umuna Junction, Orlu



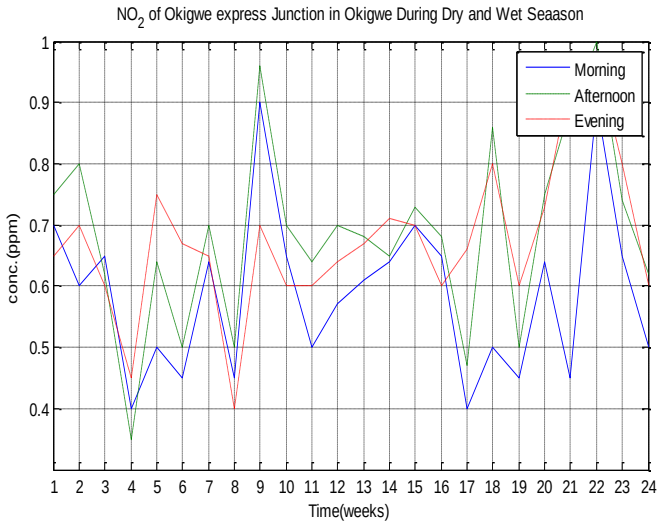

Time Series model of $NO_2$ at Banana Junction, Orlu



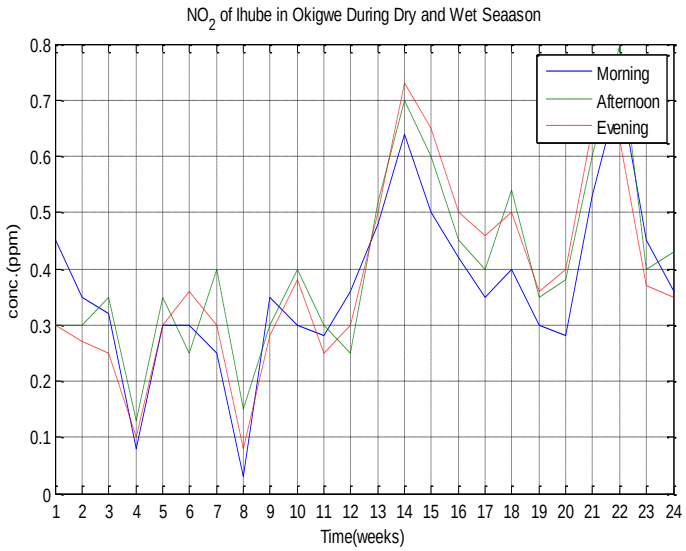

Time Series model of $NO_2$ at Umuna Junction, Okigwe



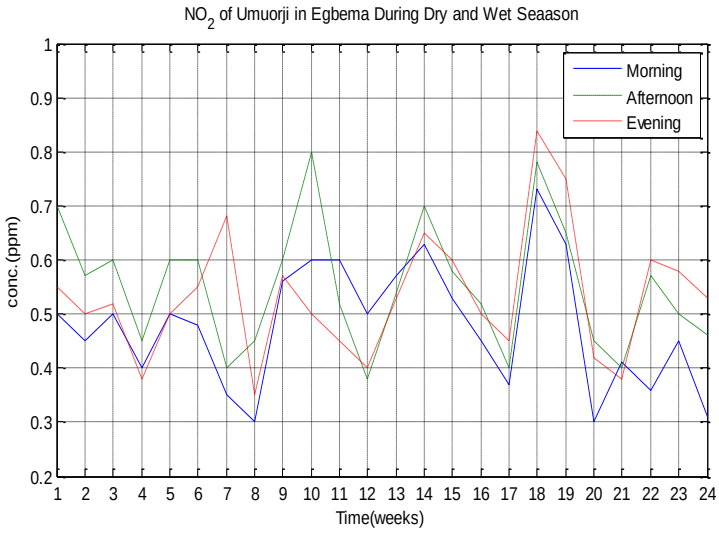

Time Series model of $NO_2$ at St. Mary's Junction, Okigwe



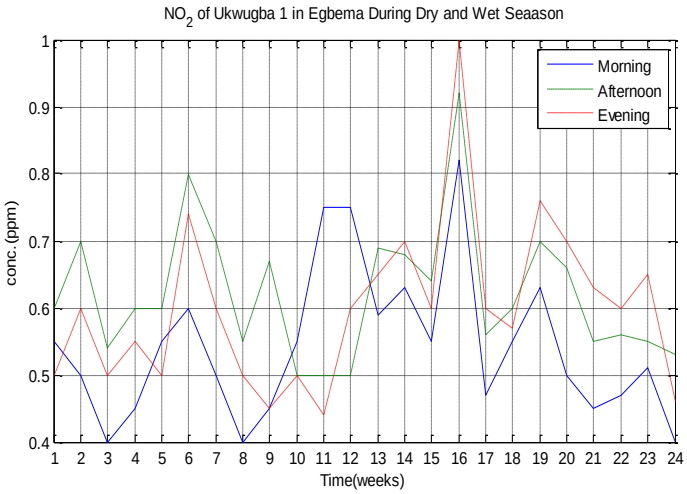

Time Series model of $NO_2$ at Okigwe Express Junction, okigwe



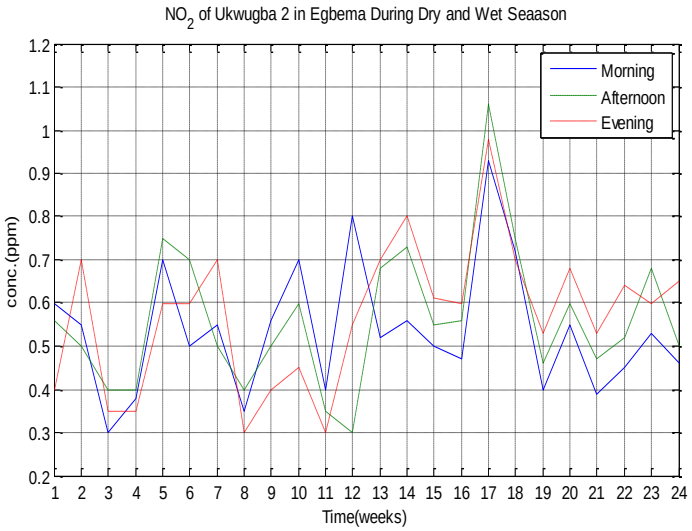

Time Series model of $NO_2$ at Ihube, Okigwe



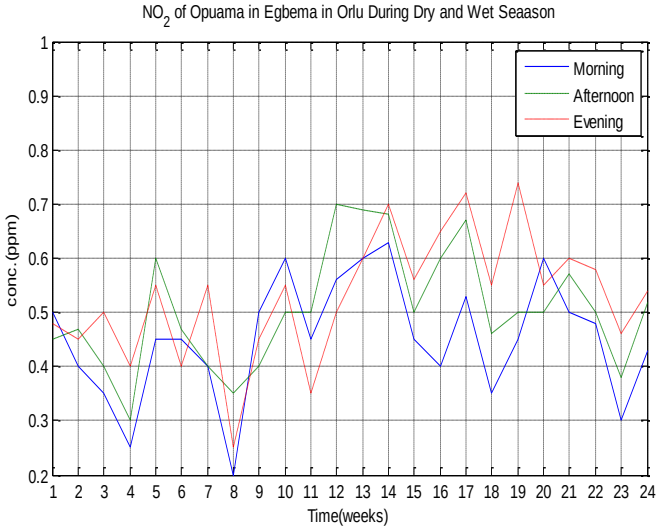

Time Series model of $NO_2$ at Umuorji, Egbema



Time Series model of $NO_2$ at Ukwugba 1, Egbema

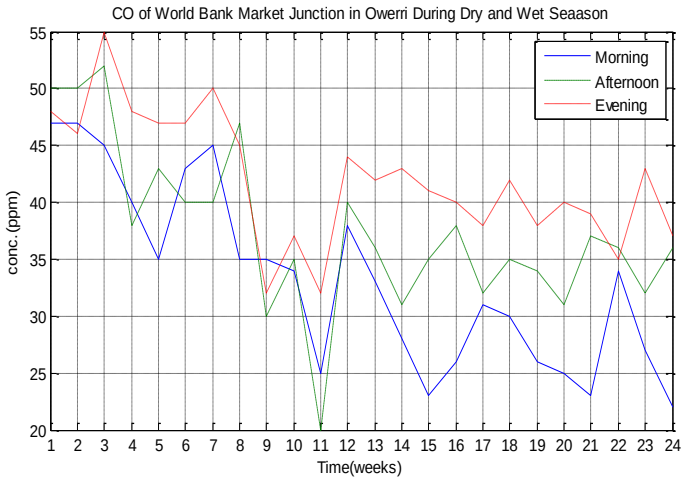



Time Series model of $NO_2$ at Ukwugba2, Egbema

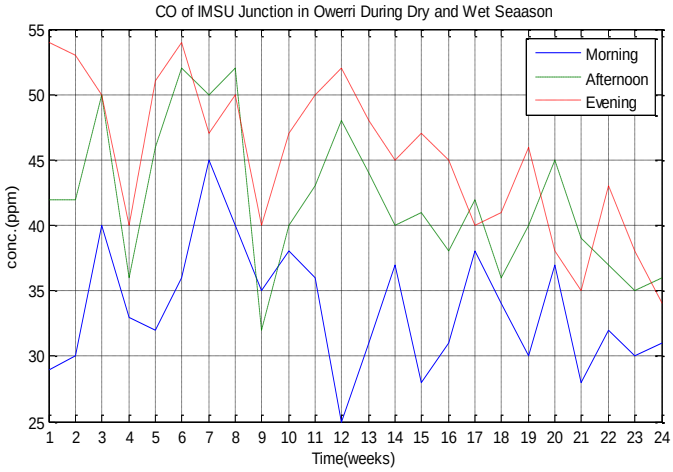



Time Series model of $NO_2$ at Opuoma, Egbema

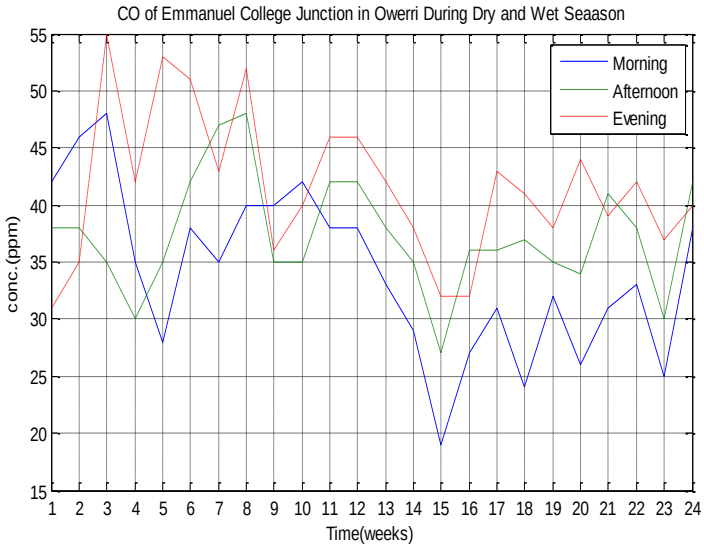
TIMESERIES MODEL FOR CO



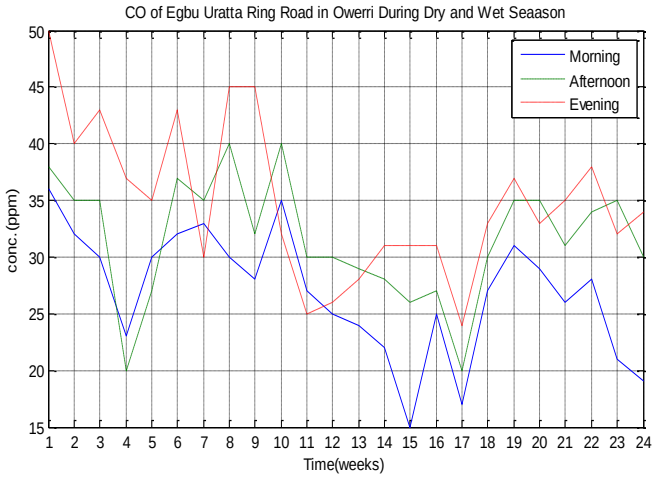

Time Series model of CO at World Bank Market Junction, Owerri



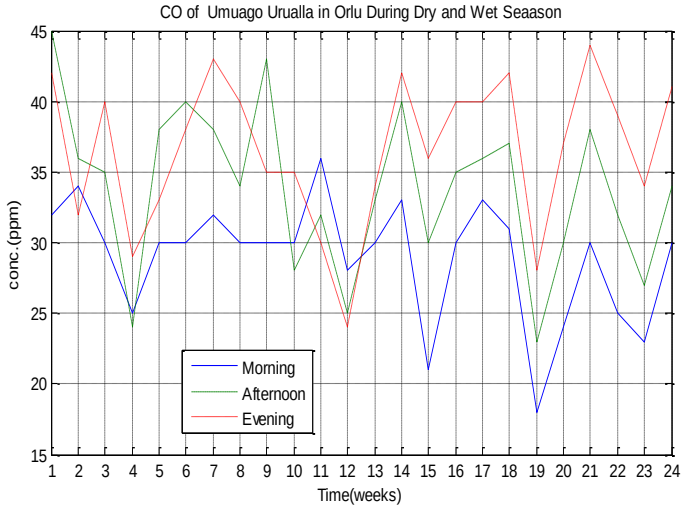

Time Series model of CO at IMSU Junction, Owerri



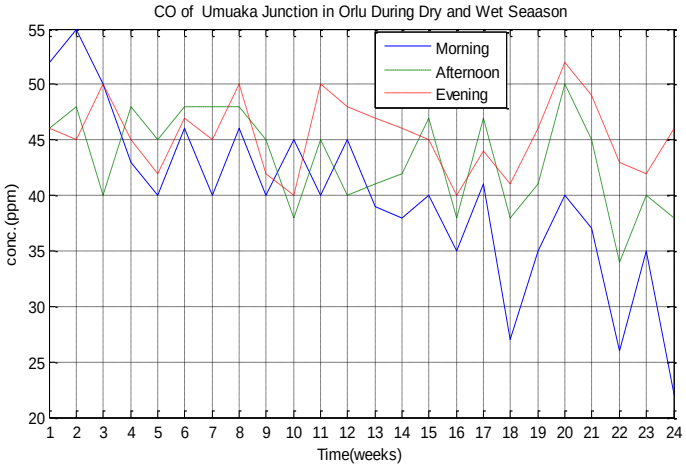
Time Series model of CO at Emmanuel College Junction, Owerri



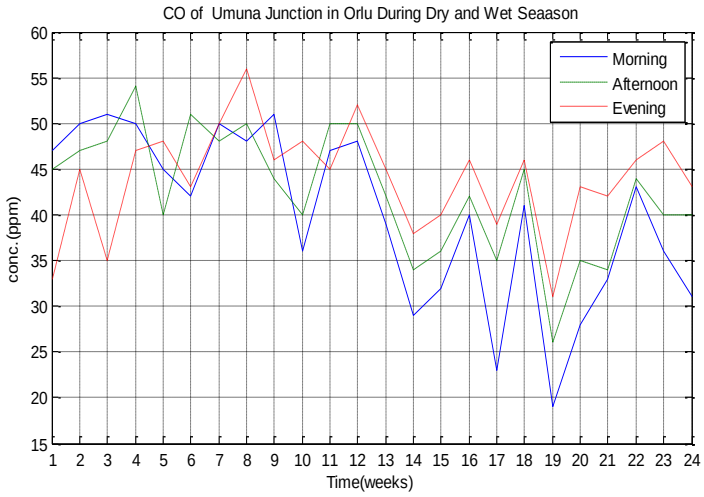

Time Series model of CO at Egbe – Uratta Ring Road, Owerri,



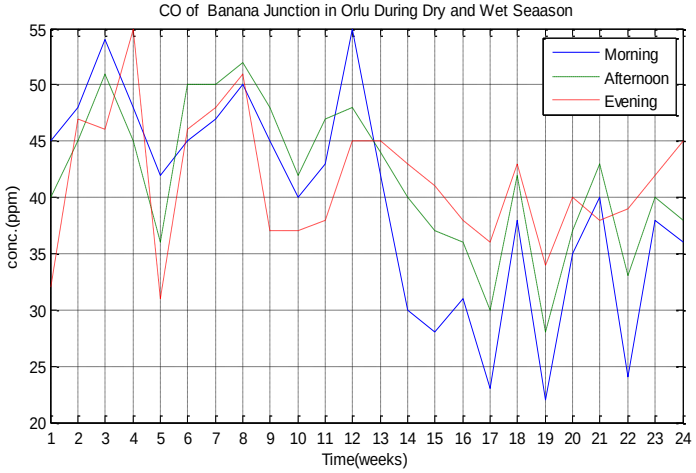

Time Series model of CO at Umuago Urulla, Orlu



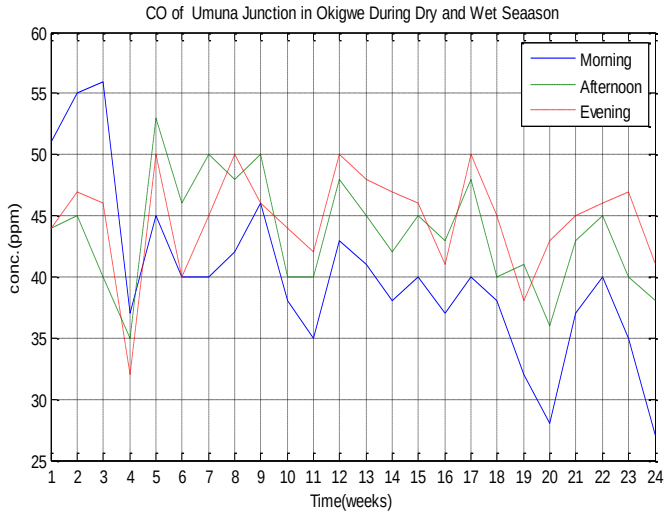
Time Series model of CO at Umuaka junction, Orlu



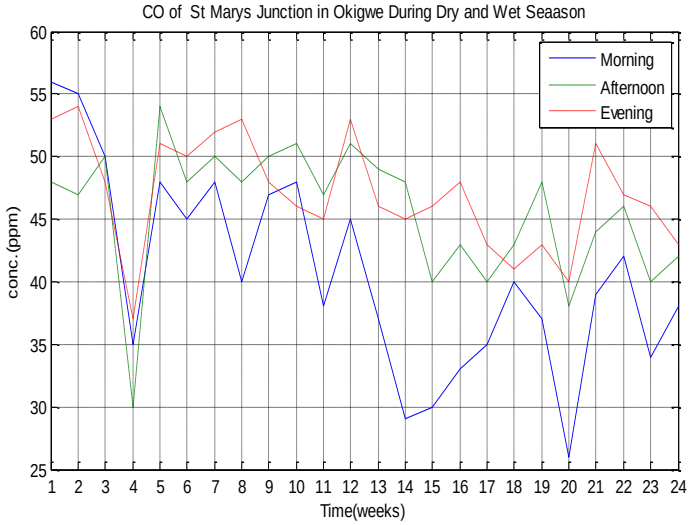

Time Series model of CO at



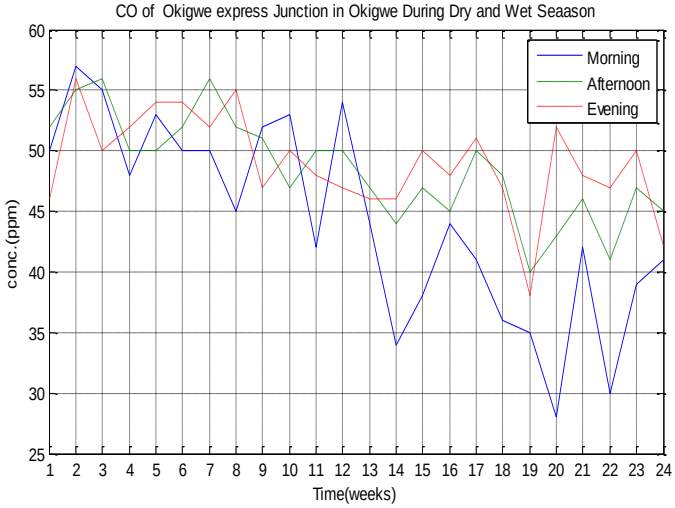

Time Series model of CO at Banana Junction, Orlu



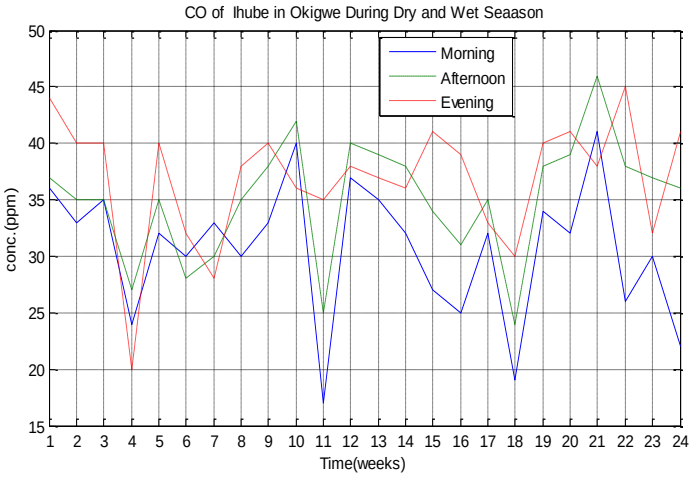

Time Series model of CO at Umuna Junction, Okigwe



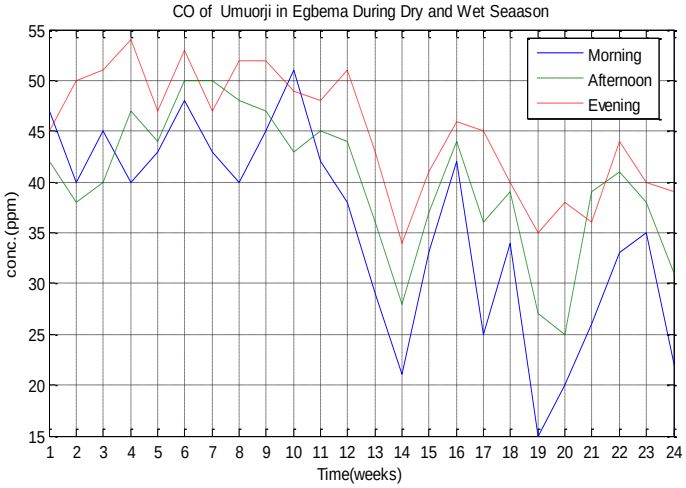

Time Series model of CO at St. Mary's Junction, Okigwe



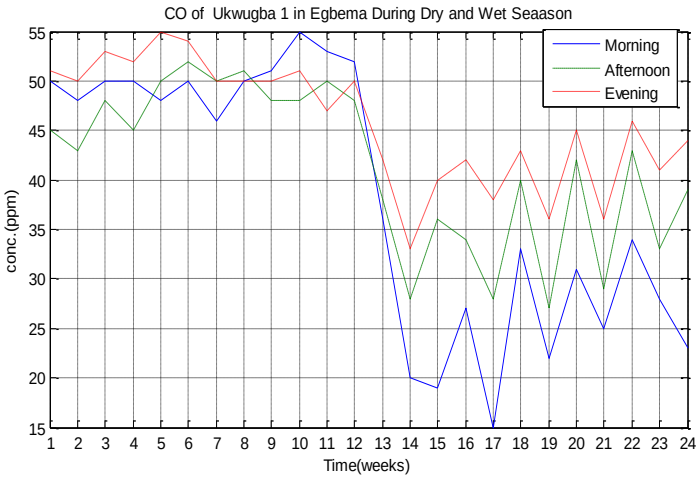
Time Series model of CO at Okigwe Express Junction



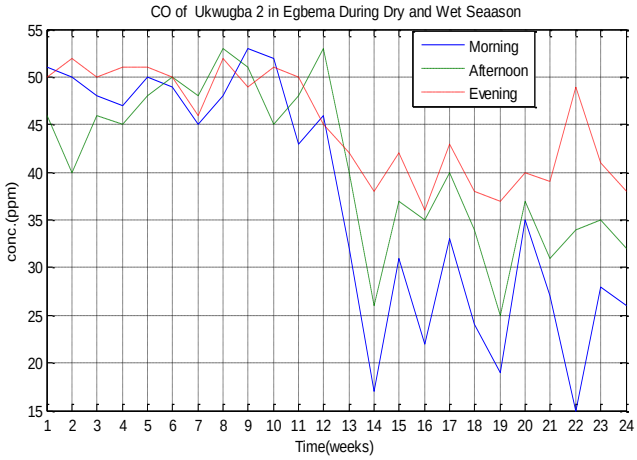

Time Series model of CO at Ihube, Okigwe



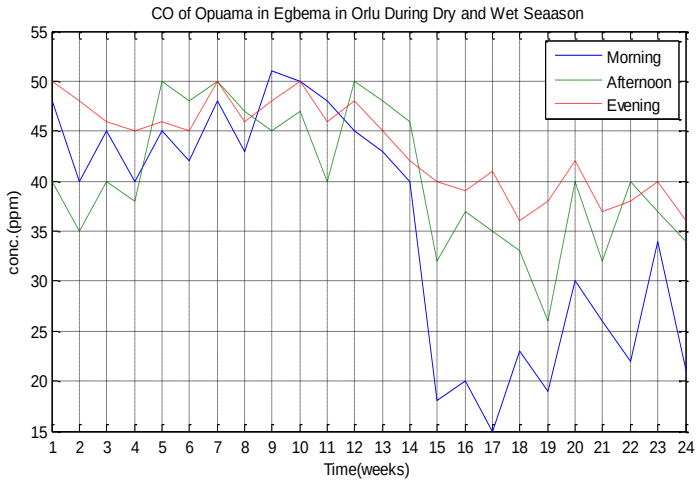

Time Series model of CO at Umuorji, Egbema



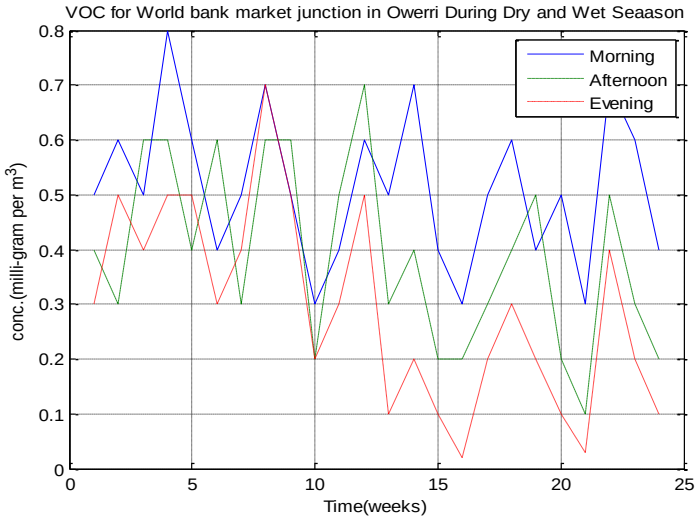

Time Series model of CO at Ukwugba1, Egbema



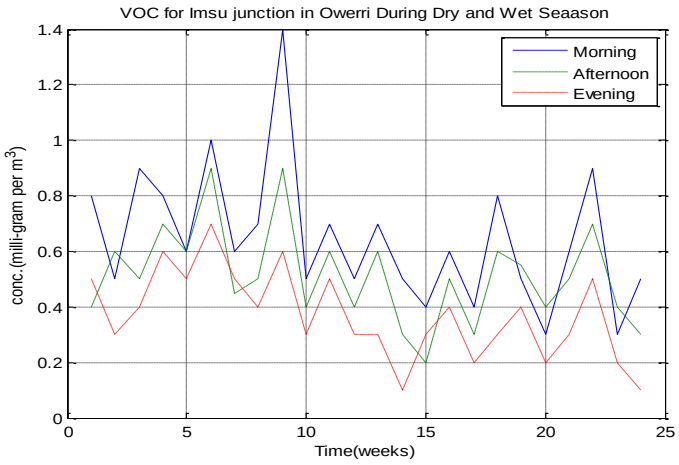

Time Series model of CO at Ukwugba 2, Egbema



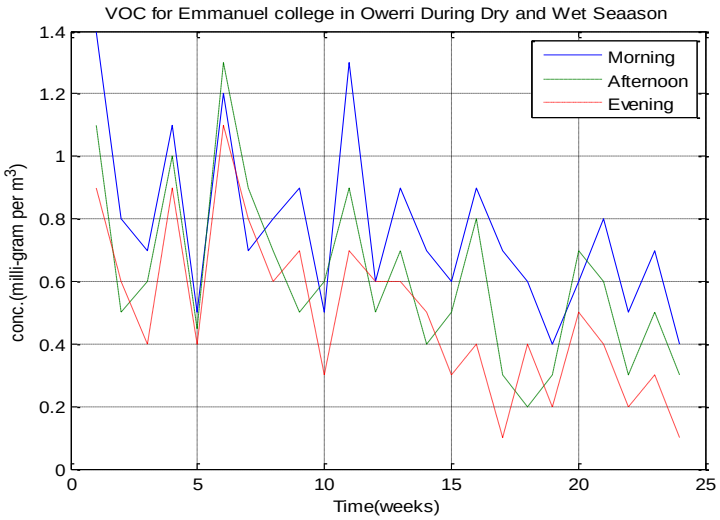

Time Series model of CO at Opuoma, Egbema



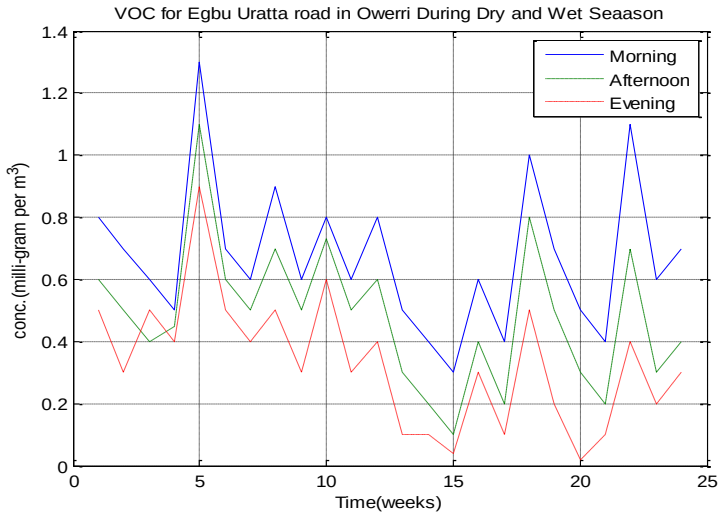

Time Series model of VOC at World Bank Market Junction, Owerri



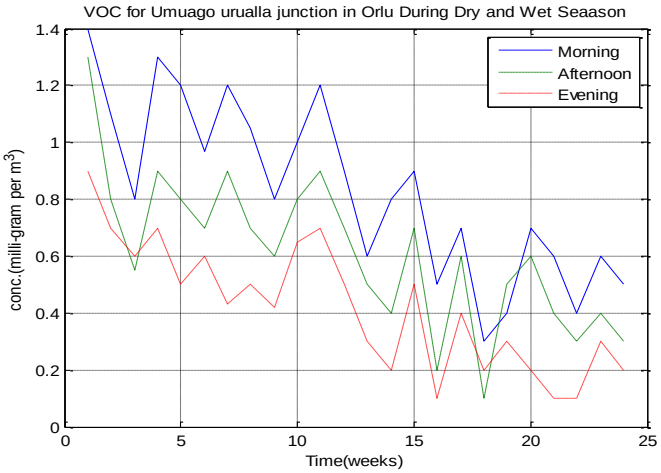

Time Series model of VOC at IMSU Junction, Owerri



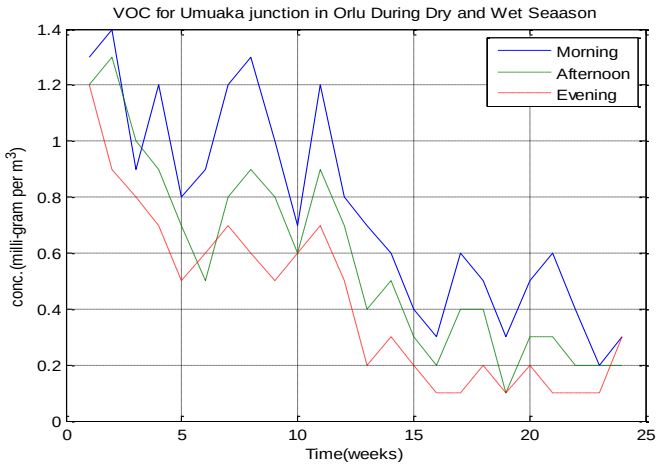
Time Series model of VOC at Emmanuel College Juntion, Owerri



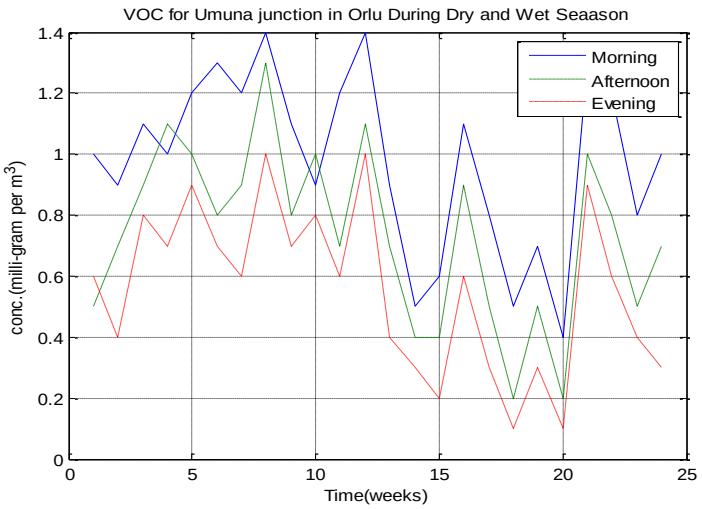

Time Series model of VOC at Egbu-Uratta Ring Road, Owerri



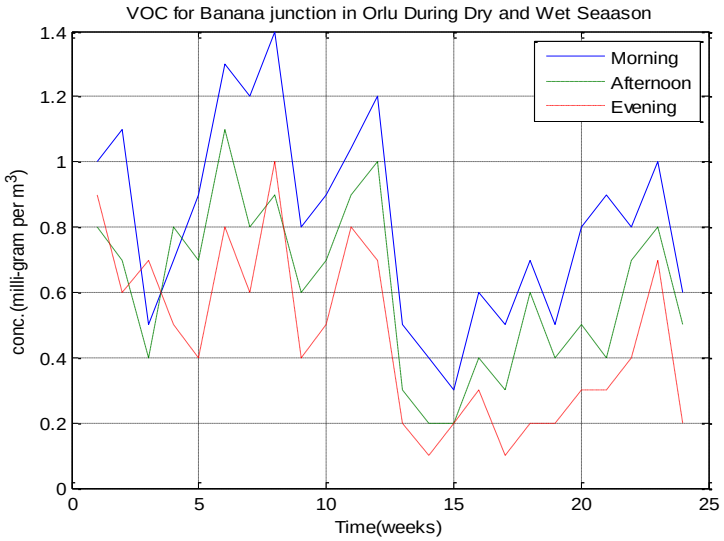

Time Series model of VOC at Umuago Urulla, Orlu



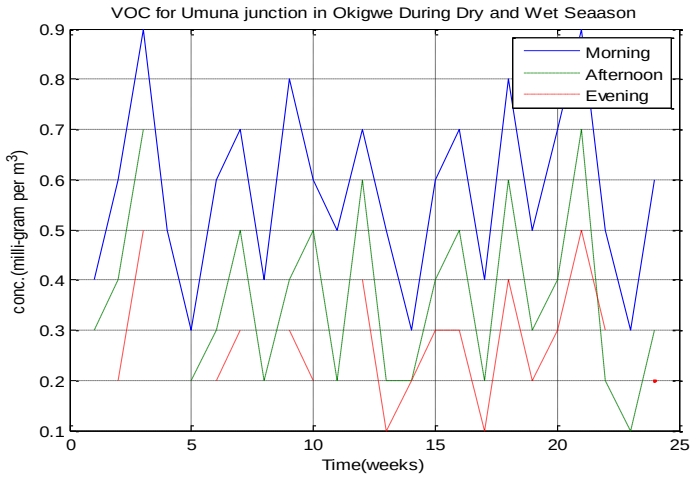
Time Series model of VOC at Umuaka Junction, Orlu



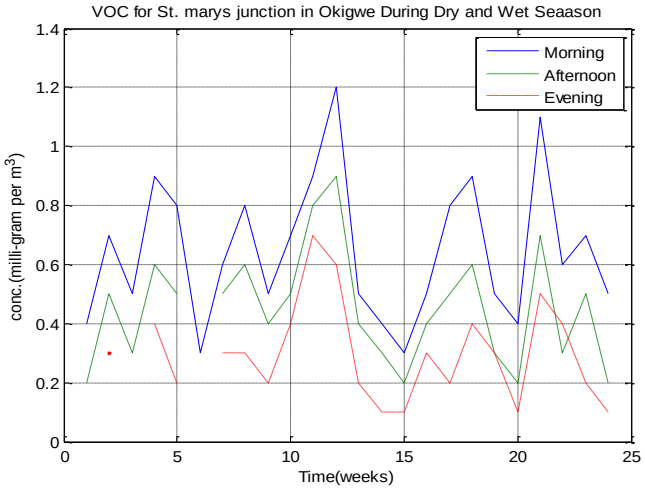

Time Series model of VOC at Umuna Junction, Owerri



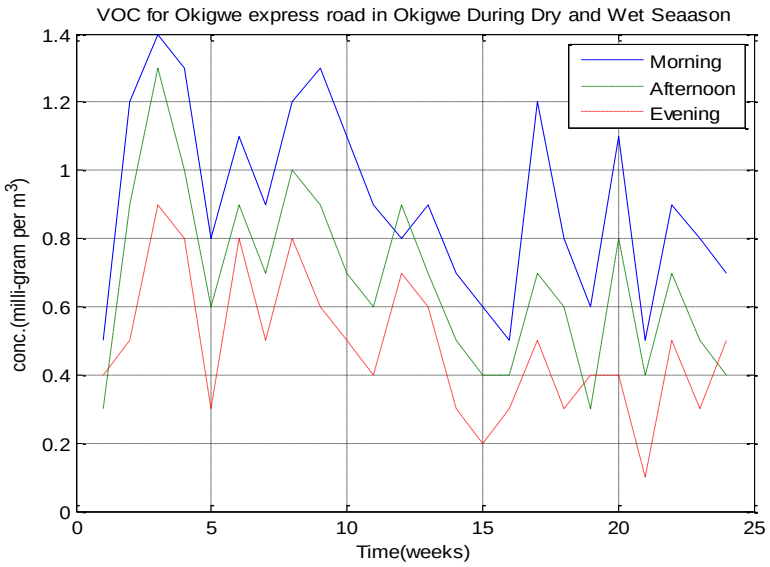

Time Series model of VOC at Banana Junction, Owerri



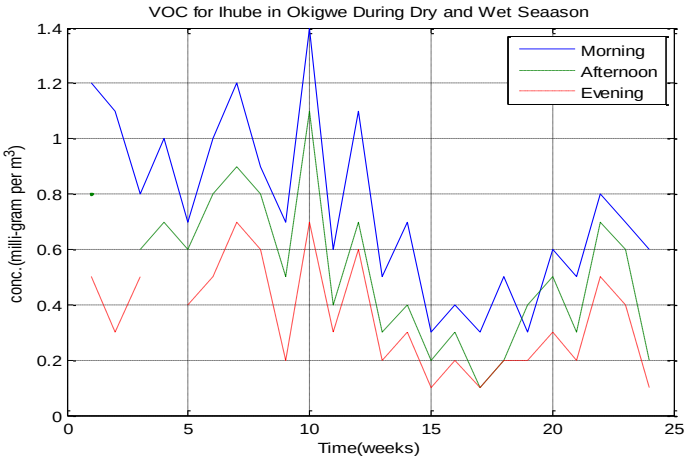

Time Series model of VOC at Umuna Junction, Okigwe



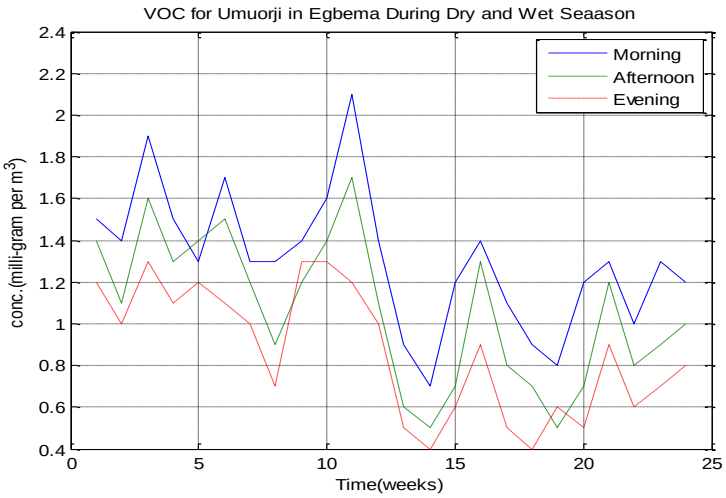

Time Series model of VOC at St. Mary's Junction, Okigwe



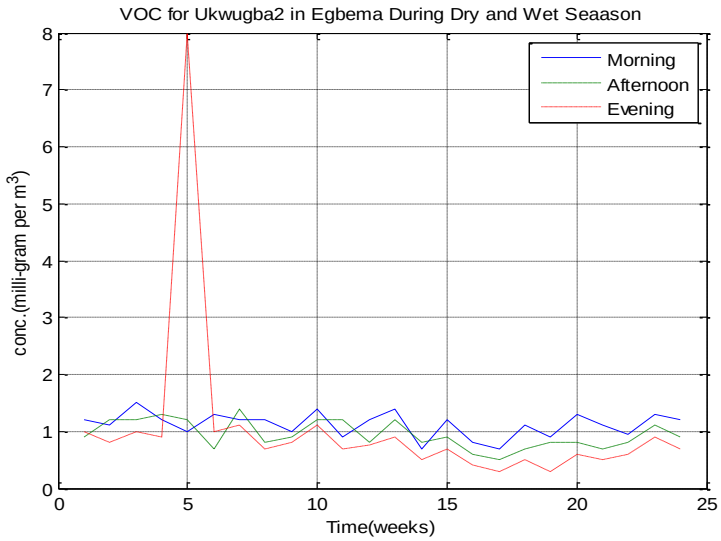

Time Series model of VOC at Okigwe Express Junction, Owerri



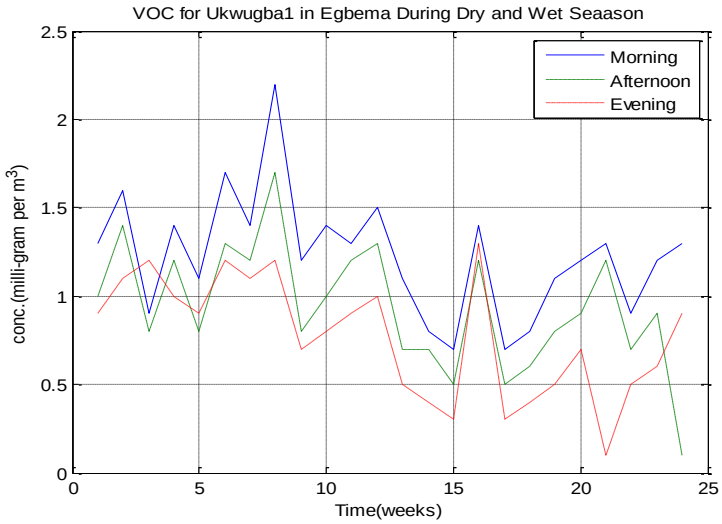

Time Series model of VOC at Ihube, Okigwe



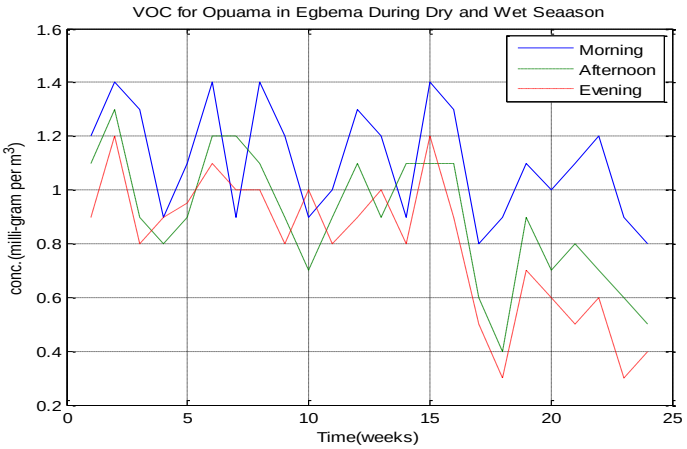
Time Series model of VOC at Umuorji, Egbema




Time Series model of VOC at Ukwugba 2




Time Series model of VOC at Ukwugba, Egbema

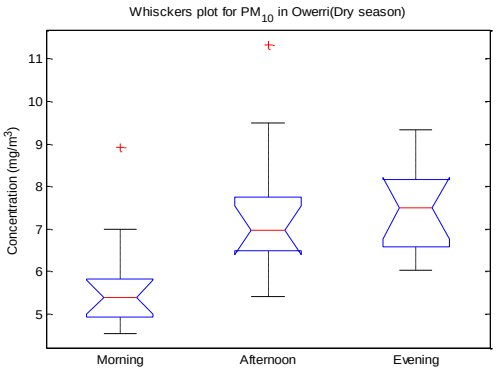


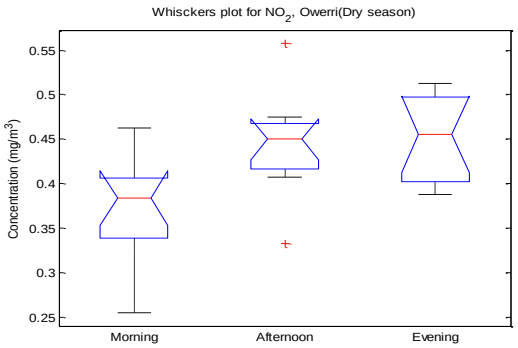

Time Series model of VOC at Opuom Egbema

## APPENDIX 7

## BOX AND WHISCKER'S PLOTS FOR DRY SEASON

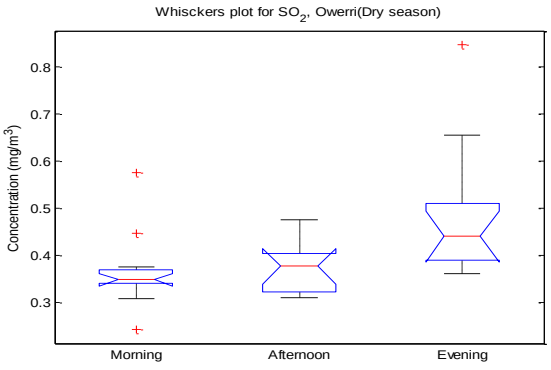
Owerri in Dry Season

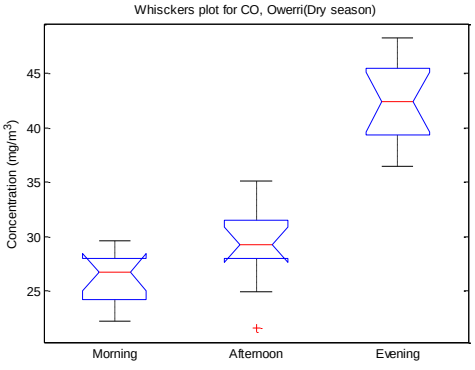



Box and Whisker plot of $PM_{10}$ in Owerri

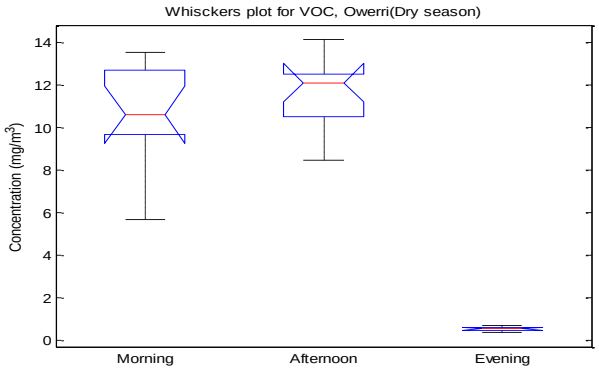
Box and Whisker plot of $NO_2$ in Owerri



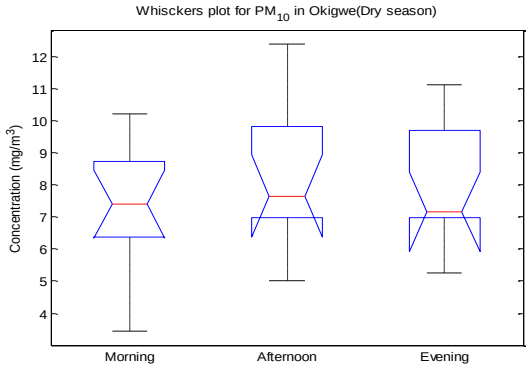

Box and Whisker plot of $SO_2$ in Owerri

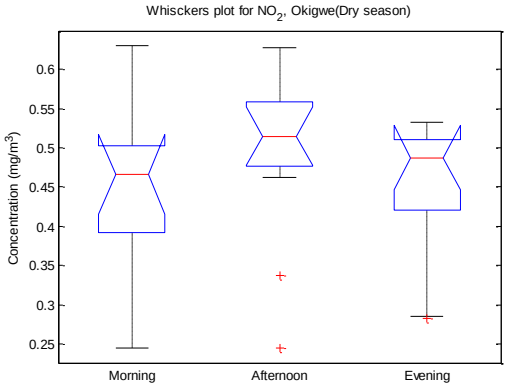
Box and Whisker plot of CO in Owerri



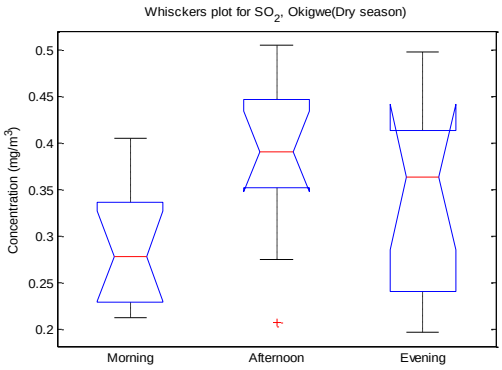

Box and Whisker plot of VOC in Owerri

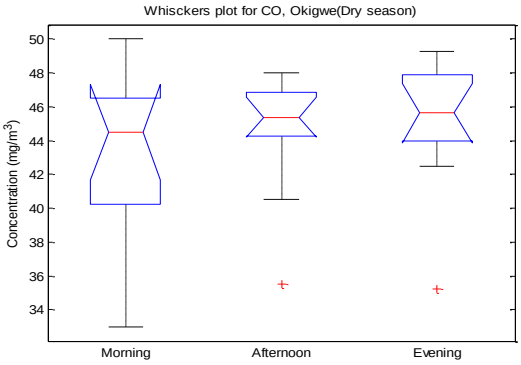
Okigwe in Dry Season



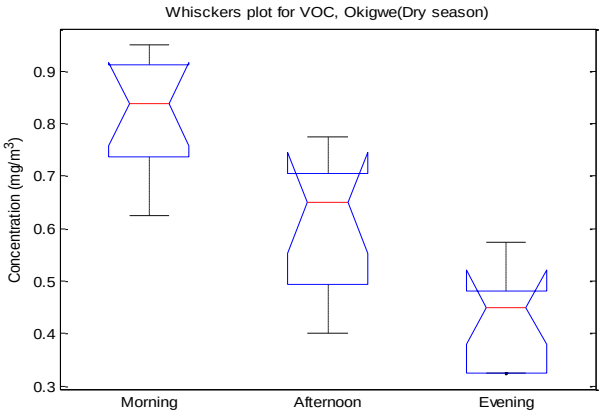




Box and Whisker plot of $PM_{10}$ in Okigwe  Box and Whisker plot of $NO_2$ in Okigwe



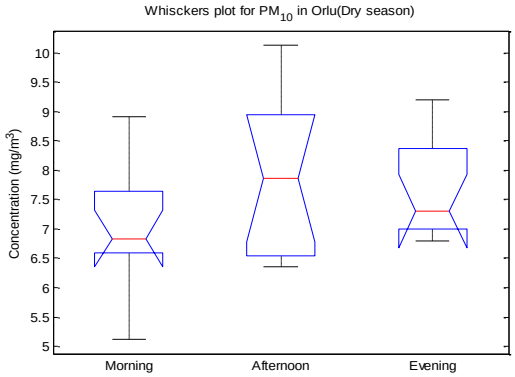




Box and Whisker plot of $SO_2$ in Okig  Box and Whisker plot of CO in Okigwe

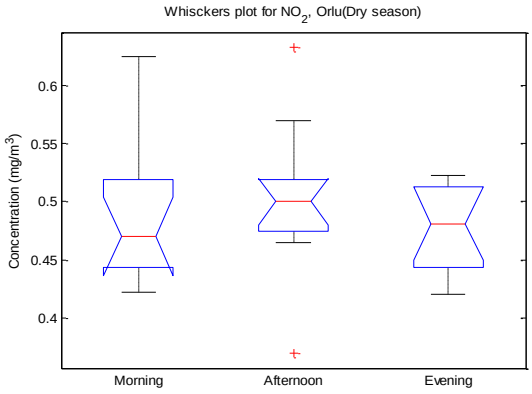



Box and Whisker plot of VOC in Okigwe

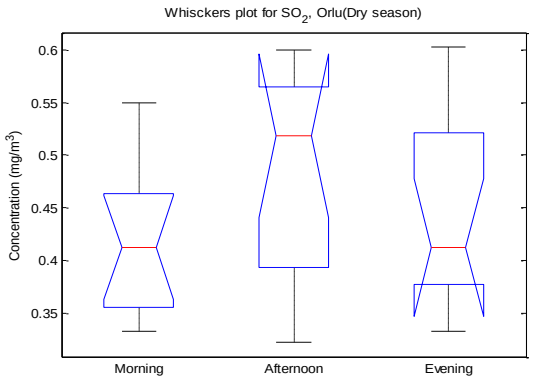
Orlu in Dry Season

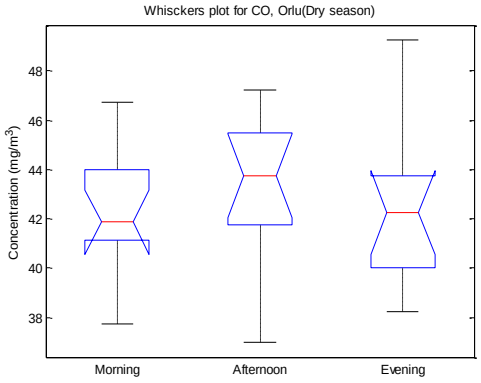



Box and Whisker plot of $PM_{10}$ in Orlu



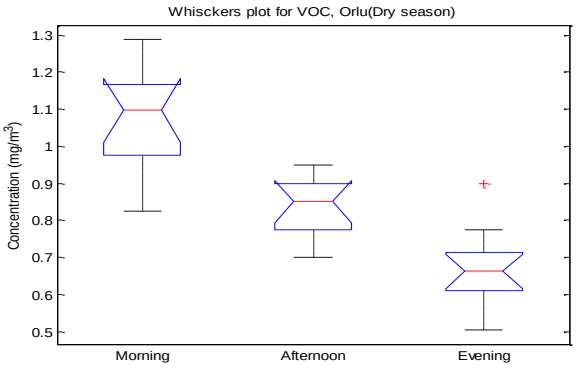

Box and Whisker plot of $NO_2$ in Orlu



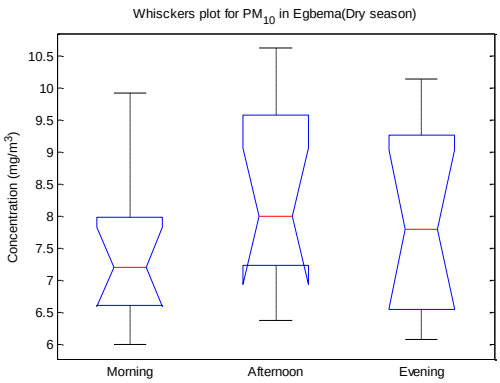

Box and Whisker plot of $SO_2$ in Orlu

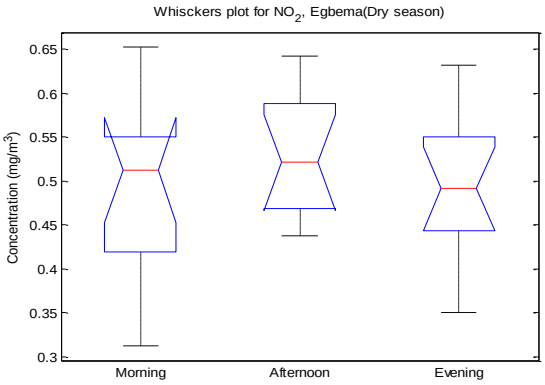
Box and Whisker plot of CO in Orlu



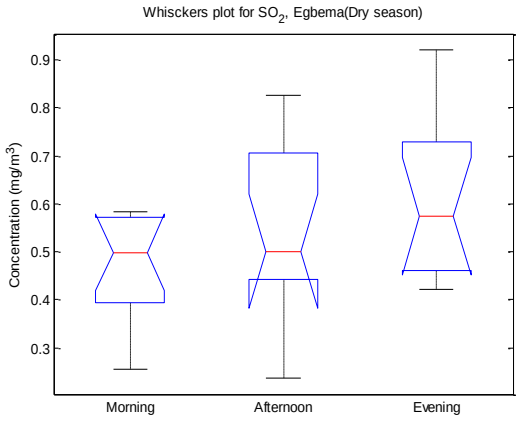

Box and Whisker plot of VOC in Orlu

Egbema in Dry Season

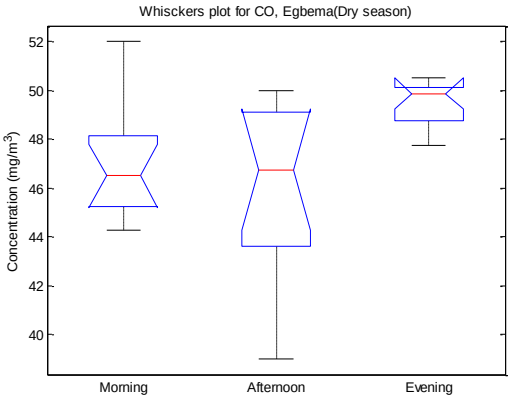


Box and Whisker plot of $PM_{10}$ in Egbema

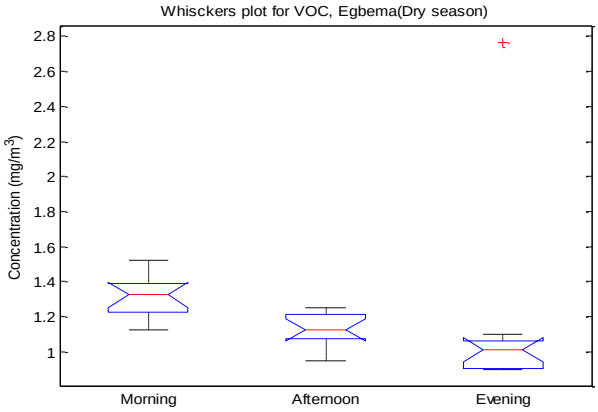



Box and Whisker plot of $NO_2$ in Egbema




Box and Whisker plot of $SO_2$ in Egbema

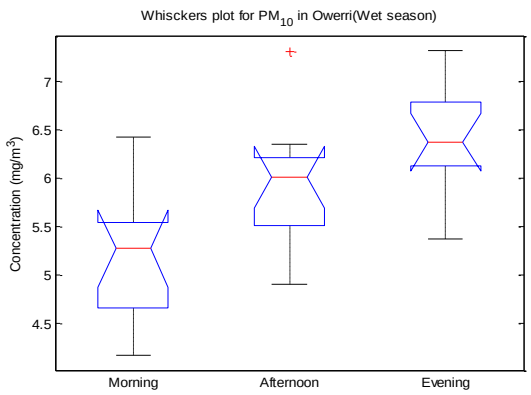
Box and Whisker plot of CO in Egbema



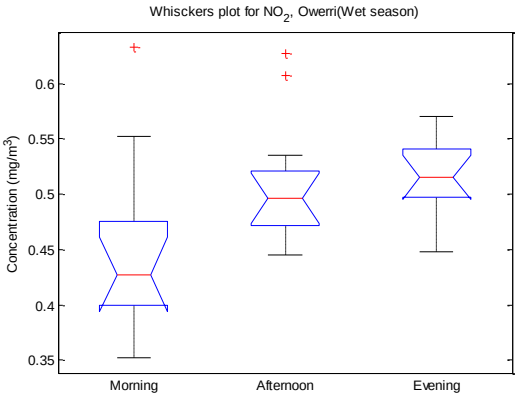

Box and Whisker plot of VOC in Egbema

**Box and Whiscker's Plots for Wet Season**

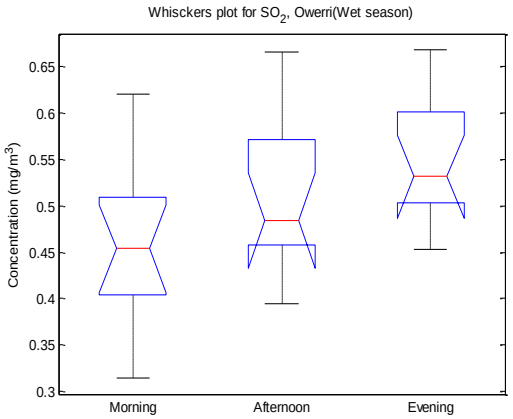
Owerri in Wet Season



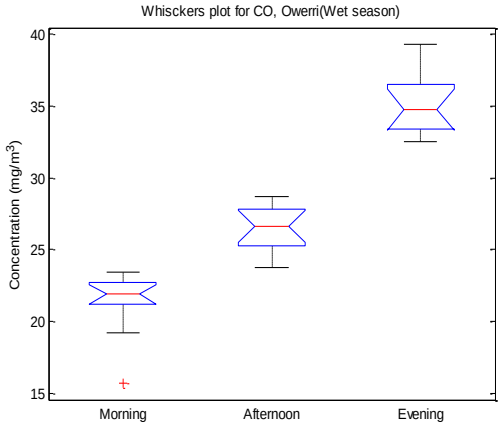

Box and Whisker plot of $PM_{10}$ in Owerri



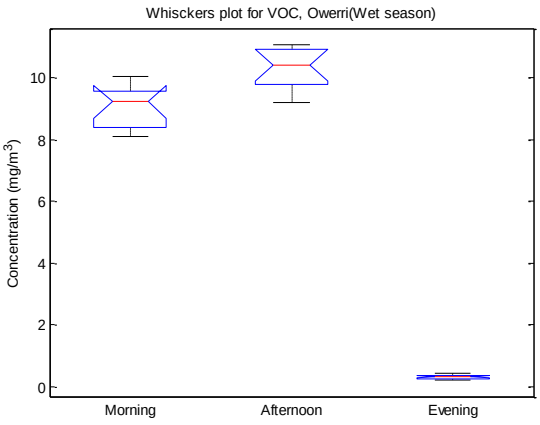

Box and Whisker plot of $NO_2$ Owerri




Box and Whisker plot of $SO_2$ in Owerri

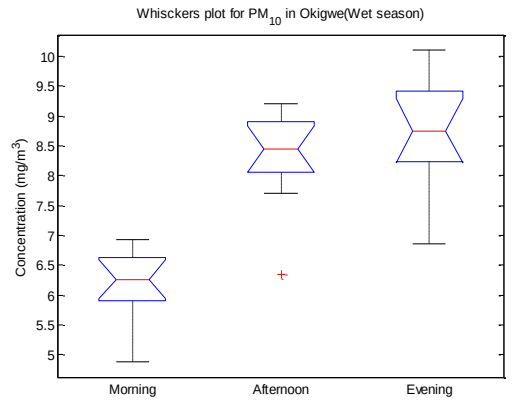



Box and Whisker plot of CO in Owerri

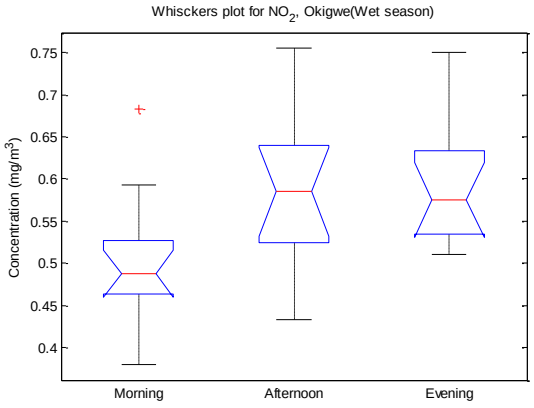



Box and Whisker plot of VOC in Owerri

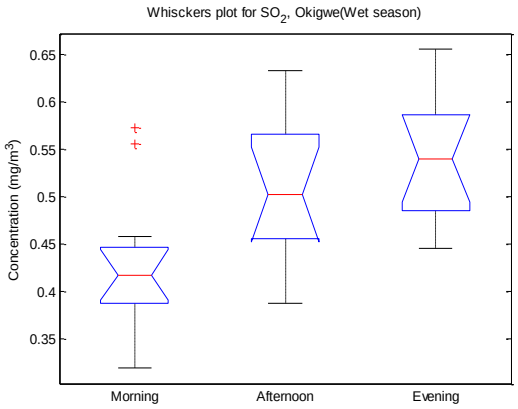
Okigwe in Wet Season



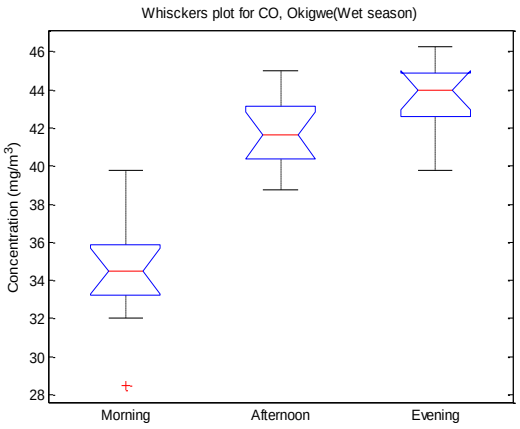

Box and Whisker plot of $PM_{10}$ in Okigwe



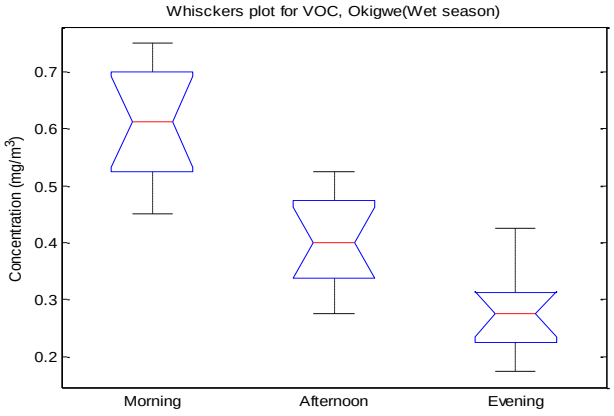

Box and Whisker plot of $NO_2$ in Okigwe




Box and Whisker plot of $SO_2$ in Okigwe

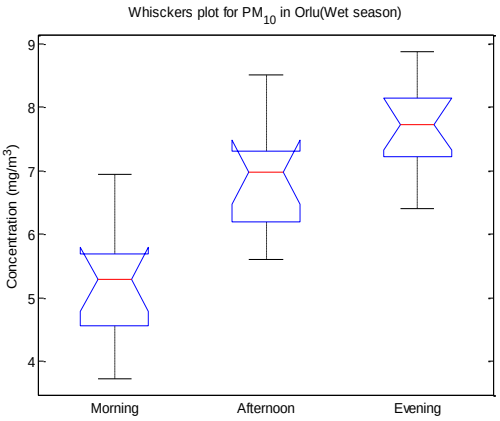



Box and Whisker plot of CO in Okigwe

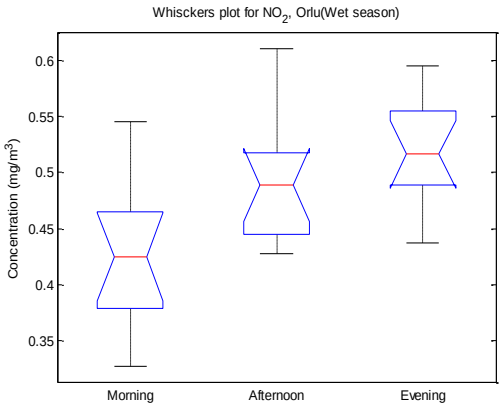



Box and Whisker plot of VOC in Okigwe

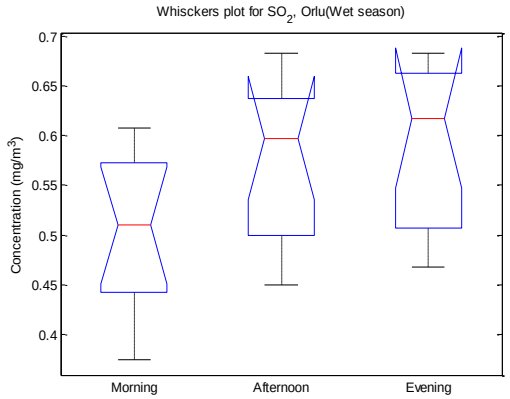
Orlu in Wet Season



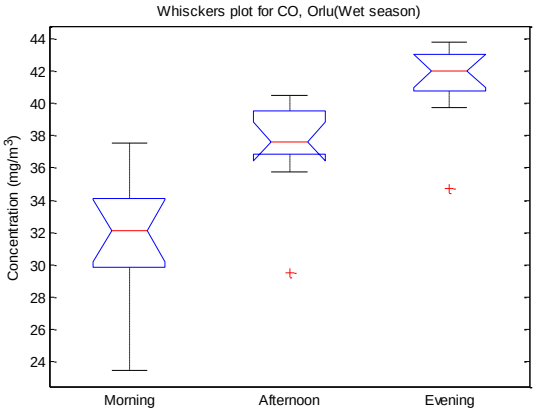

Box and Whisker plot of $PM_{10}$ in Orlu



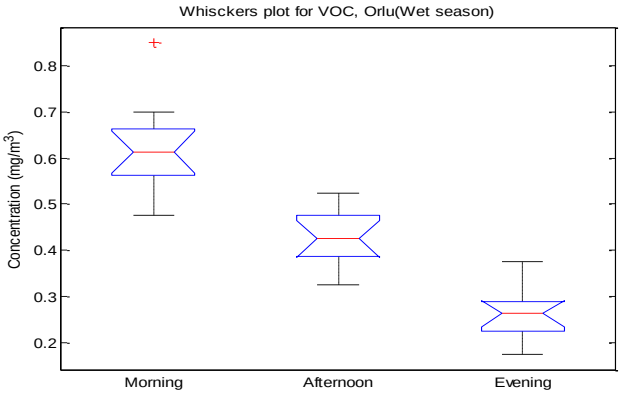

Box and Whisker plot of $NO_2$ in Orlu




Box and Whisker plot of $SO_2$ in Orlu

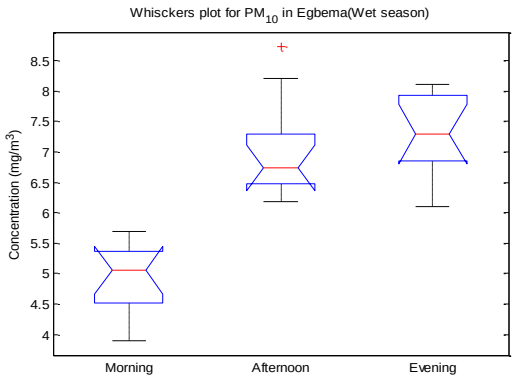



Box and Whisker plot of CO in Orlu

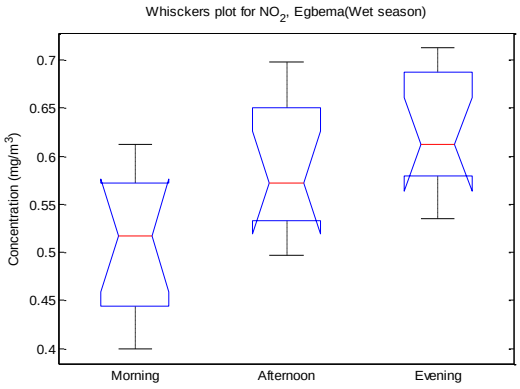



Box and Whisker plot of VOC in Orlu

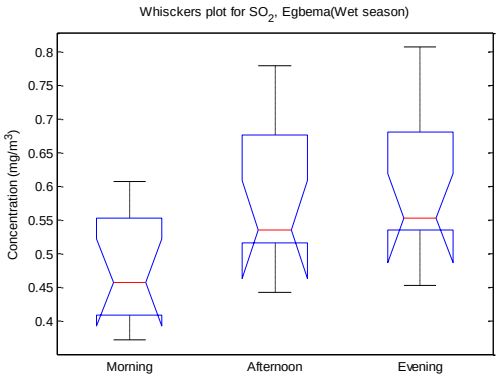
Egbema in Wet season



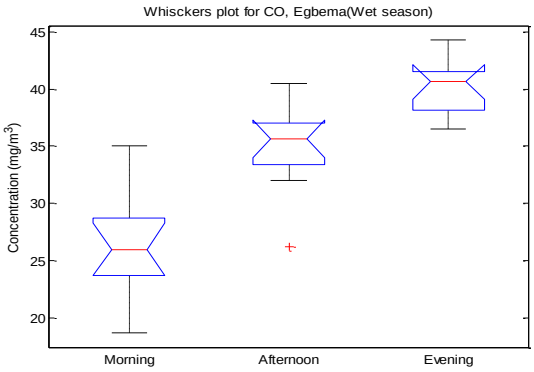

Box and Whisker plot of $PM_{10}$ in Egbema



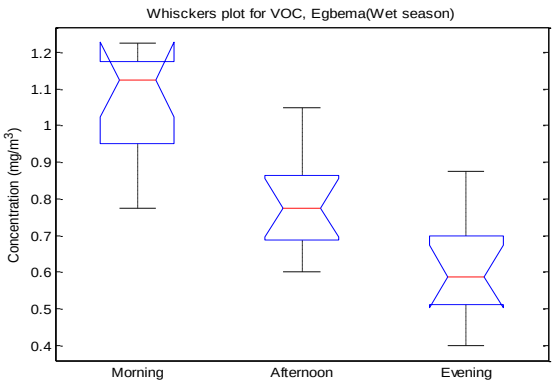

Box and Whisker plot of $NO_2$ in Egbema




Box and Whisker plot of $SO_2$ in Egbema

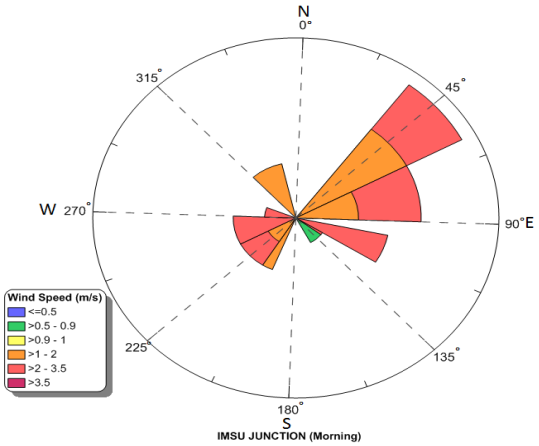



Box and Whisker plot of CO in Egbema

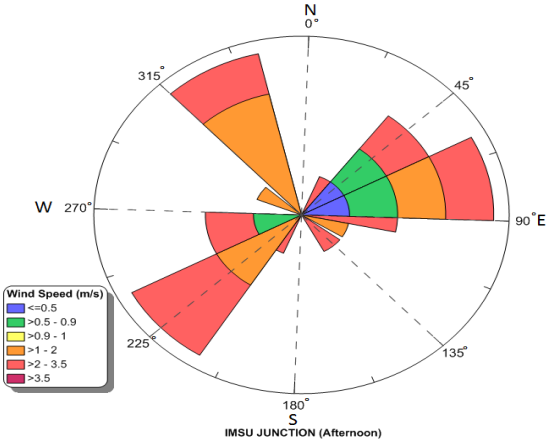



Box and Whisker plot of VOC in

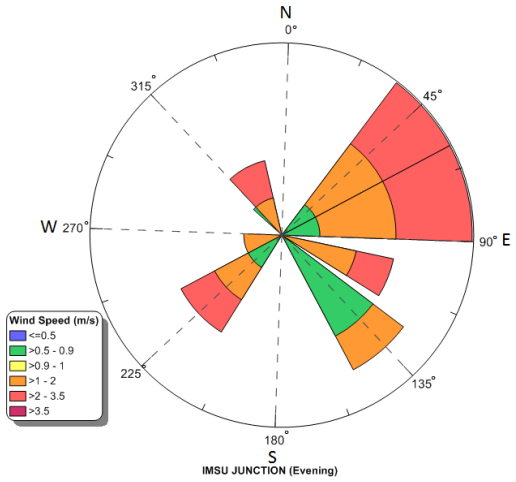
## APPENDIX 8
## Presentation of Wind Rose Models
## Owerri



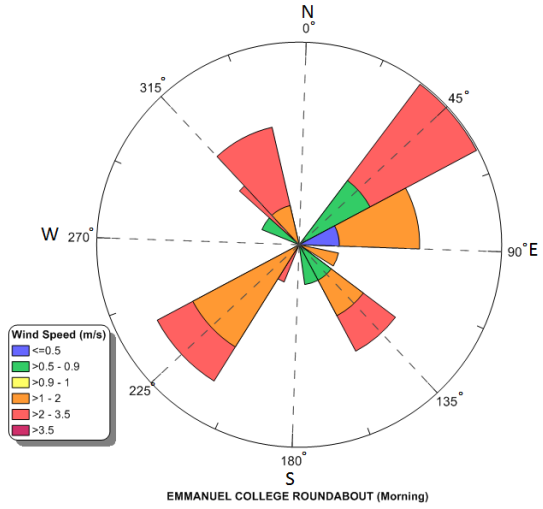

Wind rose Diagram at IMSU Junction (Morning)



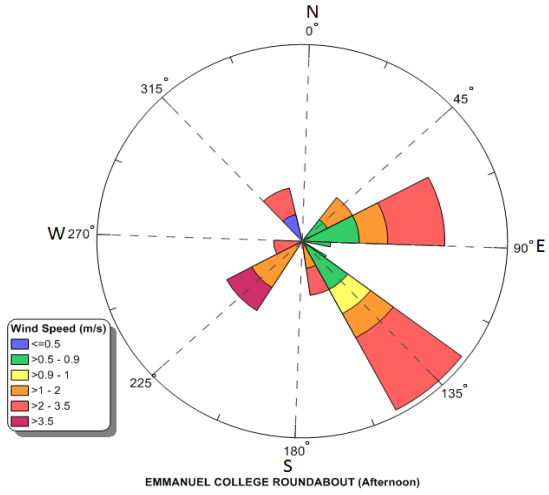

Wind rose Diagram at IMSU Junction , Owerri ( Afternoon)



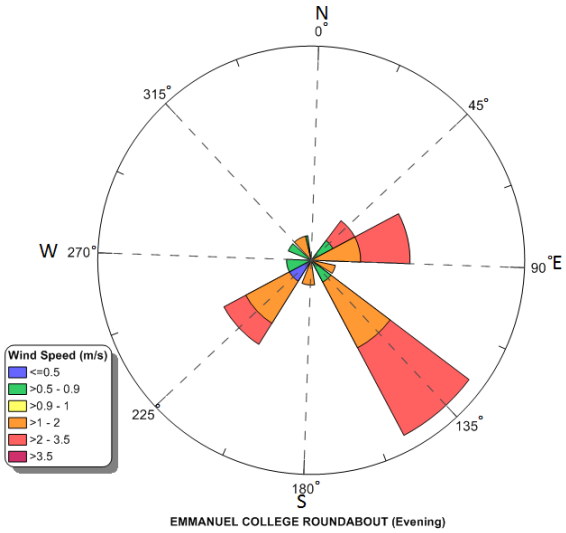

Wind rose Diagram at IMSU Junction , Owerri (Afternoon)



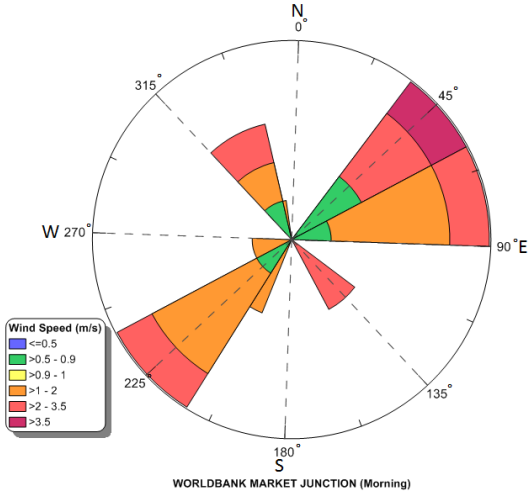

Wind rose Diagram at Emmanuel College Junction, Owerri (Morning)



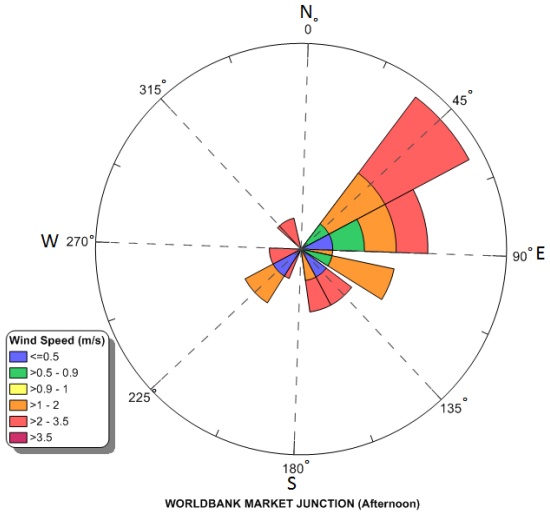

Wind rose Diagram at Emmanuel College Junction, Owerri (Afternoon)



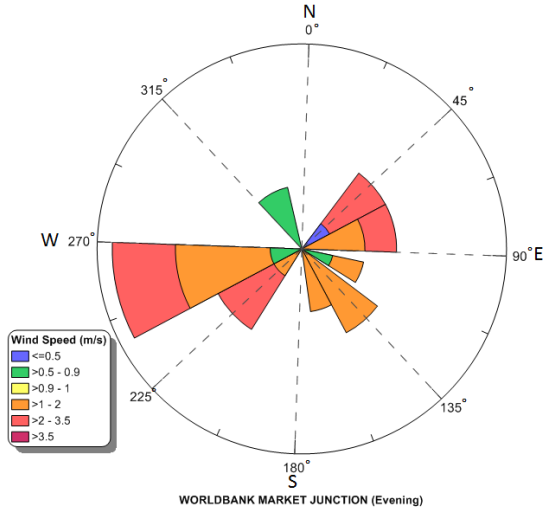

Wind rose Diagram at Emmanuel College Junction, Owerri (Evening)



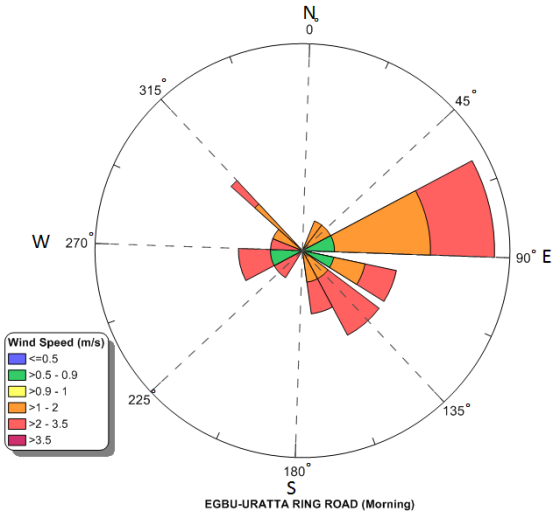

Wind rose Diagram at World Bank Market Junction, Owerri (Morning)



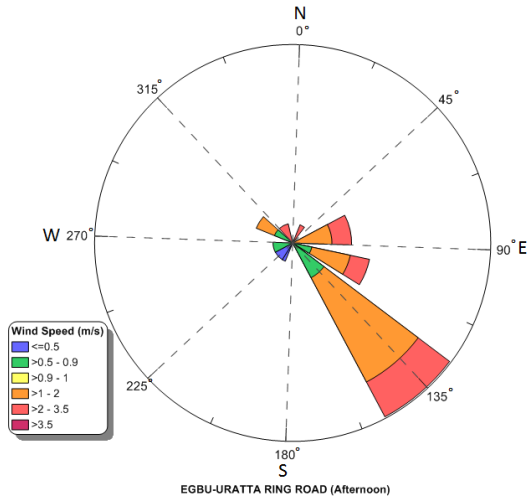
Wind rose Diagram at World Bank Market Junction, Owerri (Afternoon)



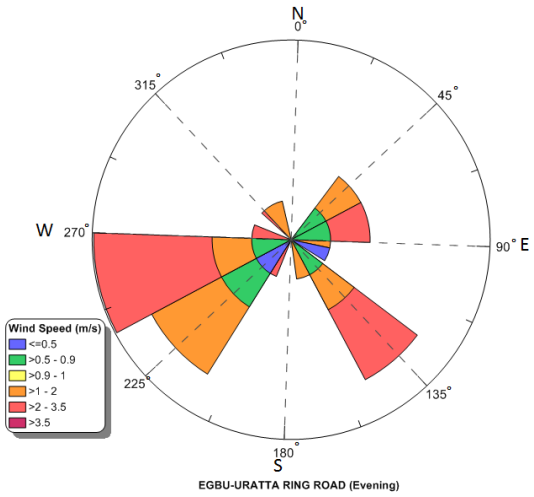

Wind rose Diagram at World Bank Market Junction, Owerri (Evening)




Wind rose Diagram at Egbu-Uratta Ring Road, Owerri (Morning)

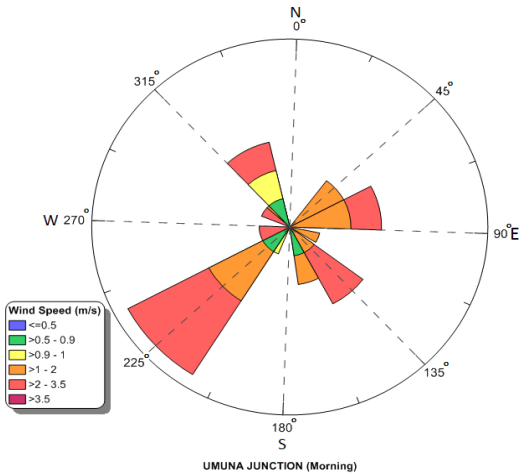



Wind rose Diagram at Egbu-Uratta Ring Road, Owerri (Afternoon)

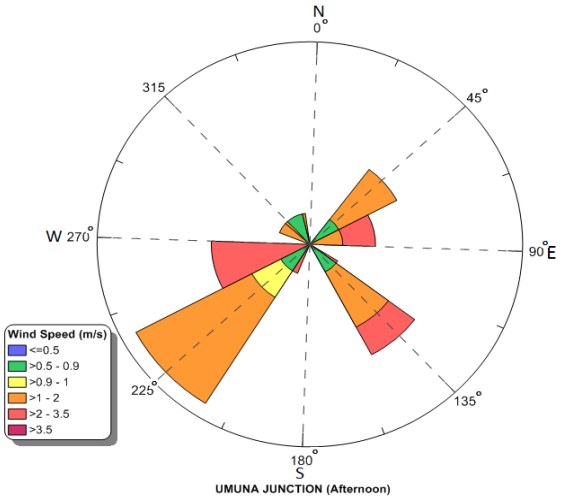



Wind rose Diagram at Egbu-Uratta Ring Road, Owerri (Evening)

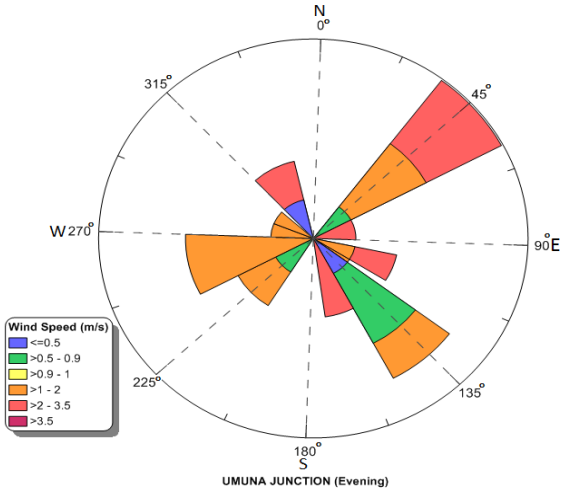
**OKIGWE**



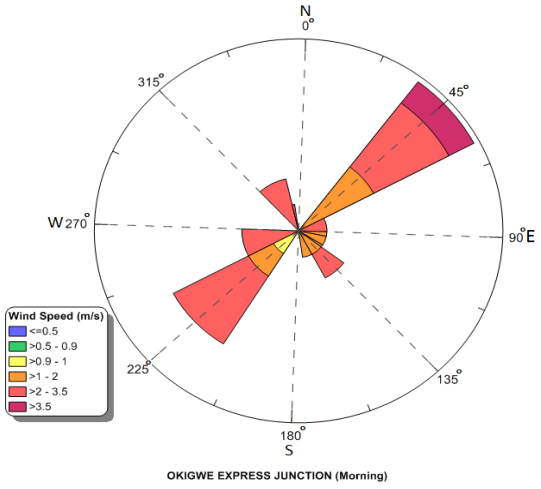
Wind rose Diagram at Umuna Junction, Okigwe (Morning)



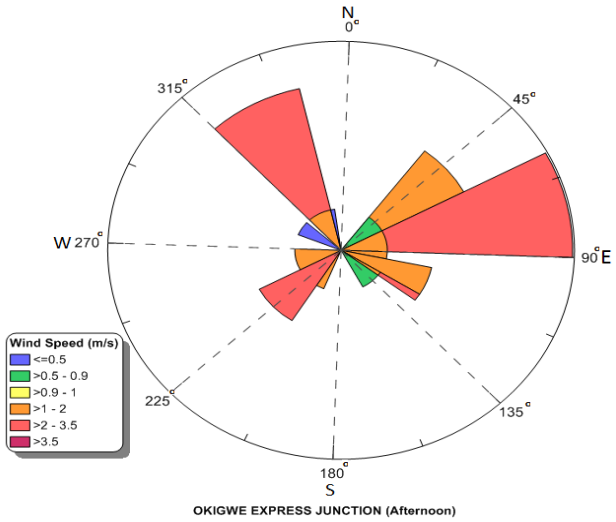

Wind rose Diagram at Umuna Junction, Okigwe (Afternoon)



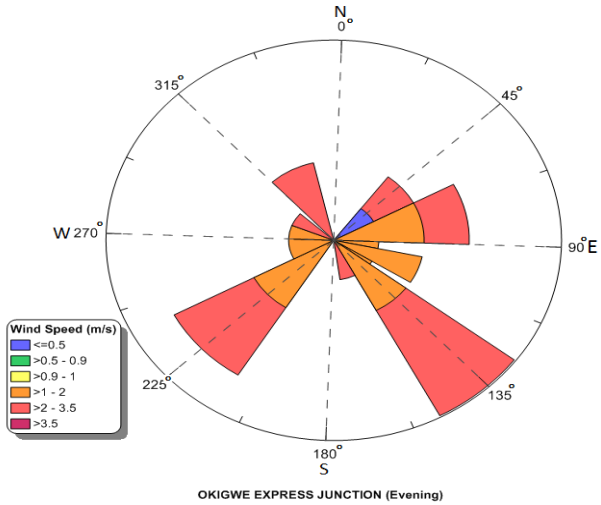

Wind rose Diagram at Umuna Junction, Okigwe (Evening)



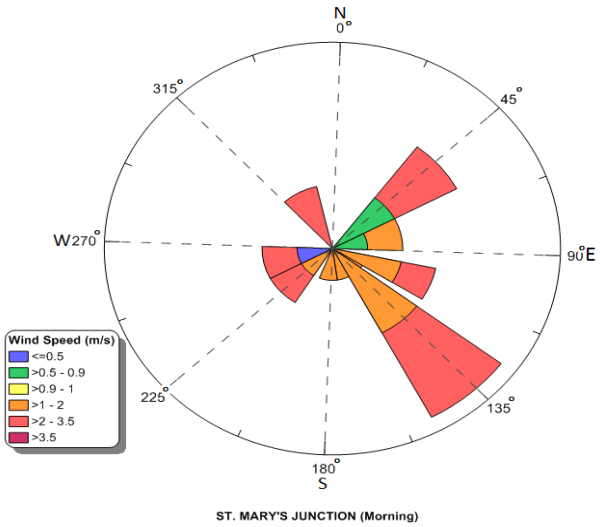
Wind rose Diagram at Okigwe Express Junction (Morning)



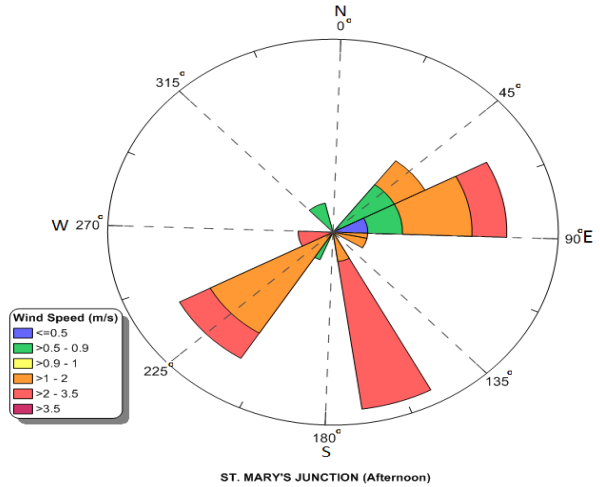

Wind rose Diagram at Okigwe Express Junction (Afternoon)



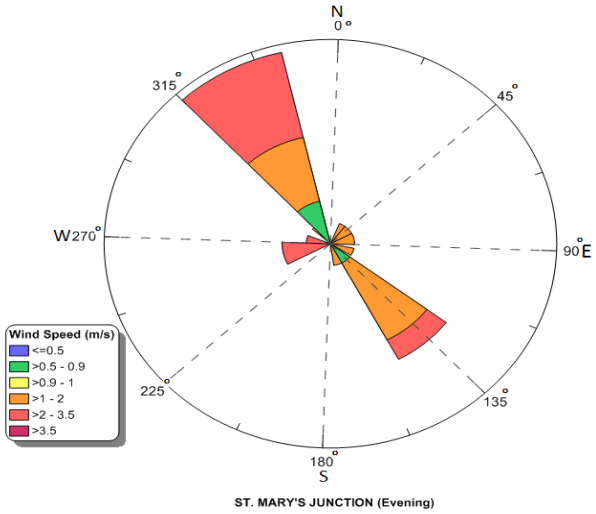

Wind rose Diagram at Okigwe Express Junction (Evening)



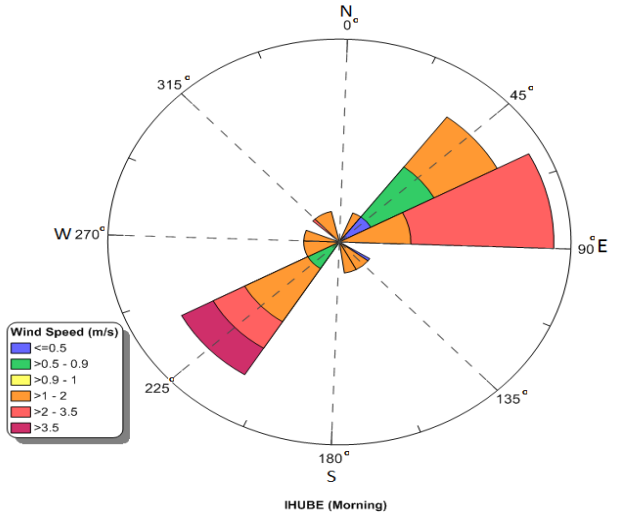

Wind rose Diagram at St. Mary's Junction, Okigwe (Morning)



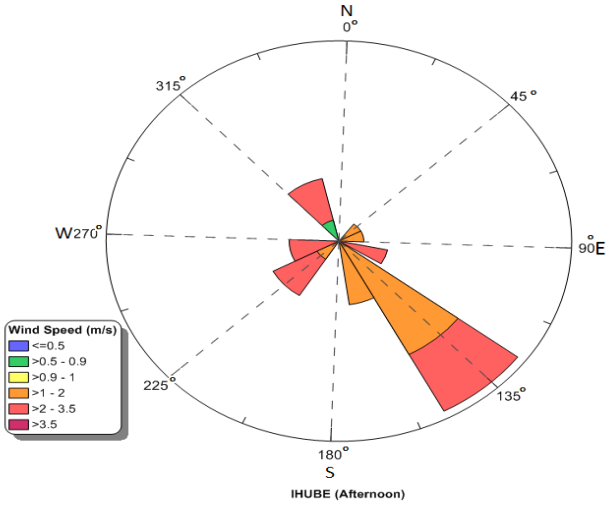

Wind rose Diagram at St. Mary's Junction, Okigwe (Afternoon)



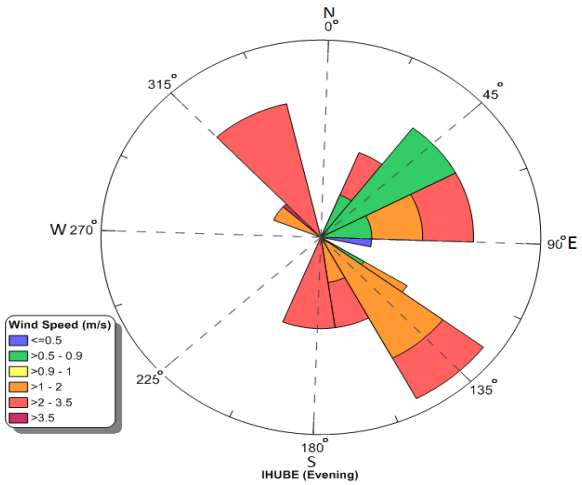
Wind rose Diagram at St. Mary's Junction, Okigwe (Evening




Wind rose Diagram at Ihube, Okigwe (Morning)

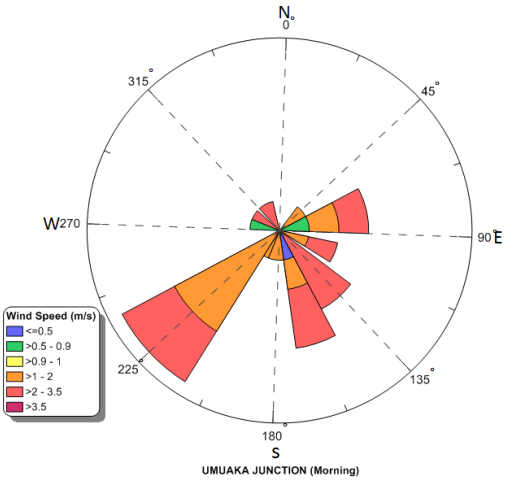



Wind rose Diagram at Ihube, Okigwe (Afternoon)

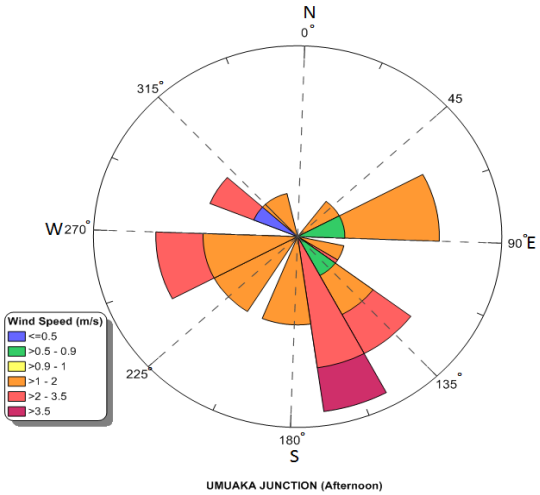



Wind rose Diagram at Ihube, Okigwe (Evening)

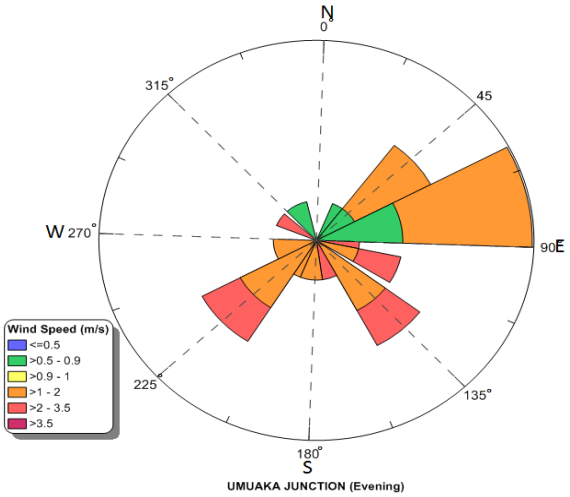
**ORLU**



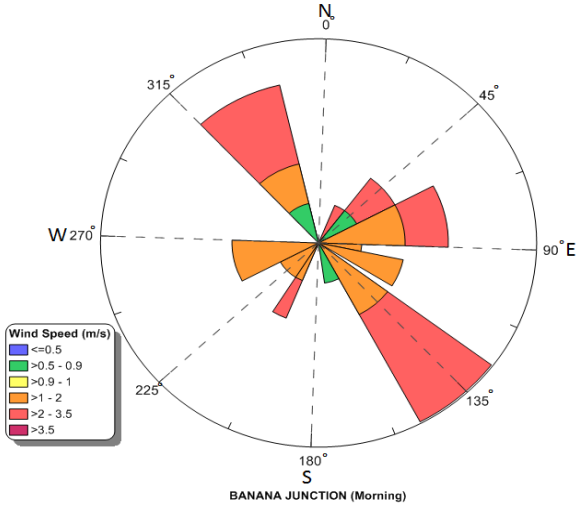

Wind rose Diagram at Umuaka Junction, Orlu (Mornning)



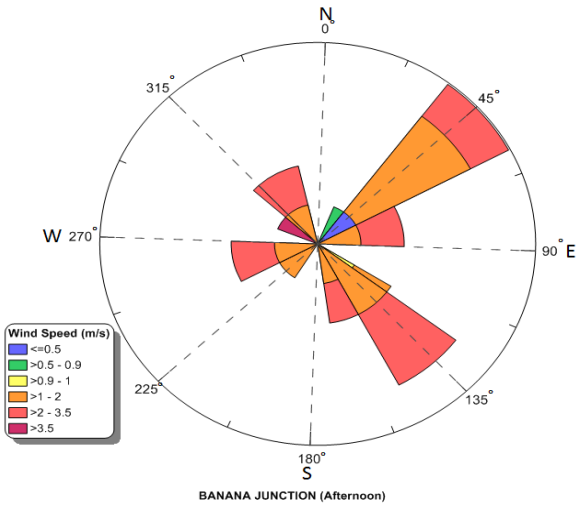
Wind rose Diagram at Umuaka Junction, Orlu (Afternoon)



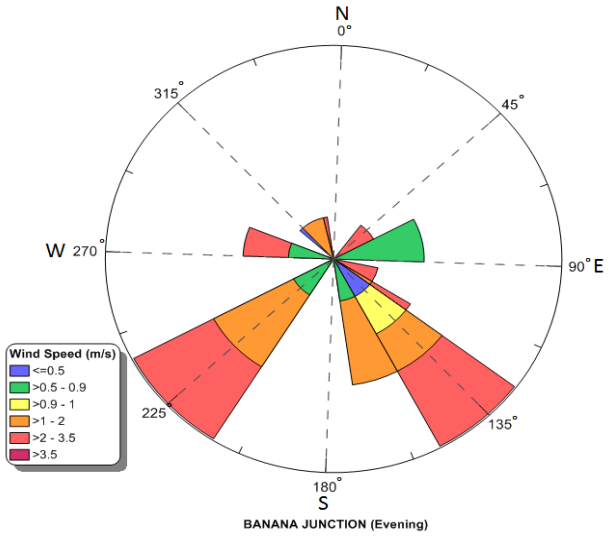

Wind rose Diagram at Umuaka Junction, Orlu (Evening)



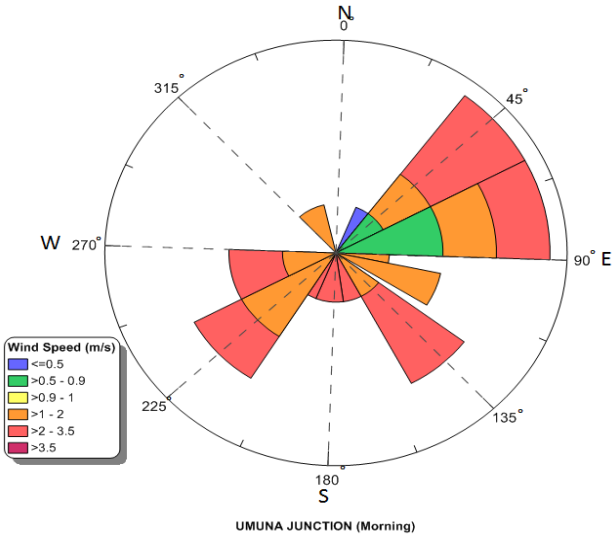

Wind rose Diagram at Banana Junction, Orlu (Morning)



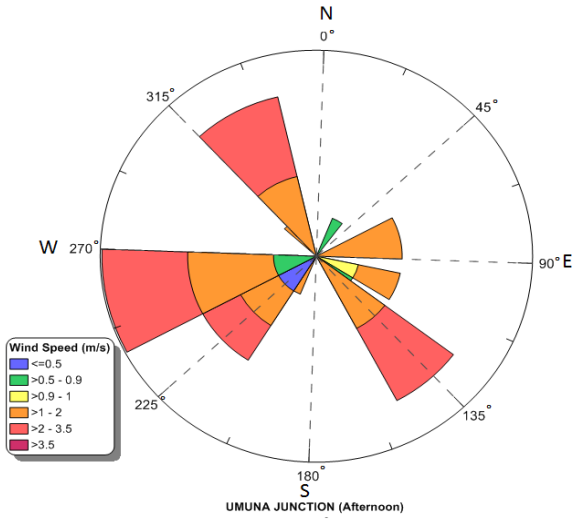

Wind rose Diagram at Banana Junction, Orlu (Afternoon)



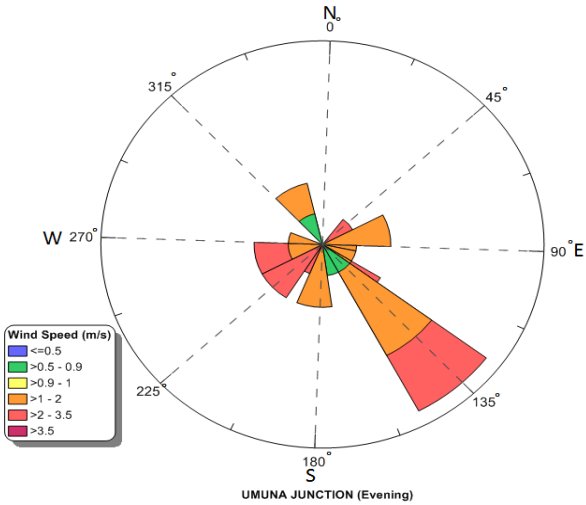

Wind rose Diagram at Banana Junction, Orlu (Evening)



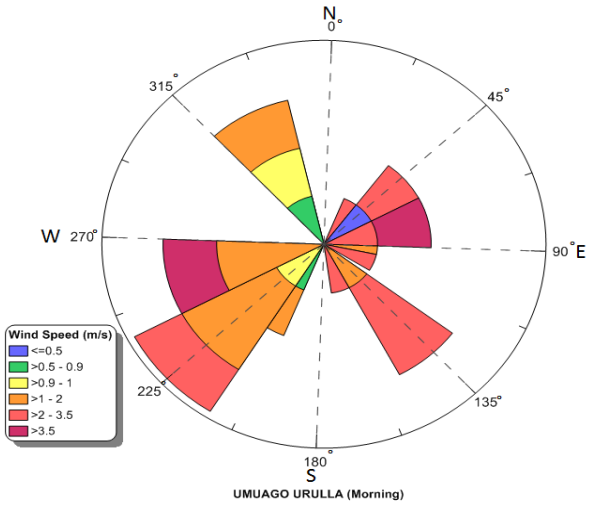
Wind rose Diagram at Umuna Junction, Orlu (Morning)



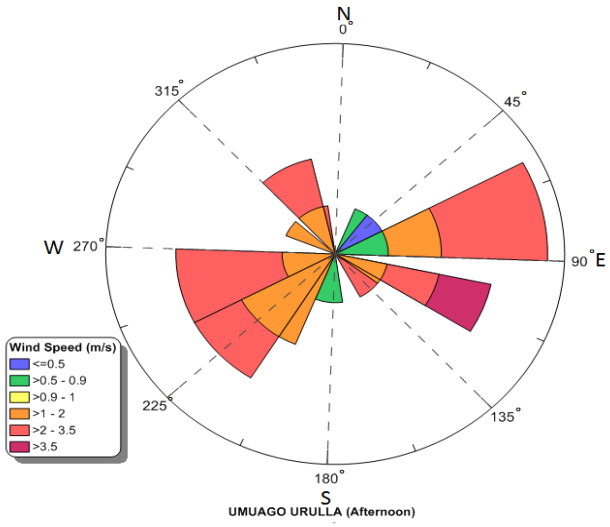

Wind rose Diagram at Umuna Junction, Orlu (Afternoon)



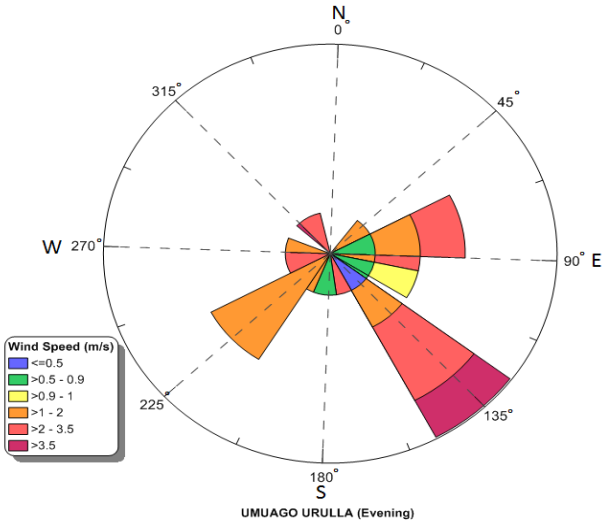

Wind rose Diagram at Umuna Junction, Orlu (Evening)




Wind rose Diagram at Umuago Urualla, Orlu (Morning)

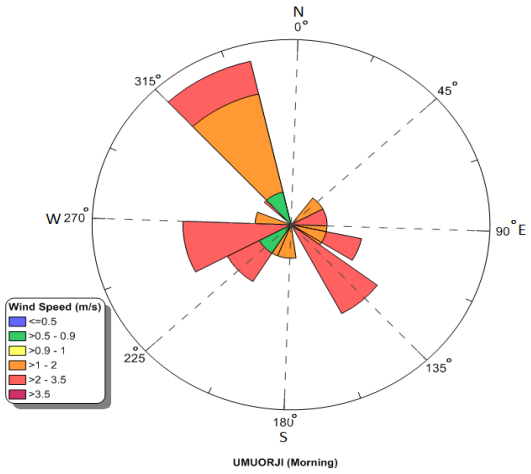



Wind rose Diagram at Umuago Urualla, Orlu (Afternoon)

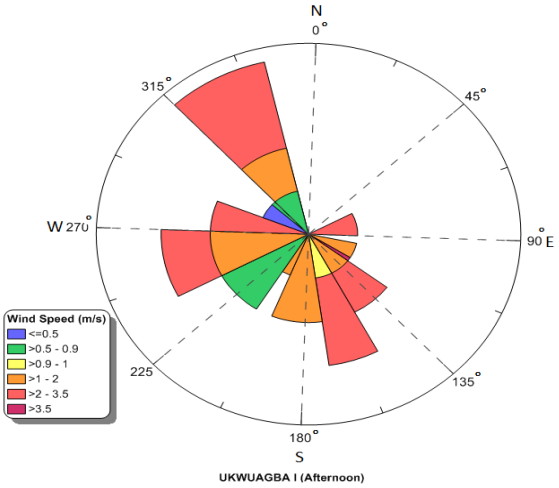


Wind rose Diagram at Umuago Urualla, Orlu (Evening)

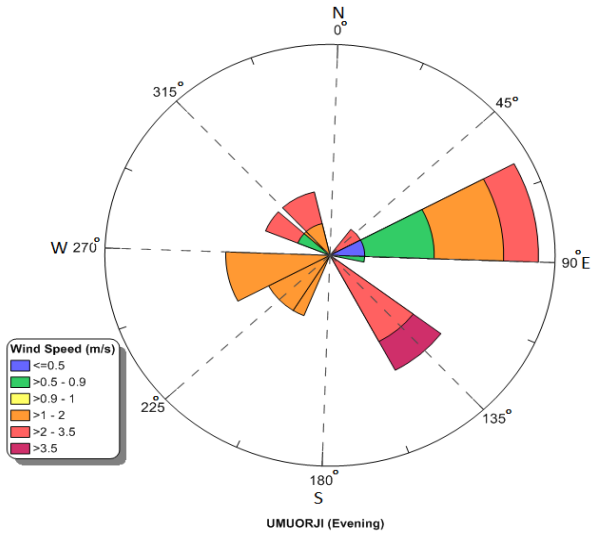
**EGBEMA**



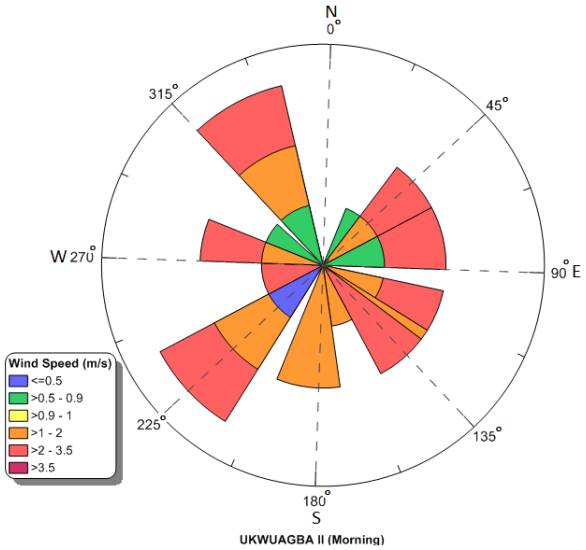

Wind rose Diagram at Umuorji, Egbema (Morning)



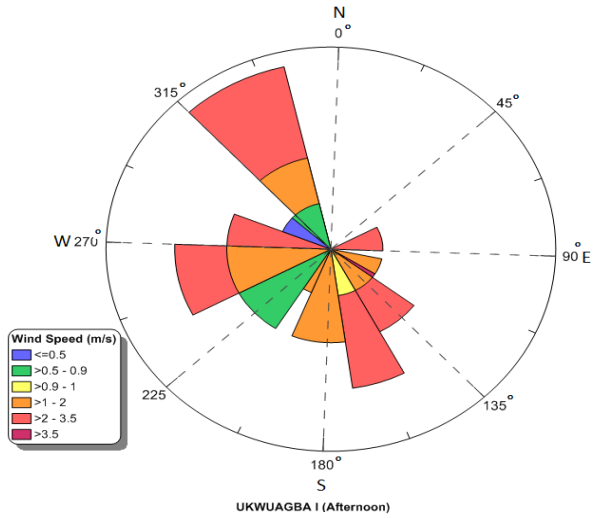

Wind rose Diagram at Umuorji, Egbema (Afternoon)



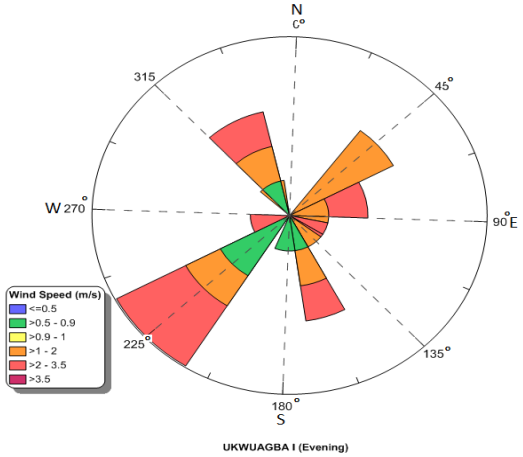

Wind rose Diagram at Umuorji, Egbema (Evening)



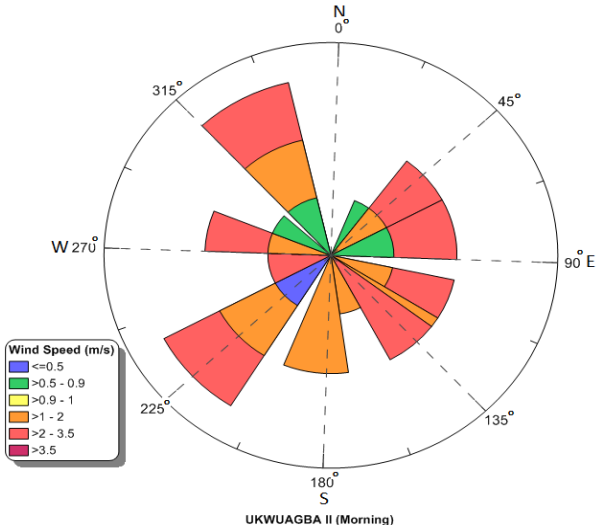

Wind rose Diagram at Ukwugba 1, Egbema (Morning)



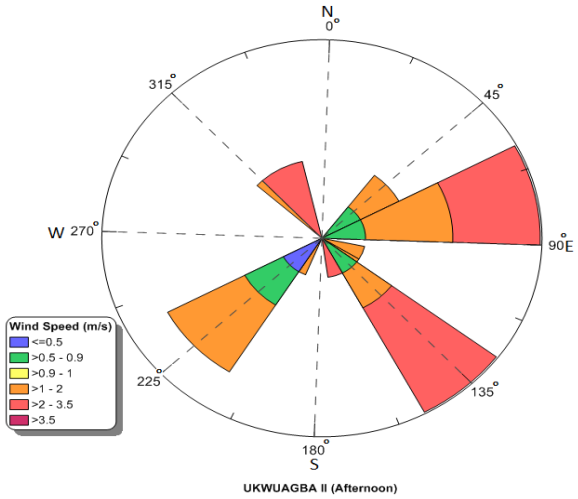

Wind rose Diagram at Ukwugba 1, Egbema (Afternoon)



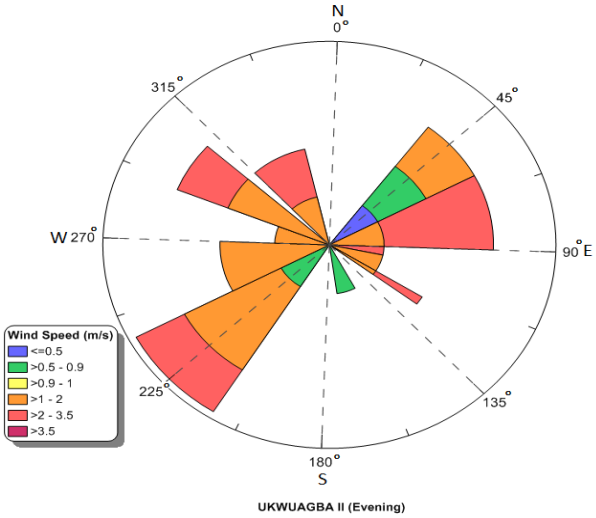

Wind rose Diagram at Ukwugba 1, Egbema (Evening)



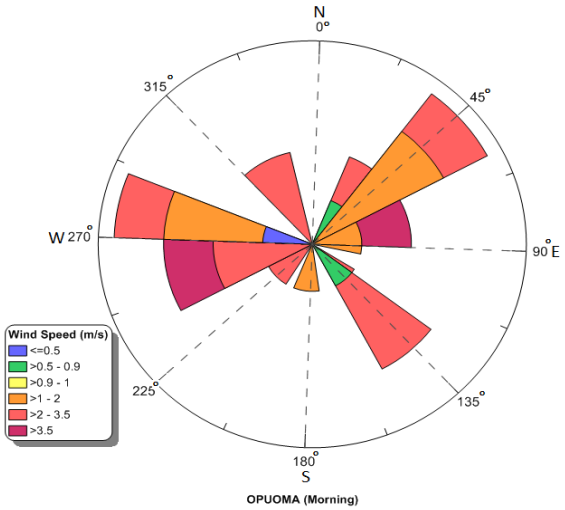
Wind rose Diagram at Ukwugba II, Egbema (Morning)



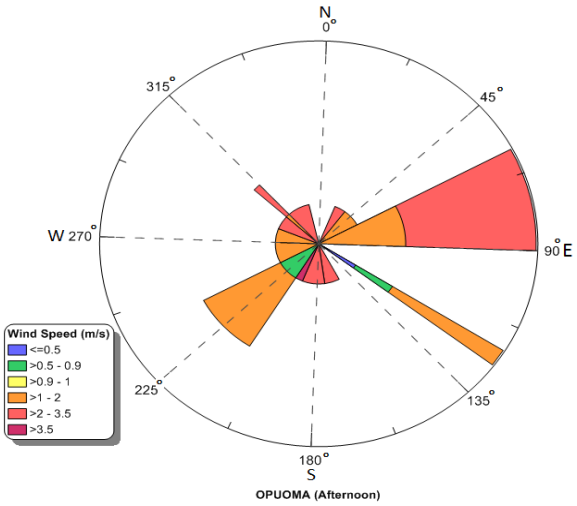

Wind rose Diagram at Ukwugba II, Egbema (Afternoon)



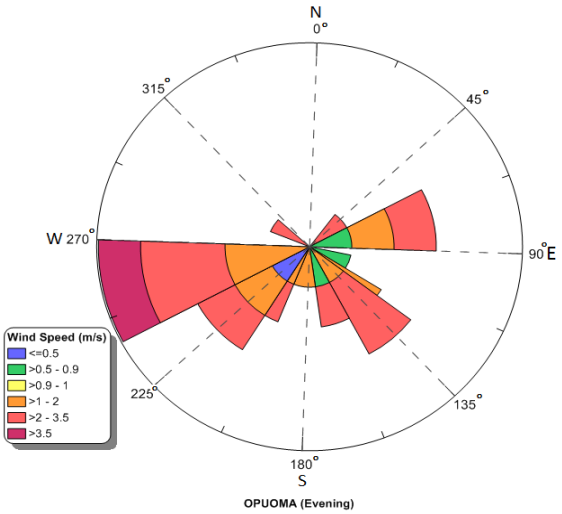

Wind rose Diagram at Ukwugba II, Egbema (Evening)




Wind rose Diagram at Opuoma, Egbema (Morning)




Wind rose Diagram at Opuoma, Egbema (Afternoon)

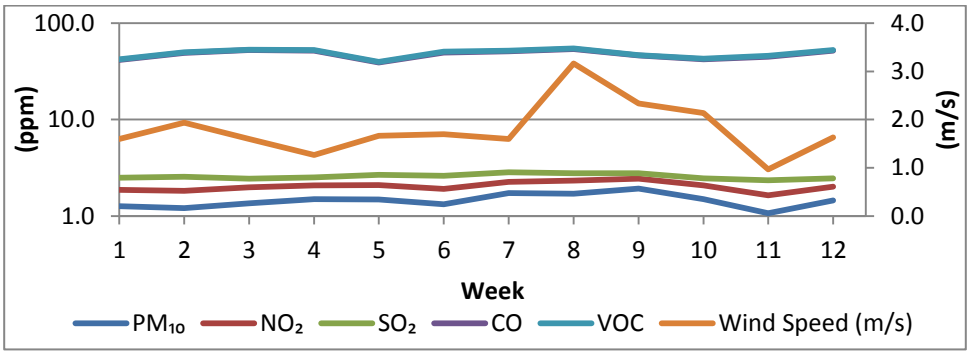


Wind rose Diagram at Opuoma, Egbema (Evening)

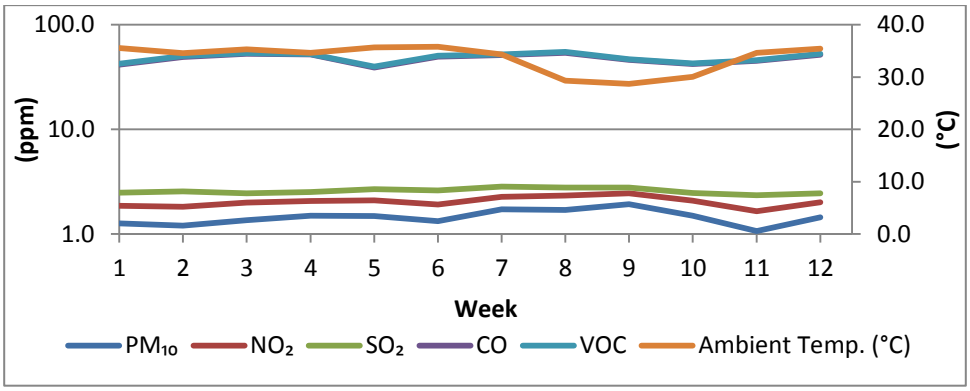
## APPENDIX 9

## Presentation of Multivariate Plots

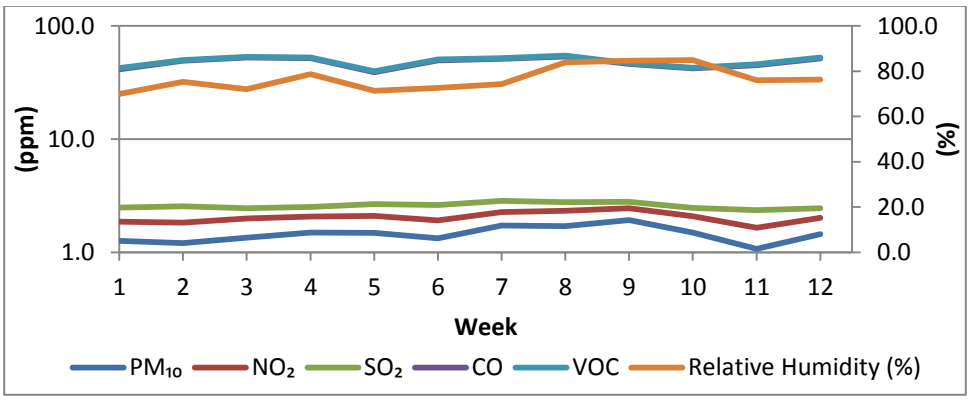
### Orlu (Dry Season)
### Banana Junction (Dry Season)



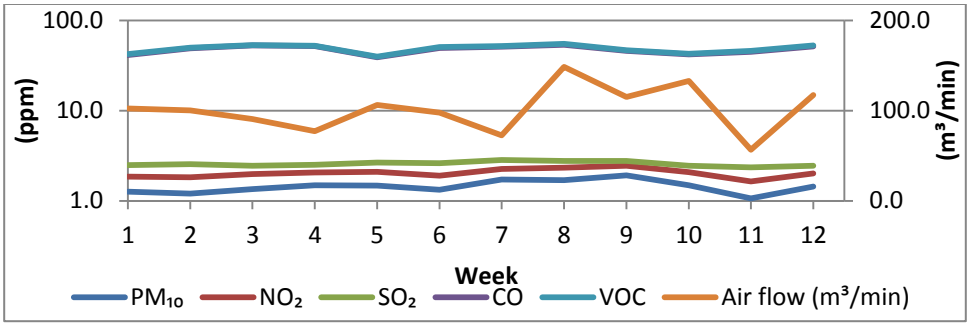

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind speed at Banana Junction



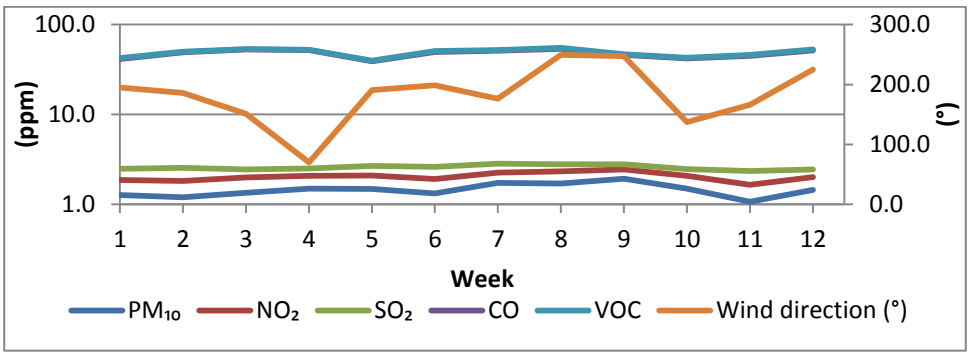

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Banana Junction



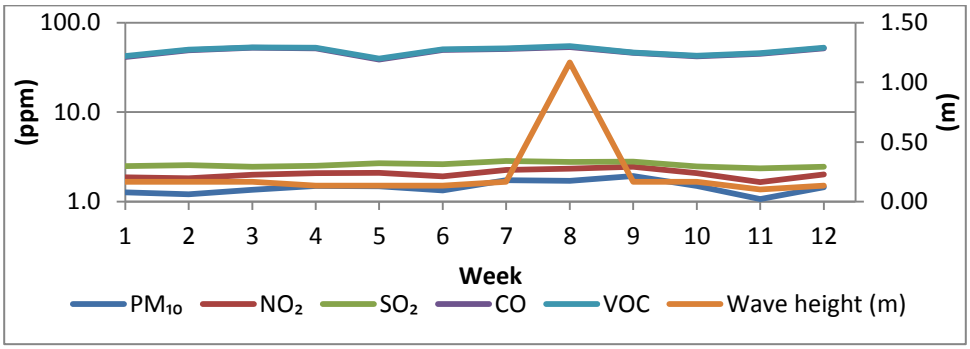

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Banana Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Banana Junction

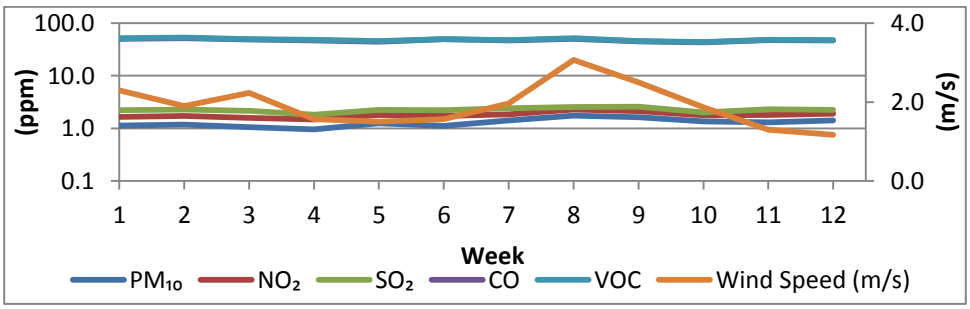



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind direction at Banana Junction

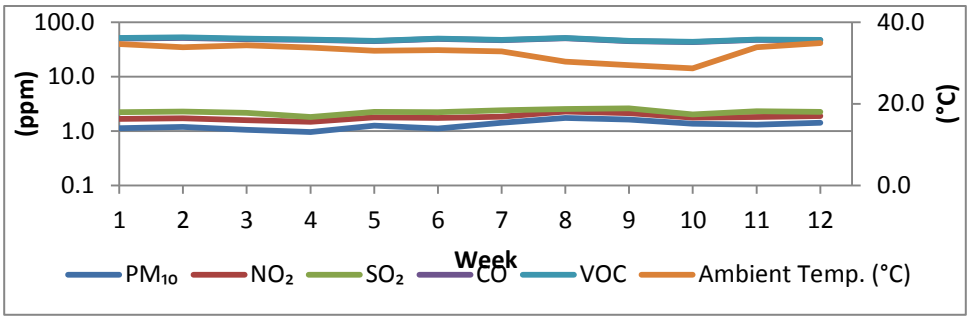



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wave height at Banana Junction

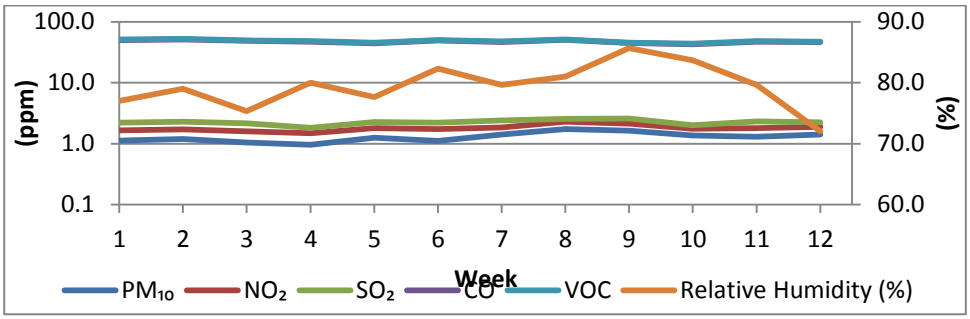
**Umuaka Junction (Dry Season)**



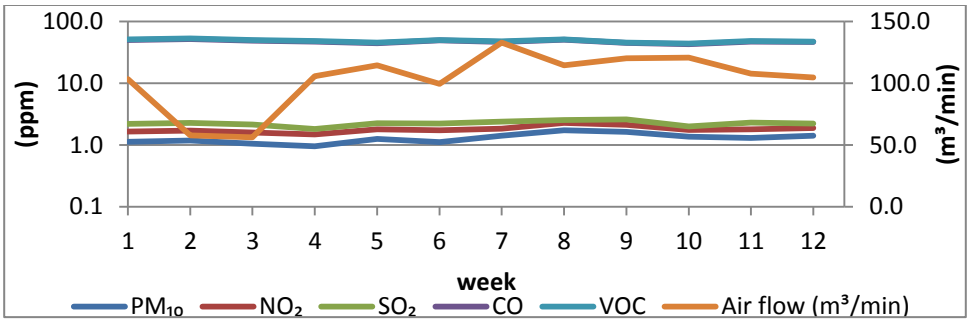
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind Speed Umuaka Junction



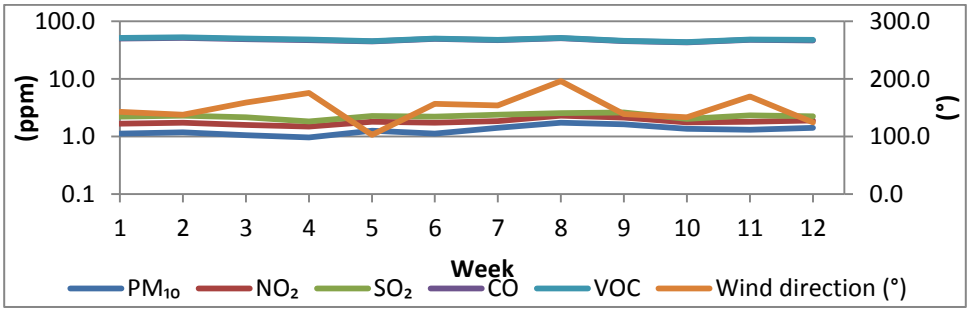

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuaka Junction



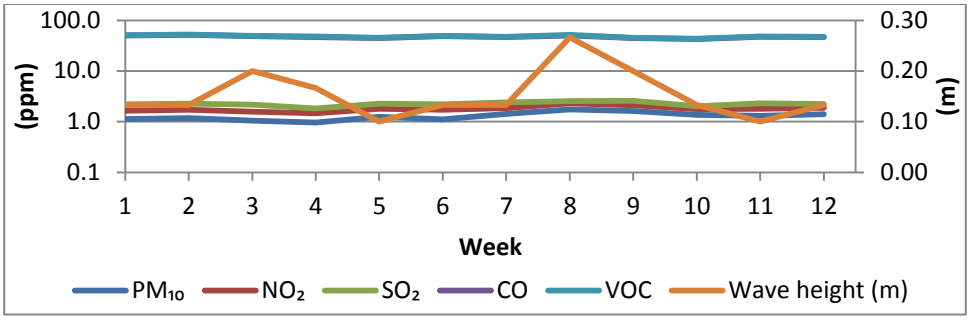

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuaka Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuaka Junction

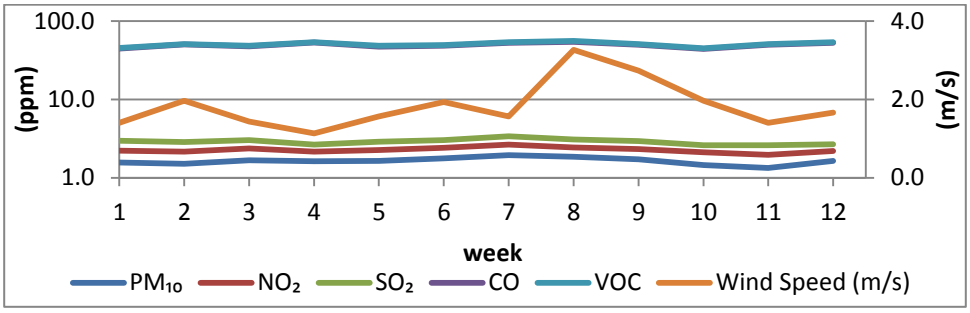



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind direction at Umuaka Junction

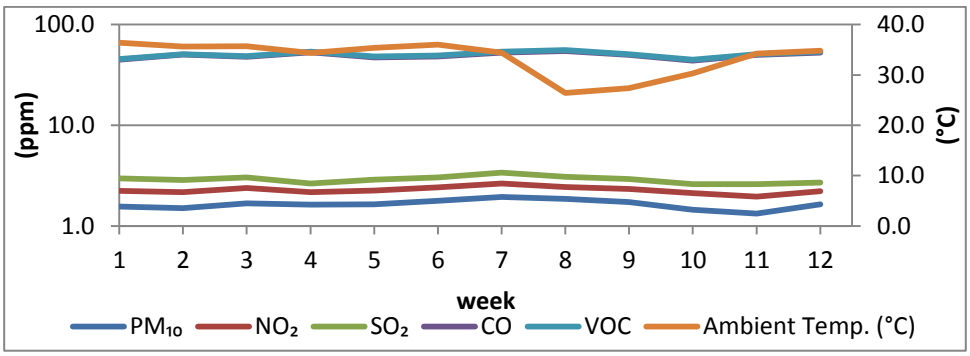



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wave height at Umuaka Junction

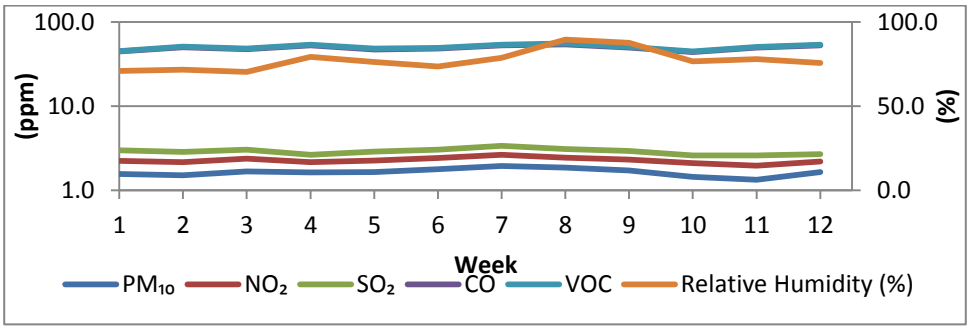
**Umuna Juncton Orlu (Dry Season)**



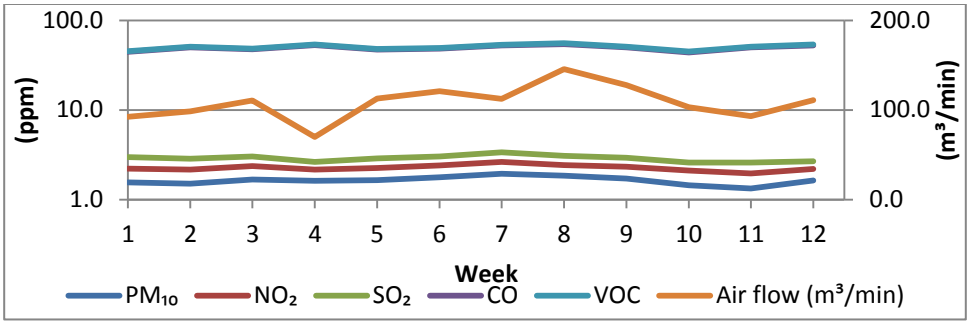

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against wind Speed at Umuna Junction



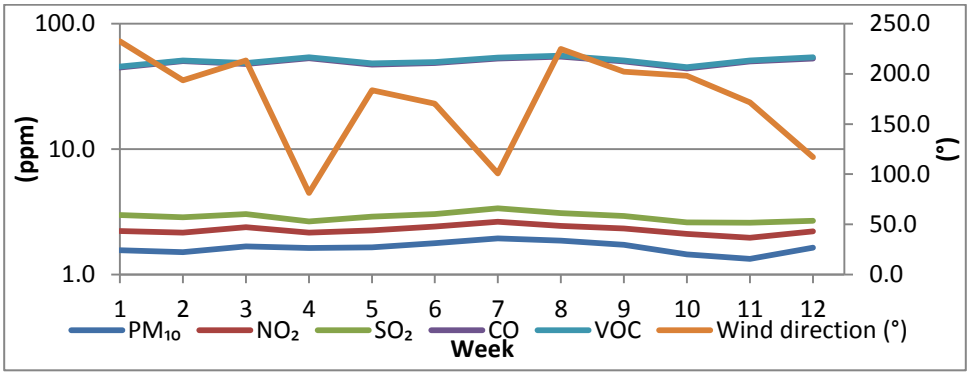

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuna Junction



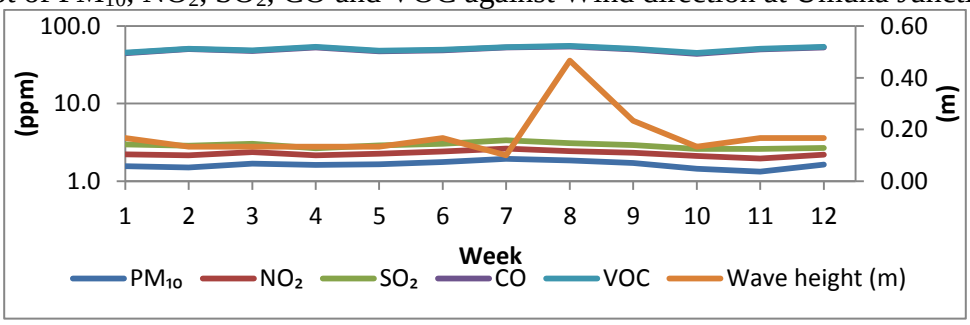

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against relative Humidity at Umuna Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuna Junction

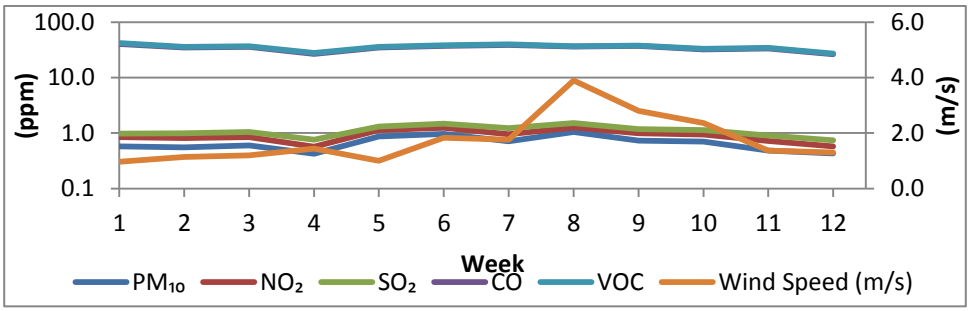



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at Umuna Junction

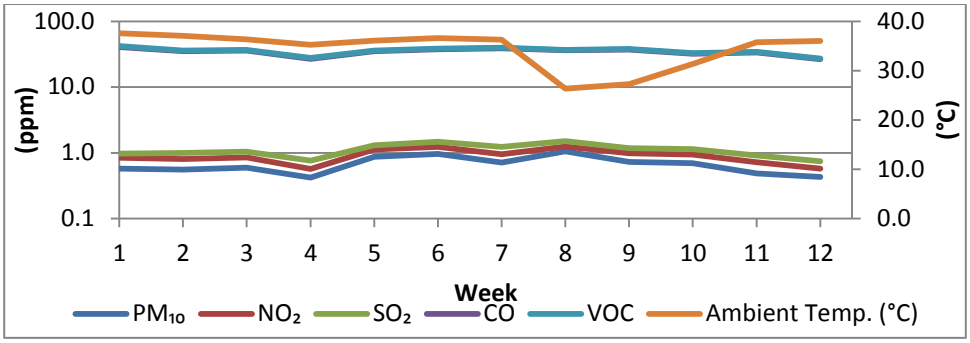



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Umuna Junction

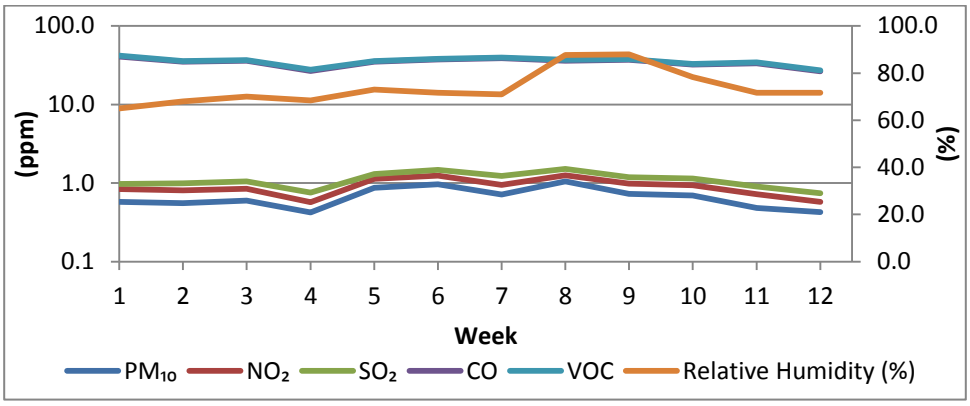
**Umuago Urualla**



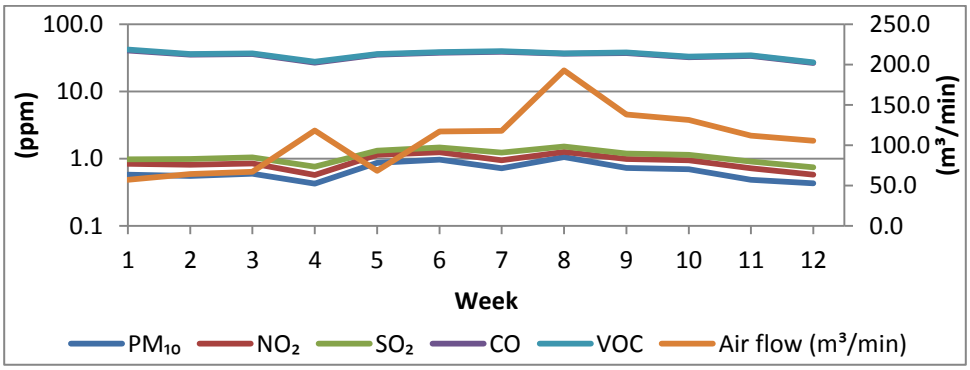

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuago Urualla



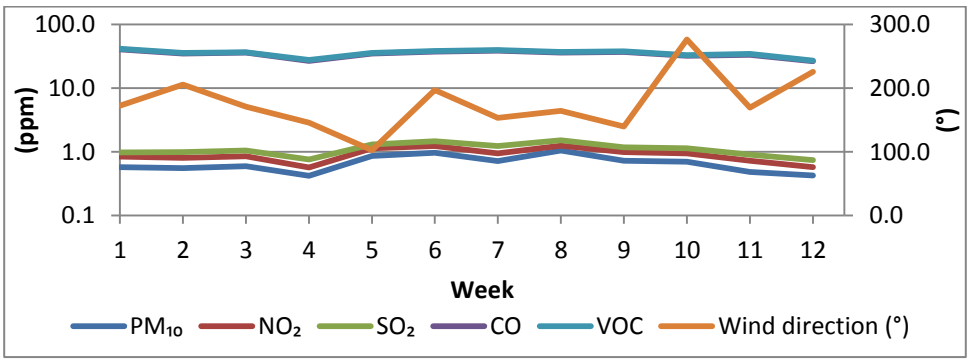

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuago Urualla



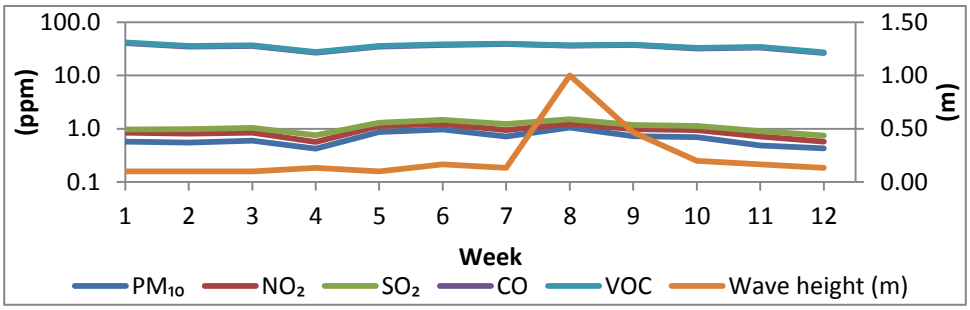

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuago Urualla




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuago Urualla

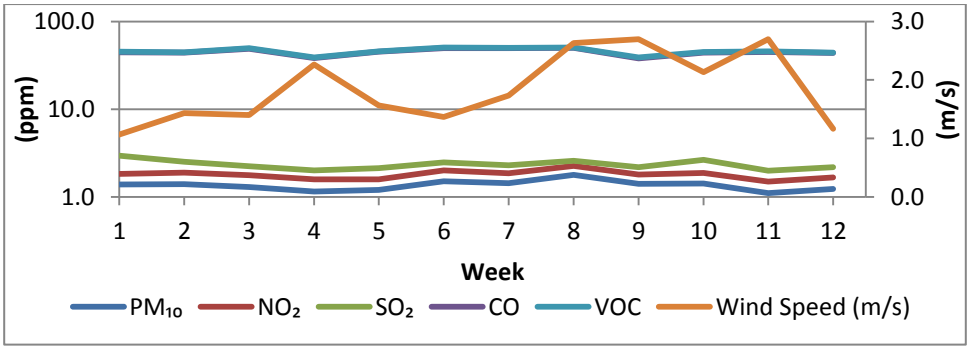


Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuago Urualla

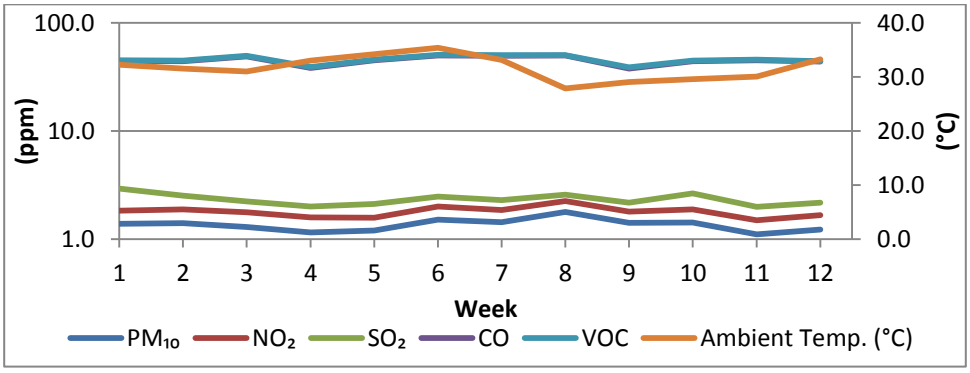



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Umuago Urualla

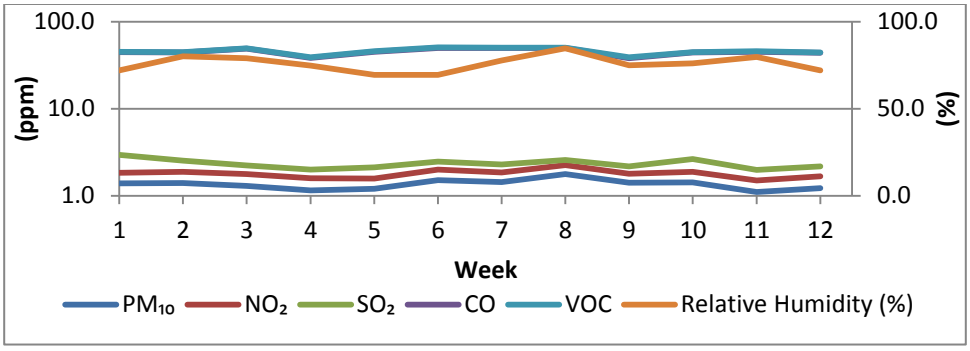
**Owerri**
**IMSU Junction (Dry Season)**



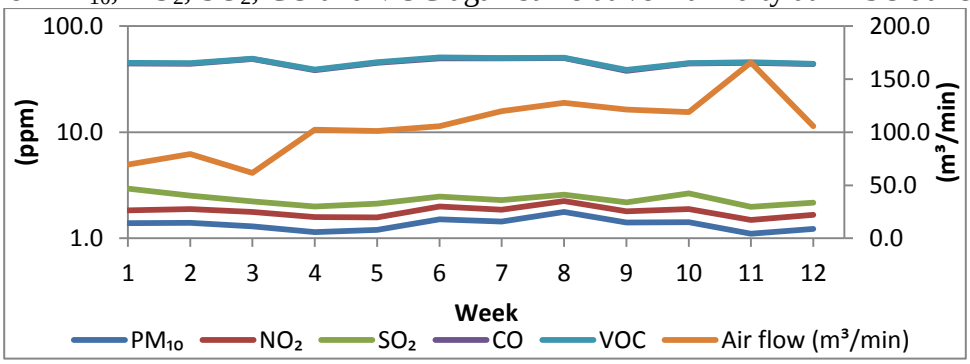

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at IMSU Junction



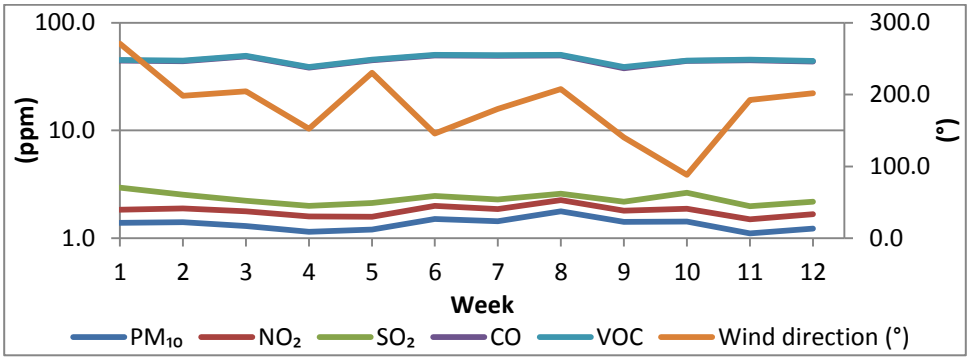

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at IMSU Junction



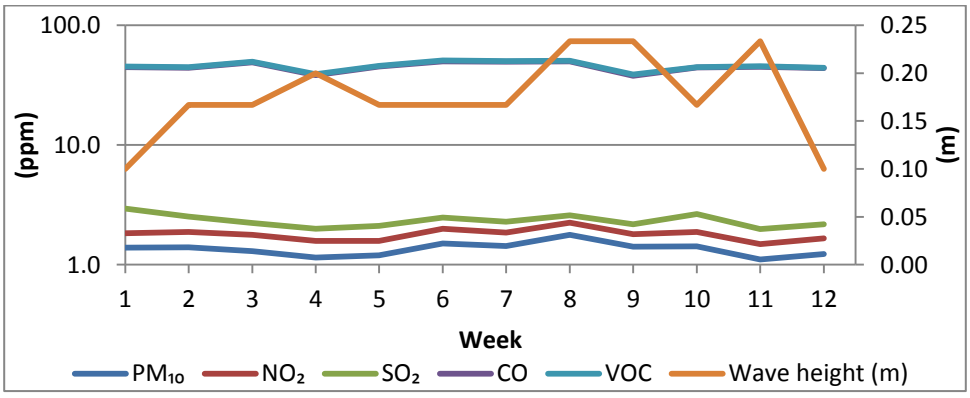

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at IMSU Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at IMSU Junction

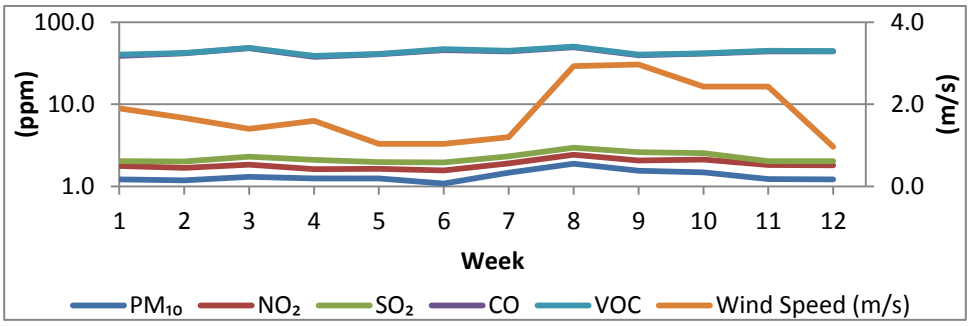



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at IMSU Junction

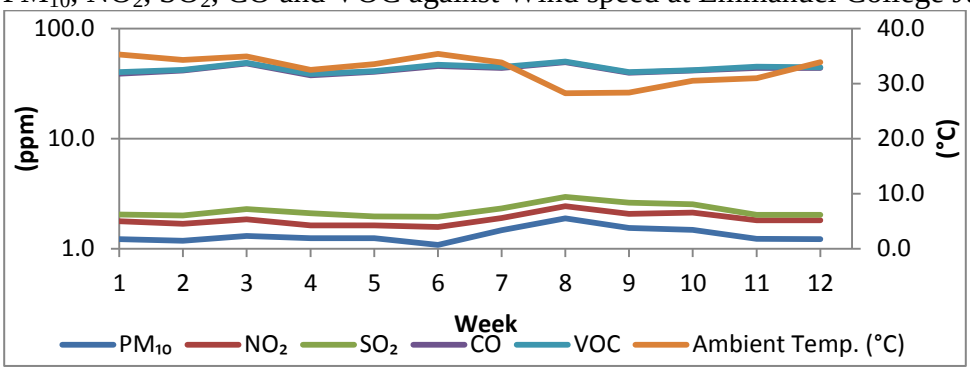



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at IMSU Junction

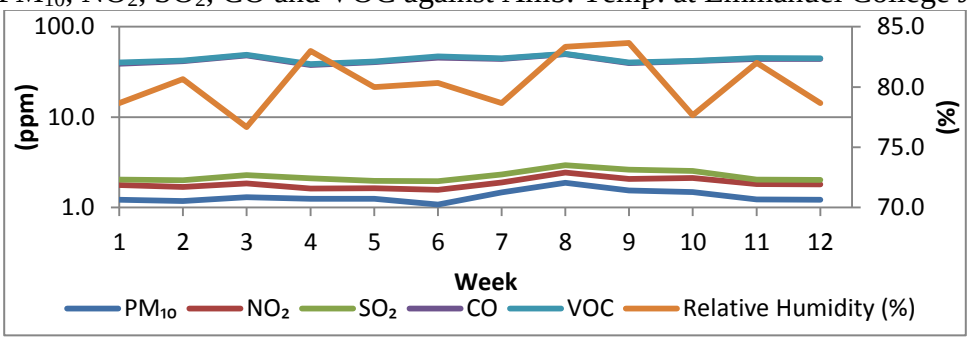
**Emmanuel College Junction (Dry Season)**



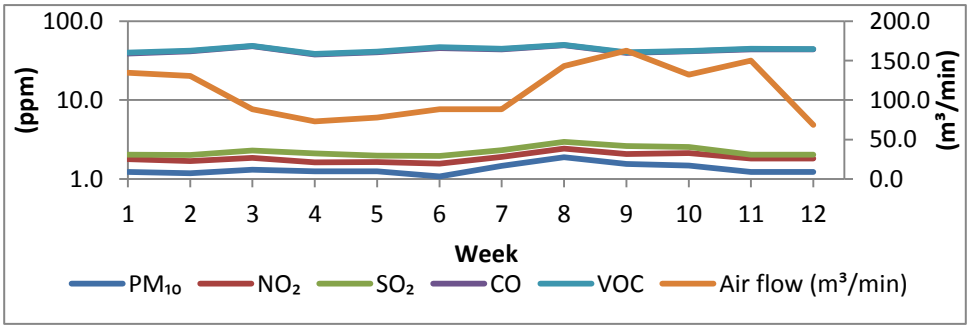

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at Emmanuel College Junction



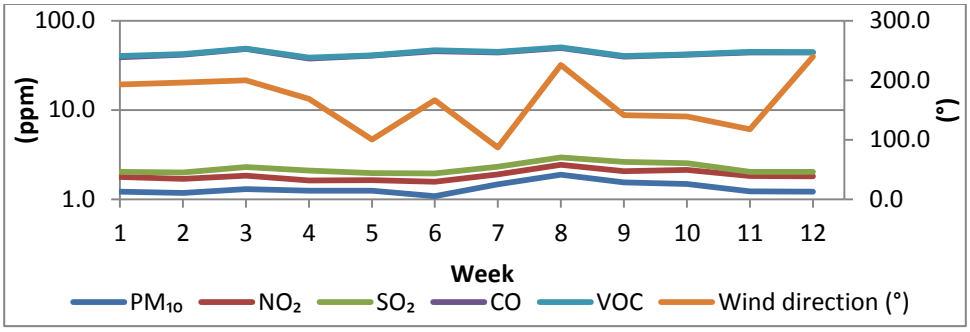

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Emmanuel College Junction



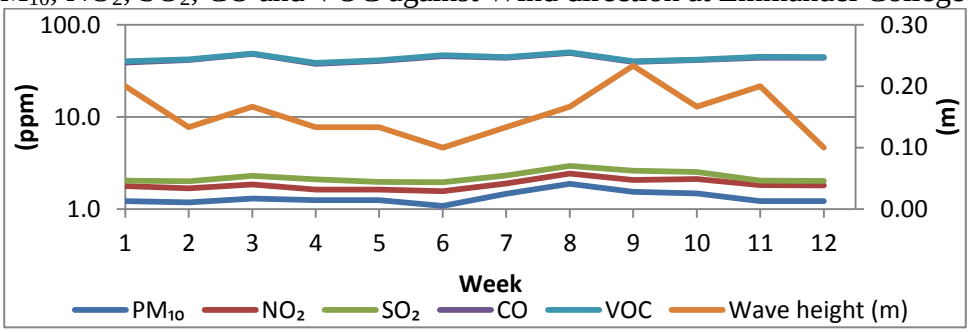

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Emmanuel College Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Emmanuel College Junction

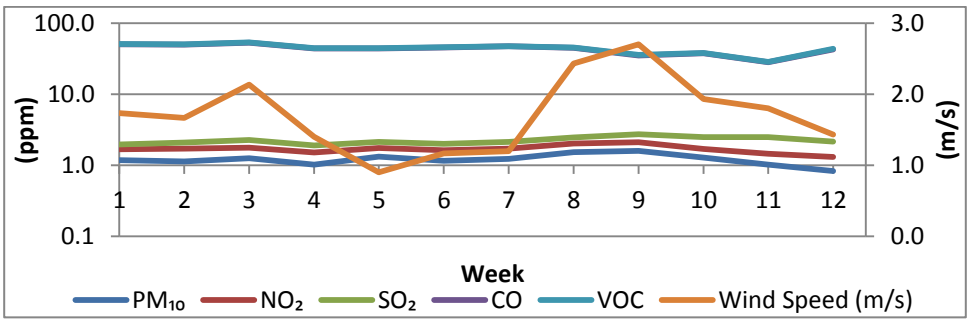



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at Emmanuel College Junction

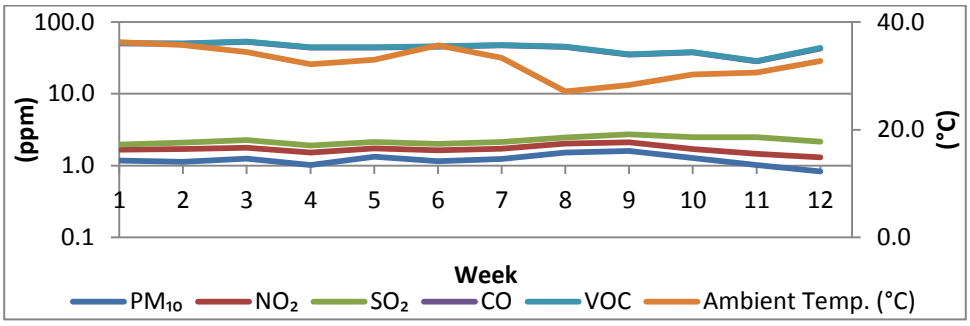



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Emmanuel College Junction

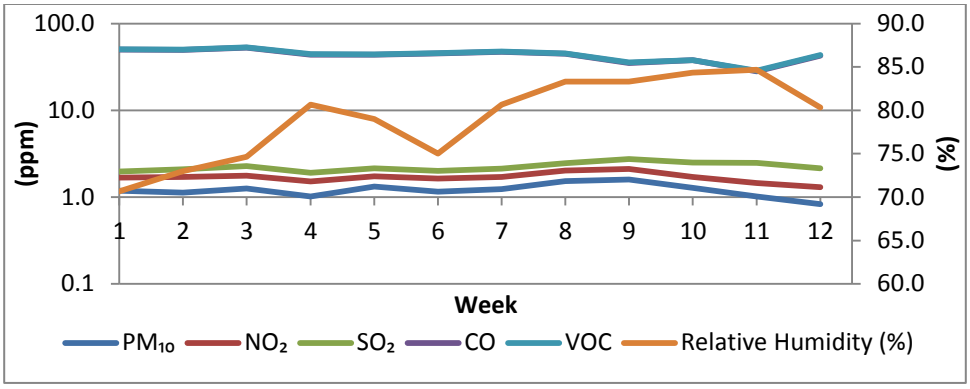
**World Bank Market Junction (Dry Season)**



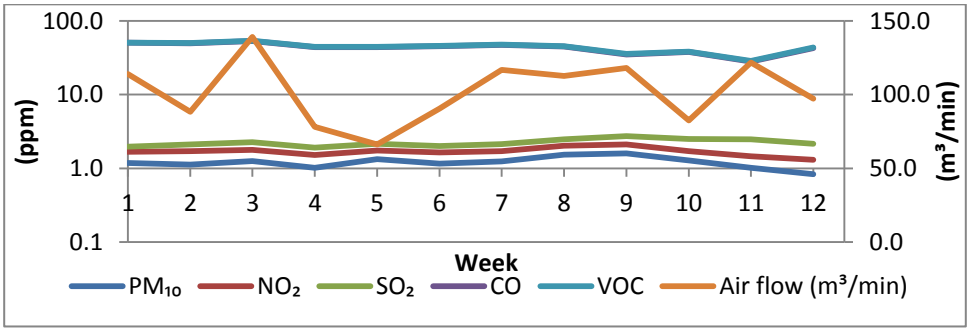

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at World Bank Market Junction



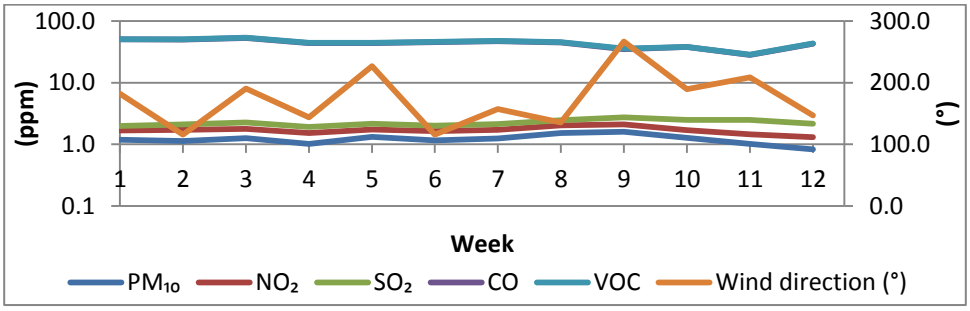

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at World Bank Market Junction



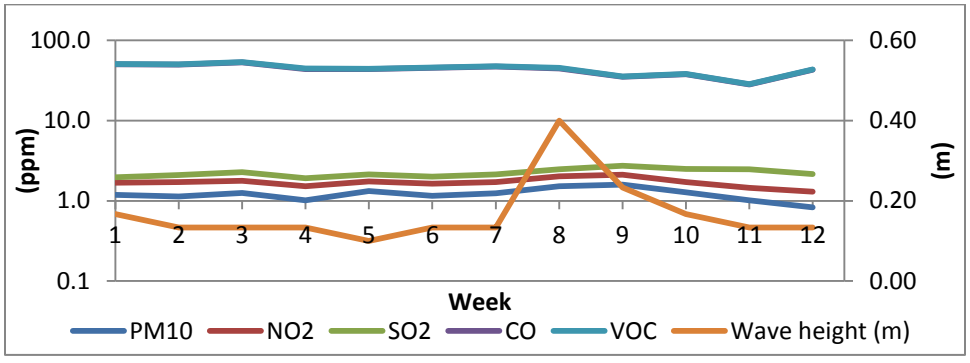

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at World Bank Market Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at World Bank Market Junction

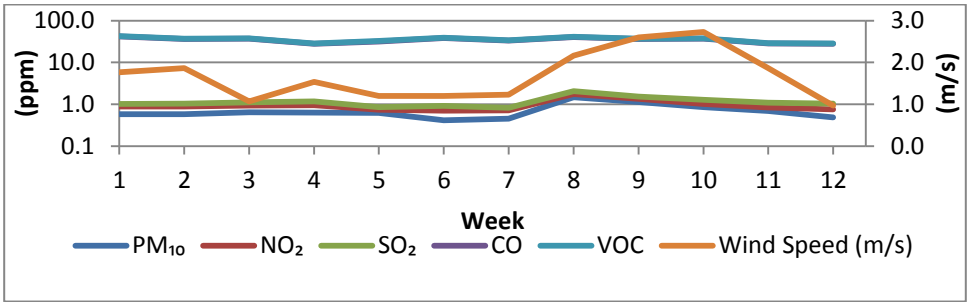



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at World Bank Market Junction

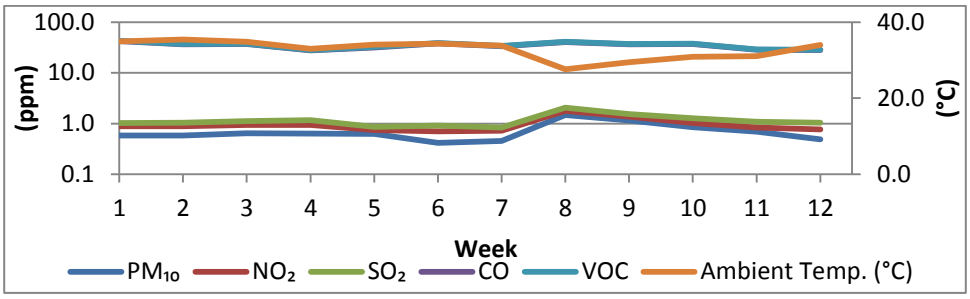



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at World Bank Market Junction

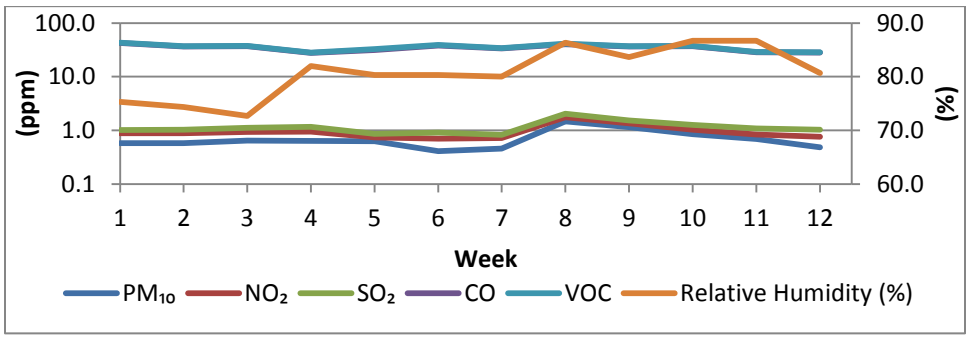
**Egbu – Uratta Ring Road (Dry Season)**



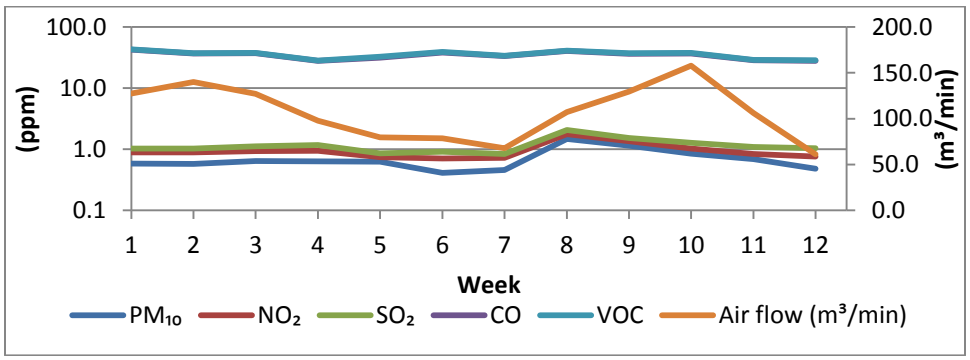

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Egbu – Uratta Ring Road



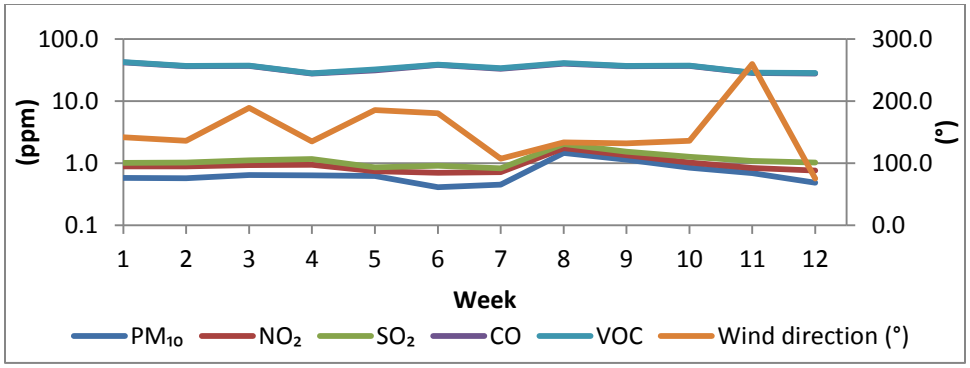

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Egbu – Uratta Ring Road



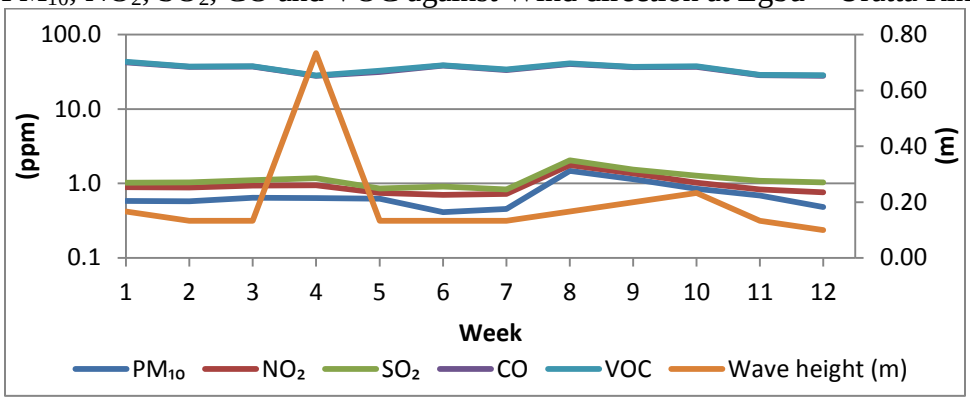

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Egbu – Uratta Ring Road




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Egbu – Uratta Ring Road



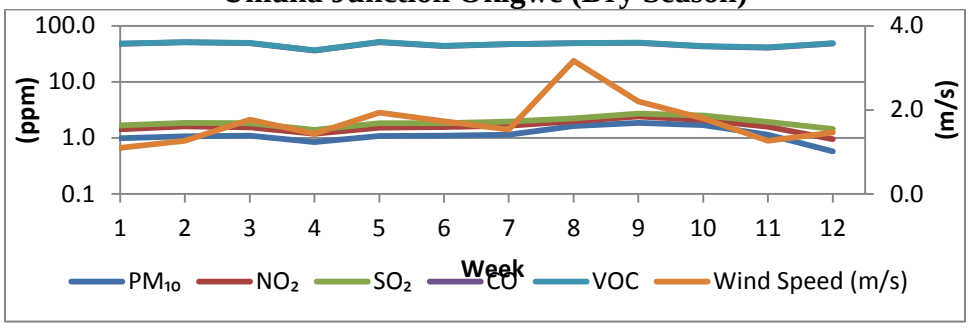

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at Egbu – Uratta Ring Road



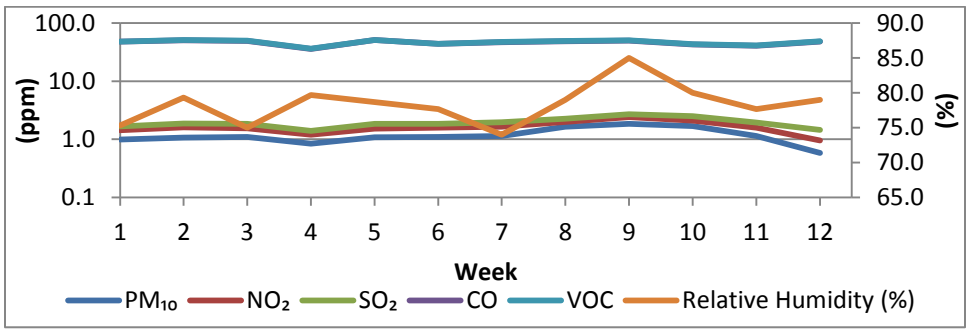

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Egbu – Uratta Ring Road

**Okigwe**

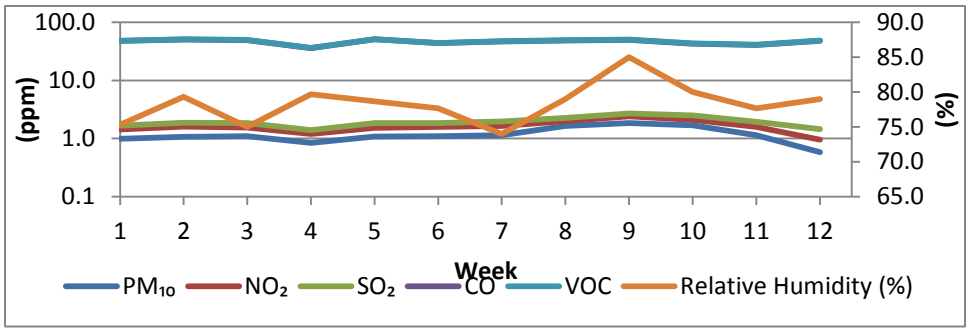
**Umuna Junction Okigwe (Dry Season)**



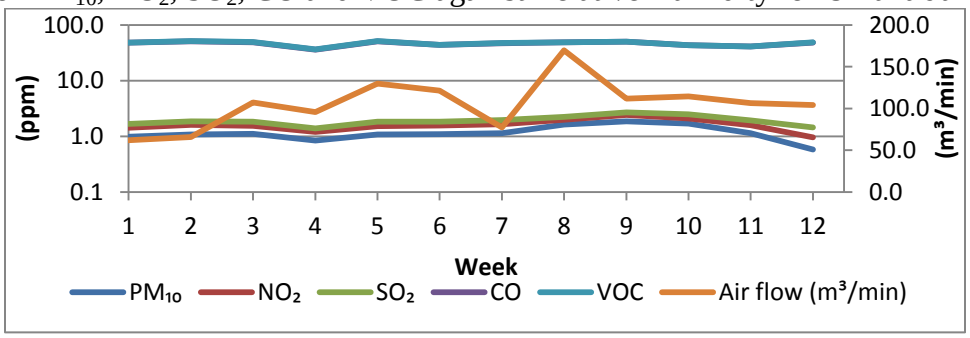

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuna Junction



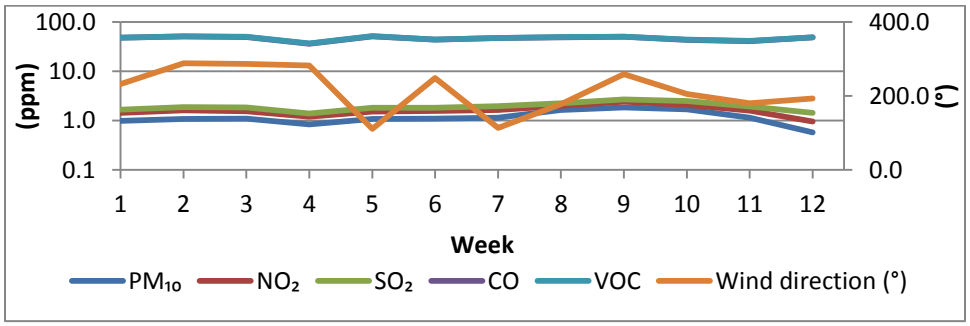
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuna Junction



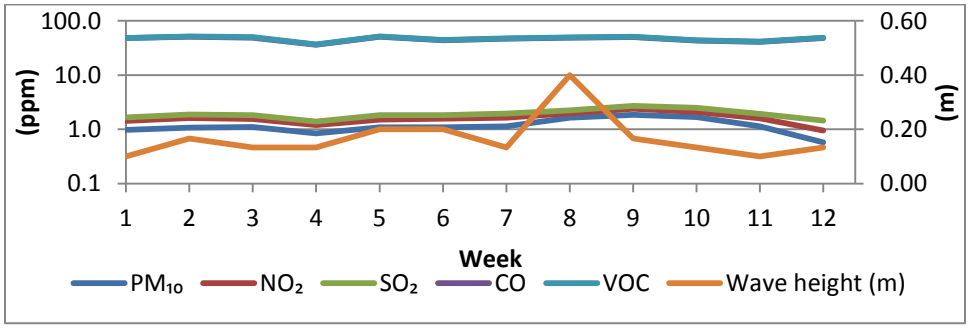

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity for Umuna Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuna Junction

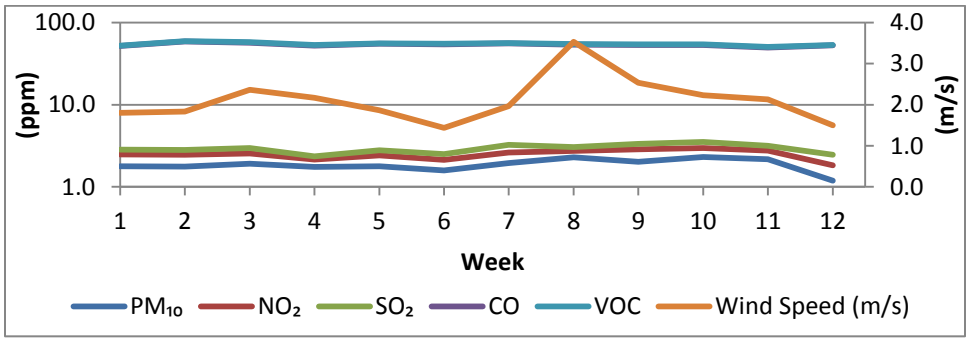



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Umuna Junction

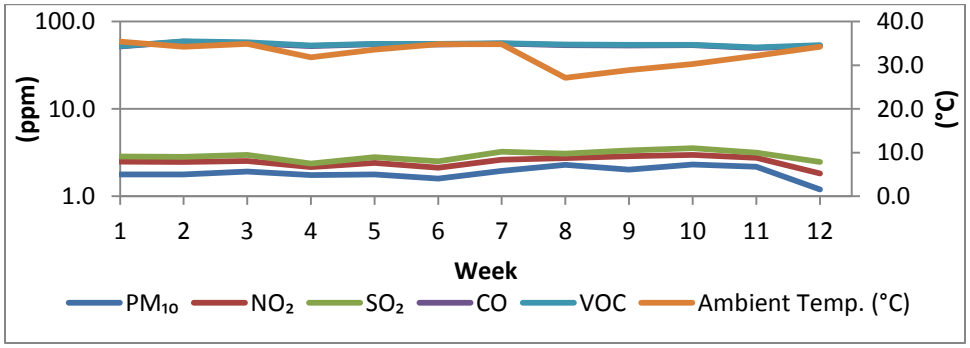



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Umuna Junction

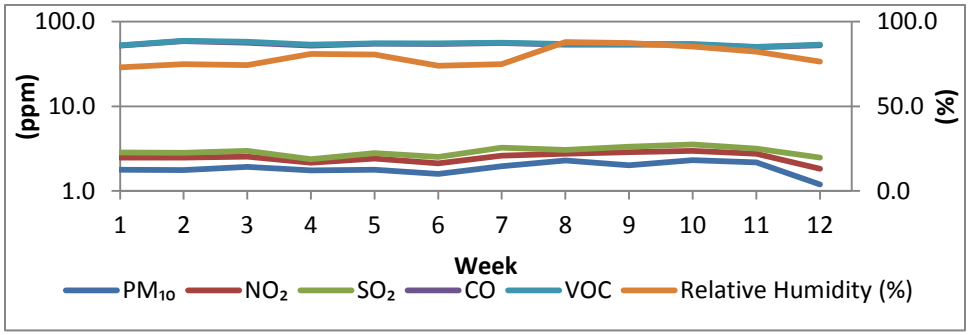
**Okigwe Express Junction (dry Season)**



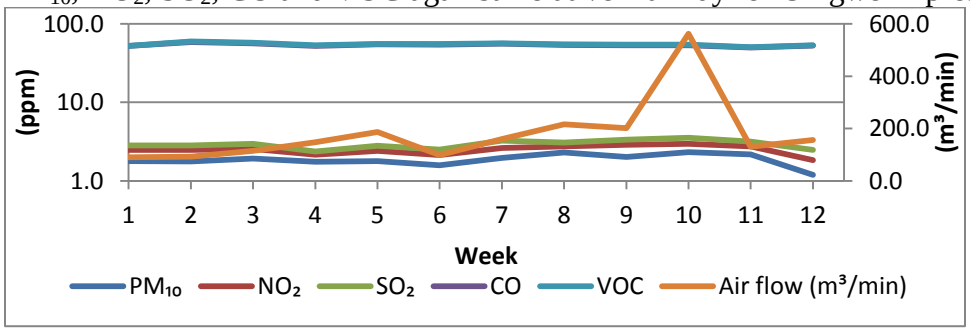

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Okigwe Express Junction



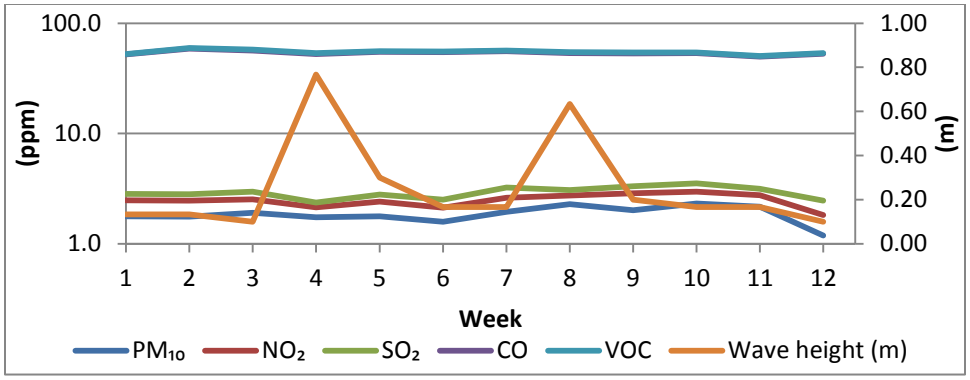

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Okigwe Express Junction



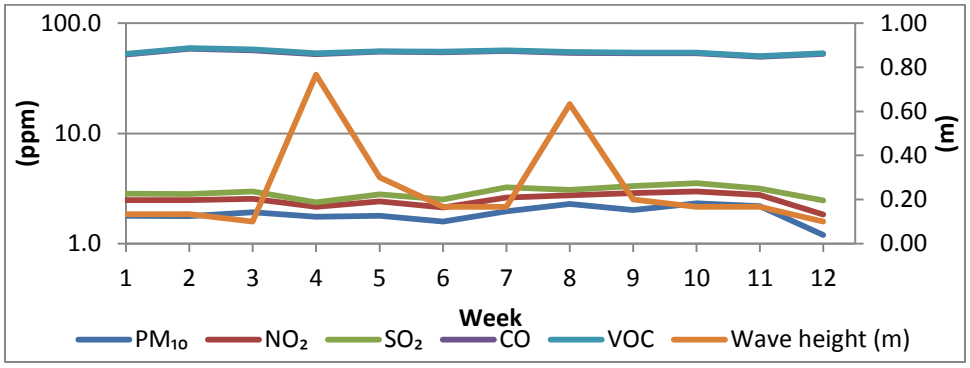

Plot of the $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidy for Okigwe Express Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Okigwe Express Junction

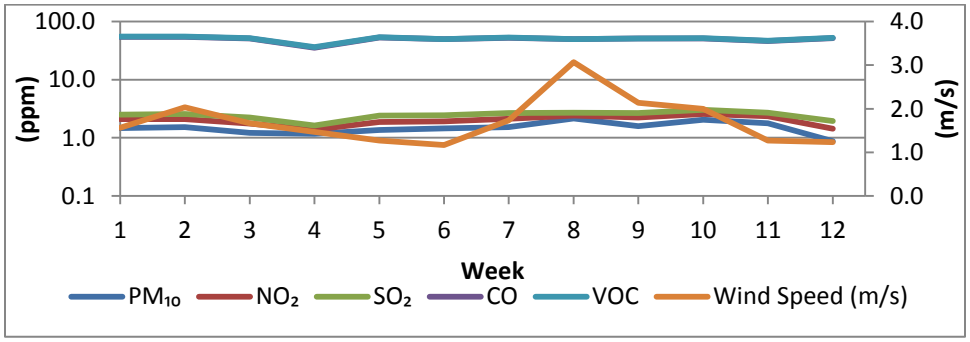



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Okigwe Express Junction

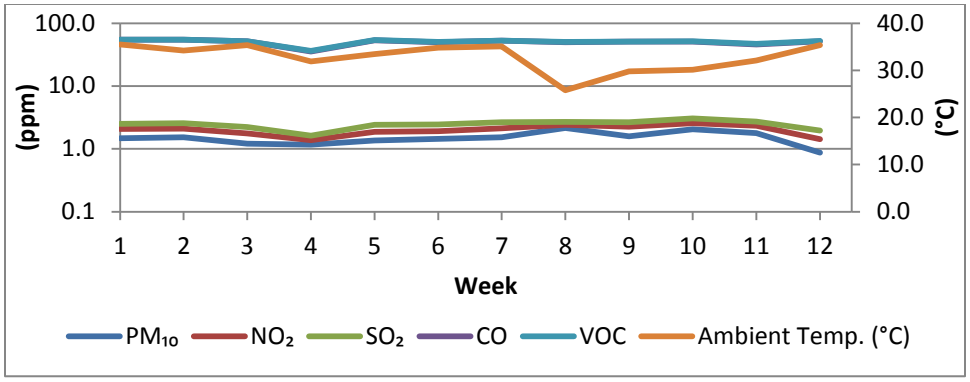



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and CO against Wave height at Okigwe Express Junction

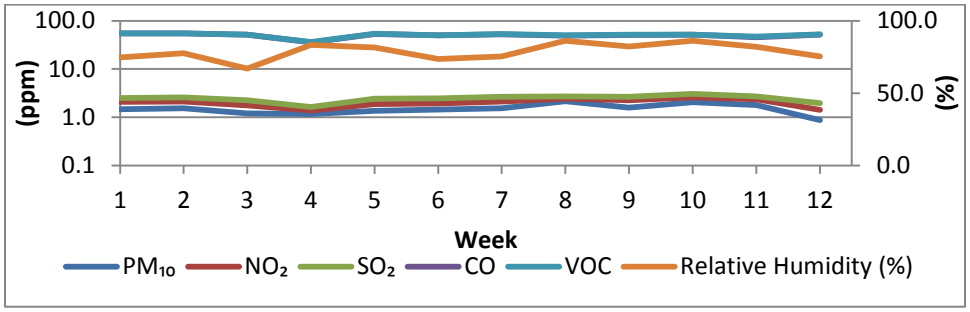
**St. Mary's Junction Okigwe**



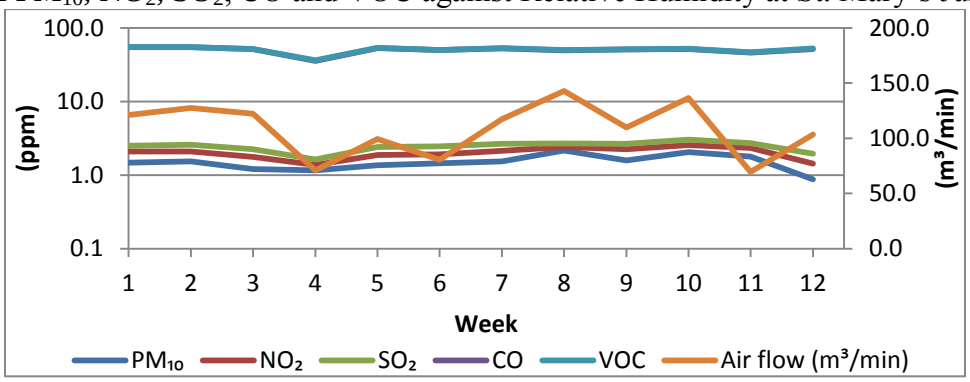

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at St. Mary's Junction



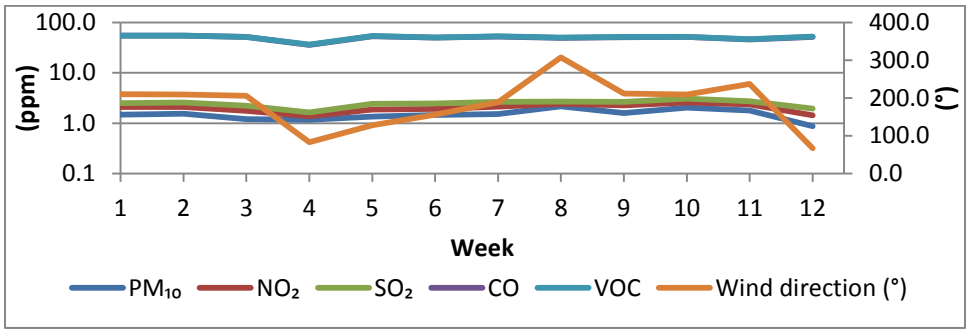

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Seed at St. Mary's Junction



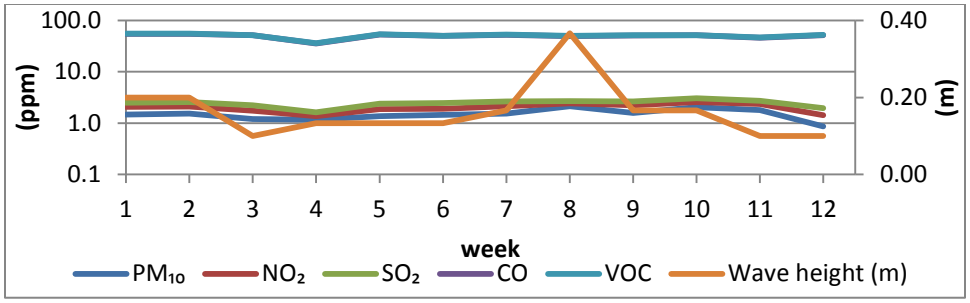

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at St. Mary's Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at St. Mary's Junction

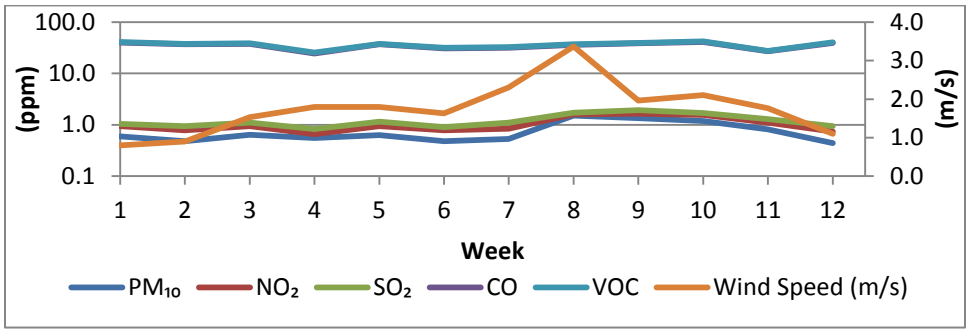



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at St. Mary's Junction

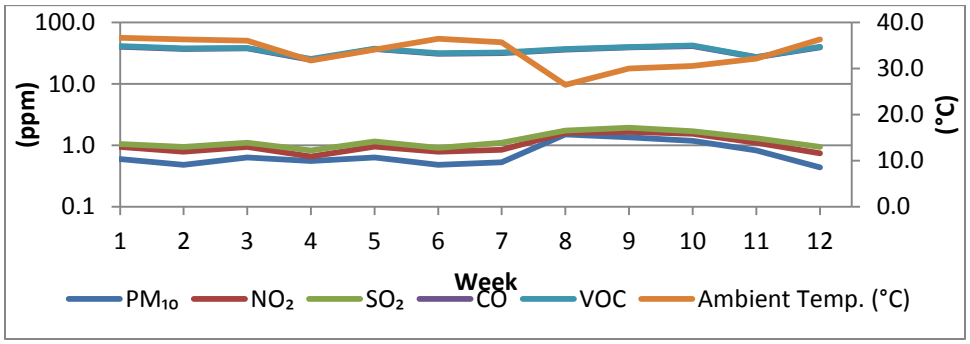



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Height at St. Mary's Junction

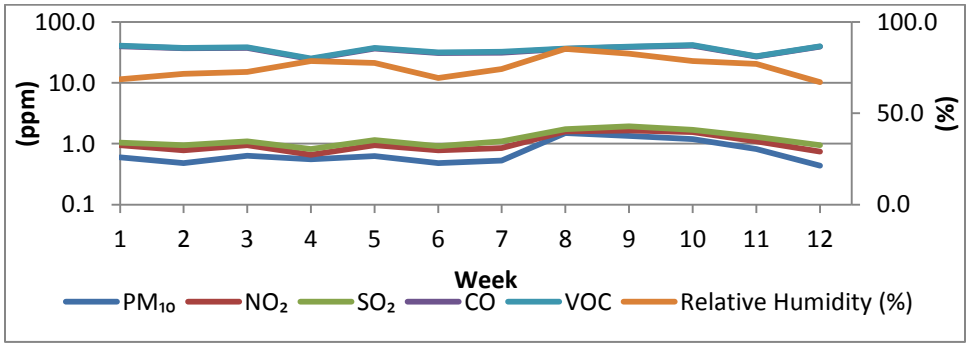
**Ihube (dry season)**



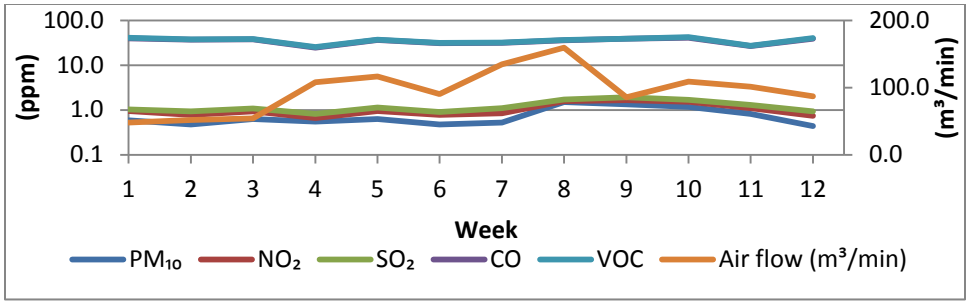

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at Ihube



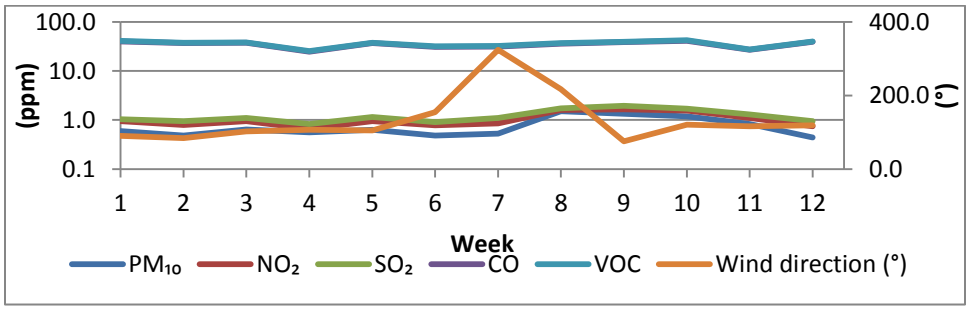

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ihube



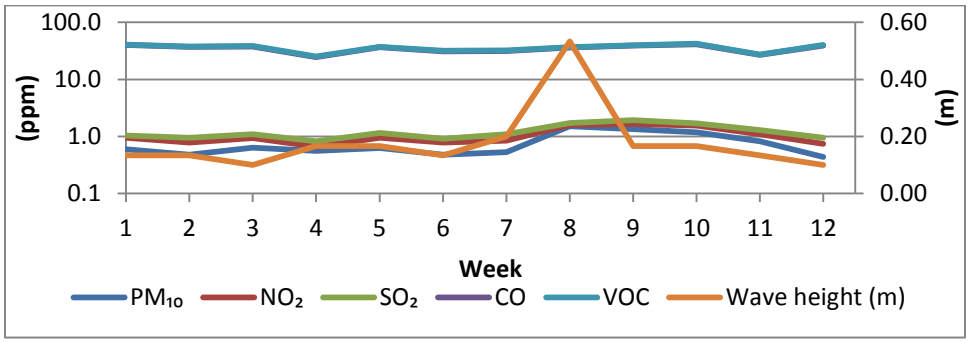

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ihube




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ihube

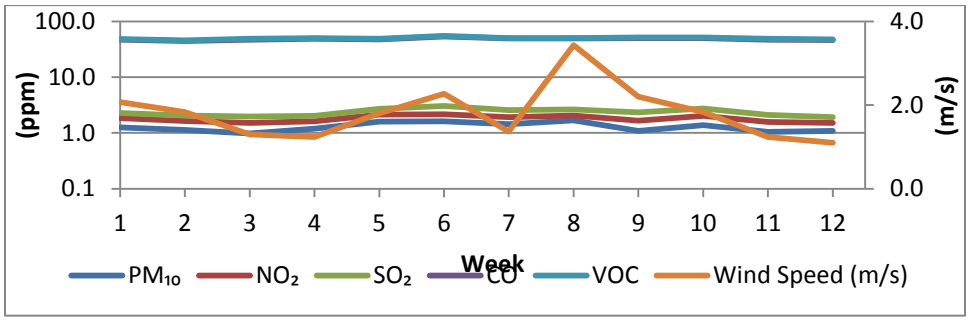



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at Ihube

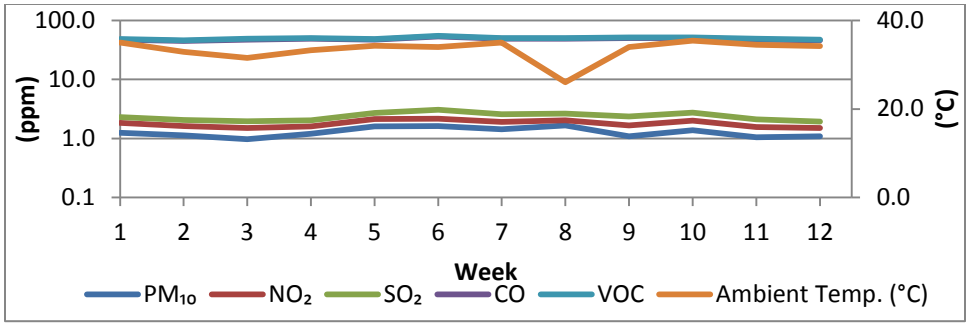



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave heigh at Ihube

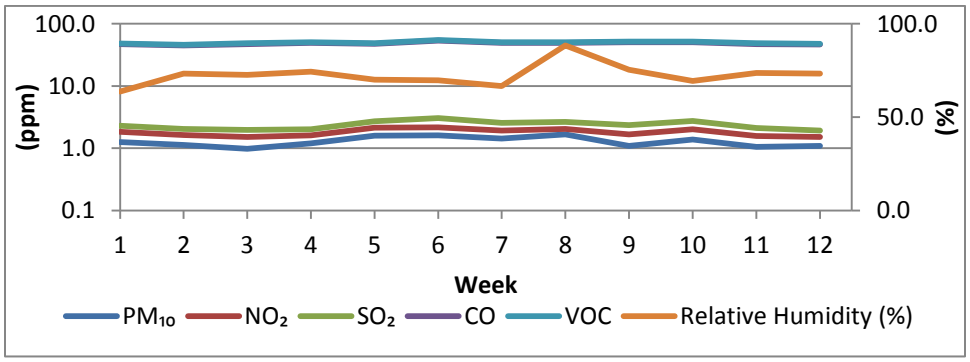
**Egbema (Dry Season)**



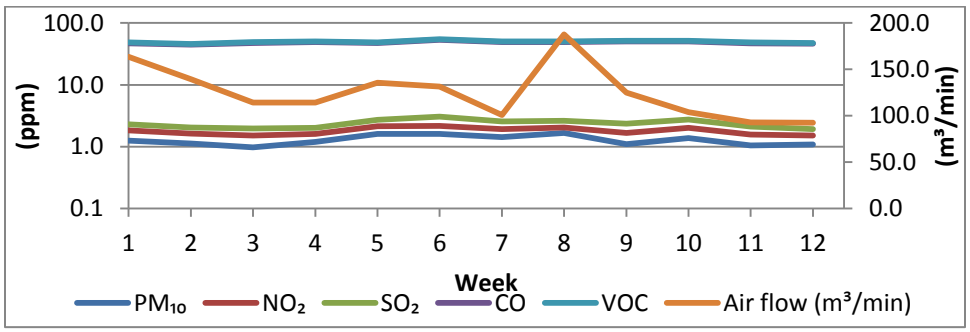

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuorji



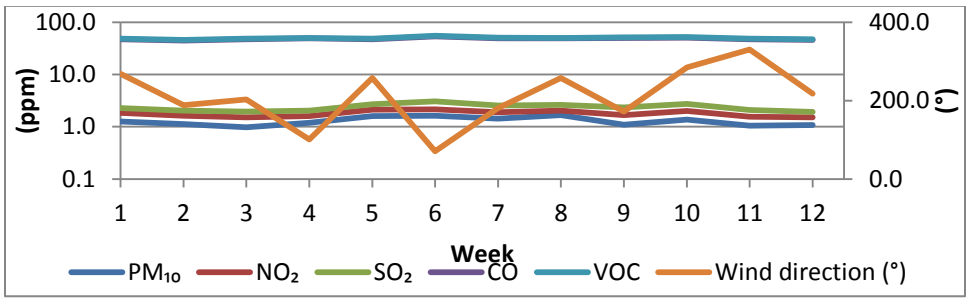

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuorji



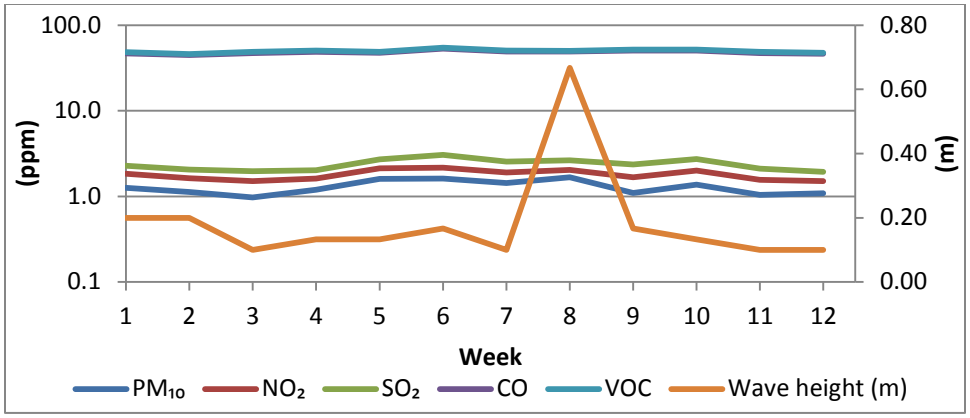

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuorji




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuorji

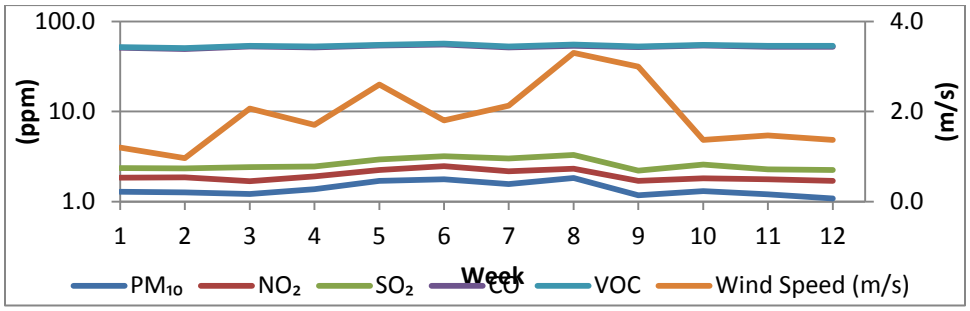



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Umuorji

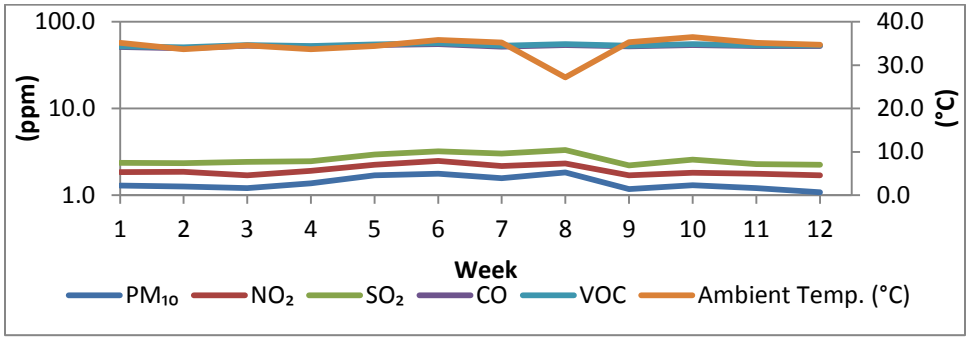



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Height at Umuorji

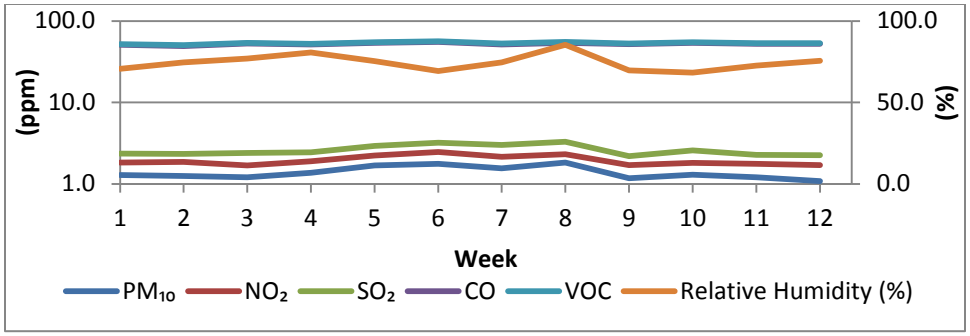
**Ukwugba 1 (Dry Season)**



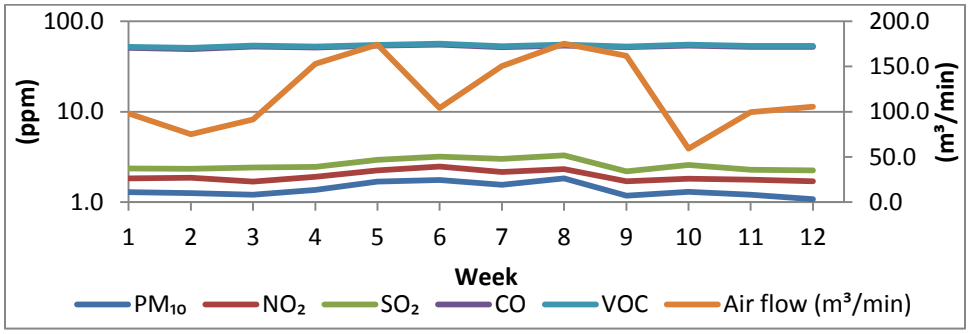

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Ukwugba 1



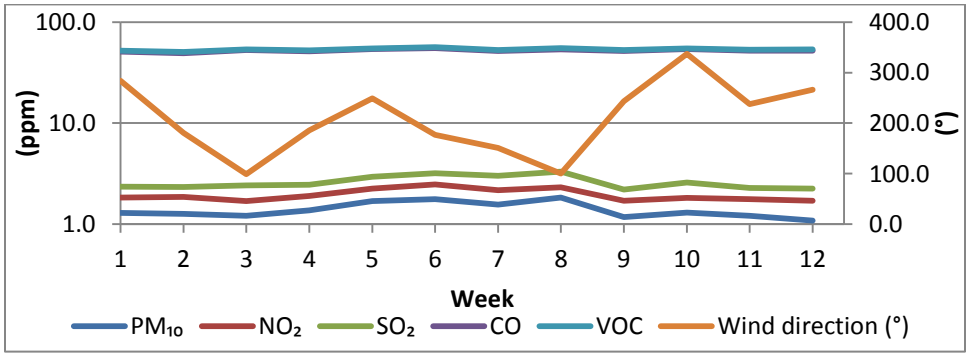

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ukwugba 1



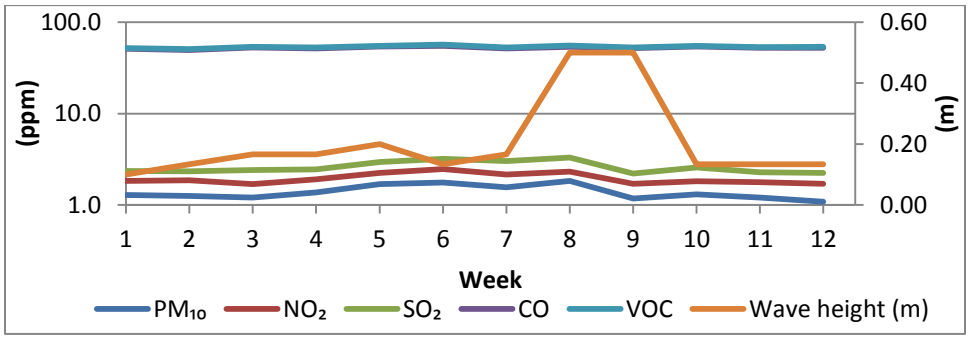

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ukwugba 1




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ukwugba 1

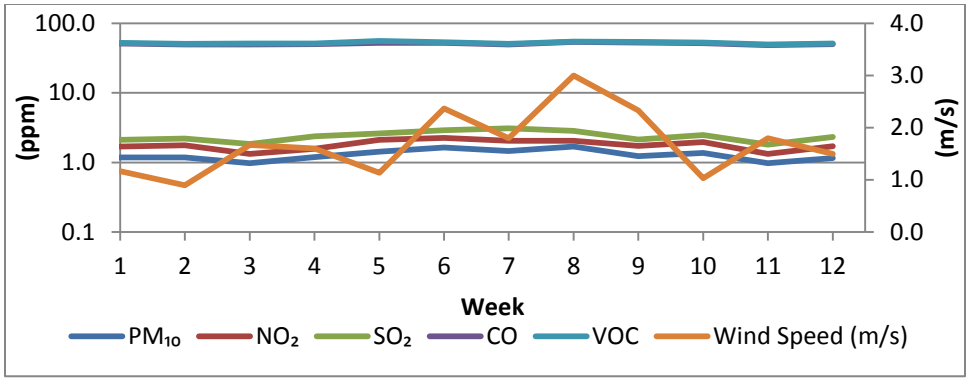



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Ukwugba 1

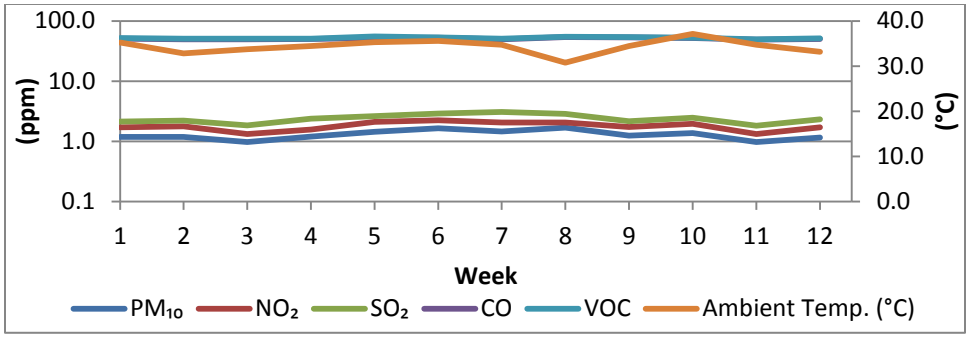



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Ukwugba 1

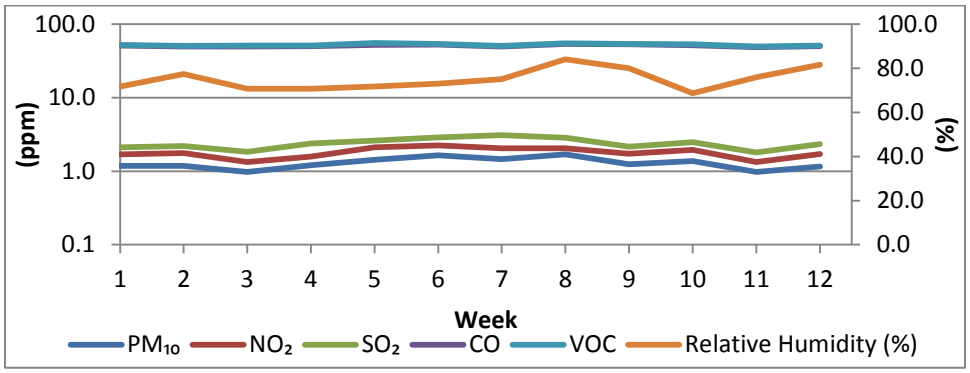
**Ukwugba 2 (Dry Season)**



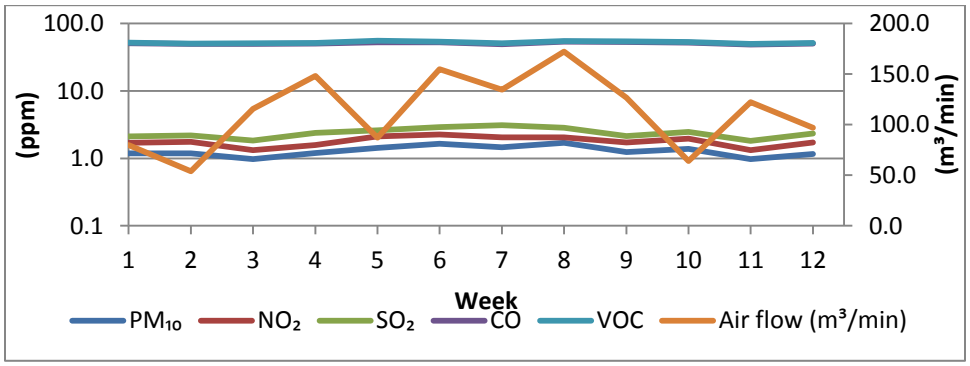

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Ukwugba 2



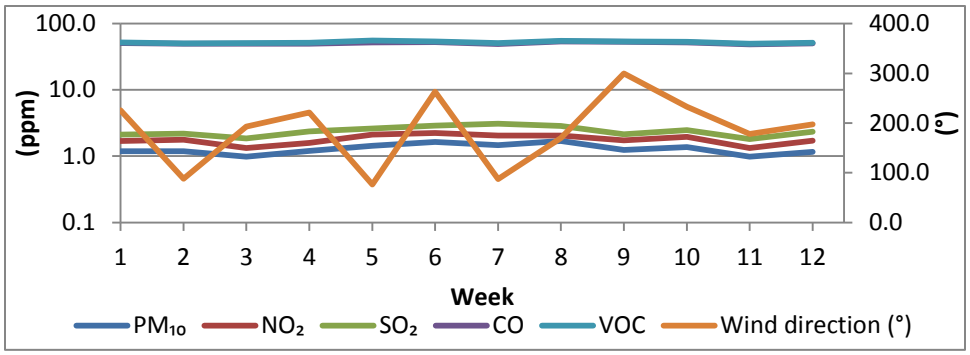

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ukwugba 2



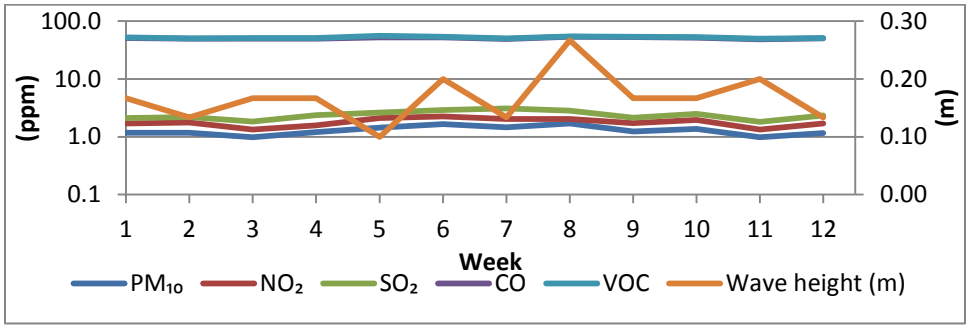

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ukwugba 2



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ukwugba 2

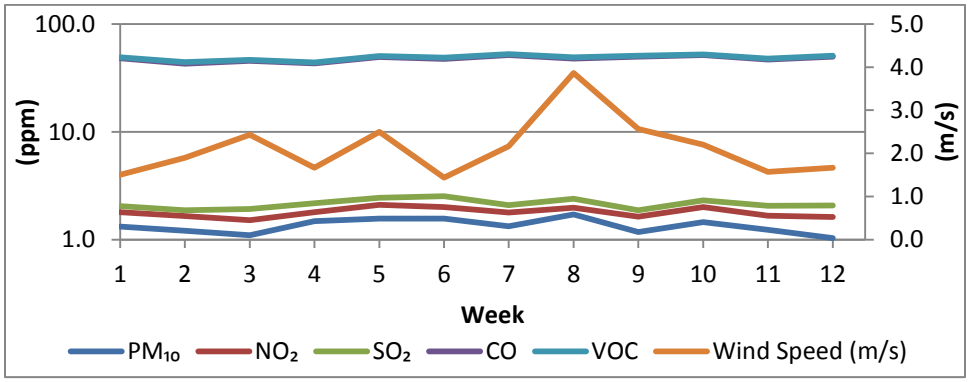



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Ukwugba 2

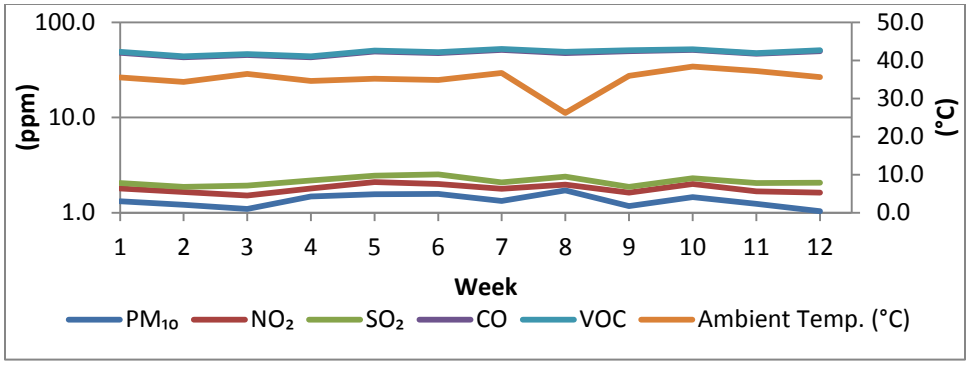



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Ukwugba 2

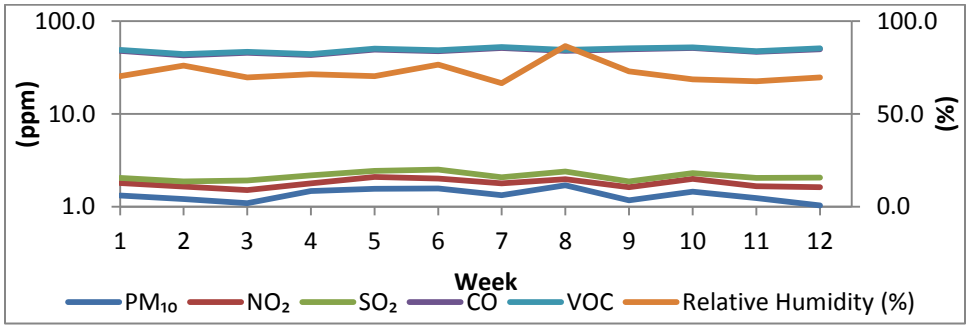
**Opuoma (Dry Season)**



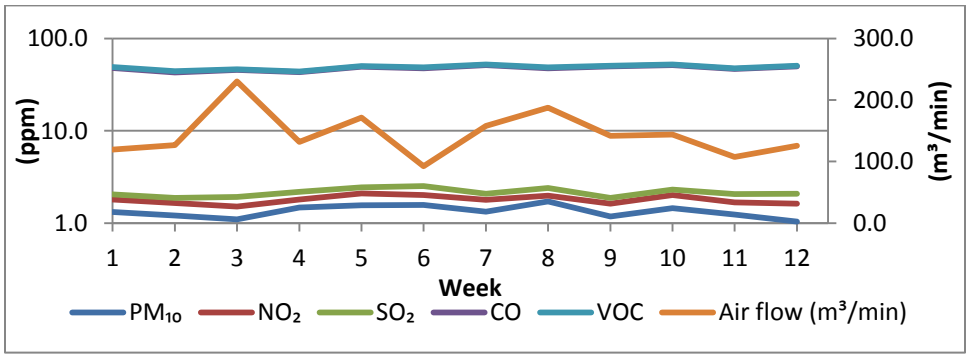

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at Opuoma



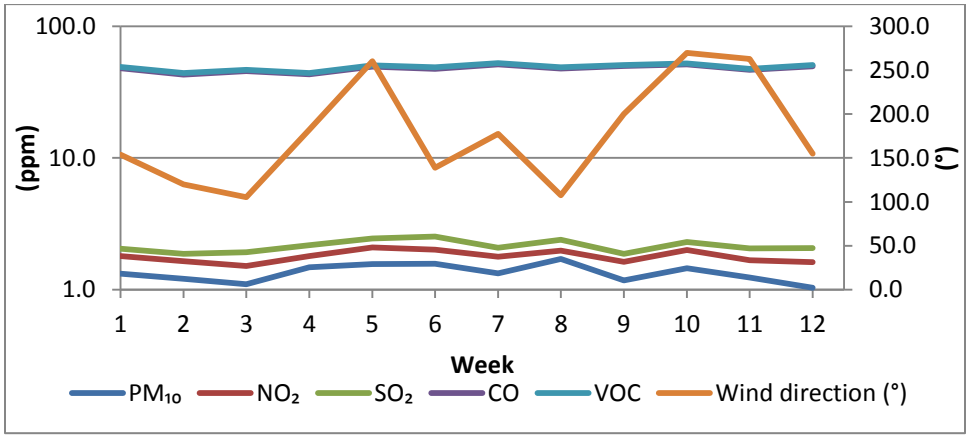

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Opuoma



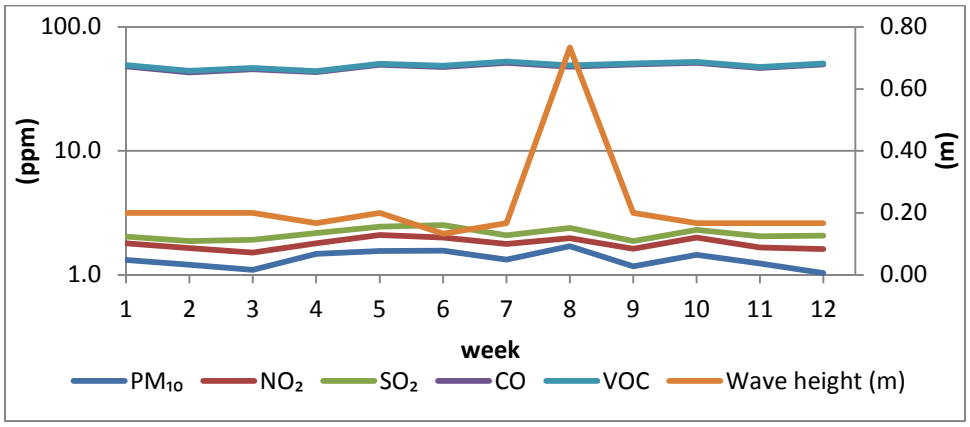

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative humidity at Opuoma




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Opuoma



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Opuoma

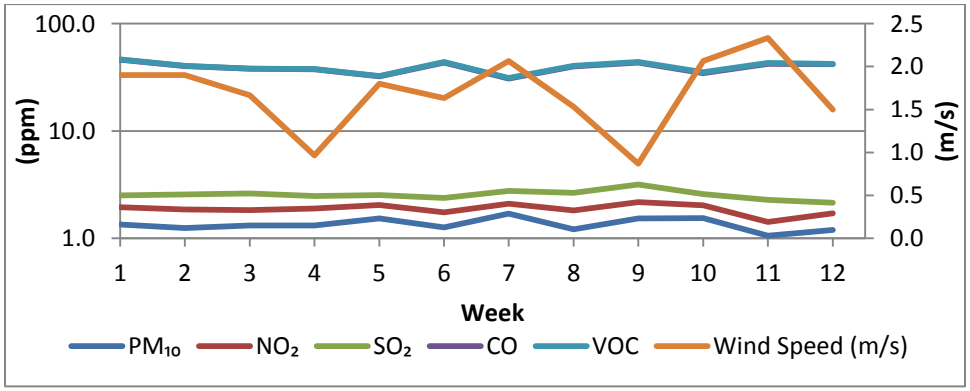



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Opuoma

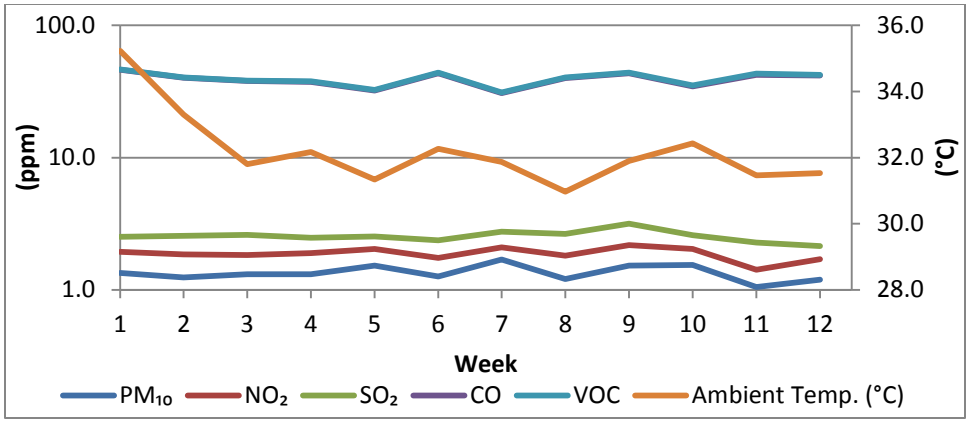
**Wet Season Multivariate Plots of the Air Pollutants**

**Orlu (Wet Season)**

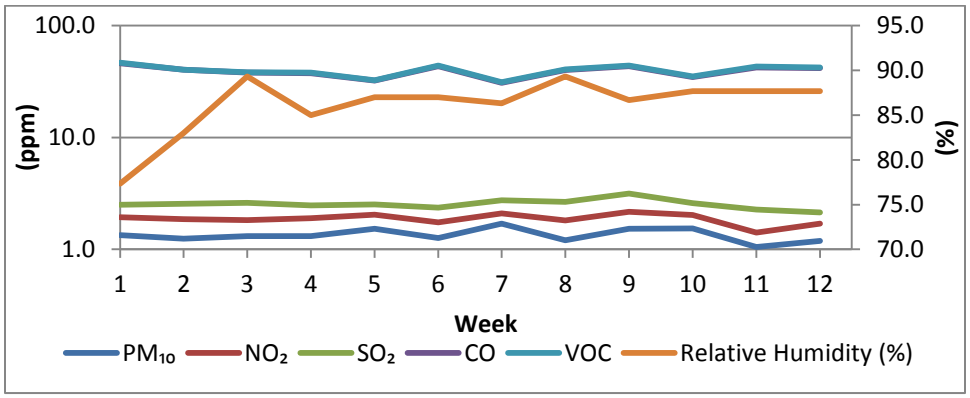
**Banana Junction (Wet Season)**



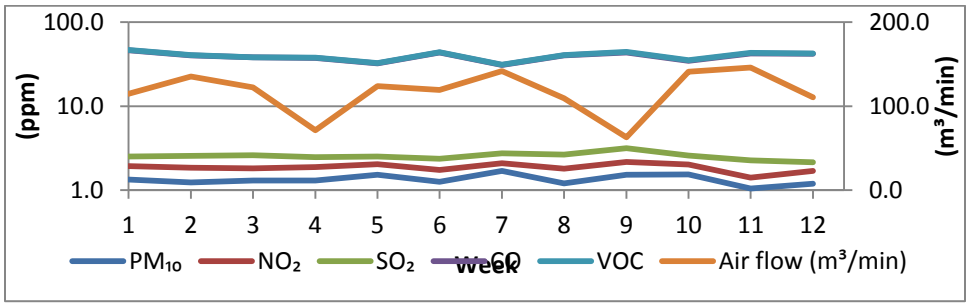

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Banana Junction



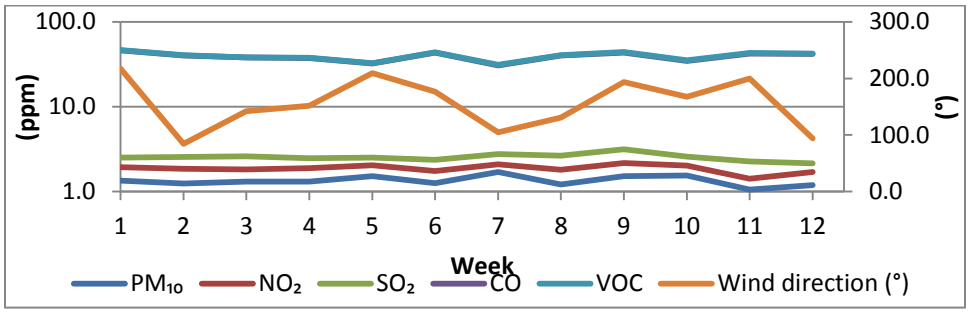

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Banana Junction



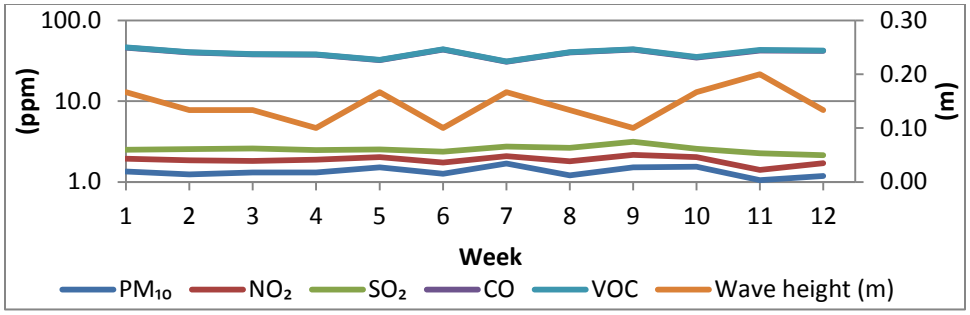

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Banana Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Banana Junction

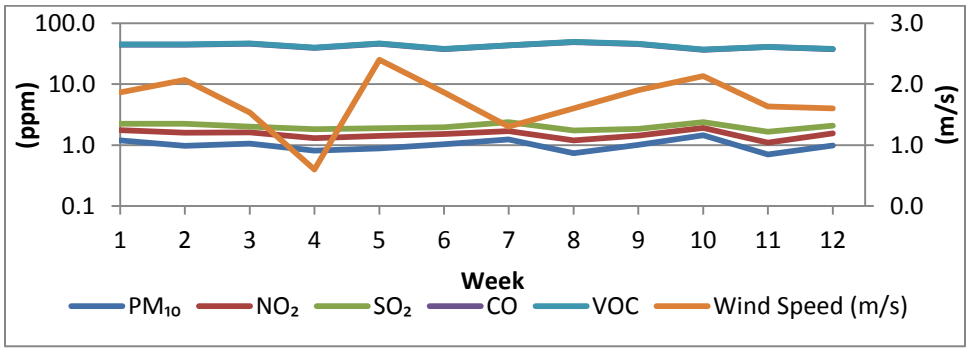



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Banana Junction

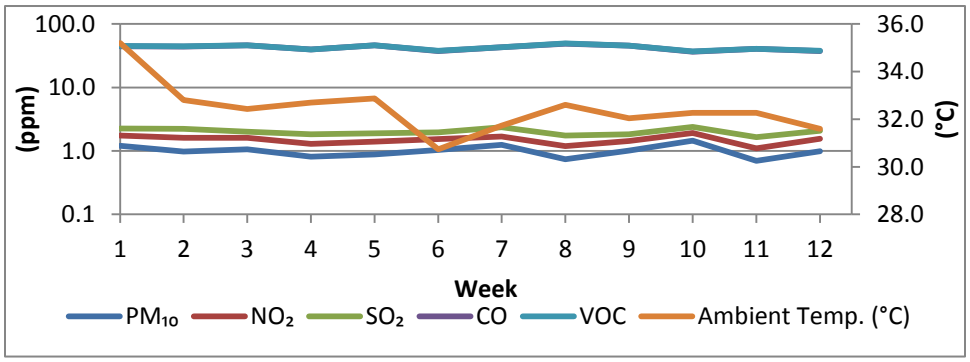



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Banana Junction

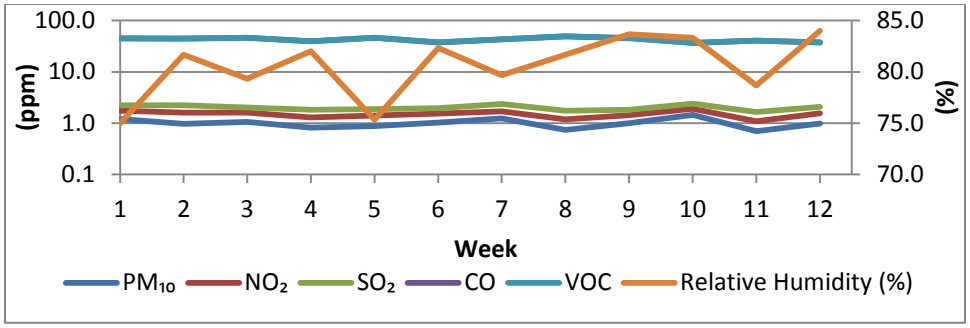
**Umuaka Junction (Wet Season)**



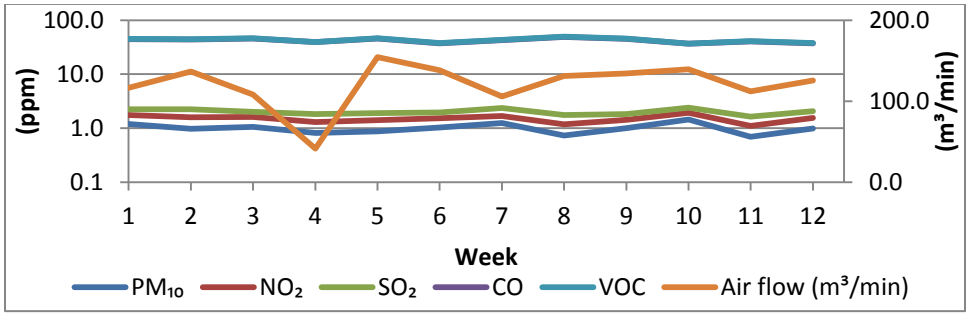

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuaka Junction



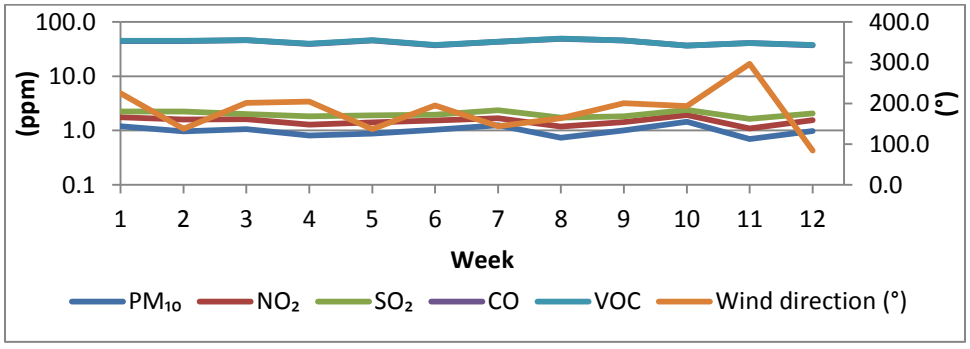

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuaka Junction



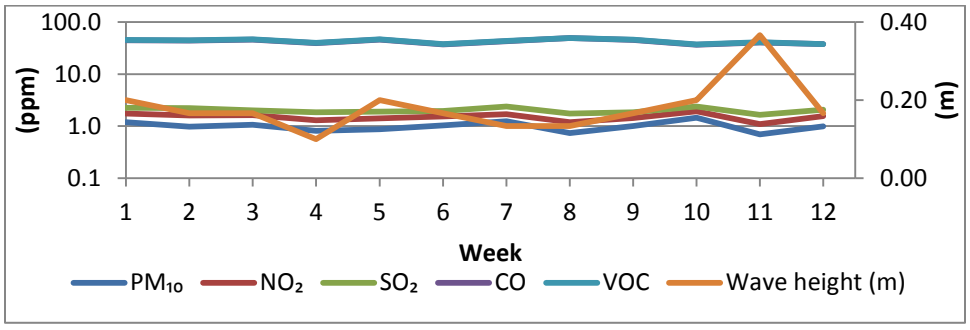

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative humidity at Umuaka Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuaka Junction

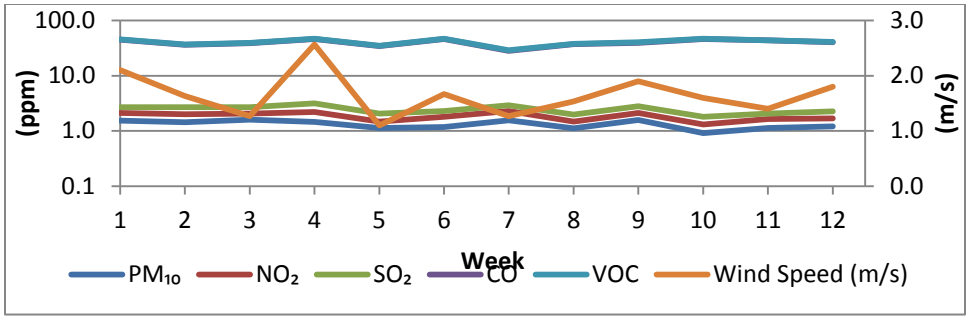



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at Umuaka Junction

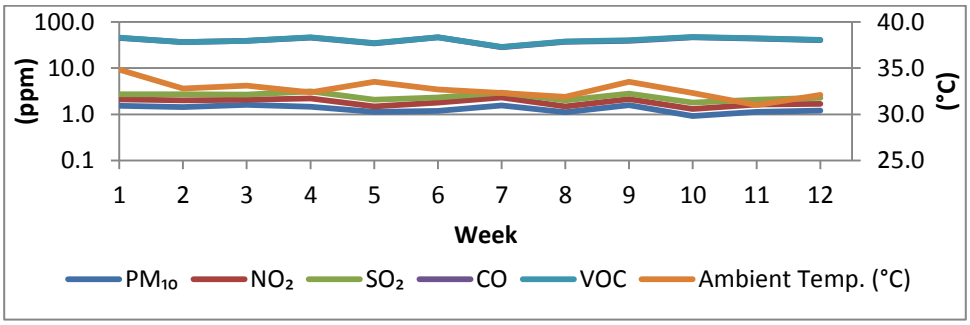



Plot of the $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height for Umuaka Junction

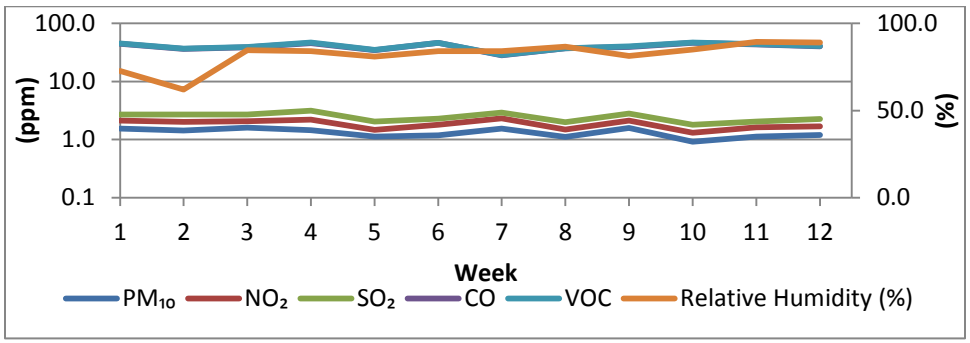
**Umuna Junction Orlu**



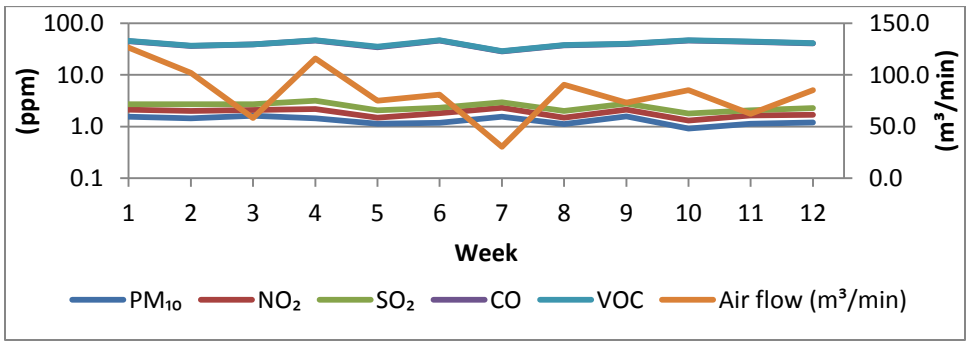

Plot of at $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuna Junction



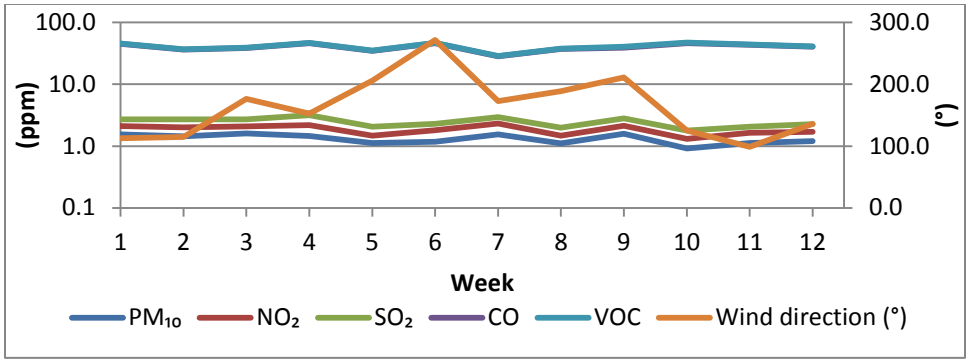

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuna Junction



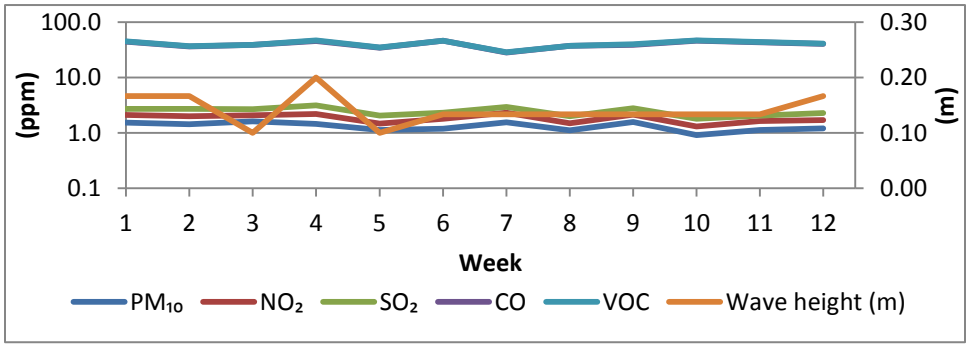

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative humidity at Umuna Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuna Junction

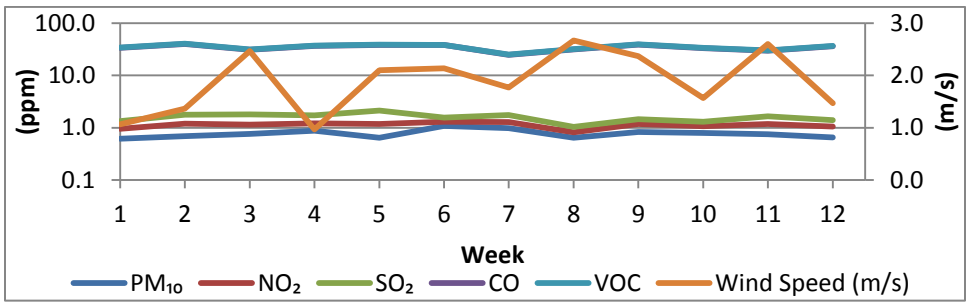



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Umuna Junction

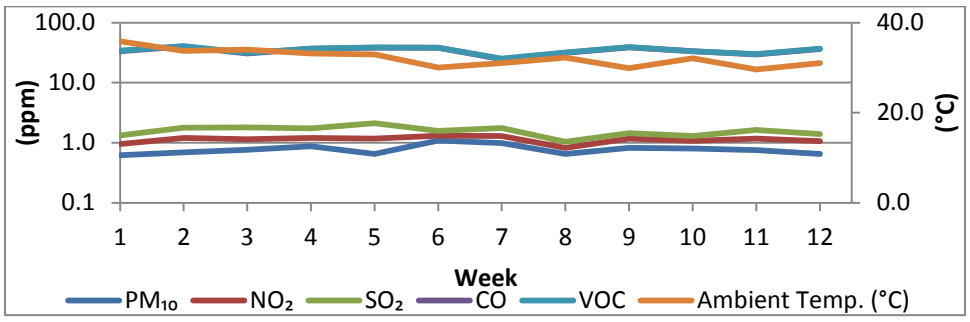



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Umuna Junction

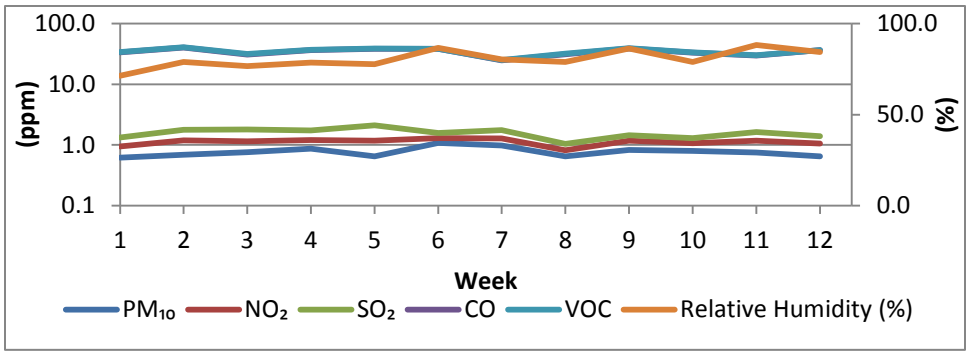
**Umuago Urualla (Wet Season)**



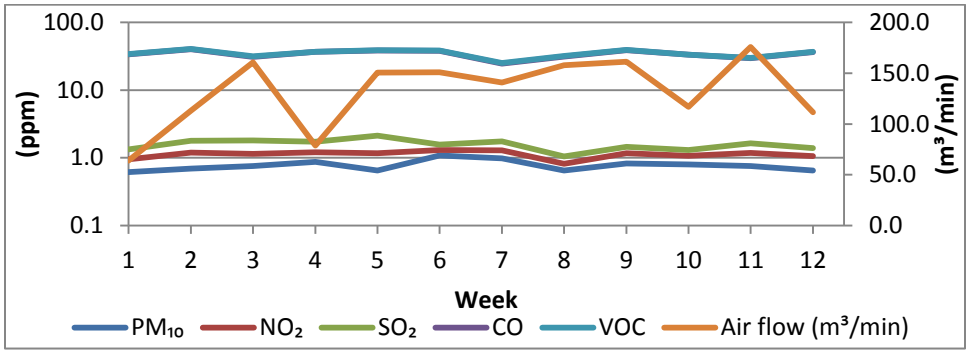

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuago Urualla



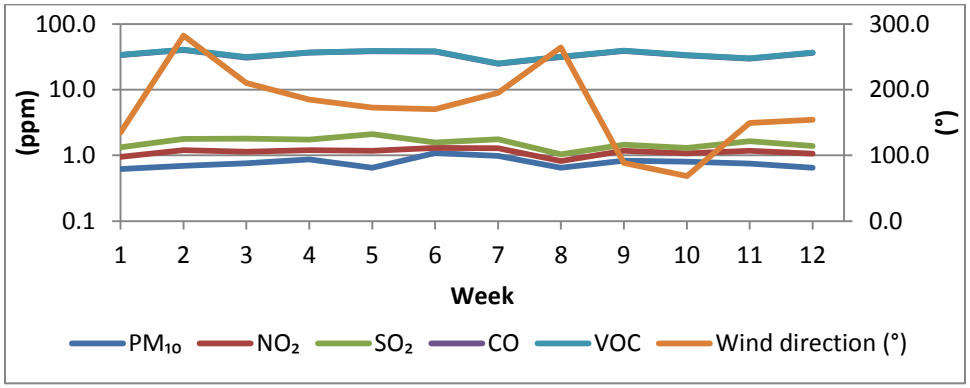
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and CO against Amb. Temp. at Umuago Urualla



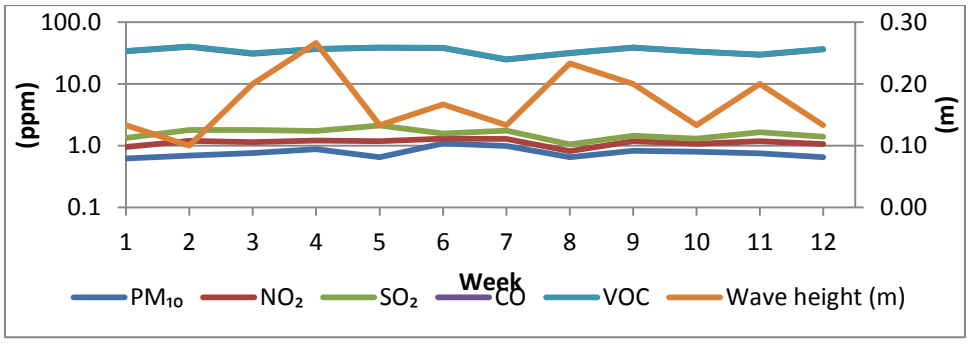

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuago Urualla



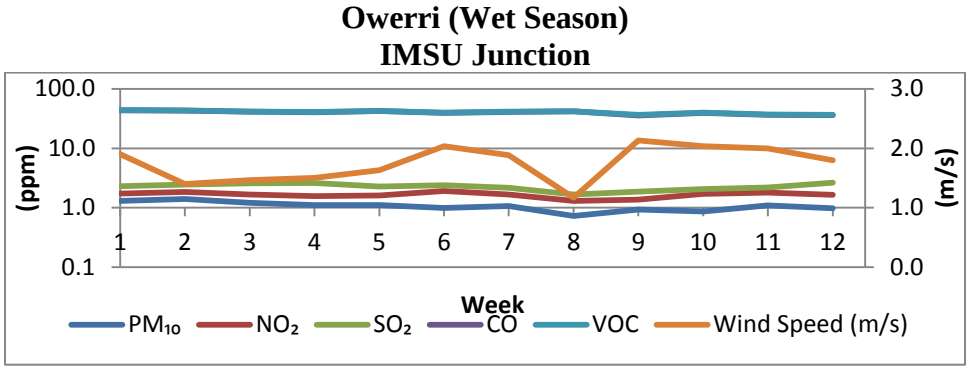

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuago Urualla



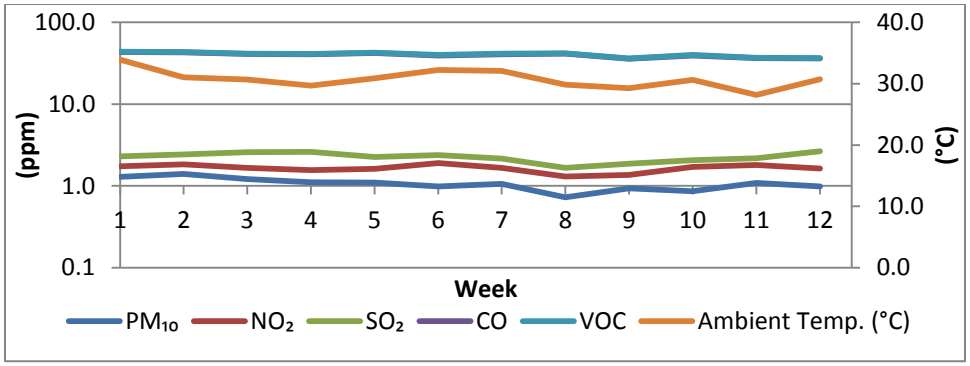

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuago Urualla



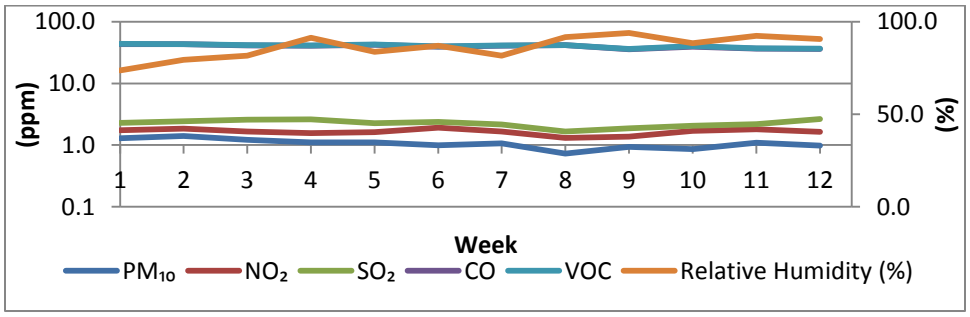
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Umuago Urualla



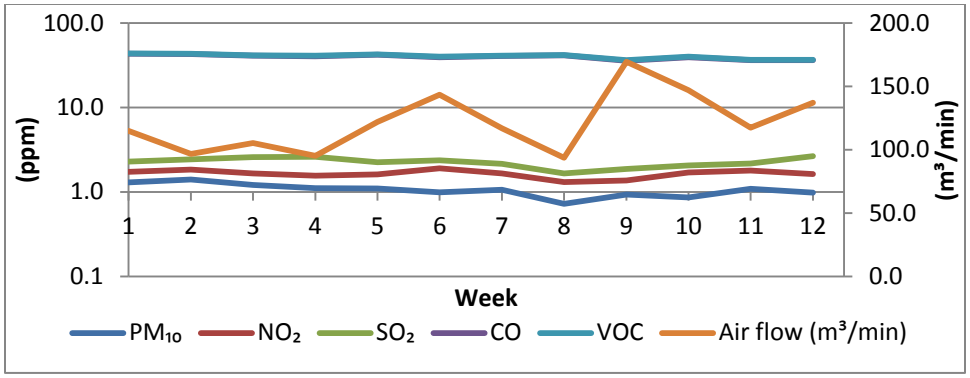

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind speed at IMSU Junction



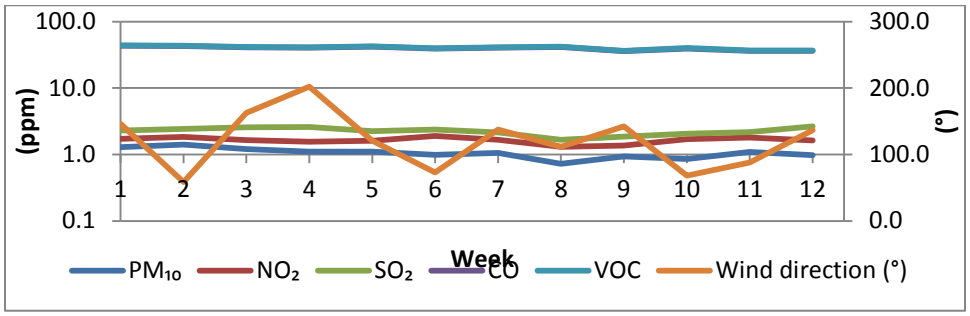

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at IMSU Junction



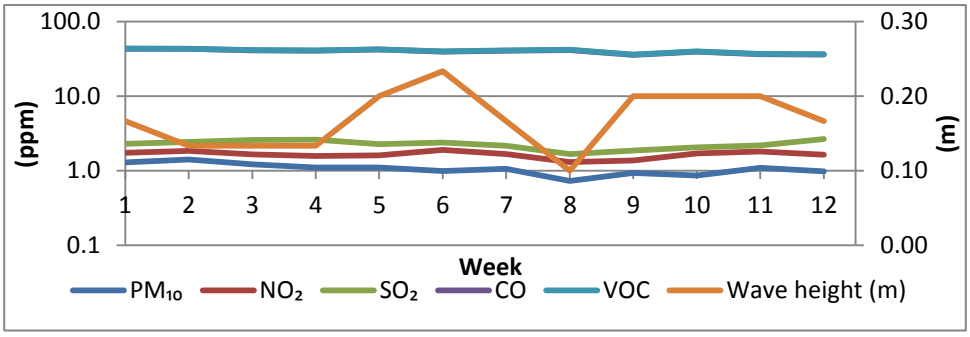

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at IMSU Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against air flow at IMSU Junction

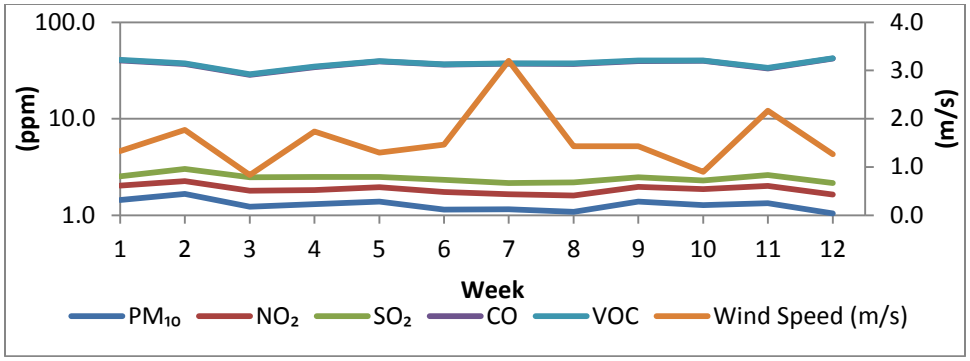



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at IMSU Junction

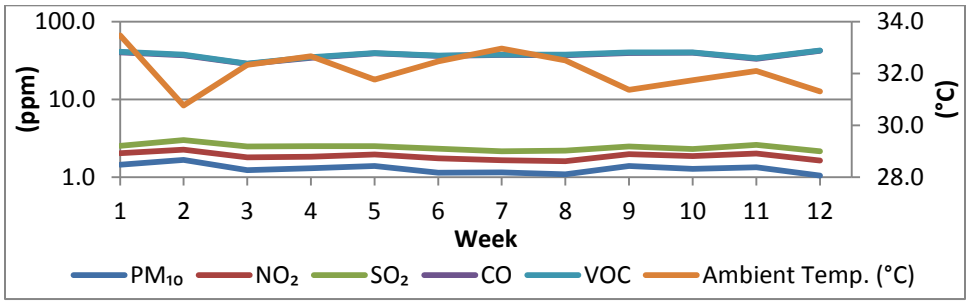



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at IMSU Junction

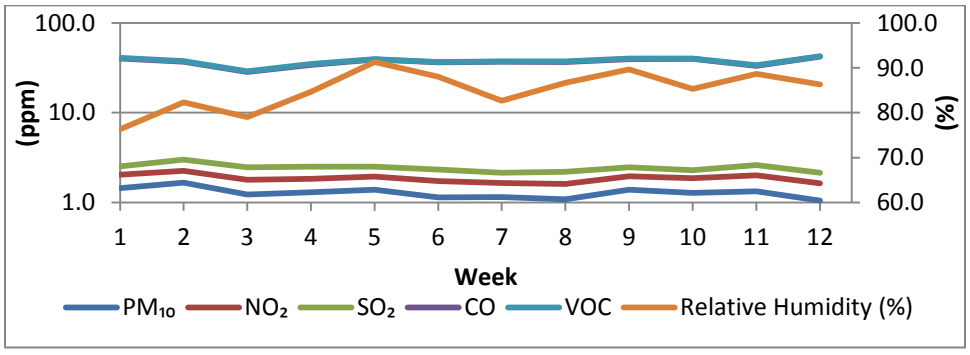
**Emmnuel College Junction (Wet Season)**



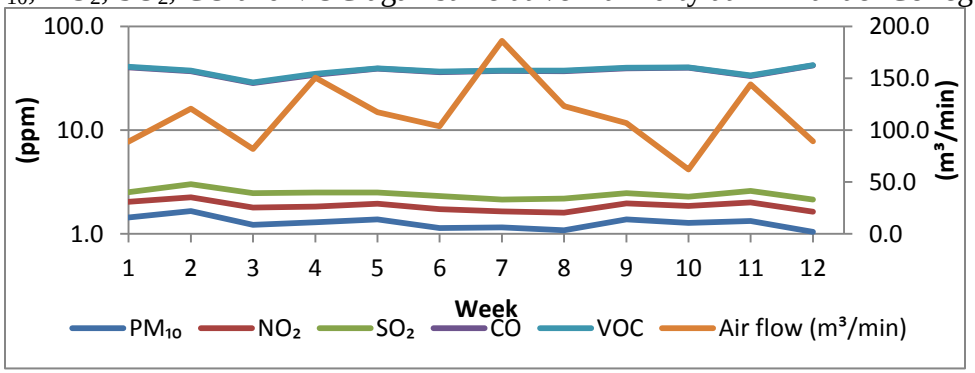

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Emmanuel College Junction



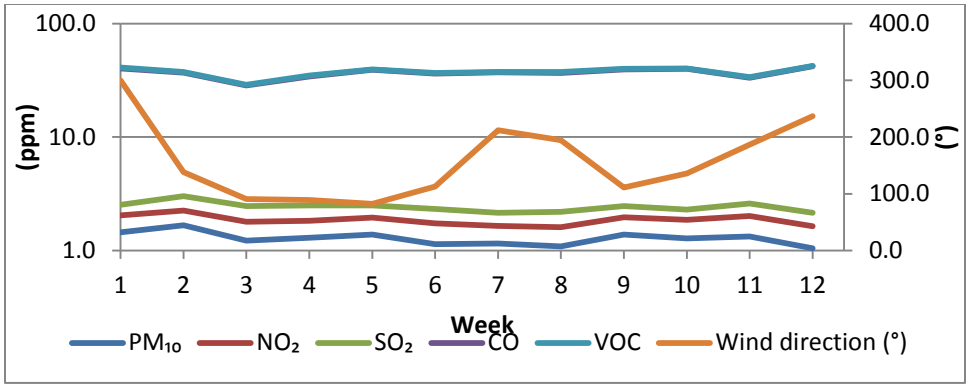

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Emmanuel College Junction



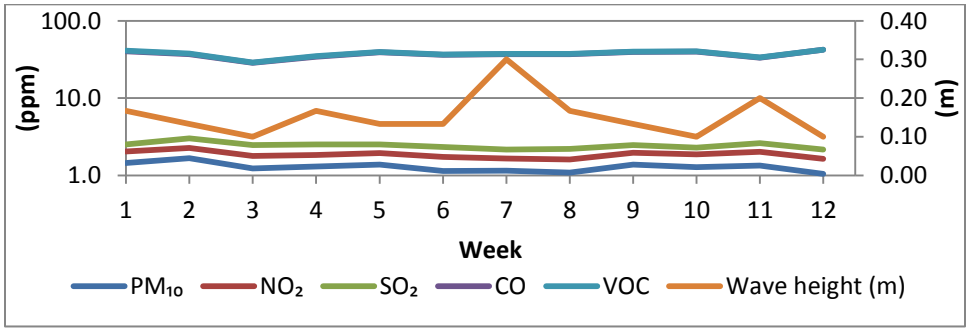

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Emmanuel College Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Emmanuel College Junction

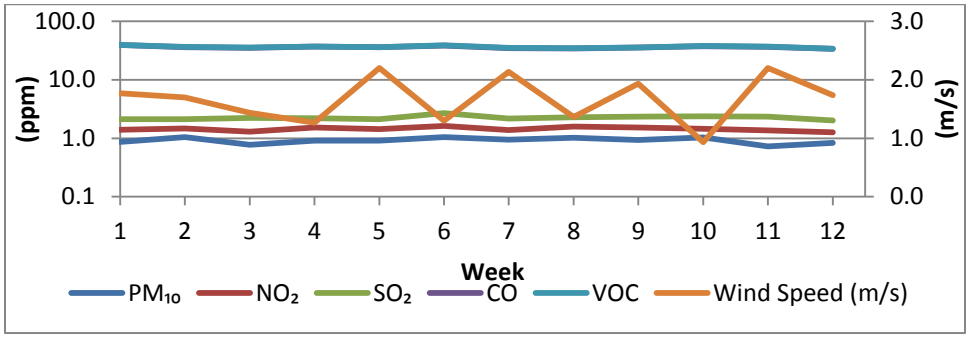



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Emmanuel College Junction

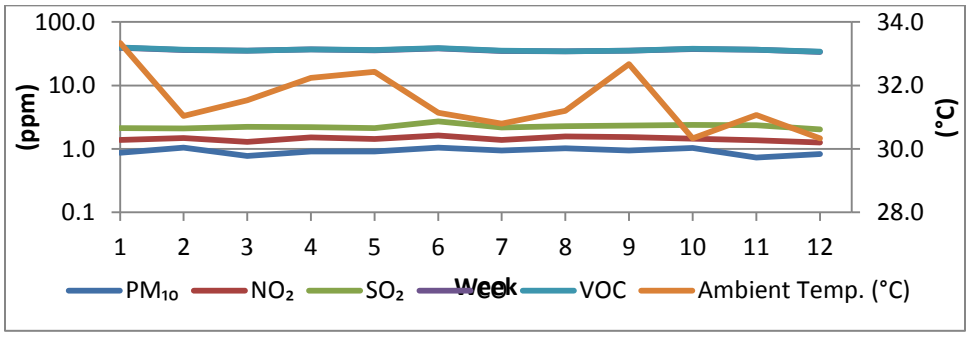



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave height at Emmanuel College Junction

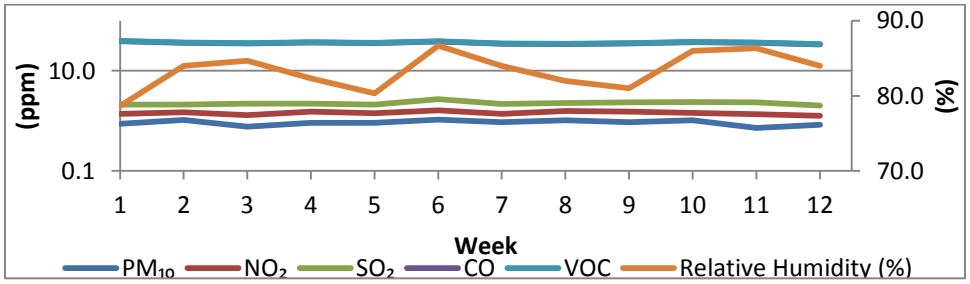
**World Bank Market Junction (Wet Season)**



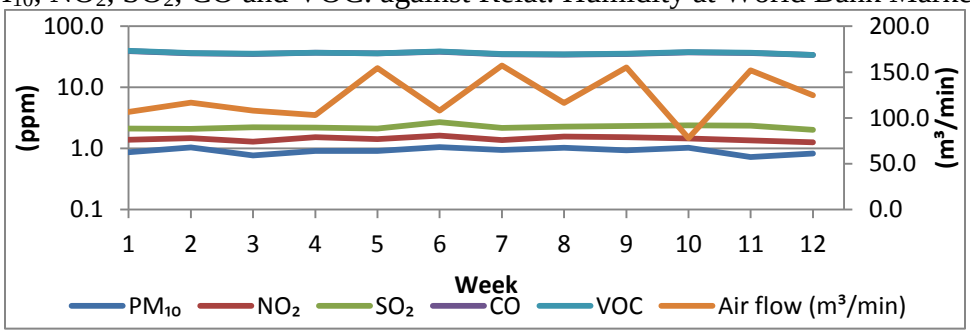

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at World Bank Market Junction



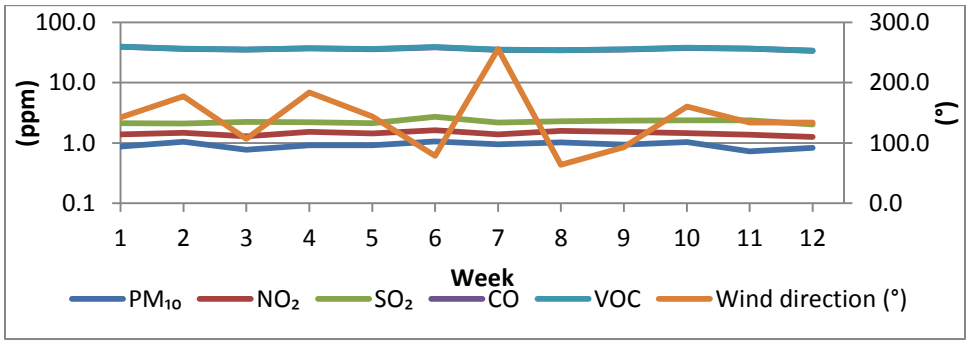
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at World Bank Market Junction



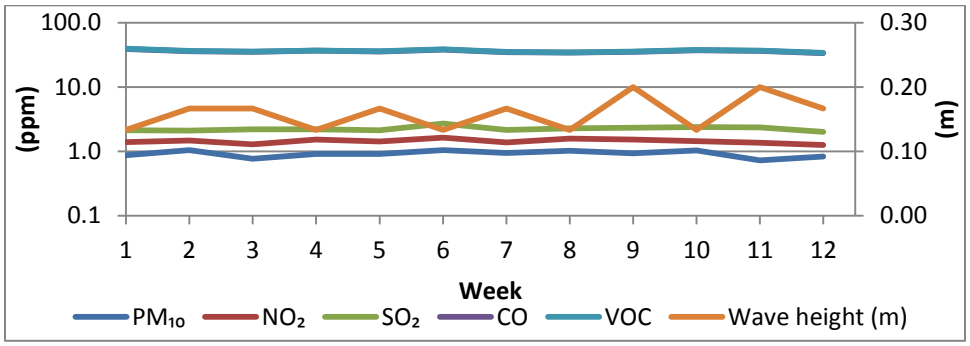

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC. against Relat. Humidity at World Bank Market Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at World Bank Market Junction

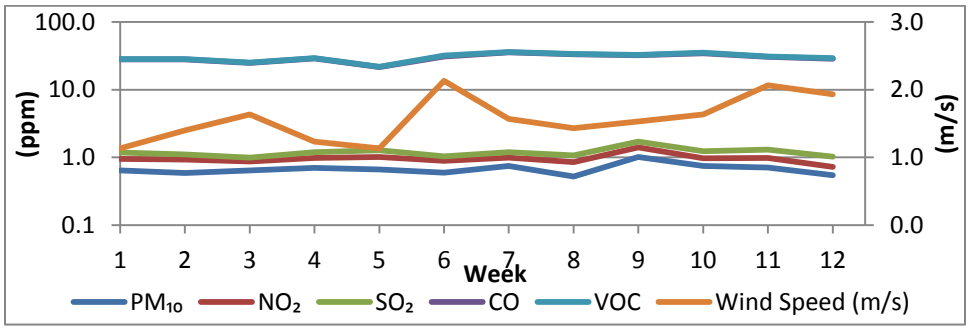



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at World Bank Market Junction

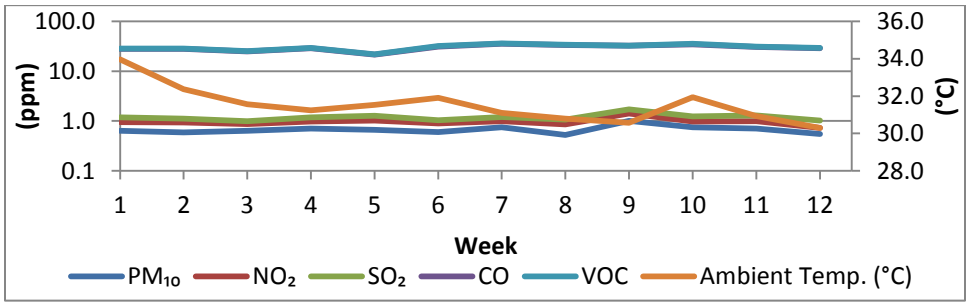



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at World Bank Market Junction

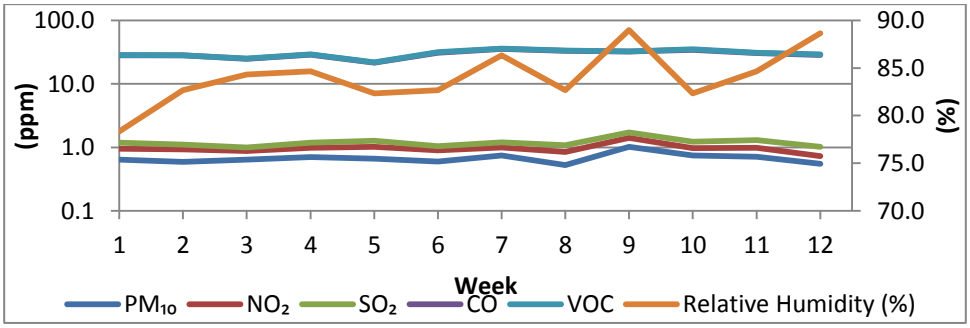
**Egbu – Uratta Ring Road (wet Season)**



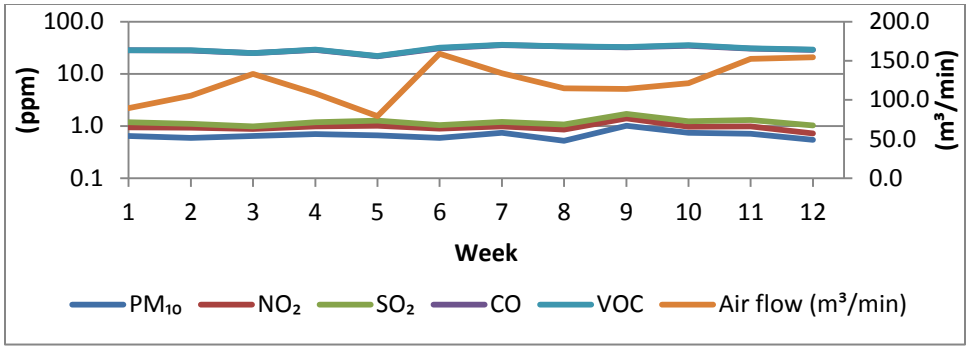

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Egbu-Uratta Ring Road



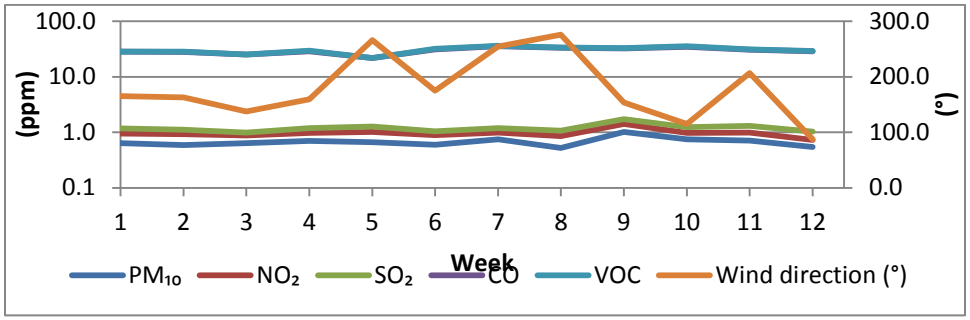

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. Egbu-Uratta Ring Road



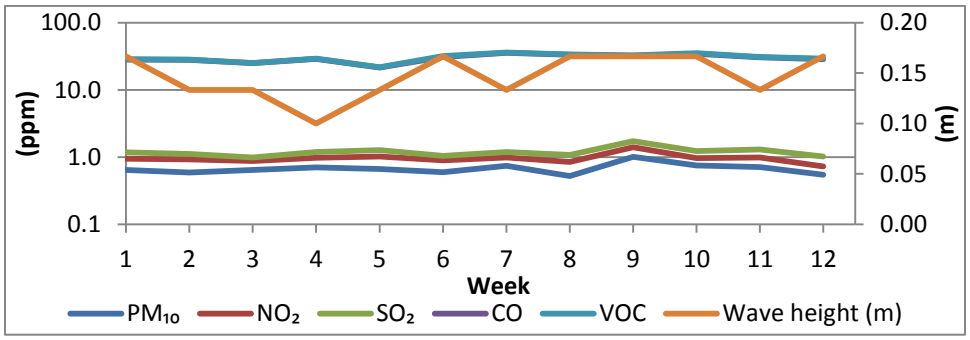

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative humidity at Egbu-Uratta Ring Road




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Egbu-Uratta Ring Road



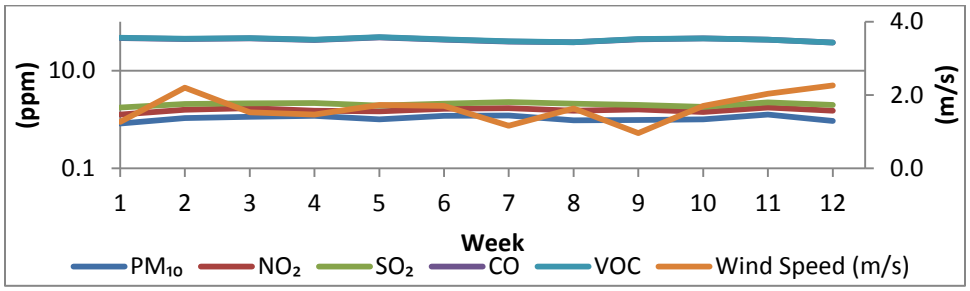

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Egbu-Uratta Ring Road



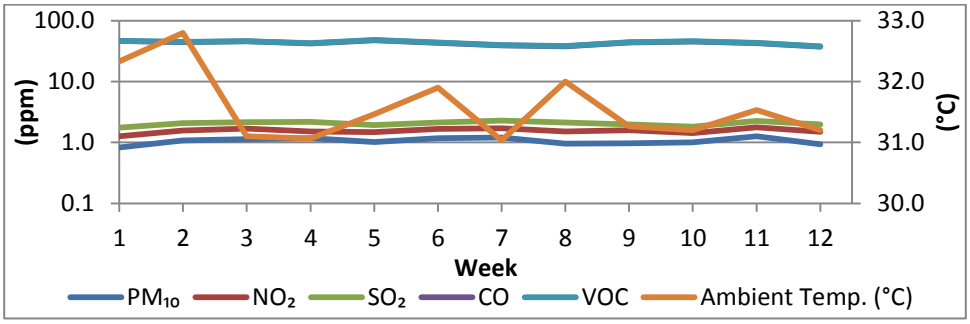

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Egbu-Uratta Ring Road

**Okigwe**

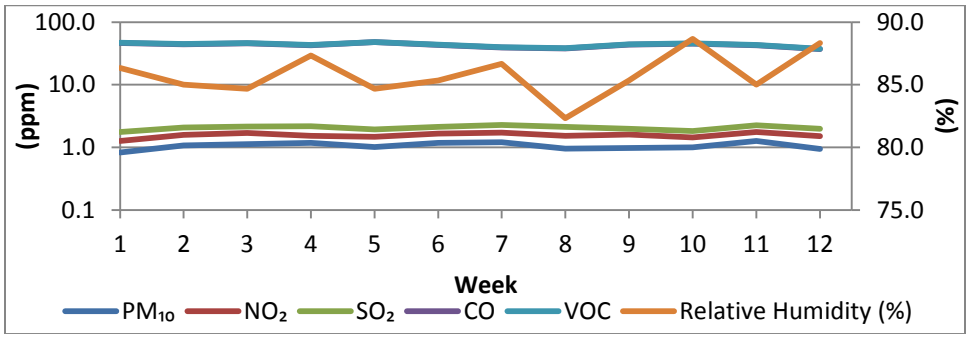
**Umuna Junction, Okigwe (Wet Season)**



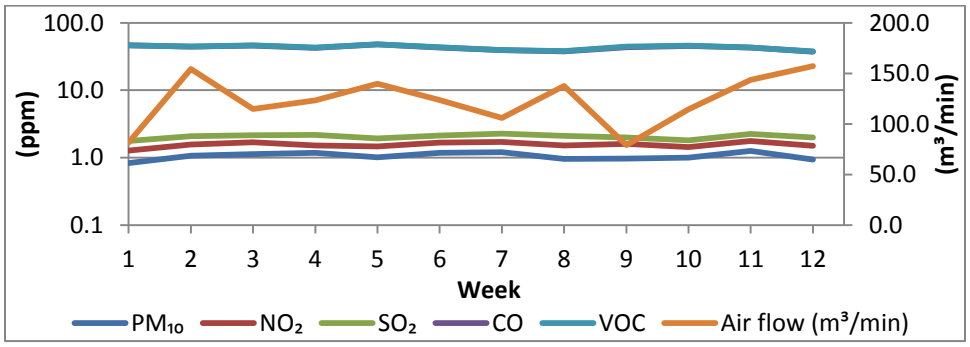
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuna Junction Okigwe



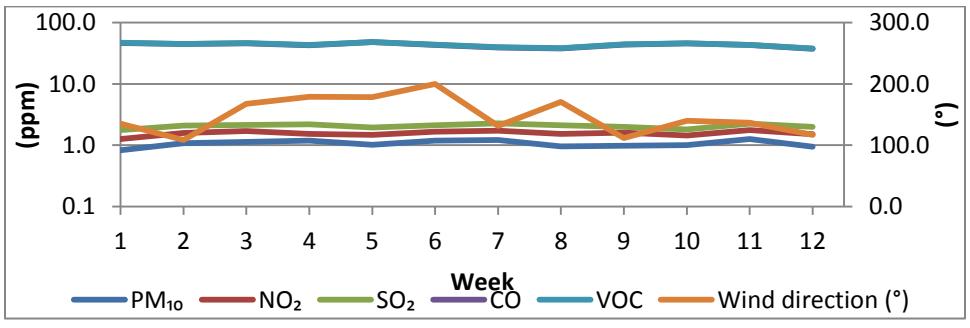

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuna Junction, Okigwe



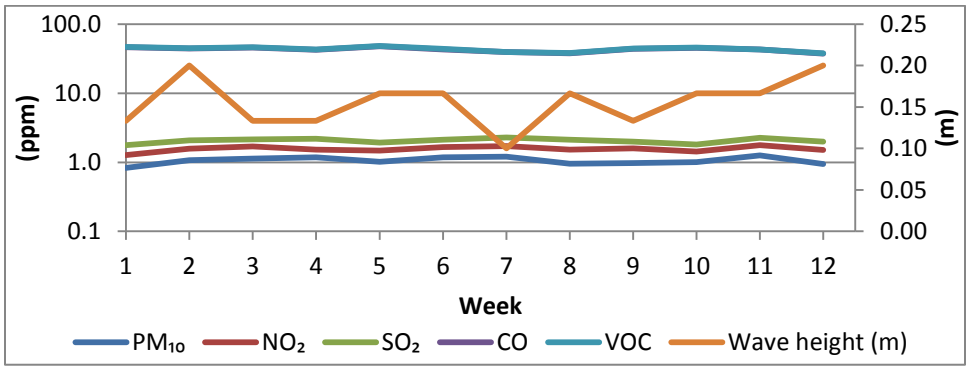

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuna, Okigwe




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuna Junction, Okigwe

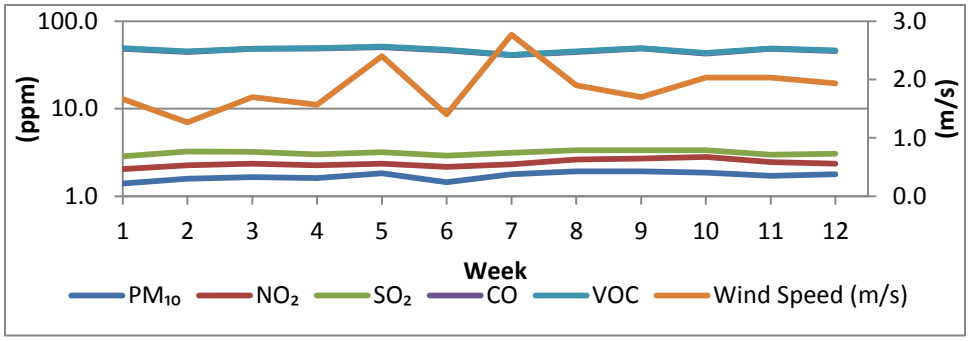



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Umuna

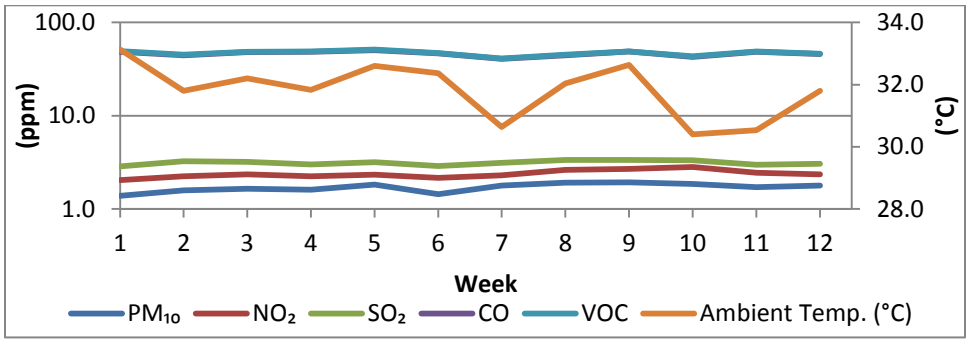



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Umuna Junction, Okigwe

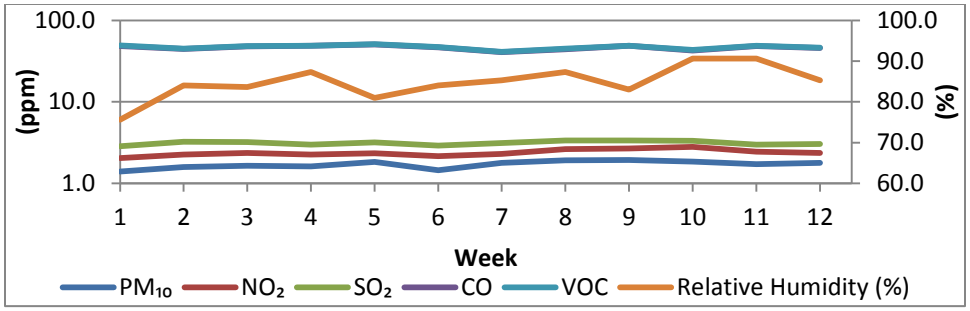
**Okigwe Express Junction (Wet Season)**



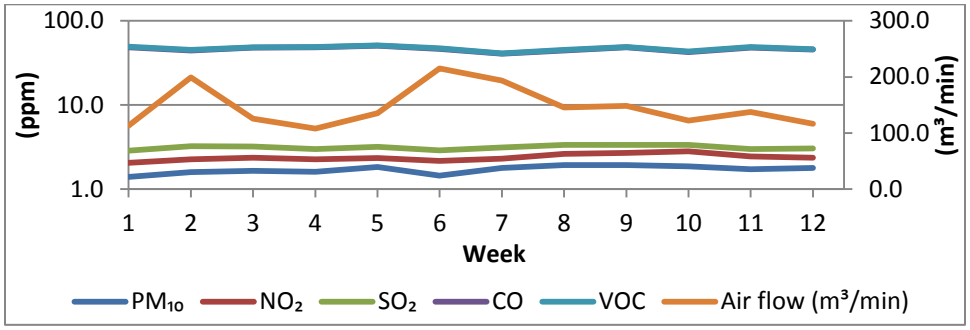

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Okigwe Express Junction



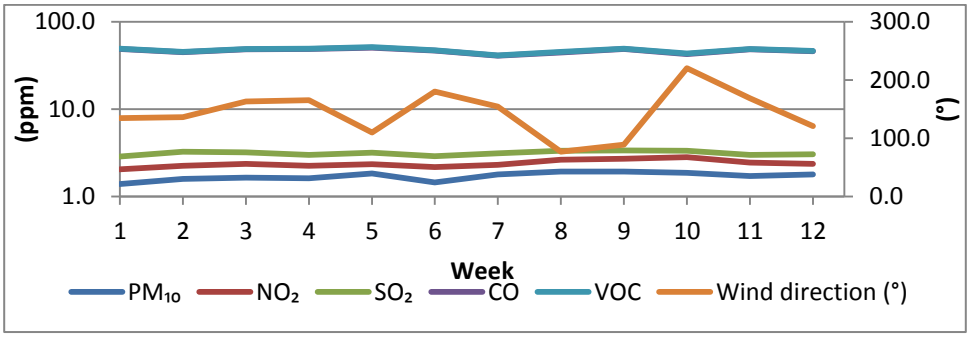

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Okigwe Express Junction



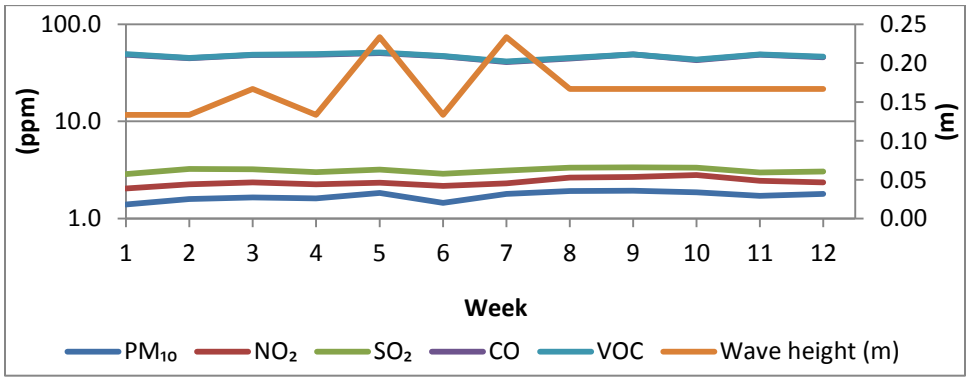

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Okigwe Express Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Okigwe Express Junction

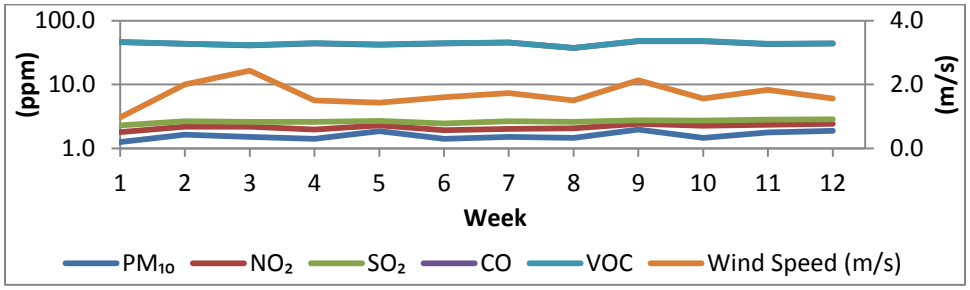



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Okigwe Express Junction

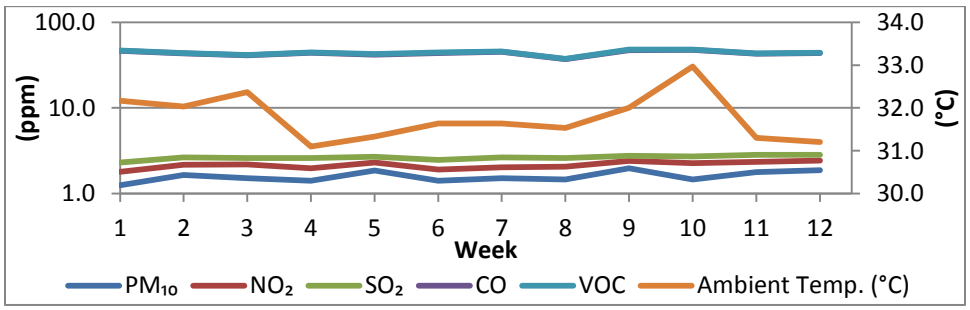



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Okigwe Express Junction

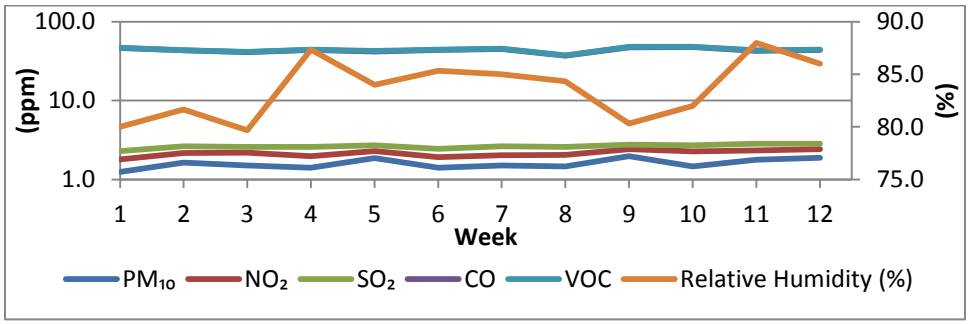
**St. Mary's Junction, Okigwe (Wet Season)**



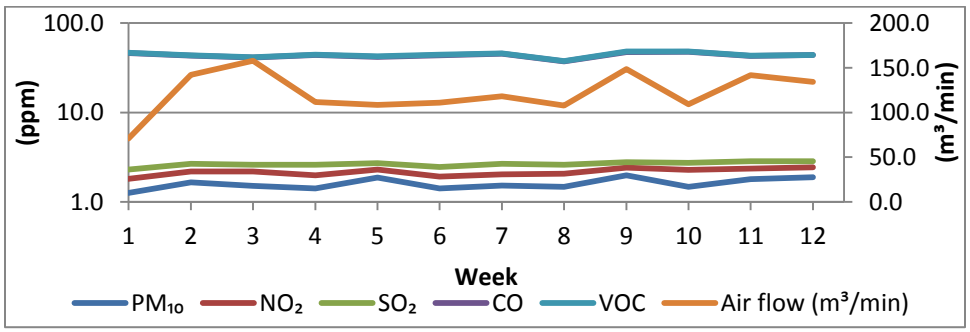

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at St. Mary's Junction



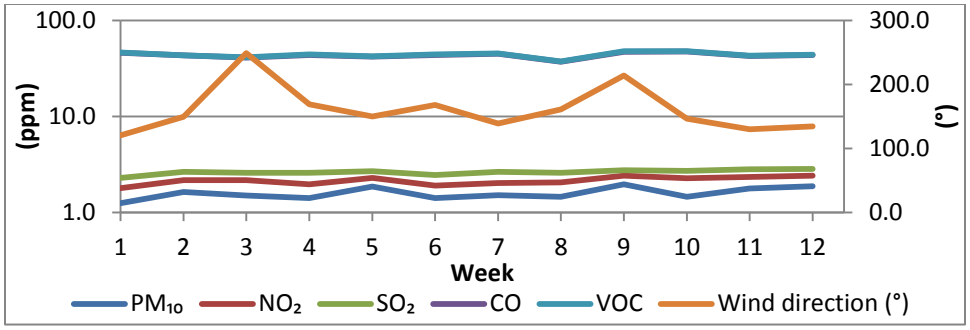

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at St. Mary's Junction



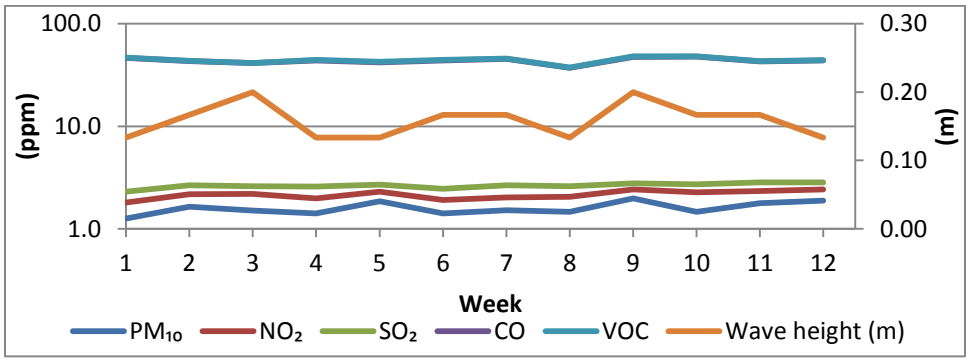

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative humidity at St. Mary's Junction




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air Flow at St. Mary's Junction

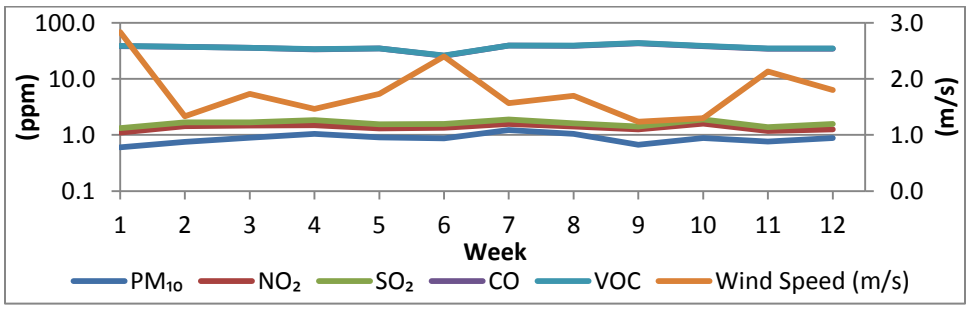



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at St. Mary's Junction

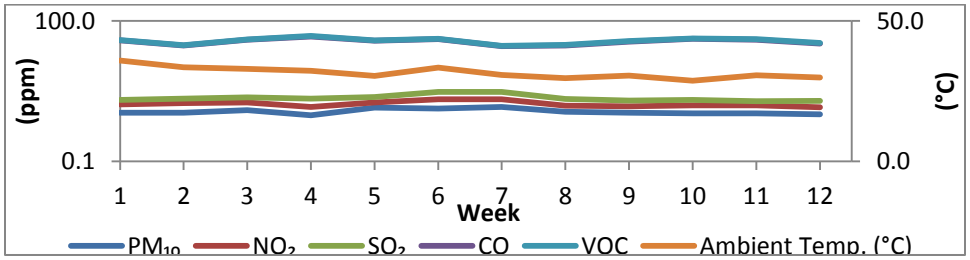



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at St. Mary's Junction

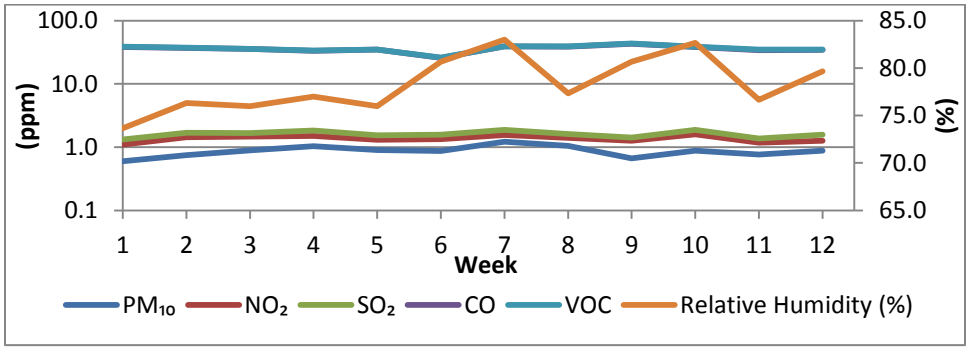
**Ihube Okigwe (Wet Season)**



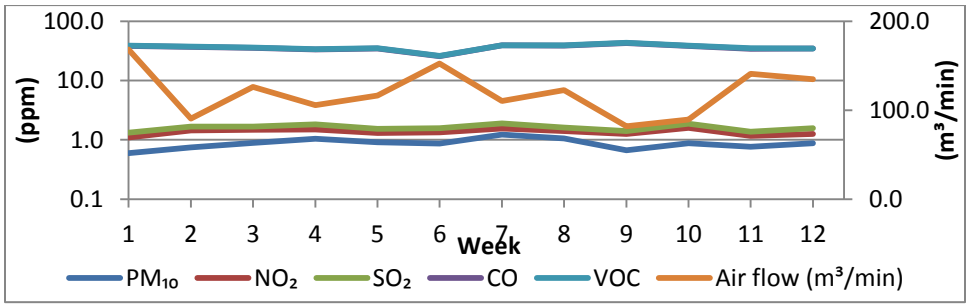

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Ihube



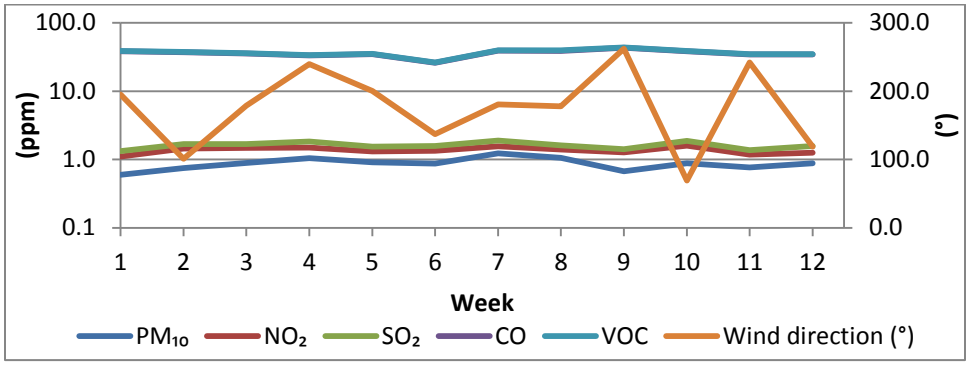
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ihube



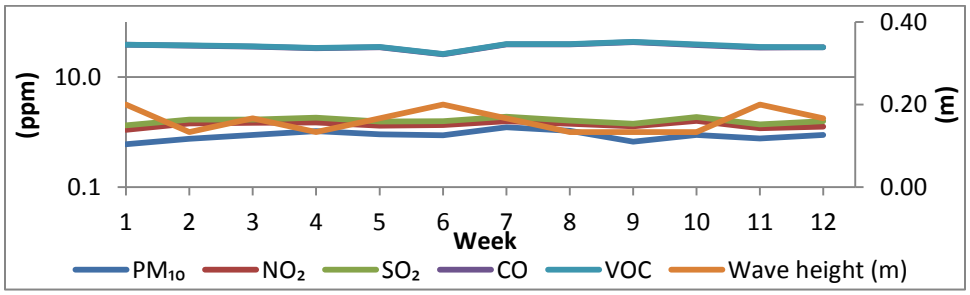

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ihube




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ihube



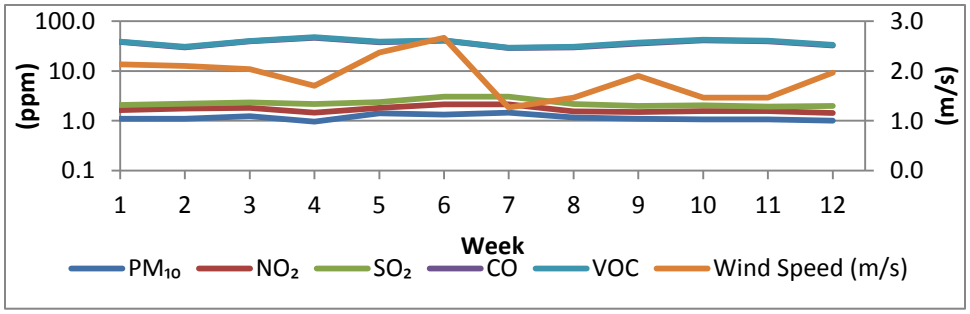

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Ihube



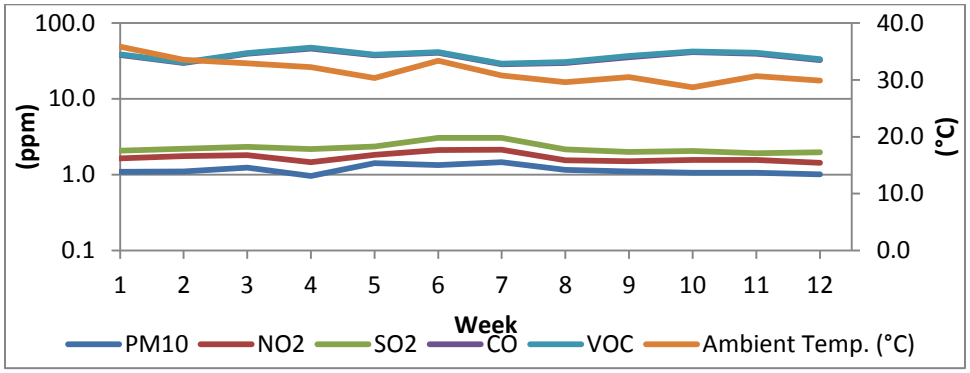

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height. at Ihube

## Egbema (Wet Season)

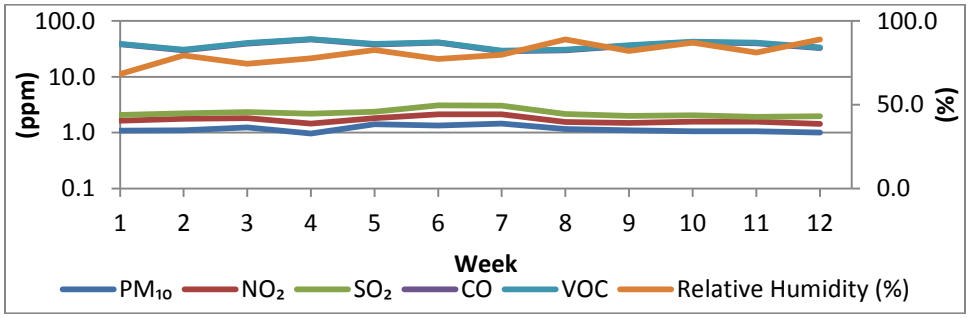
### Umuorji



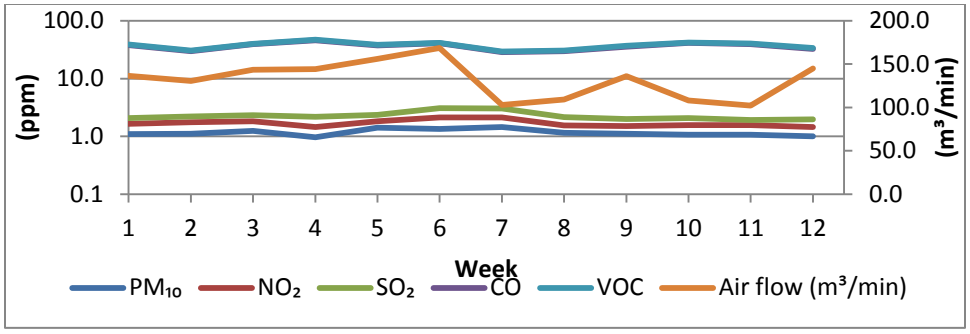

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Umuorji



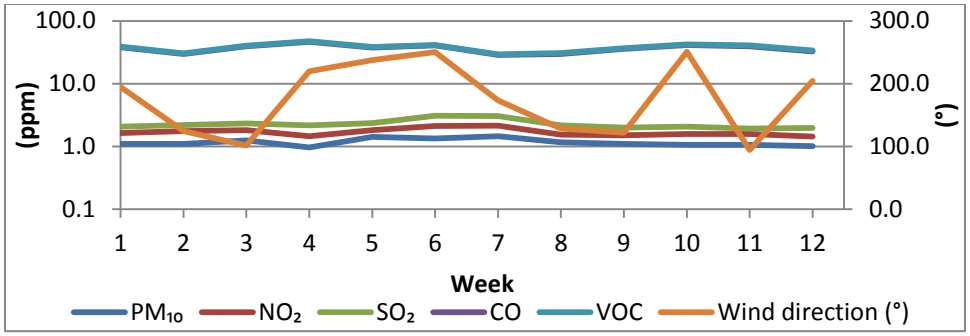

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Umuorji



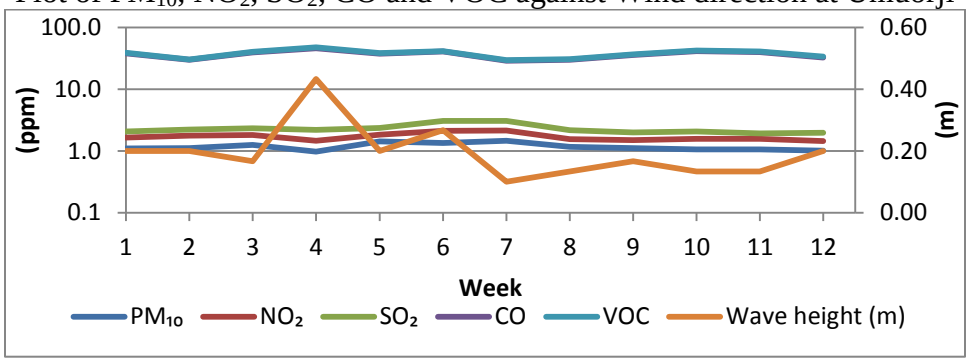

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Umuorji




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Umuorji

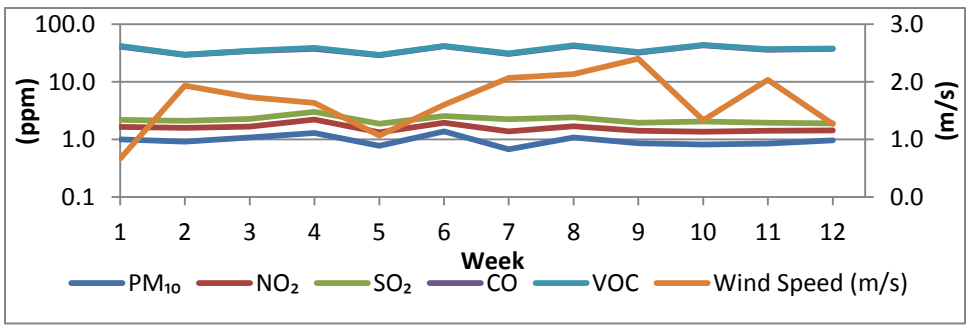



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind direction at Umuorji

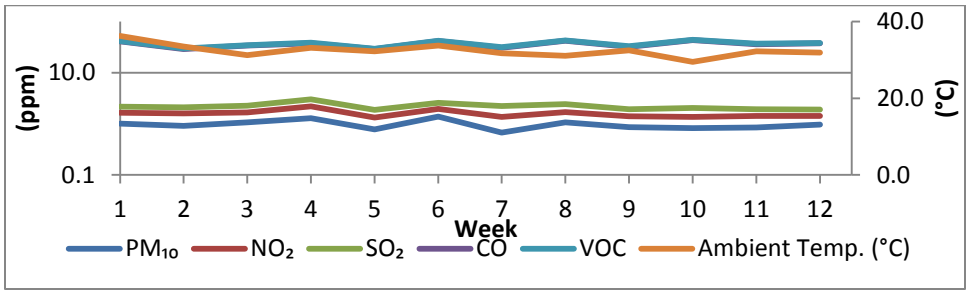



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Umuorji

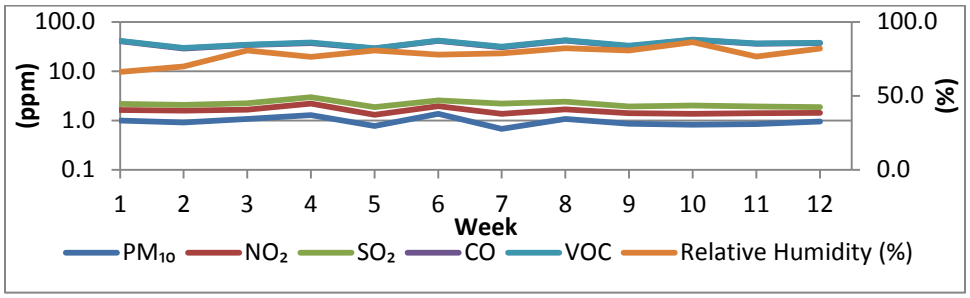
Ukwugba 1



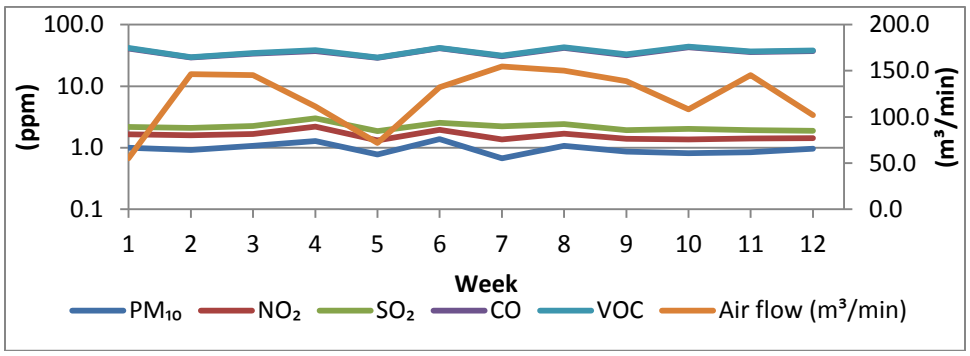
Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Ukwugba 1



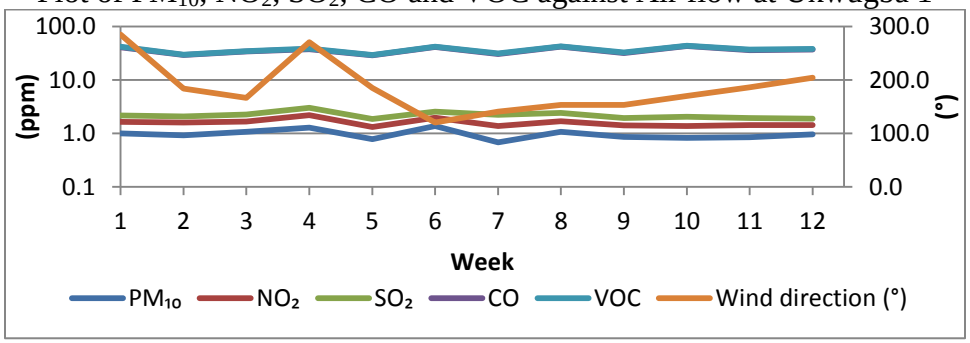

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ukwugba 1



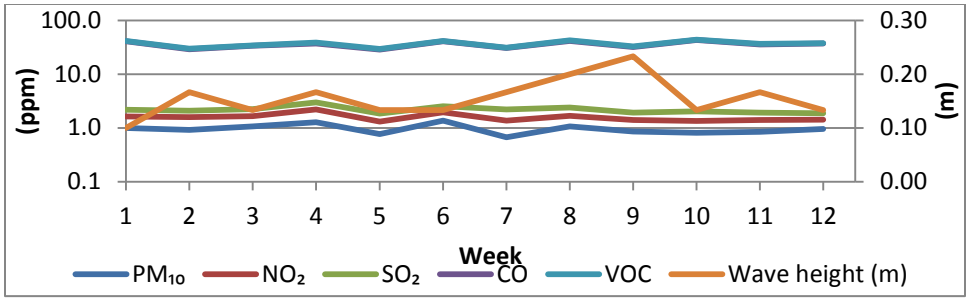

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ukwugba 1




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ukwugba 1

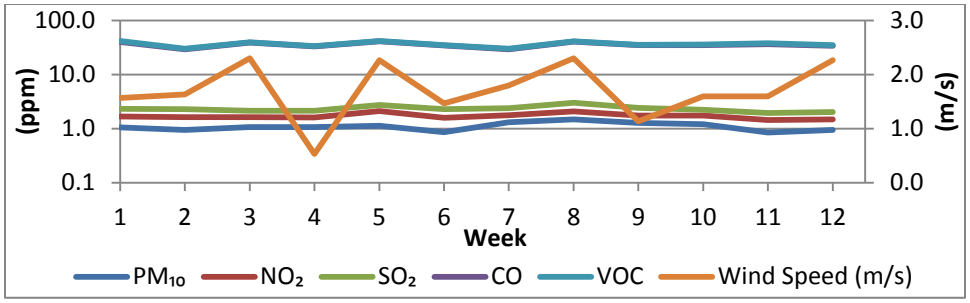



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Ukwugba 1

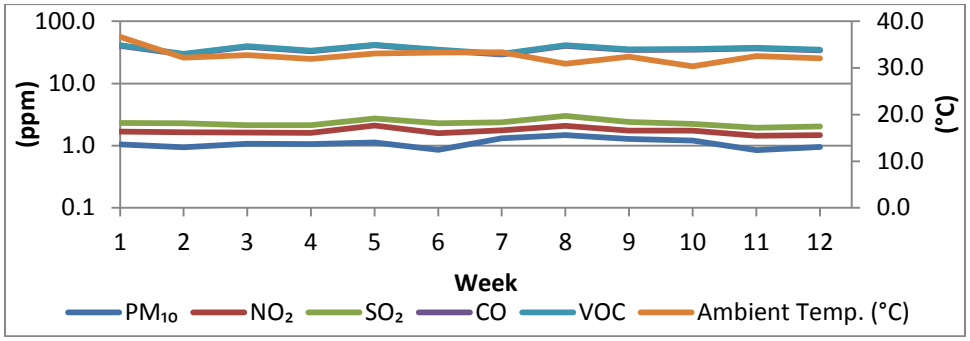



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Ukwugba 1

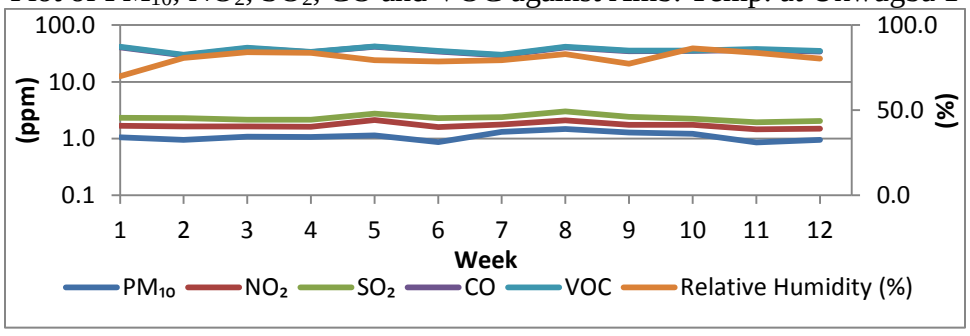
**Ukwugba 2 (Wet Season)**



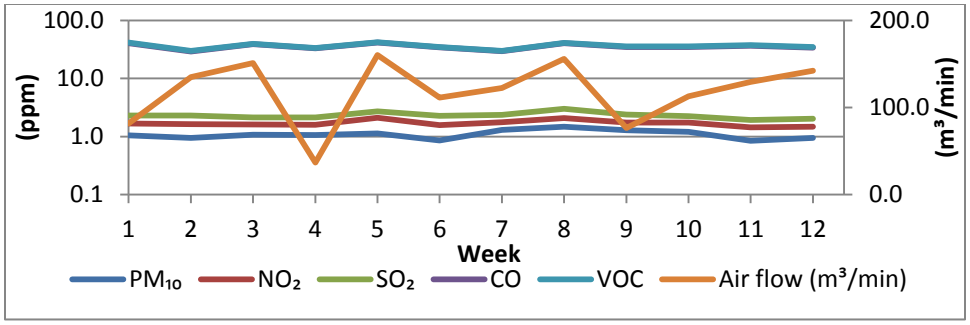

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Ukwugba 2



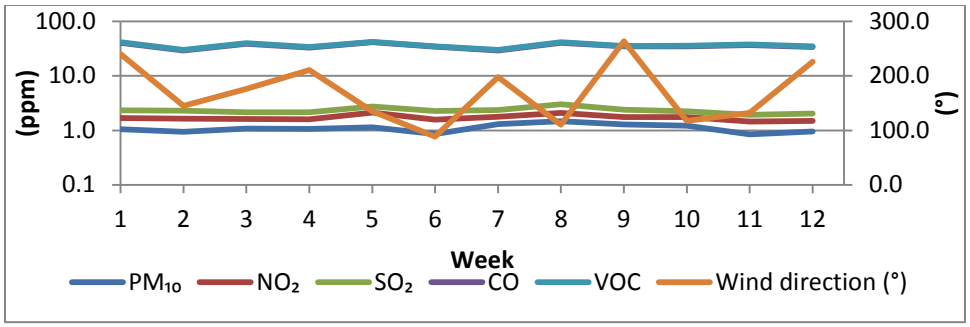

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Ukwugba 1



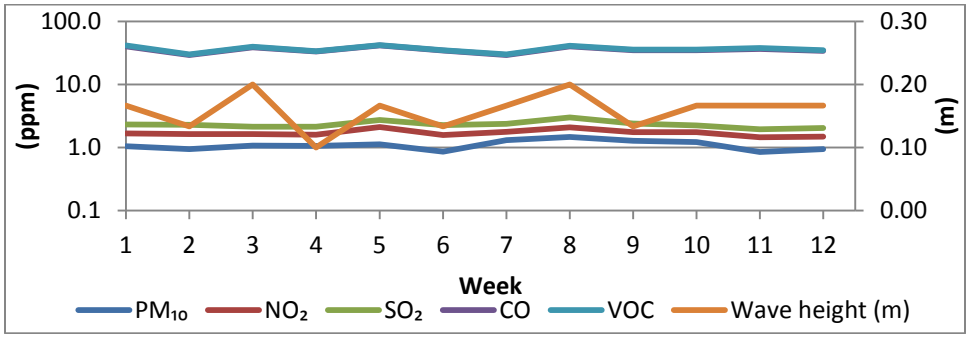

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Ukwugba 2




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Ukwugba 2

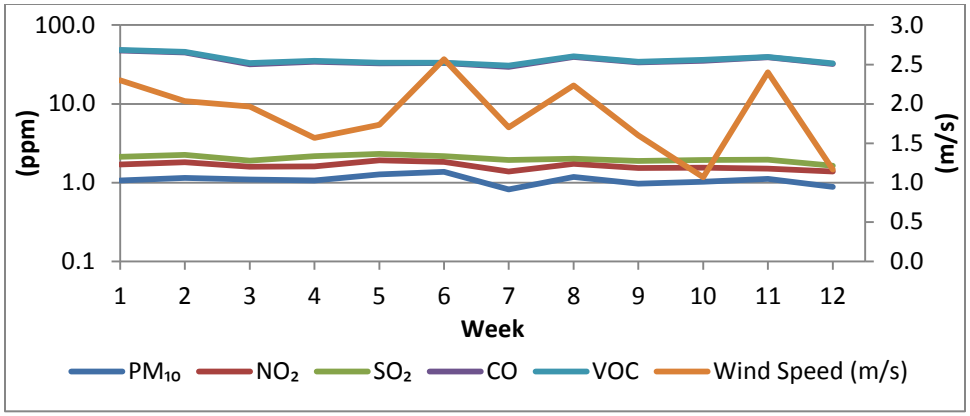



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Ukwugba 2

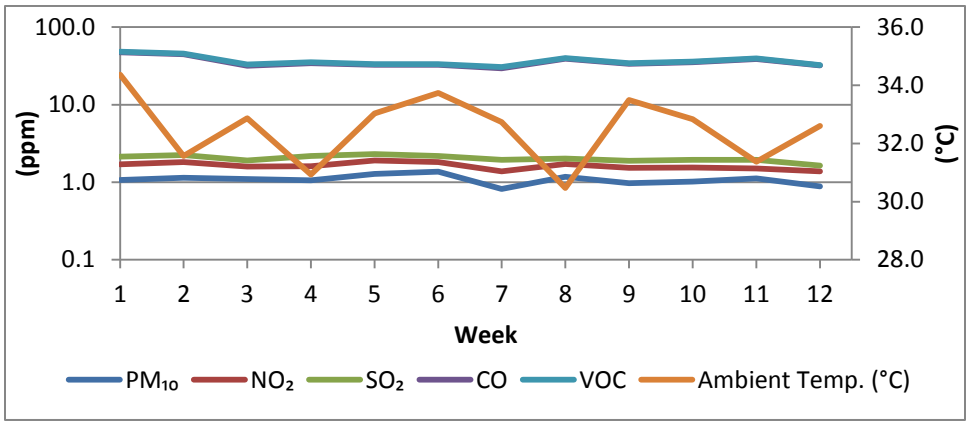



Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wave Height at Ukwugba 2

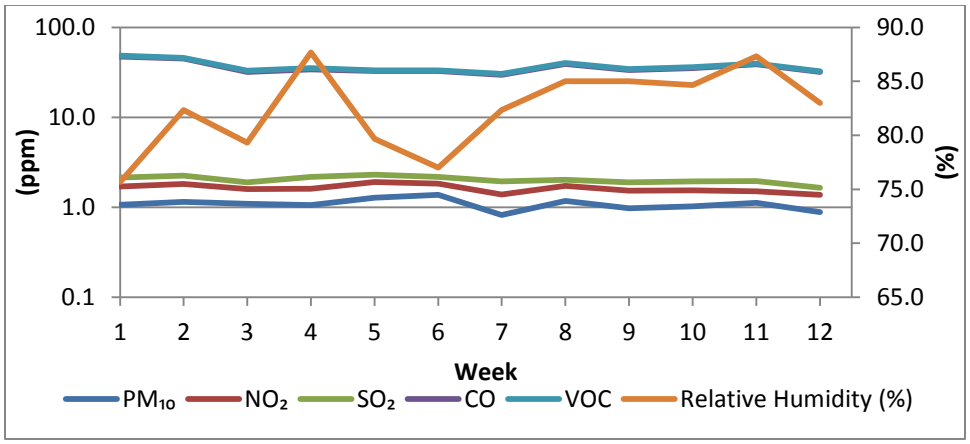
**Opuoma (Wet Season)**



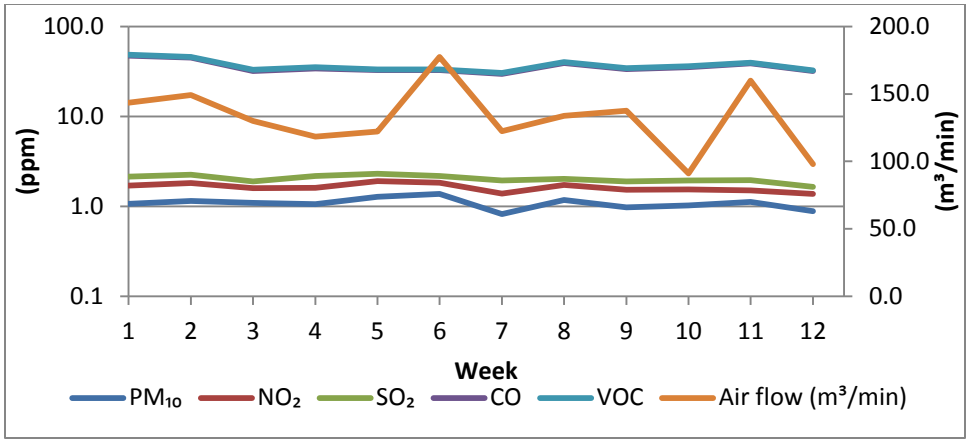

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Speed at Opuoma



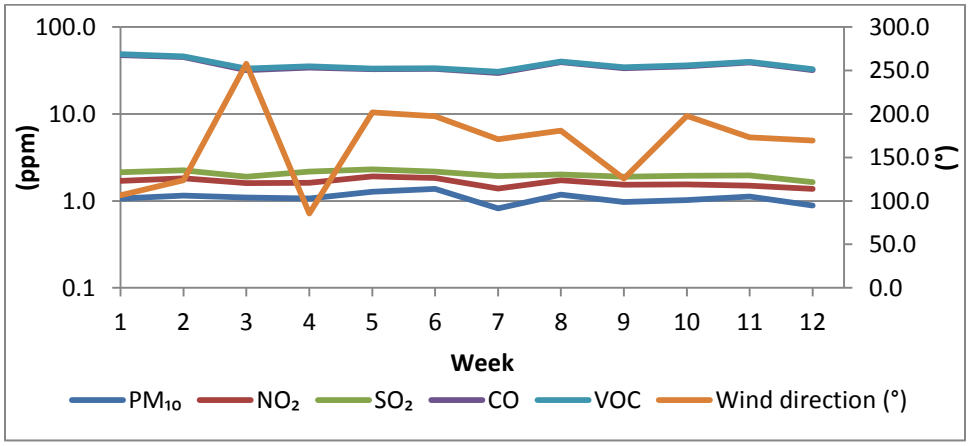

Plot of PM10, $NO_2$, $SO_2$, CO and VOC against Amb. Temp. at Opuoma



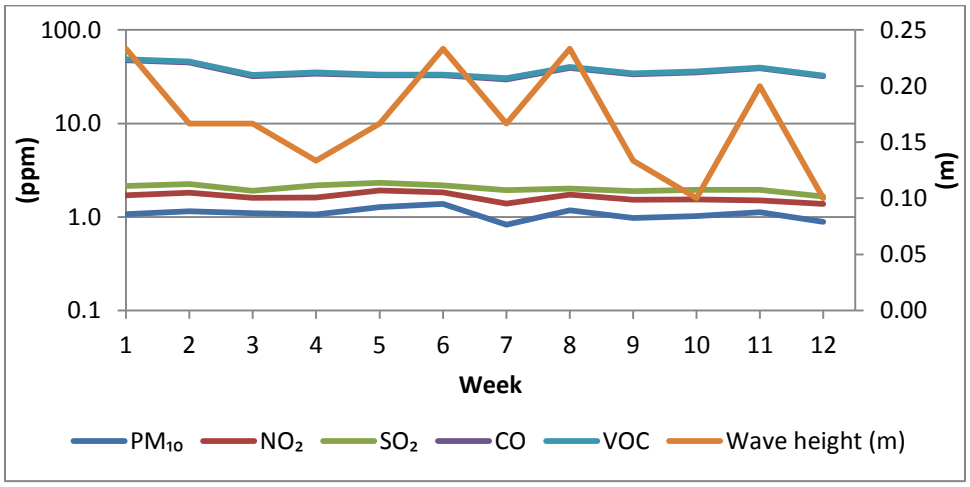

Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Relative Humidity at Opuoma




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Air flow at Opuoma




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Opuoma




Plot of $PM_{10}$, $NO_2$, $SO_2$, CO and VOC against Wind Direction at Opuo

# APPENDIX

## APPENDIX 10

**CONCENTRATION OF AIR POLLUTANTS MONITORED IN THE STUDY AREAS**

**OWERRI IN DRY SEASOCONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT IMSU JUNCTION**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.60 | 8.40 | 10.64 | 0.30 | 0.43 | 0.60 | 0.15 | 0.31 | 2.87 | 29.00 | 42.00 | 54.00 | 0.80 | 0.40 | 0.50 | ND | ND | ND |
| **2** | 6.10 | 9.30 | 9.50 | 0.35 | 0.40 | 0.70 | 0.20 | 0.32 | 1.40 | 30.00 | 42.00 | 53.00 | 0.50 | 0.60 | 0.30 | ND | ND | ND |
| **3** | 5.20 | 6.80 | 11.05 | 0.38 | 0.40 | 0.65 | 0.30 | 0.36 | 0.70 | 40.00 | 50.00 | 50.00 | 0.90 | 0.50 | 0.40 | 0.006 | ND | ND |
| **4** | 5.70 | 5.20 | 9.50 | 0.40 | 0.36 | 0.55 | 0.48 | 0.36 | 0.40 | 33.00 | 36.00 | 40.00 | 0.80 | 0.70 | 0.60 | ND | ND | ND |
| **5** | 4.70 | 7.20 | 9.40 | 0.28 | 0.36 | 0.50 | 0.25 | 0.50 | 0.87 | 32.00 | 46.00 | 51.00 | 0.60 | 0.60 | 0.50 | ND | ND | 0.01 |
| **6** | 5.80 | 10.30 | 10.70 | 0.32 | 0.50 | 0.65 | 0.40 | 0.35 | 0.67 | 36.00 | 52.00 | 54.00 | 1.00 | 0.90 | 0.70 | ND | ND | ND |
| **7** | 6.70 | 8.50 | 10.30 | 0.37 | 0.54 | 0.35 | 0.47 | 0.28 | 0.55 | 45.00 | 50.00 | 47.00 | 0.60 | 0.45 | 0.50 | 0.02 | ND | ND |
| **8** | 8.50 | 12.60 | 10.50 | 0.28 | 0.60 | 0.53 | 0.22 | 0.40 | 0.38 | 40.00 | 52.00 | 50.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **9** | 7.20 | 9.60 | 8.30 | 0.45 | 0.30 | 0.40 | 0.36 | 0.38 | 0.40 | 35.00 | 32.00 | 40.00 | 1.40 | 0.90 | 0.60 | ND | ND | ND |
| **10** | 6.20 | 8.70 | 10.40 | 0.35 | 0.42 | 0.60 | 1.20 | 0.60 | 0.50 | 38.00 | 40.00 | 47.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |
| **11** | 5.30 | 7.80 | 6.60 | 0.43 | 0.37 | 0.35 | 0.53 | 0.40 | 0.55 | 36.00 | 43.00 | 50.00 | 0.70 | 0.60 | 0.50 | 0.01 | ND | ND |
| **12** | 4.90 | 7.50 | 9.40 | 0.38 | 0.40 | 0.54 | 0.45 | 0.52 | 0.55 | 25.00 | 48.00 | 52.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **13** | 6.00 | 7.50 | 9.55 | 0.39 | 0.44 | 0.48 | 0.53 | 0.61 | 0.53 | 31.00 | 44.00 | 48.00 | 0.70 | 0.60 | 0.30 | ND | ND | ND |
| **14** | 7.10 | 8.20 | 9.70 | 0.40 | 0.47 | 0.42 | 0.60 | 0.70 | 0.50 | 37.00 | 40.00 | 45.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **15** | 8.10 | 6.30 | 7.20 | 0.40 | 0.43 | 0.50 | 0.80 | 0.91 | 1.07 | 28.00 | 41.00 | 47.00 | 0.40 | 0.20 | 0.30 | ND | ND | ND |
| **16** | 6.00 | 7.20 | 6.50 | 0.38 | 0.40 | 0.60 | 1.00 | 1.20 | 0.92 | 31.00 | 38.00 | 45.00 | 0.60 | 0.50 | 0.40 | ND | ND | ND |
| **17** | 4.70 | 6.50 | 8.40 | 0.43 | 0.50 | 0.60 | 0.60 | 0.76 | 0.59 | 38.00 | 42.00 | 40.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |
| **18** | 5.20 | 5.30 | 7.10 | 1.20 | 1.00 | 0.55 | 0.40 | 0.53 | 0.50 | 34.00 | 36.00 | 41.00 | 0.80 | 0.60 | 0.30 | ND | ND | ND |
| **19** | 5.40 | 7.10 | 6.40 | 0.60 | 0.70 | 0.50 | 0.43 | 0.50 | 0.57 | 30.00 | 40.00 | 46.00 | 0.50 | 0.55 | 0.40 | ND | ND | ND |
| **20** | 4.20 | 4.80 | 3.90 | 0.50 | 0.60 | 0.65 | 0.30 | 0.37 | 0.40 | 37.00 | 45.00 | 38.00 | 0.30 | 0.40 | 0.20 | ND | ND | ND |
| **21** | 6.30 | 5.20 | 5.10 | 0.50 | 0.45 | 0.35 | 0.47 | 0.50 | 0.54 | 28.00 | 39.00 | 35.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **22** | 4.30 | 5.80 | 5.20 | 0.80 | 0.90 | 0.83 | 0.30 | 0.40 | 0.38 | 32.00 | 37.00 | 43.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **23** | 5.30 | 6.70 | 7.40 | 0.67 | 0.75 | 0.71 | 0.36 | 0.38 | 0.41 | 30.00 | 35.00 | 38.00 | 0.30 | 0.40 | 0.20 | ND | ND | ND |
| **24** | 5.70 | 6.10 | 5.70 | 0.52 | 0.76 | 0.68 | 0.93 | 1.10 | 1.00 | 31.00 | 36.00 | 34.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **TOTAL** | 140.20 | 178.60 | 198.44 | 11.08 | 12.48 | 13.29 | 11.73 | 12.74 | 17.25 | 806.00 | 1006.00 | 1088.00 | 14.05 | 11.90 | 8.50 | 0.03 | 0.00 | 0.01 |
| **MEAN** | 5.84 | 7.44 | 8.27 | 0.46 | 0.52 | 0.55 | 0.49 | 0.53 | 0.72 | 33.58 | 41.92 | 45.33 | 0.59 | 0.50 | 0.35 | 0.01 | 0.00 | 0.01 |
| **MIN** | 4.20 | 4.80 | 3.90 | 0.28 | 0.30 | 0.35 | 0.15 | 0.28 | 0.38 | 25.00 | 32.00 | 34.00 | 0.30 | 0.20 | 0.10 | 0.01 | 0.00 | 0.01 |
| **MAX** | 8.50 | 12.60 | 11.05 | 1.20 | 1.00 | 0.83 | 1.20 | 1.20 | 2.87 | 45.00 | 52.00 | 54.00 | 1.00 | 0.90 | 0.70 | 0.01 | 0.00 | 0.01 |
| **SD** | 2.17 | 3.97 | 3.60 | 0.49 | 0.36 | 0.24 | 0.54 | 0.48 | 1.35 | 10.03 | 10.00 | 10.03 | 0.18 | 0.16 | 0.15 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT ASSUMPTA ROUNDABOUT**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.20 | 7.60 | 5.51 | 0.40 | 0.47 | 0.40 | 0.26 | 0.23 | 0.11 | 37.00 | 46.00 | 40.00 | 0.70 | 0.80 | 0.60 | ND | ND | ND |
| **2** | 6.50 | 6.80 | 6.40 | 0.30 | 0.43 | 0.60 | 0.27 | 0.25 | 0.30 | 42.00 | 46.00 | 43.00 | 0.60 | 0.65 | 0.62 | ND | ND | ND |
| **3** | 6.10 | 9.52 | 7.20 | 0.35 | 0.40 | 0.50 | 0.40 | 0.35 | 0.30 | 46.00 | 48.00 | 47.00 | 1.50 | 0.70 | 0.90 | ND | ND | ND |
| **4** | 5.20 | 7.60 | 10.20 | 0.37 | 0.30 | 0.40 | 0.45 | 0.30 | 0.35 | 40.00 | 43.00 | 47.00 | 1.10 | 1.30 | 0.80 | 0.003 | ND | ND |
| **5** | 6.40 | 8.30 | 8.70 | 0.34 | 0.45 | 0.55 | 0.30 | 0.35 | 0.48 | 35.00 | 47.00 | 45.00 | 1.40 | 0.75 | 0.60 | ND | ND | ND |
| **6** | 6.20 | 7.20 | 6.80 | 0.35 | 0.43 | 0.50 | 0.32 | 0.35 | 0.48 | 43.00 | 50.00 | 48.00 | 1.30 | 1.10 | 0.70 | 0.01 | ND | ND |
| **7** | 5.40 | 9.20 | 8.70 | 0.40 | 0.45 | 0.73 | 0.45 | 0.38 | 0.67 | 36.00 | 40.00 | 48.00 | 0.70 | 0.80 | 0.50 | ND | ND | ND |
| **8** | 9.10 | 10.80 | 10.10 | 0.45 | 0.50 | 0.48 | 0.35 | 0.50 | 0.45 | 43.00 | 54.00 | 48.00 | 1.00 | 0.90 | 0.70 | ND | ND | ND |
| **9** | 8.40 | 6.70 | 7.50 | 0.50 | 0.58 | 0.55 | 0.27 | 0.25 | 0.20 | 43.00 | 45.00 | 47.00 | 1.20 | 0.80 | 0.40 | ND | ND | ND |
| **10** | 7.50 | 9.30 | 8.60 | 0.43 | 0.50 | 0.48 | 0.34 | 0.45 | 0.42 | 44.00 | 47.00 | 50.00 | 0.70 | 0.50 | 0.60 | 0.01 | ND | ND |
| **11** | 6.10 | 5.50 | 7.20 | 0.60 | 0.73 | 0.50 | 0.40 | 0.56 | 0.40 | 40.00 | 46.00 | 52.00 | 1.30 | 1.00 | 0.90 | ND | ND | ND |
| **12** | 6.30 | 8.20 | 7.60 | 0.47 | 0.65 | 0.62 | 0.37 | 0.45 | 0.50 | 46.00 | 50.00 | 47.00 | 0.60 | 0.70 | 0.50 | ND | ND | ND |
| **13** | 4.95 | 7.05 | 8.60 | 0.59 | 0.72 | 0.61 | 0.54 | 0.69 | 0.65 | 35.00 | 43.00 | 44.00 | 0.60 | 0.50 | 0.20 | ND | ND | ND |
| **14** | 3.60 | 5.90 | 6.50 | 0.70 | 0.78 | 0.60 | 0.70 | 0.92 | 0.80 | 25.00 | 36.00 | 42.00 | 0.80 | 0.70 | 0.50 | ND | 0.01 | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | 4.20 | 7.30 | 6.70 | 0.30 | 0.46 | 0.40 | 0.37 | 0.40 | 0.45 | 23.00 | 27.00 | 32.00 | 0.30 | 0.40 | 0.10 | ND | ND | ND |
| **16** | 5.10 | 6.50 | 7.20 | 0.33 | 0.50 | 0.60 | 0.33 | 0.40 | 0.54 | 27.00 | 31.00 | 36.00 | 0.70 | 0.50 | 0.20 | ND | ND | ND |
| **17** | 6.20 | 6.80 | 8.10 | 0.40 | 0.55 | 0.68 | 0.48 | 0.50 | 0.54 | 28.00 | 35.00 | 40.00 | 0.60 | 0.30 | 0.10 | ND | ND | ND |
| **18** | 5.20 | 7.10 | 9.20 | 0.50 | 0.60 | 0.67 | 0.45 | 0.53 | 0.60 | 31.00 | 37.00 | 43.00 | 0.90 | 0.60 | 0.20 | ND | ND | ND |
| **19** | 6.10 | 8.10 | 8.50 | 0.44 | 0.45 | 0.55 | 0.38 | 0.42 | 0.51 | 33.00 | 36.00 | 40.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |
| **20** | 5.30 | 7.00 | 7.50 | 0.46 | 0.50 | 0.56 | 0.44 | 0.50 | 0.48 | 38.00 | 41.00 | 44.00 | 0.60 | 0.50 | 0.60 | ND | ND | ND |
| **21** | 4.80 | 6.50 | 8.60 | 0.47 | 0.60 | 0.72 | 0.70 | 0.75 | 0.84 | 26.00 | 39.00 | 42.00 | 0.80 | 0.40 | 0.30 | 0.001 | ND | ND |
| **22** | 7.30 | 9.30 | 9.80 | 0.60 | 0.70 | 0.75 | 0.50 | 0.60 | 0.67 | 32.00 | 43.00 | 45.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **23** | 6.20 | 7.60 | 8.30 | 0.70 | 0.78 | 0.73 | 0.40 | 0.47 | 0.53 | 27.00 | 38.00 | 46.00 | 0.40 | 0.30 | 0.10 | ND | ND | ND |
| **24** | 6.80 | 8.40 | 9.70 | 0.44 | 0.55 | 0.61 | 0.37 | 0.41 | 0.48 | 21.00 | 35.00 | 41.00 | 0.50 | 0.60 | 0.30 | ND | ND | ND |
| **TOTAL** | 144.15 | 184.27 | 193.21 | 10.89 | 13.08 | 13.79 | 9.84 | 11.01 | 11.75 | 841.00 | 1003.00 | 1057.00 | 19.60 | 16.00 | 11.52 | 0.02 | 0.01 | 0.00 |
| **MEAN** | 6.01 | 7.68 | 8.05 | 0.45 | 0.55 | 0.57 | 0.41 | 0.46 | 0.49 | 35.04 | 41.79 | 44.04 | 0.82 | 0.67 | 0.48 | 0.01 | 0.01 | 0.00 |
| **MIN** | 3.60 | 5.50 | 5.51 | 0.30 | 0.30 | 0.40 | 0.26 | 0.23 | 0.11 | 21.00 | 27.00 | 32.00 | 0.30 | 0.30 | 0.10 | 0.00 | 0.01 | 0.00 |
| **MAX** | 9.10 | 10.80 | 10.20 | 0.70 | 0.78 | 0.75 | 0.70 | 0.92 | 0.84 | 46.00 | 54.00 | 52.00 | 1.50 | 1.30 | 0.90 | 0.01 | 0.01 | 0.00 |
| **SD** | 2.75 | 2.66 | 2.35 | 0.20 | 0.24 | 0.17 | 0.22 | 0.35 | 0.37 | 12.53 | 13.52 | 10.07 | 0.32 | 0.25 | 0.25 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season result, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT EMMANUEL**

**COLLEGE ROUDABOUT**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.80 | 8.10 | 7.80 | 0.60 | 0.57 | 0.50 | 0.35 | 0.28 | 0.15 | 42.00 | 38.00 | 31.00 | 1.40 | 1.10 | 0.90 | ND | ND | ND |
| **2** | 7.20 | 8.10 | 5.70 | 0.50 | 0.54 | 0.48 | 0.38 | 0.32 | 0.25 | 46.00 | 38.00 | 35.00 | 0.80 | 0.50 | 0.60 | ND | ND | 0.01 |
| **3** | 7.20 | 7.80 | 8.20 | 0.57 | 0.60 | 0.45 | 0.40 | 0.40 | 0.55 | 48.00 | 35.00 | 55.00 | 0.70 | 0.60 | 0.40 | ND | ND | ND |
| **4** | 6.30 | 6.70 | 9.20 | 0.35 | 0.43 | 0.35 | 0.47 | 0.45 | 0.50 | 35.00 | 30.00 | 42.00 | 1.10 | 1.00 | 0.90 | ND | ND | ND |
| **5** | 5.20 | 7.80 | 9.20 | 0.30 | 0.40 | 0.45 | 0.25 | 0.36 | 0.40 | 28.00 | 35.00 | 53.00 | 0.50 | 0.45 | 0.40 | ND | ND | ND |
| **6** | 5.40 | 6.30 | 7.50 | 0.47 | 0.52 | 0.48 | 0.30 | 0.45 | 0.40 | 38.00 | 42.00 | 51.00 | 1.20 | 1.30 | 1.10 | ND | ND | ND |
| **7** | 6.50 | 10.30 | 9.30 | 0.35 | 0.55 | 0.40 | 0.35 | 0.40 | 0.50 | 35.00 | 47.00 | 43.00 | 0.70 | 0.90 | 0.80 | ND | ND | ND |
| **8** | 10.30 | 13.50 | 9.70 | 0.30 | 0.70 | 0.65 | 0.42 | 0.60 | 0.54 | 40.00 | 48.00 | 52.00 | 0.80 | 0.70 | 0.60 | 0.01 | ND | ND |
| **9** | 5.90 | 10.40 | 11.20 | 0.46 | 0.60 | 0.50 | 0.40 | 0.60 | 0.65 | 40.00 | 35.00 | 36.00 | 0.90 | 0.50 | 0.70 | 0.01 | ND | ND |
| **10** | 6.70 | 10.40 | 9.20 | 0.64 | 0.70 | 0.60 | 0.45 | 0.40 | 0.38 | 42.00 | 35.00 | 40.00 | 0.50 | 0.60 | 0.30 | ND | ND | ND |
| **11** | 5.80 | 7.30 | 8.70 | 0.52 | 0.65 | 0.60 | 0.14 | 0.20 | 0.31 | 38.00 | 42.00 | 46.00 | 1.30 | 0.90 | 0.70 | ND | ND | ND |
| **12** | 5.80 | 7.30 | 8.60 | 0.52 | 0.65 | 0.60 | 0.14 | 0.20 | 0.31 | 38.00 | 42.00 | 46.00 | 0.60 | 0.50 | 0.60 | ND | ND | ND |
| **13** | 7.60 | 8.75 | 9.30 | 0.51 | 0.63 | 0.64 | 0.42 | 0.48 | 0.56 | 33.00 | 38.00 | 42.00 | 0.90 | 0.70 | 0.60 | ND | ND | ND |
| **14** | 9.40 | 10.20 | 10.00 | 0.50 | 0.60 | 0.67 | 0.70 | 0.76 | 0.80 | 29.00 | 35.00 | 38.00 | 0.70 | 0.40 | 0.50 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | 6.80 | 7.20 | 7.80 | 0.51 | 0.57 | 0.61 | 0.68 | 0.70 | 0.65 | 19.00 | 27.00 | 32.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **16** | 7.30 | 8.30 | 7.50 | 0.47 | 0.54 | 0.58 | 0.62 | 0.67 | 0.73 | 27.00 | 36.00 | 32.00 | 0.90 | 0.80 | 0.40 | ND | ND | ND |
| **17** | 8.20 | 8.70 | 7.70 | 0.50 | 0.60 | 0.60 | 0.50 | 0.55 | 0.60 | 31.00 | 36.00 | 43.00 | 0.70 | 0.30 | 0.10 | ND | ND | ND |
| **18** | 5.30 | 6.60 | 8.40 | 0.56 | 0.60 | 0.63 | 0.58 | 0.60 | 0.58 | 24.00 | 37.00 | 41.00 | 0.60 | 0.20 | 0.40 | ND | ND | ND |
| **19** | 4.80 | 7.50 | 8.20 | 0.45 | 0.53 | 0.50 | 0.46 | 0.50 | 0.55 | 32.00 | 35.00 | 38.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |
| **20** | 6.20 | 5.70 | 7.40 | 0.48 | 0.51 | 0.57 | 0.53 | 0.60 | 0.63 | 26.00 | 34.00 | 44.00 | 0.60 | 0.70 | 0.50 | ND | ND | ND |
| **21** | 7.20 | 8.60 | 8.80 | 0.57 | 0.58 | 0.60 | 0.41 | 0.52 | 0.57 | 31.00 | 41.00 | 39.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **22** | 6.80 | 7.20 | 8.70 | 0.46 | 0.64 | 0.65 | 0.35 | 0.41 | 0.53 | 33.00 | 38.00 | 42.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **23** | 6.30 | 8.10 | 9.30 | 0.67 | 0.70 | 0.68 | 0.51 | 0.60 | 0.65 | 25.00 | 30.00 | 37.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **24** | 4.20 | 5.80 | 8.60 | 0.54 | 0.63 | 0.60 | 0.47 | 0.52 | 0.55 | 38.00 | 42.00 | 40.00 | 0.40 | 0.30 | 0.10 | ND | ND | ND |
| **TOTAL** | 158.20 | 196.65 | 206.00 | 11.80 | 14.04 | 13.39 | 10.28 | 11.57 | 12.34 | 818.00 | 896.00 | 998.00 | 18.30 | 14.65 | 12.00 | 0.02 | 0.00 | 0.01 |
| **MEAN** | 6.59 | 8.19 | 8.58 | 0.49 | 0.59 | 0.56 | 0.43 | 0.48 | 0.51 | 34.08 | 37.33 | 41.58 | 0.76 | 0.61 | 0.50 | 0.01 | 0.00 | 0.01 |
| **MIN** | 4.20 | 5.70 | 5.70 | 0.30 | 0.40 | 0.35 | 0.14 | 0.20 | 0.15 | 19.00 | 27.00 | 31.00 | 0.40 | 0.20 | 0.10 | 0.01 | 0.00 | 0.01 |
| **MAX** | 10.30 | 13.50 | 11.20 | 0.67 | 0.70 | 0.68 | 0.70 | 0.76 | 0.80 | 48.00 | 48.00 | 55.00 | 1.40 | 1.30 | 1.10 | 0.01 | 0.00 | 0.01 |
| **SD** | 3.07 | 3.98 | 2.75 | 0.185 | 0.15 | 0.166 | 0.28 | 0.28 | 0.33 | 14.50 | 10.50 | 12.03 | 0.27 | 0.28 | 0.26 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season result, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT FIRE SERVICE ROUNDABOUT**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 4.80 | 5.20 | 4.29 | 0.65 | 0.54 | 0.60 | 0.33 | 0.46 | 0.86 | 44.00 | 47.00 | 39.00 | 0.80 | 0.90 | 0.70 | ND | ND | ND |
| **2** | 6.60 | 7.10 | 5.27 | 0.60 | 0.57 | 0.70 | 0.35 | 0.48 | 0.75 | 50.00 | 47.00 | 40.00 | 0.70 | 0.80 | 0.60 | ND | ND | ND |
| **3** | 5.60 | 6.50 | 6.30 | 0.55 | 0.65 | 0.55 | 0.35 | 0.50 | 0.70 | 40.00 | 45.00 | 46.00 | 0.60 | 0.40 | 0.45 | ND | ND | ND |
| **4** | 5.10 | 5.60 | 7.40 | 0.46 | 0.60 | 0.45 | 0.40 | 0.35 | 0.40 | 40.00 | 38.00 | 48.00 | 0.50 | 0.50 | 0.60 | ND | ND | ND |
| **5** | 6.10 | 8.50 | 7.60 | 0.50 | 0.47 | 0.55 | 0.30 | 0.40 | 0.75 | 45.00 | 40.00 | 48.00 | 1.10 | 1.20 | 0.80 | ND | 0.01 | ND |
| **6** | 6.20 | 8.30 | 5.80 | 0.56 | 0.50 | 0.46 | 0.28 | 0.46 | 0.64 | 40.00 | 37.00 | 48.00 | 0.80 | 0.70 | 0.60 | ND | ND | ND |
| **7** | 7.40 | 8.20 | 9.60 | 0.40 | 0.56 | 0.80 | 0.40 | 0.35 | 0.62 | 40.00 | 38.00 | 47.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **8** | 9.20 | 10.20 | 8.70 | 0.40 | 0.65 | 0.70 | 0.45 | 0.50 | 0.70 | 45.00 | 50.00 | 54.00 | 0.90 | 0.50 | 0.30 | 0.01 | ND | ND |
| **9** | 6.30 | 7.80 | 7.50 | 0.50 | 0.45 | 0.60 | 0.32 | 0.30 | 0.25 | 45.00 | 43.00 | 48.00 | 0.80 | 0.60 | 0.70 | ND | ND | ND |
| **10** | 5.10 | 6.90 | 7.30 | 0.74 | 0.60 | 0.65 | 0.40 | 0.55 | 0.46 | 47.00 | 42.00 | 51.00 | 1.20 | 0.90 | 0.95 | ND | ND | ND |
| **11** | 5.20 | 5.60 | 4.90 | 0.48 | 0.50 | 0.45 | 0.48 | 0.35 | 0.38 | 47.00 | 33.00 | 49.00 | 0.50 | 0.70 | 0.60 | ND | ND | ND |
| **12** | 5.40 | 6.30 | 8.70 | 0.60 | 0.67 | 0.55 | 0.48 | 0.65 | 0.53 | 42.00 | 46.00 | 43.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **13** | 5.50 | 6.75 | 8.30 | 0.55 | 0.62 | 0.58 | 0.59 | 0.67 | 0.52 | 35.00 | 42.00 | 43.00 | 0.50 | 0.70 | 0.40 | ND | ND | ND |
| **14** | 5.60 | 7.20 | 7.90 | 0.50 | 0.56 | 0.60 | 0.70 | 0.73 | 0.50 | 28.00 | 38.00 | 42.00 | 0.60 | 0.30 | 0.20 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | 3.60 | 4.80 | 5.70 | 0.40 | 0.47 | 0.56 | 0.91 | 1.20 | 1.00 | 28.00 | 34.00 | 38.00 | 0.70 | 0.60 | 0.50 | ND | ND | ND |
| **16** | 6.20 | 6.50 | 7.10 | 0.52 | 0.61 | 0.75 | 0.54 | 0.67 | 0.74 | 21.00 | 38.00 | 41.00 | 0.80 | 0.70 | 0.40 | ND | ND | ND |
| **17** | 4.70 | 5.90 | 6.30 | 0.61 | 0.70 | 0.71 | 0.49 | 0.50 | 0.67 | 23.00 | 35.00 | 37.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **18** | 5.20 | 6.20 | 6.80 | 0.50 | 0.63 | 0.68 | 0.51 | 0.52 | 0.55 | 31.00 | 34.00 | 40.00 | 0.80 | 0.70 | 0.30 | ND | ND | ND |
| **19** | 4.30 | 5.10 | 7.30 | 0.46 | 0.57 | 0.62 | 0.60 | 0.62 | 0.78 | 28.00 | 37.00 | 39.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **20** | 5.30 | 6.60 | 5.70 | 0.61 | 0.70 | 0.82 | 0.36 | 0.47 | 0.59 | 37.00 | 41.00 | 40.00 | 0.60 | 0.50 | 0.20 | ND | ND | ND |
| **21** | 5.70 | 6.30 | 7.40 | 0.62 | 0.68 | 0.70 | 0.46 | 0.52 | 0.60 | 19.00 | 28.00 | 47.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **22** | 6.20 | 7.10 | 7.80 | 0.50 | 0.62 | 0.67 | 0.52 | 0.55 | 0.62 | 26.00 | 32.00 | 44.00 | 0.90 | 0.60 | 0.50 | ND | ND | ND |
| **23** | 4.80 | 5.30 | 6.50 | 0.43 | 0.54 | 0.60 | 0.48 | 0.50 | 0.53 | 28.00 | 33.00 | 48.00 | 0.40 | 0.20 | 0.04 | ND | ND | ND |
| **24** | 3.70 | 4.80 | 5.40 | 0.58 | 0.62 | 0.73 | 0.57 | 0.60 | 0.60 | 24.00 | 39.00 | 40.00 | 0.70 | 0.60 | 0.30 | ND | ND | ND |
| **TOTAL** | 133.80 | 158.75 | 165.56 | 12.72 | 14.08 | 15.08 | 11.27 | 12.90 | 14.74 | 853.00 | 937.00 | 1060.00 | 17.00 | 14.20 | 10.64 | 0.01 | 0.01 | 0.00 |
| **MEAN** | 5.58 | 6.61 | 6.90 | 0.53 | 0.59 | 0.63 | 0.47 | 0.54 | 0.61 | 35.54 | 39.04 | 44.17 | 0.71 | 0.59 | 0.44 | 0.01 | 0.01 | 0.00 |
| **MIN** | 3.60 | 4.80 | 4.29 | 0.40 | 0.45 | 0.45 | 0.28 | 0.30 | 0.25 | 19.00 | 28.00 | 37.00 | 0.40 | 0.20 | 0.04 | 0.01 | 0.01 | 0.00 |
| **MAX** | 9.20 | 10.20 | 9.60 | 0.74 | 0.70 | 0.82 | 0.91 | 1.20 | 1.00 | 50.00 | 50.00 | 54.00 | 1.20 | 1.20 | 0.95 | 0.01 | 0.01 | 0.00 |
| **SD** | 2.84 | 2.75 | 2.66 | 0.17 | 0.13 | 0.19 | 0.32 | 0.47 | 0.38 | 15.52 | 11.00 | 8.53 | 0.19 | 0.22 | 0.22 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening , MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT WORLD BANK MARKET JUNCTION**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 6.40 | 7.40 | 7.20 | 0.38 | 0.55 | 0.55 | 0.28 | 0.32 | 0.30 | 47.00 | 50.00 | 48.00 | 0.50 | 0.40 | 0.30 | ND | ND | 0.003 |
| **2** | 5.30 | 8.20 | 6.56 | 0.70 | 0.60 | 0.45 | 0.40 | 0.40 | 0.36 | 47.00 | 50.00 | 46.00 | 0.60 | 0.30 | 0.50 | 0.01 | ND | ND |
| **3** | 6.41 | 8.10 | 7.80 | 0.45 | 0.50 | 0.60 | 0.30 | 0.35 | 0.85 | 45.00 | 52.00 | 55.00 | 0.50 | 0.60 | 0.40 | ND | 0.10 | ND |
| **4** | 5.10 | 5.60 | 7.40 | 0.46 | 0.60 | 0.45 | 0.40 | 0.35 | 0.40 | 40.00 | 38.00 | 48.00 | 0.80 | 0.60 | 0.50 | 0.02 | 0.004 | ND |
| **5** | 5.60 | 8.70 | 9.30 | 0.35 | 0.40 | 0.50 | 0.20 | 0.35 | 0.65 | 35.00 | 43.00 | 47.00 | 0.60 | 0.40 | 0.50 | ND | ND | ND |
| **6** | 5.30 | 7.40 | 7.90 | 0.30 | 0.53 | 0.60 | 0.30 | 0.34 | 0.45 | 43.00 | 40.00 | 47.00 | 0.40 | 0.60 | 0.30 | 0.01 | ND | ND |
| **7** | 4.10 | 7.60 | 10.30 | 0.55 | 0.40 | 0.48 | 0.30 | 0.45 | 0.50 | 45.00 | 40.00 | 50.00 | 0.50 | 0.30 | 0.40 | 0.01 | ND | ND |
| **8** | 8.20 | 9.80 | 9.10 | 0.35 | 0.58 | 0.55 | 0.30 | 0.55 | 0.50 | 35.00 | 47.00 | 45.00 | 0.70 | 0.60 | 0.70 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **9** | 9.10 | 10.60 | 8.70 | 0.60 | 0.54 | 0.40 | 0.60 | 0.78 | 0.50 | 35.00 | 30.00 | 32.00 | 0.50 | 0.60 | 0.50 | 0.01 | ND | ND |
| **10** | 6.04 | 8.10 | 8.60 | 0.40 | 0.45 | 0.43 | 0.80 | 0.93 | 0.65 | 34.00 | 35.00 | 37.00 | 0.30 | 0.20 | 0.20 | ND | ND | ND |
| **11** | 6.40 | 6.10 | 5.60 | 0.35 | 0.46 | 0.50 | 1.50 | 0.90 | 0.68 | 25.00 | 20.00 | 32.00 | 0.40 | 0.50 | 0.30 | 0.01 | ND | ND |
| **12** | 4.80 | 5.60 | 4.40 | 0.40 | 0.52 | 0.50 | 0.80 | 0.97 | 0.75 | 38.00 | 40.00 | 44.00 | 0.60 | 0.70 | 0.50 | ND | ND | ND |
| **13** | 4.95 | 4.30 | 6.20 | 0.50 | 0.51 | 0.55 | 0.69 | 0.78 | 0.73 | 33.00 | 36.00 | 42.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **14** | 5.10 | 6.40 | 7.10 | 0.20 | 0.49 | 0.60 | 0.58 | 0.60 | 0.71 | 28.00 | 31.00 | 43.00 | 0.70 | 0.40 | 0.20 | ND | ND | ND |
| **15** | 3.80 | 4.70 | 5.20 | 0.41 | 0.56 | 0.60 | 0.80 | 1.02 | 0.95 | 23.00 | 35.00 | 41.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **16** | 4.70 | 5.10 | 6.40 | 0.62 | 0.65 | 0.57 | 0.73 | 0.97 | 0.36 | 26.00 | 38.00 | 40.00 | 0.30 | 0.20 | 0.02 | 0.001 | ND | ND |
| **17** | 5.20 | 5.70 | 5.30 | 0.43 | 0.52 | 0.60 | 0.50 | 0.75 | 0.85 | 31.00 | 32.00 | 38.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **18** | 6.10 | 6.50 | 6.10 | 0.51 | 0.60 | 0.63 | 0.90 | 1.20 | 1.10 | 30.00 | 35.00 | 42.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **19** | 4.30 | 5.20 | 7.30 | 0.34 | 0.46 | 0.51 | 0.63 | 0.82 | 0.91 | 26.00 | 34.00 | 38.00 | 0.40 | 0.50 | 0.20 | 0.001 | ND | ND |
| **20** | 5.40 | 6.00 | 6.80 | 0.52 | 0.54 | 0.60 | 0.51 | 0.76 | 0.82 | 25.00 | 31.00 | 40.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **21** | 4.20 | 5.30 | 7.20 | 0.56 | 0.60 | 0.61 | 0.73 | 0.84 | 0.86 | 23.00 | 37.00 | 39.00 | 0.30 | 0.10 | 0.03 | ND | ND | ND |
| **22** | 5.70 | 6.40 | 6.30 | 0.35 | 0.40 | 0.50 | 0.89 | 0.94 | 0.96 | 34.00 | 36.00 | 35.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **23** | 3.10 | 4.60 | 5.20 | 0.60 | 0.68 | 0.63 | 0.96 | 1.02 | 1.00 | 27.00 | 32.00 | 43.00 | 0.60 | 0.30 | 0.20 | ND | ND | ND |
| **24** | 4.30 | 5.00 | 5.50 | 0.40 | 0.45 | 0.42 | 0.62 | 0.78 | 0.89 | 22.00 | 36.00 | 37.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **TOTAL** | 129.60 | 158.40 | 167.46 | 10.73 | 12.59 | 12.83 | 14.72 | 17.17 | 16.73 | 797.00 | 898.00 | 1009.00 | 12.30 | 9.40 | 7.05 | 0.07 | 0.10 | 0.00 |
| **MEAN** | 5.40 | 6.60 | 6.98 | 0.45 | 0.52 | 0.53 | 0.61 | 0.72 | 0.70 | 33.21 | 37.42 | 42.04 | 0.51 | 0.39 | 0.29 | 0.01 | 0.05 | 0.00 |
| **MIN** | 3.10 | 4.30 | 4.40 | 0.20 | 0.40 | 0.40 | 0.20 | 0.32 | 0.30 | 22.00 | 20.00 | 32.00 | 0.30 | 0.10 | 0.02 | 0.00 | 0.00 | 0.00 |
| **MAX** | 9.10 | 10.60 | 10.30 | 0.70 | 0.68 | 0.63 | 1.50 | 1.20 | 1.10 | 47.00 | 52.00 | 55.00 | 0.80 | 0.70 | 0.70 | 0.02 | 0.10 | 0.00 |
| **SD** | 3.03 | 3.19 | 2.96 | 0.25 | 0.14 | 0.12 | 0.66 | 0.44 | 0.40 | 12.52 | 16.02 | 11.53 | 0.14 | 0.17 | 0.18 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

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**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT INDUSTRAL LAYOUT IRETE**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 4.60 | 4.80 | 5.10 | 0.29 | 0.30 | 0.45 | 0.36 | 0.34 | 0.56 | 38.00 | 40.00 | 46.00 | 0.40 | 0.50 | 0.30 | ND | ND | ND |
| **2** | 5.30 | 5.60 | 4.30 | 0.30 | 0.52 | 0.40 | 0.30 | 0.20 | 0.18 | 38.00 | 37.00 | 40.00 | 0.70 | 0.60 | 0.40 | 0.02 | ND | 0.001 |
| **3** | 4.80 | 5.20 | 5.13 | 0.35 | 0.35 | 0.40 | 0.25 | 0.28 | 0.60 | 36.00 | 45.00 | 50.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **4** | 4.10 | 3.80 | 5.20 | 0.32 | 0.25 | 0.30 | 0.35 | 0.30 | 0.40 | 28.00 | 30.00 | 25.00 | 0.70 | 0.80 | 0.50 | 0.02 | ND | ND |
| **5** | 4.10 | 5.20 | 5.60 | 0.20 | 0.25 | 0.23 | 0.25 | 0.35 | 0.30 | 36.00 | 46.00 | 48.00 | 0.80 | 0.40 | 0.50 | ND | ND | ND |
| **6** | 3.70 | 5.80 | 5.60 | 0.20 | 0.45 | 0.47 | 0.27 | 0.30 | 0.35 | 35.00 | 40.00 | 42.00 | 0.40 | 0.50 | 0.20 | 0.01 | ND | ND |
| **7** | 4.20 | 5.10 | 8.40 | 0.28 | 0.35 | 0.40 | 0.20 | 0.25 | 0.28 | 30.00 | 40.00 | 45.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **8** | 9.60 | 10.30 | 11.20 | 0.30 | 0.60 | 0.47 | 0.30 | 0.45 | 0.38 | 35.00 | 45.00 | 50.00 | 1.10 | 0.80 | 0.70 | ND | ND | ND |
| **9** | 7.60 | 8.30 | 6.30 | 0.30 | 0.25 | 0.37 | 0.30 | 0.35 | 0.32 | 26.00 | 30.00 | 40.00 | 0.50 | 0.35 | 0.60 | 0.004 | ND | ND |
| **10** | 5.60 | 7.50 | 7.20 | 0.26 | 0.30 | 0.35 | 0.19 | 0.26 | 0.35 | 28.00 | 30.00 | 34.00 | 0.70 | 0.50 | 0.80 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **11** | 4.80 | 5.07 | 5.40 | 0.26 | 0.30 | 0.37 | 0.22 | 0.28 | 0.17 | 23.00 | 35.00 | 30.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **12** | 3.60 | 4.50 | 4.80 | 0.30 | 0.36 | 0.43 | 0.32 | 0.46 | 0.35 | 28.00 | 35.00 | 37.00 | 1.00 | 0.70 | 0.50 | ND | ND | ND |
| **13** | 4.30 | 4.90 | 5.10 | 0.35 | 0.38 | 0.44 | 0.36 | 0.48 | 0.46 | 27.00 | 38.00 | 40.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **14** | 4.90 | 5.20 | 5.10 | 0.40 | 0.40 | 0.45 | 0.40 | 0.50 | 0.56 | 26.00 | 41.00 | 45.00 | 0.70 | 0.50 | 0.20 | ND | ND | ND |
| **15** | 6.70 | 6.90 | 5.20 | 0.35 | 0.40 | 0.50 | 0.36 | 0.50 | 0.40 | 32.00 | 39.00 | 43.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **16** | 4.70 | 5.30 | 6.30 | 0.40 | 0.35 | 0.47 | 0.30 | 0.45 | 0.60 | 35.00 | 40.00 | 46.00 | 1.00 | 0.80 | 0.60 | 0.002 | ND | ND |
| **17** | 5.30 | 6.30 | 4.90 | 0.30 | 0.50 | 0.47 | 0.40 | 0.60 | 0.30 | 28.00 | 38.00 | 34.00 | 0.70 | 0.50 | 0.20 | ND | ND | ND |
| **18** | 4.80 | 5.40 | 6.40 | 0.50 | 0.60 | 0.50 | 0.24 | 0.40 | 0.40 | 27.00 | 40.00 | 46.00 | 0.60 | 0.40 | 0.10 | ND | ND | ND |
| **19** | 5.10 | 6.20 | 5.90 | 0.30 | 0.45 | 0.45 | 0.30 | 0.50 | 0.55 | 30.00 | 42.00 | 46.00 | 1.10 | 0.60 | 0.30 | ND | ND | ND |
| **20** | 4.60 | 5.40 | 6.70 | 0.45 | 0.50 | 0.56 | 0.50 | 0.59 | 0.70 | 34.00 | 46.00 | 40.00 | 0.70 | 0.50 | 0.20 | 0.001 | ND | ND |
| **21** | 5.30 | 6.50 | 5.80 | 0.55 | 0.50 | 0.47 | 0.60 | 0.57 | 0.50 | 35.00 | 38.00 | 39.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **22** | 5.80 | 8.20 | 6.10 | 0.60 | 0.40 | 0.46 | 0.70 | 0.50 | 0.60 | 27.00 | 37.00 | 44.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **23** | 6.30 | 7.10 | 5.20 | 0.30 | 0.50 | 0.43 | 0.30 | 0.40 | 0.45 | 21.00 | 40.00 | 38.00 | 0.60 | 0.40 | 0.20 | ND | ND | ND |
| **24** | 5.10 | 4.20 | 4.00 | 0.40 | 0.55 | 0.68 | 0.43 | 0.52 | 0.50 | 32.00 | 38.00 | 41.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **TOTAL** | 124.90 | 142.77 | 140.93 | 8.26 | 9.81 | 10.52 | 8.20 | 9.83 | 10.26 | 735.00 | 930.00 | 989.00 | 16.10 | 11.55 | 8.00 | 0.06 | 0.00 | 0.00 |
| **MEAN** | 5.20 | 5.95 | 5.87 | 0.34 | 0.41 | 0.44 | 0.34 | 0.41 | 0.43 | 30.63 | 38.75 | 41.21 | 0.67 | 0.48 | 0.33 | 0.01 | 0.00 | 0.00 |
| **MIN** | 3.60 | 3.80 | 4.00 | 0.20 | 0.25 | 0.23 | 0.19 | 0.20 | 0.17 | 21.00 | 30.00 | 25.00 | 0.40 | 0.20 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 9.60 | 10.30 | 11.20 | 0.60 | 0.60 | 0.68 | 0.70 | 0.60 | 0.70 | 38.00 | 46.00 | 50.00 | 1.10 | 0.80 | 0.80 | 0.02 | 0.00 | 0.00 |
| **SD** | 3.11 | 3.31 | 3.74 | 0.20 | 0.18 | 0.23 | 0.26 | 0.20 | 0.27 | 8.52 | 8.01 | 12.68 | 0.21 | 0.17 | 0.20 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT EGBU –URATTA RING ROAD**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 4.22 | 4.10 | 2.02 | 0.20 | 0.32 | 0.40 | 0.18 | 0.13 | 0.09 | 36.00 | 38.00 | 50.00 | 0.80 | 0.60 | 0.50 | ND | ND | ND |
| **2** | 4.05 | 3.80 | 2.40 | 0.30 | 0.33 | 0.30 | 0.18 | 0.15 | 0.10 | 32.00 | 35.00 | 40.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **3** | 4.05 | 4.30 | 3.10 | 0.27 | 0.30 | 0.30 | 0.20 | 0.19 | 0.15 | 30.00 | 35.00 | 43.00 | 0.60 | 0.40 | 0.50 | ND | ND | ND |
| **4** | 3.40 | 4.20 | 3.70 | 0.35 | 0.30 | 0.27 | 0.24 | 0.20 | 0.25 | 23.00 | 20.00 | 37.00 | 0.50 | 0.45 | 0.40 | ND | ND | ND |
| **5** | 3.70 | 4.10 | 3.30 | 0.09 | 0.17 | 0.10 | 0.07 | 0.13 | 0.15 | 30.00 | 27.00 | 35.00 | 1.30 | 1.10 | 0.90 | ND | ND | ND |
| **6** | 3.05 | 2.20 | 2.10 | 0.24 | 0.35 | 0.28 | 0.15 | 0.28 | 0.20 | 32.00 | 37.00 | 43.00 | 0.70 | 0.60 | 0.50 | ND | ND | ND |
| **7** | 2.70 | 3.10 | 2.30 | 0.25 | 0.20 | 0.35 | 0.14 | 0.10 | 0.09 | 33.00 | 35.00 | 30.00 | 0.60 | 0.50 | 0.40 | ND | ND | ND |
| **8** | 8.70 | 9.40 | 8.05 | 0.28 | 0.35 | 0.25 | 0.23 | 0.35 | 0.30 | 30.00 | 40.00 | 45.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **9** | 5.80 | 7.40 | 7.10 | 0.15 | 0.20 | 0.30 | 0.20 | 0.16 | 0.17 | 28.00 | 32.00 | 45.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **10** | 4.80 | 5.30 | 5.02 | 0.20 | 0.23 | 0.09 | 0.20 | 0.30 | 0.25 | 35.00 | 40.00 | 32.00 | 0.80 | 0.73 | 0.60 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **11** | 3.70 | 4.50 | 4.10 | 0.08 | 0.15 | 0.20 | 0.30 | 0.20 | 0.26 | 27.00 | 30.00 | 25.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **12** | 2.70 | 3.20 | 2.70 | 0.25 | 0.30 | 0.28 | 0.25 | 0.30 | 0.27 | 25.00 | 30.00 | 26.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **13** | 3.40 | 3.80 | 4.20 | 0.28 | 0.31 | 0.33 | 0.21 | 0.24 | 0.25 | 24.00 | 29.00 | 28.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **14** | 4.10 | 4.40 | 2.02 | 0.31 | 0.32 | 0.38 | 0.16 | 0.18 | 0.20 | 22.00 | 28.00 | 31.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **15** | 3.60 | 3.70 | 4.10 | 0.17 | 0.22 | 0.31 | 0.08 | 0.12 | 0.15 | 15.00 | 26.00 | 31.00 | 0.30 | 0.10 | 0.04 | ND | ND | ND |
| **16** | 4.02 | 4.20 | 4.30 | 0.25 | 0.28 | 0.30 | 0.21 | 0.22 | 0.20 | 25.00 | 27.00 | 31.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **17** | 3.70 | 4.00 | 4.07 | 0.34 | 0.37 | 0.36 | 0.23 | 0.27 | 0.26 | 17.00 | 20.00 | 24.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **18** | 3.30 | 3.80 | 3.50 | 0.26 | 0.31 | 0.32 | 0.13 | 0.15 | 0.17 | 27.00 | 30.00 | 33.00 | 1.00 | 0.80 | 0.50 | ND | ND | ND |
| **19** | 4.20 | 4.50 | 4.56 | 0.20 | 0.25 | 0.28 | 0.15 | 0.22 | 0.25 | 31.00 | 35.00 | 37.00 | 0.70 | 0.50 | 0.20 | ND | ND | ND |
| **20** | 2.80 | 3.10 | 3.40 | 0.30 | 0.33 | 0.35 | 0.19 | 0.21 | 0.27 | 29.00 | 35.00 | 33.00 | 0.50 | 0.30 | 0.02 | ND | ND | ND |
| **21** | 5.01 | 6.30 | 6.70 | 0.37 | 0.40 | 0.42 | 0.30 | 0.30 | 0.33 | 26.00 | 31.00 | 35.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **22** | 3.60 | 4.40 | 5.30 | 0.18 | 0.20 | 0.29 | 0.21 | 0.27 | 0.30 | 28.00 | 34.00 | 38.00 | 1.10 | 0.70 | 0.40 | ND | ND | ND |
| **23** | 3.90 | 4.20 | 4.50 | 0.27 | 0.30 | 0.26 | 0.30 | 0.33 | 0.32 | 21.00 | 35.00 | 32.00 | 0.60 | 0.30 | 0.20 | ND | ND | ND |
| **24** | 2.50 | 3.20 | 4.03 | 0.15 | 0.19 | 0.20 | 0.28 | 0.31 | 0.30 | 19.00 | 30.00 | 34.00 | 0.70 | 0.40 | 0.30 | ND | ND | ND |
| **TOTAL** | 95.00 | 105.20 | 96.57 | 5.74 | 6.68 | 6.92 | 4.79 | 5.31 | 5.28 | 645.00 | 759.00 | 838.00 | 16.10 | 11.58 | 7.96 | 0.00 | 0.00 | 0.00 |
| **MEAN** | 3.96 | 4.38 | 4.02 | 0.24 | 0.28 | 0.29 | 0.20 | 0.22 | 0.22 | 26.88 | 31.63 | 34.92 | 0.67 | 0.48 | 0.33 | 0.00 | 0.00 | 0.00 |
| **MIN** | 2.50 | 2.20 | 2.02 | 0.08 | 0.15 | 0.09 | 0.07 | 0.10 | 0.09 | 15.00 | 20.00 | 24.00 | 0.30 | 0.10 | 0.02 | 0.00 | 0.00 | 0.00 |
| **MAX** | 8.70 | 9.40 | 8.05 | 0.37 | 0.40 | 0.42 | 0.30 | 0.35 | 0.33 | 36.00 | 40.00 | 50.00 | 1.30 | 1.10 | 0.90 | 0.00 | 0.00 | 0.00 |
| **SD** | 3.24 | 3.69 | 3.07 | 0.15 | 0.13 | 0.17 | 0.12 | 0.13 | 0.12 | 10.53 | 10.04 | 13.06 | 0.23 | 0.23 | 0.21 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**OKIGWE**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT ANARA JUNCTION**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.20 | 6.70 | 8.20 | 0.30 | 0.40 | 0.48 | 0.16 | 0.28 | 0.35 | 43.00 | 46.00 | 51.00 | 0.80 | 0.50 | 0.40 | ND | ND | ND |
| **2** | 5.60 | 7.50 | 7.10 | 0.40 | 0.46 | 0.40 | 0.22 | 0.30 | 0.27 | 45.00 | 44.00 | 56.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **3** | 5.60 | 6.00 | 6.20 | 0.30 | 0.35 | 0.40 | 0.30 | 0.25 | 0.40 | 40.00 | 42.00 | 50.00 | 0.70 | 0.40 | 0.30 | 0.01 | ND | ND |
| **4** | 4.80 | 5.30 | 5.00 | 0.20 | 0.30 | 0.25 | 0.20 | 0.18 | 0.20 | 34.00 | 28.00 | 36.00 | 0.90 | 0.70 | 0.50 | ND | 0.002 | ND |
| **5** | 6.20 | 6.80 | 5.70 | 0.40 | 0.47 | 0.55 | 0.25 | 0.27 | 0.36 | 40.00 | 47.00 | 52.00 | 1.00 | 0.80 | 0.60 | ND | ND | ND |
| **6** | 4.30 | 5.70 | 6.50 | 0.27 | 0.40 | 0.30 | 0.30 | 0.33 | 0.28 | 35.00 | 40.00 | 46.00 | 0.70 | 0.50 | 0.60 | 0.001 | ND | ND |
| **7** | 6.40 | 8.60 | 7.20 | 0.35 | 0.50 | 0.45 | 0.40 | 0.35 | 0.50 | 45.00 | 42.00 | 50.00 | 0.60 | 0.30 | 0.40 | ND | ND | ND |
| **8** | 9.20 | 10.50 | 8.70 | 0.24 | 0.30 | 0.20 | 0.19 | 0.25 | 0.20 | 40.00 | 50.00 | 52.00 | 0.50 | 0.20 | ND | ND | ND | ND |
| **9** | 8.90 | 11.40 | 10.20 | 0.30 | 0.37 | 0.32 | 0.23 | 0.33 | 0.35 | 36.00 | 42.00 | 41.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **10** | 9.60 | 11.30 | 10.20 | 0.46 | 0.50 | 0.53 | 0.40 | 0.45 | 0.47 | 40.00 | 35.00 | 42.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **11** | 5.40 | 6.60 | 5.80 | 0.29 | 0.46 | 0.50 | 0.30 | 0.45 | 0.40 | 28.00 | 34.00 | 38.00 | 0.80 | 0.70 | 0.50 | ND | ND | ND |
| **12** | 2.40 | 3.60 | 3.90 | 0.47 | 0.55 | 0.40 | 0.32 | 0.46 | 0.37 | 32.00 | 46.00 | 40.00 | 0.90 | 0.60 | 0.50 | ND | ND | ND |
| **13** | 2.80 | 5.60 | 6.20 | 0.42 | 0.48 | 0.43 | 0.26 | 0.37 | 0.36 | 34.00 | 43.00 | 42.00 | 0.40 | 0.10 | 0.03 | ND | ND | ND |
| **14** | 3.10 | 7.60 | 8.50 | 0.37 | 0.40 | 0.45 | 0.19 | 0.27 | 0.34 | 36.00 | 41.00 | 43.00 | 0.60 | 0.20 | 0.10 | ND | 0.001 | ND |
| **15** | 4.20 | 6.80 | 8.90 | 0.41 | 0.46 | 0.44 | 0.23 | 0.30 | 0.35 | 32.00 | 44.00 | 46.00 | 0.30 | 0.10 | 0.10 | ND | ND | ND |
| **16** | 3.50 | 6.00 | 6.30 | 0.31 | 0.40 | 0.40 | 0.32 | 0.35 | 0.40 | 28.00 | 42.00 | 40.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **17** | 2.80 | 5.30 | 7.40 | 0.29 | 0.38 | 0.42 | 0.40 | 0.40 | 0.44 | 34.00 | 40.00 | 38.00 | 0.20 | 0.10 | 0.02 | 0.001 | ND | ND |
| **18** | 3.20 | 5.70 | 8.20 | 0.42 | 0.47 | 0.50 | 0.35 | 0.40 | 0.38 | 40.00 | 47.00 | 43.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **19** | 4.10 | 7.10 | 7.00 | 0.20 | 0.40 | 0.38 | 0.46 | 0.50 | 0.50 | 27.00 | 38.00 | 44.00 | 0.10 | 0.02 | ND | ND | ND | ND |
| **20** | 4.80 | 6.80 | 8.10 | 0.33 | 0.53 | 0.47 | 0.38 | 0.40 | 0.45 | 31.00 | 42.00 | 40.00 | 0.30 | 0.20 | 0.01 | ND | ND | ND |
| **21** | 5.20 | 8.20 | 9.30 | 0.45 | 0.57 | 0.60 | 0.16 | 0.25 | 0.23 | 39.00 | 43.00 | 45.00 | 0.10 | 0.01 | ND | ND | ND | ND |
| **22** | 3.70 | 6.90 | 7.40 | 0.50 | 0.50 | 0.54 | 0.22 | 0.28 | 0.32 | 26.00 | 33.00 | 41.00 | 0.50 | 0.40 | 0.20 | ND | ND | ND |
| **23** | 2.60 | 6.30 | 5.80 | 0.37 | 0.40 | 0.40 | 0.37 | 0.40 | 0.45 | 32.00 | 35.00 | 47.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **24** | 3.30 | 5.70 | 6.70 | 0.58 | 0.60 | 0.65 | 0.27 | 0.30 | 0.40 | 25.00 | 34.00 | 38.00 | 0.20 | 0.20 | 0.10 | ND | ND | ND |
| **TOTAL** | 116.90 | 168.00 | 174.50 | 8.63 | 10.65 | 10.46 | 6.88 | 8.12 | 8.77 | 842.00 | 978.00 | 1061.00 | 12.30 | 7.83 | 5.36 | 0.01 | 0.00 | 0.00 |
| **MEAN** | 4.87 | 7.00 | 7.27 | 0.36 | 0.44 | 0.44 | 0.29 | 0.34 | 0.37 | 35.08 | 40.75 | 44.21 | 0.51 | 0.33 | 0.26 | 0.00 | 0.00 | 0.00 |
| **MIN** | 2.40 | 3.60 | 3.90 | 0.20 | 0.30 | 0.20 | 0.16 | 0.18 | 0.20 | 25.00 | 28.00 | 36.00 | 0.10 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| **MAX** | 9.60 | 11.40 | 10.20 | 0.58 | 0.60 | 0.65 | 0.46 | 0.50 | 0.50 | 45.00 | 50.00 | 56.00 | 1.00 | 0.80 | 0.60 | 0.01 | 0.00 | 0.00 |
| **SD** | 3.66 | 3.91 | 3.15 | 0.19 | 0.15 | 0.23 | 0.15 | 0.16 | 0.15 | 10.01 | 11.05 | 10.05 | 0.26 | 0.22 | 0.20 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UMUNA JUNCTION, OKIGWE**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 6.10 | 5.60 | 5.80 | 0.40 | 0.55 | 0.40 | 0.19 | 0.19 | 0.32 | 51.00 | 44.00 | 44.00 | 0.40 | 0.30 | ND | ND | ND | ND |
| **2** | 6.30 | 6.20 | 6.60 | 0.45 | 0.65 | 0.50 | 0.28 | 0.20 | 0.30 | 55.00 | 45.00 | 47.00 | 0.60 | 0.40 | 0.20 | ND | ND | ND |
| **3** | 5.80 | 7.10 | 6.70 | 0.50 | 0.48 | 0.35 | 0.30 | 0.23 | 0.35 | 56.00 | 40.00 | 46.00 | 0.90 | 0.70 | 0.50 | 0.01 | ND | ND |
| **4** | 5.10 | 4.60 | 5.30 | 0.35 | 0.30 | 0.40 | 0.15 | 0.20 | 0.25 | 37.00 | 35.00 | 32.00 | 0.50 | ND | ND | ND | ND | ND |
| **5** | 5.60 | 7.30 | 6.40 | 0.36 | 0.45 | 0.50 | 0.20 | 0.32 | 0.42 | 45.00 | 53.00 | 50.00 | 0.30 | 0.20 | ND | ND | ND | ND |
| **6** | 7.20 | 6.80 | 5.40 | 0.40 | 0.60 | 0.45 | 0.23 | 0.30 | 0.25 | 40.00 | 46.00 | 40.00 | 0.60 | 0.30 | 0.20 | ND | 0.001 | ND |
| **7** | 5.20 | 7.80 | 7.30 | 0.45 | 0.57 | 0.50 | 0.28 | 0.34 | 0.30 | 40.00 | 50.00 | 45.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **8** | 8.60 | 11.20 | 9.30 | 0.30 | 0.35 | 0.40 | 0.23 | 0.30 | 0.25 | 42.00 | 48.00 | 50.00 | 0.40 | 0.20 | ND | ND | ND | ND |
| **9** | 9.30 | 12.60 | 11.00 | 0.53 | 0.60 | 0.55 | 0.18 | 0.28 | 0.42 | 46.00 | 50.00 | 46.00 | 0.80 | 0.40 | 0.30 | ND | ND | ND |
| **10** | 8.70 | 10.50 | 10.80 | 0.35 | 0.47 | 0.40 | 0.35 | 0.50 | 0.36 | 38.00 | 40.00 | 44.00 | 0.60 | 0.50 | 0.20 | ND | ND | ND |
| **11** | 6.20 | 7.80 | 6.30 | 0.37 | 0.52 | 0.45 | 0.45 | 0.40 | 0.19 | 35.00 | 40.00 | 42.00 | 0.50 | 0.20 | ND | 0.01 | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **12** | 3.20 | 3.70 | 3.40 | 0.36 | 0.42 | 0.35 | 0.40 | 0.56 | 0.50 | 43.00 | 48.00 | 50.00 | 0.70 | 0.60 | 0.40 | ND | ND | ND |
| **13** | 4.00 | 4.90 | 5.80 | 0.38 | 0.51 | 0.43 | 0.41 | 0.53 | 0.54 | 41.00 | 45.00 | 48.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **14** | 4.80 | 6.10 | 8.20 | 0.40 | 0.60 | 0.50 | 0.45 | 0.50 | 0.57 | 38.00 | 42.00 | 47.00 | 0.30 | 0.20 | 0.20 | ND | ND | ND |
| **15** | 5.20 | 7.20 | 7.70 | 0.52 | 0.58 | 0.60 | 0.40 | 0.44 | 0.50 | 40.00 | 45.00 | 46.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **16** | 4.20 | 8.30 | 8.50 | 0.33 | 0.30 | 0.40 | 0.60 | 0.67 | 0.71 | 37.00 | 43.00 | 41.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **17** | 3.70 | 6.80 | 7.50 | 0.42 | 0.46 | 0.50 | 0.40 | 0.45 | 0.54 | 40.00 | 48.00 | 50.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **18** | 5.30 | 7.30 | 8.40 | 0.47 | 0.51 | 0.48 | 0.37 | 0.48 | 0.50 | 38.00 | 40.00 | 45.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **19** | 4.10 | 8.10 | 9.30 | 0.45 | 0.50 | 0.57 | 0.66 | 0.72 | 0.30 | 32.00 | 41.00 | 38.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **20** | 5.30 | 6.30 | 5.40 | 0.50 | 0.60 | 0.60 | 0.45 | 0.70 | 0.63 | 28.00 | 36.00 | 43.00 | 0.70 | 0.40 | 0.30 | ND | ND | ND |
| **21** | 3.90 | 5.10 | 8.30 | 0.58 | 0.63 | 0.66 | 0.29 | 0.35 | 0.52 | 37.00 | 43.00 | 45.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **22** | 4.20 | 6.40 | 7.20 | 0.37 | 0.40 | 0.53 | 0.35 | 0.40 | 0.38 | 40.00 | 45.00 | 46.00 | 0.50 | 0.20 | 0.30 | ND | ND | ND |
| **23** | 5.50 | 7.80 | 9.10 | 0.40 | 0.52 | 0.60 | 0.45 | 0.47 | 0.54 | 35.00 | 40.00 | 47.00 | 0.30 | 0.10 | ND | ND | ND | ND |
| **24** | 3.40 | 6.50 | 6.80 | 0.53 | 0.57 | 0.60 | 0.41 | 0.52 | 0.50 | 27.00 | 38.00 | 41.00 | 0.60 | 0.30 | 0.20 | ND | ND | ND |
| **TOTAL** | 130.90 | 172.00 | 176.50 | 10.17 | 12.14 | 11.72 | 8.48 | 10.05 | 10.14 | 961.00 | 1045.00 | 1073.00 | 13.80 | 8.40 | 5.00 | 0.02 | 0.00 | 0.00 |
| **MEAN** | 5.45 | 7.17 | 7.35 | 0.42 | 0.51 | 0.49 | 0.35 | 0.42 | 0.42 | 40.04 | 43.54 | 44.71 | 0.58 | 0.37 | 0.28 | 0.01 | 0.00 | 0.00 |
| **MIN** | 3.20 | 3.70 | 3.40 | 0.30 | 0.30 | 0.35 | 0.15 | 0.19 | 0.19 | 27.00 | 35.00 | 32.00 | 0.30 | 0.10 | 0.10 | 0.01 | 0.00 | 0.00 |
| **MAX** | 9.30 | 12.60 | 11.00 | 0.58 | 0.65 | 0.66 | 0.66 | 0.72 | 0.71 | 56.00 | 53.00 | 50.00 | 0.90 | 0.70 | 0.50 | 0.01 | 0.00 | 0.00 |
| **SD** | 3.084 | 4.49 | 3.80 | 0.14 | 0.18 | 0.16 | 0.26 | 0.27 | 0.26 | 14.52 | 9.00 | 9.25 | 0.18 | 0.17 | 0.12 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT**

**OKIGWE EXPRESS JUNCTION**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 11.80 | 9.50 | 10.40 | 0.70 | 0.75 | 0.65 | 0.27 | 0.35 | 0.45 | 50.00 | 52.00 | 46.00 | 0.50 | 0.30 | 0.40 | ND | ND | ND |
| **2** | 10.20 | 10.50 | 10.80 | 0.60 | 0.80 | 0.70 | 0.30 | 0.40 | 0.35 | 57.00 | 55.00 | 56.00 | 1.20 | 0.90 | 0.50 | ND | ND | ND |
| **3** | 12.50 | 10.20 | 11.40 | 0.65 | 0.62 | 0.60 | 0.40 | 0.40 | 0.50 | 55.00 | 56.00 | 50.00 | 1.40 | 1.30 | 0.90 | ND | ND | ND |
| **4** | 9.70 | 10.80 | 10.60 | 0.40 | 0.35 | 0.45 | 0.25 | 0.20 | 0.19 | 48.00 | 50.00 | 52.00 | 1.30 | 1.00 | 0.80 | ND | ND | ND |
| **5** | 9.40 | 11.50 | 10.80 | 0.50 | 0.64 | 0.75 | 0.30 | 0.45 | 0.40 | 53.00 | 50.00 | 54.00 | 0.80 | 0.60 | 0.30 | ND | ND | ND |
| **6** | 8.20 | 9.70 | 10.30 | 0.45 | 0.50 | 0.67 | 0.30 | 0.46 | 0.40 | 50.00 | 52.00 | 54.00 | 1.10 | 0.90 | 0.80 | ND | ND | ND |
| **7** | 10.60 | 13.50 | 10.70 | 0.64 | 0.70 | 0.65 | 0.50 | 0.73 | 0.65 | 50.00 | 56.00 | 52.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **8** | 10.30 | 15.60 | 14.80 | 0.45 | 0.50 | 0.40 | 0.30 | 0.35 | 0.33 | 45.00 | 52.00 | 55.00 | 1.20 | 1.00 | 0.80 | ND | ND | ND |
| **9** | 11.60 | 10.50 | 13.80 | 0.90 | 0.96 | 0.70 | 0.47 | 0.50 | 0.43 | 52.00 | 51.00 | 47.00 | 1.30 | 0.90 | 0.60 | ND | ND | ND |
| **10** | 12.40 | 14.70 | 14.10 | 0.65 | 0.70 | 0.60 | 0.46 | 0.60 | 0.65 | 53.00 | 47.00 | 50.00 | 1.10 | 0.70 | 0.50 | ND | ND | ND |
| **11** | 10.10 | 14.20 | 14.40 | 0.50 | 0.64 | 0.60 | 0.40 | 0.45 | 0.35 | 42.00 | 50.00 | 48.00 | 0.90 | 0.60 | 0.40 | ND | ND | ND |
| **12** | 5.10 | 7.40 | 8.70 | 0.57 | 0.70 | 0.64 | 0.57 | 0.70 | 0.65 | 54.00 | 50.00 | 47.00 | 0.80 | 0.90 | 0.70 | ND | ND | ND |
| **13** | 6.40 | 8.80 | 9.55 | 0.61 | 0.68 | 0.67 | 0.71 | 0.82 | 0.93 | 44.00 | 47.00 | 46.00 | 0.90 | 0.70 | 0.60 | ND | ND | ND |
| **14** | 7.60 | 10.20 | 10.40 | 0.64 | 0.65 | 0.71 | 0.84 | 0.94 | 1.20 | 34.00 | 44.00 | 46.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **15** | 8.20 | 11.30 | 9.80 | 0.70 | 0.73 | 0.70 | 0.77 | 0.80 | 0.98 | 38.00 | 47.00 | 50.00 | 0.60 | 0.40 | 0.20 | ND | ND | ND |
| **16** | 6.90 | 11.50 | 10.20 | 0.65 | 0.68 | 0.60 | 0.68 | 0.70 | 0.85 | 44.00 | 45.00 | 48.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **17** | 10.20 | 11.80 | 10.60 | 0.40 | 0.47 | 0.66 | 0.78 | 0.80 | 0.93 | 41.00 | 50.00 | 51.00 | 1.20 | 0.70 | 0.50 | ND | ND | ND |
| **18** | 5.80 | 9.70 | 10.20 | 0.50 | 0.86 | 0.80 | 0.65 | 0.70 | 0.84 | 36.00 | 48.00 | 47.00 | 0.80 | 0.60 | 0.30 | ND | ND | ND |
| **19** | 8.70 | 10.60 | 12.50 | 0.45 | 0.50 | 0.60 | 0.76 | 0.83 | 0.86 | 35.00 | 40.00 | 38.00 | 0.60 | 0.30 | 0.40 | ND | ND | ND |
| **20** | 9.30 | 13.50 | 11.40 | 0.64 | 0.75 | 0.73 | 0.59 | 0.73 | 0.83 | 28.00 | 43.00 | 52.00 | 1.10 | 0.80 | 0.40 | ND | ND | ND |
| **21** | 8.40 | 12.30 | 13.60 | 0.45 | 0.89 | 0.94 | 0.60 | 0.68 | 0.73 | 42.00 | 46.00 | 48.00 | 0.50 | 0.40 | 0.10 | ND | ND | ND |
| **22** | 8.50 | 11.10 | 13.40 | 0.90 | 1.00 | 0.97 | 0.48 | 0.50 | 0.60 | 30.00 | 41.00 | 47.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **23** | 7.90 | 10.70 | 11.90 | 0.65 | 0.74 | 0.80 | 0.43 | 0.53 | 0.65 | 39.00 | 47.00 | 50.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **24** | 9.40 | 10.20 | 12.20 | 0.50 | 0.62 | 0.60 | 0.60 | 0.69 | 0.76 | 41.00 | 45.00 | 42.00 | 0.70 | 0.40 | 0.50 | ND | ND | ND |
| **TOTAL** | 219.20 | 269.80 | 276.55 | 14.10 | 16.43 | 16.19 | 12.41 | 14.31 | 15.51 | 1061.00 | 1164.00 | 1176.00 | 21.80 | 16.20 | 11.60 | 0.00 | 0.00 | 0.00 |
| **MEAN** | 9.13 | 11.24 | 11.52 | 0.59 | 0.68 | 0.67 | 0.52 | 0.60 | 0.65 | 44.21 | 48.50 | 49.00 | 0.91 | 0.68 | 0.48 | 0.00 | 0.00 | 0.00 |
| **MIN** | 5.10 | 7.40 | 8.70 | 0.40 | 0.35 | 0.40 | 0.25 | 0.20 | 0.19 | 28.00 | 40.00 | 38.00 | 0.50 | 0.30 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 12.50 | 15.60 | 14.80 | 0.90 | 1.00 | 0.97 | 0.84 | 0.94 | 1.20 | 57.00 | 56.00 | 56.00 | 1.40 | 1.30 | 0.90 | 0.00 | 0.00 | 0.00 |
| **STDEV** | 3.71 | 4.10 | 3.05 | 0.25 | 0.32 | 0.29 | 0.30 | 0.37 | 0.51 | 14.53 | 8.01 | 9.07 | 0.27 | 0.25 | 0.21 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season result, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT ST. MARY'S JUNCTION**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 8.60 | 8.50 | 9.10 | 0.70 | 0.60 | 0.55 | 0.34 | 0.76 | 0.15 | 56.00 | 48.00 | 53.00 | 0.40 | 0.20 | ND | ND | ND | ND |
| **2** | 9.80 | 8.90 | 8.60 | 0.65 | 0.55 | 0.50 | 0.37 | 0.65 | 0.40 | 55.00 | 47.00 | 54.00 | 0.70 | 0.50 | 0.30 | ND | ND | ND |
| **3** | 7.20 | 7.50 | 6.80 | 0.50 | 0.65 | 0.50 | 0.38 | 0.60 | 0.45 | 50.00 | 50.00 | 48.00 | 0.50 | 0.30 | ND | 0.01 | ND | ND |
| **4** | 7.50 | 6.50 | 6.70 | 0.25 | 0.20 | 0.19 | 0.30 | 0.25 | 0.20 | 35.00 | 30.00 | 37.00 | 0.90 | 0.60 | 0.40 | ND | 0.007 | ND |
| **5** | 7.10 | 8.90 | 8.20 | 0.47 | 0.55 | 0.50 | 0.40 | 0.60 | 0.63 | 48.00 | 54.00 | 51.00 | 0.80 | 0.50 | 0.20 | ND | ND | ND |
| **6** | 6.40 | 9.60 | 9.80 | 0.35 | 0.50 | 0.55 | 0.30 | 0.60 | 0.70 | 45.00 | 48.00 | 50.00 | 0.30 | ND | ND | ND | ND | ND |
| **7** | 8.30 | 9.70 | 9.20 | 0.58 | 0.60 | 0.62 | 0.46 | 0.65 | 0.50 | 48.00 | 50.00 | 52.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **8** | 13.70 | 13.20 | 11.30 | 0.20 | 0.35 | 0.25 | 0.25 | 0.30 | 0.27 | 40.00 | 48.00 | 53.00 | 0.80 | 0.60 | 0.30 | ND | ND | ND |
| **9** | 10.40 | 9.01 | 8.70 | 0.74 | 0.65 | 0.60 | 0.30 | 0.65 | 0.28 | 47.00 | 50.00 | 48.00 | 0.50 | 0.40 | 0.20 | 0.009 | ND | ND |
| **10** | 10.30 | 13.60 | 12.50 | 0.52 | 0.50 | 0.55 | 0.45 | 0.50 | 0.48 | 48.00 | 51.00 | 46.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **11** | 9.70 | 11.30 | 10.80 | 0.48 | 0.50 | 0.70 | 0.36 | 0.52 | 0.20 | 38.00 | 47.00 | 45.00 | 0.90 | 0.80 | 0.70 | ND | ND | ND |
| **12** | 3.80 | 5.50 | 6.20 | 0.62 | 0.68 | 0.37 | 0.45 | 0.52 | 0.60 | 45.00 | 51.00 | 53.00 | 1.20 | 0.90 | 0.60 | ND | ND | ND |
| **13** | 6.55 | 7.85 | 7.90 | 0.56 | 0.64 | 0.44 | 0.43 | 0.52 | 0.55 | 37.00 | 49.00 | 46.00 | 0.50 | 0.40 | 0.20 | ND | ND | ND |
| **14** | 9.30 | 10.20 | 9.70 | 0.50 | 0.60 | 0.50 | 0.40 | 0.52 | 0.50 | 29.00 | 48.00 | 45.00 | 0.40 | 0.30 | 0.10 | ND | 0.001 | ND |
| **15** | 8.70 | 8.90 | 9.20 | 0.65 | 0.70 | 0.68 | 0.37 | 0.47 | 0.40 | 30.00 | 40.00 | 46.00 | 0.30 | 0.20 | 0.10 | 0.02 | ND | ND |
| **16** | 7.20 | 9.30 | 8.60 | 0.50 | 0.64 | 0.55 | 0.60 | 0.68 | 0.57 | 33.00 | 43.00 | 48.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |
| **17** | 10.10 | 10.70 | 12.30 | 0.35 | 0.40 | 0.56 | 0.36 | 0.40 | 0.45 | 35.00 | 40.00 | 43.00 | 0.80 | 0.50 | 0.20 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **18** | 7.10 | 8.90 | 9.10 | 0.47 | 0.54 | 0.50 | 0.40 | 0.60 | 0.63 | 40.00 | 43.00 | 41.00 | 0.90 | 0.60 | 0.40 | ND | ND | ND |
| **19** | 6.80 | 9.60 | 10.50 | 0.45 | 0.51 | 0.57 | 0.55 | 0.63 | 0.70 | 37.00 | 48.00 | 43.00 | 0.50 | 0.30 | 0.30 | 0.01 | ND | ND |
| **20** | 7.60 | 9.70 | 8.70 | 0.56 | 0.60 | 0.62 | 0.47 | 0.65 | 0.50 | 26.00 | 38.00 | 40.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **21** | 9.60 | 13.20 | 12.30 | 0.36 | 0.45 | 0.51 | 0.30 | 0.36 | 0.40 | 39.00 | 44.00 | 51.00 | 1.10 | 0.70 | 0.50 | ND | ND | ND |
| **22** | 8.30 | 9.01 | 8.70 | 0.74 | 0.82 | 0.87 | 0.25 | 0.58 | 0.50 | 42.00 | 46.00 | 47.00 | 0.60 | 0.30 | 0.40 | ND | ND | ND |
| **23** | 7.90 | 13.60 | 10.20 | 0.52 | 0.61 | 0.55 | 0.45 | 0.53 | 0.48 | 34.00 | 40.00 | 46.00 | 0.70 | 0.50 | 0.20 | ND | ND | ND |
| **24** | 9.60 | 11.30 | 12.50 | 0.48 | 0.50 | 0.65 | 0.37 | 0.48 | 0.40 | 38.00 | 42.00 | 43.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **TOTAL** | 201.55 | 234.47 | 227.60 | 12.20 | 13.34 | 12.88 | 9.31 | 13.02 | 10.94 | 975.00 | 1095.00 | 1129.00 | 15.50 | 10.40 | 6.30 | 0.05 | 0.01 | 0.00 |
| **MEAN** | 8.40 | 9.77 | 9.48 | 0.51 | 0.56 | 0.54 | 0.39 | 0.54 | 0.46 | 40.63 | 45.63 | 47.04 | 0.65 | 0.45 | 0.30 | 0.01 | 0.00 | 0.00 |
| **MIN** | 3.80 | 5.50 | 6.20 | 0.20 | 0.20 | 0.19 | 0.25 | 0.25 | 0.15 | 26.00 | 30.00 | 37.00 | 0.30 | 0.20 | 0.10 | 0.01 | 0.00 | 0.00 |
| **MAX** | 13.70 | 13.60 | 12.50 | 0.74 | 0.82 | 0.87 | 0.60 | 0.76 | 0.70 | 56.00 | 54.00 | 54.00 | 1.20 | 0.90 | 0.70 | 0.02 | 0.01 | 0.00 |
| **SD** | 4.95 | 4.05 | 3.15 | 0.27 | 0.31 | 0.34 | 0.17 | 0.25 | 0.27 | 15.00 | 12.18 | 8.55 | 0.24 | 0.19 | 0.16 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT OKIGWE LGA HEADQUARTER**

| | | **PM ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 4.30 | 5.40 | 5.90 | 0.80 | 0.60 | 0.40 | 0.06 | 0.21 | 0.17 | 49.00 | 45.00 | 48.00 | 0.50 | ND | ND | ND | ND | ND |
| **2** | 4.10 | 5.10 | 6.50 | 0.70 | 0.50 | 0.48 | 0.20 | 0.25 | 0.20 | 50.00 | 43.00 | 46.00 | 0.60 | 0.30 | 0.40 | 0.01 | ND | ND |
| **3** | 4.60 | 5.10 | 4.50 | 0.75 | 0.55 | 0.42 | 0.17 | 0.27 | 0.30 | 45.00 | 47.00 | 42.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **4** | 3.80 | 3.50 | 3.20 | 0.17 | 0.25 | 0.20 | 0.18 | 0.20 | 0.17 | 28.00 | 25.00 | 30.00 | 0.50 | 0.40 | 0.20 | ND | ND | ND |
| **5** | 5.30 | 5.70 | 6.30 | 0.40 | 0.50 | 0.60 | 0.20 | 0.35 | 0.27 | 40.00 | 47.00 | 42.00 | 1.20 | 0.90 | 0.80 | ND | ND | ND |
| **6** | 3.70 | 5.40 | 5.20 | 0.40 | 0.45 | 0.50 | 0.18 | 0.30 | 0.25 | 35.00 | 40.00 | 38.00 | 0.30 | ND | ND | 0.02 | ND | ND |
| **7** | 5.20 | 5.80 | 4.60 | 0.40 | 0.55 | 0.50 | 0.30 | 0.47 | 0.40 | 42.00 | 45.00 | 40.00 | 0.60 | 0.40 | 0.20 | ND | 0.005 | ND |
| **8** | 9.80 | 10.30 | 10.10 | 0.10 | 0.20 | 0.12 | 0.20 | 0.25 | 0.24 | 38.00 | 45.00 | 40.00 | 0.40 | ND | ND | ND | ND | ND |
| **9** | 9.30 | 9.80 | 8.20 | 0.85 | 0.70 | 0.78 | 0.14 | 0.45 | 0.40 | 39.00 | 42.00 | 45.00 | 0.80 | 0.50 | 0.10 | ND | ND | ND |
| **10** | 8.50 | 9.20 | 10.03 | 0.45 | 0.57 | 0.42 | 0.30 | 0.28 | 0.33 | 37.00 | 40.00 | 43.00 | 0.70 | 0.60 | 0.40 | ND | ND | ND |
| **11** | 7.30 | 6.70 | 4.60 | 0.26 | 0.35 | 0.30 | 0.30 | 0.42 | 0.35 | 24.00 | 32.00 | 40.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **12** | 2.60 | 4.80 | 3.50 | 0.40 | 0.35 | 0.38 | 0.30 | 0.25 | 0.37 | 40.00 | 46.00 | 44.00 | 1.10 | 0.90 | 0.60 | ND | ND | ND |
| **13** | 3.40 | 5.20 | 4.90 | 0.50 | 0.57 | 0.53 | 0.20 | 0.23 | 0.34 | 37.00 | 43.00 | 40.00 | 0.10 | 0.10 | 0.20 | 0.01 | ND | ND |
| **14** | 4.20 | 5.60 | 6.30 | 0.60 | 0.65 | 0.68 | 0.10 | 0.21 | 0.30 | 34.00 | 40.00 | 45.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **15** | 3.80 | 4.80 | 5.60 | 0.70 | 0.81 | 1.20 | 0.32 | 0.42 | 0.45 | 27.00 | 43.00 | 46.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **16** | 8.30 | 9.50 | 10.20 | 0.60 | 0.66 | 0.72 | 0.25 | 0.30 | 0.30 | 32.00 | 40.00 | 44.00 | 0.20 | 0.20 | 0.10 | ND | 0.004 | ND |
| **17** | 3.90 | 4.20 | 4.10 | 0.47 | 0.52 | 0.63 | 0.19 | 0.23 | 0.36 | 28.00 | 37.00 | 40.00 | 0.10 | ND | ND | ND | ND | ND |
| **18** | 5.40 | 5.60 | 6.20 | 0.40 | 0.50 | 0.60 | 0.37 | 0.42 | 0.40 | 31.00 | 43.00 | 42.00 | 0.20 | 0.10 | 0.10 | ND | ND | ND |
| **19** | 3.80 | 5.30 | 6.10 | 0.35 | 0.40 | 4.30 | 0.40 | 0.45 | 0.48 | 36.00 | 45.00 | 39.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **20** | 5.10 | 5.80 | 7.30 | 0.42 | 0.50 | 0.55 | 0.31 | 0.36 | 0.43 | 29.00 | 37.00 | 40.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |
| **21** | 8.90 | 10.30 | 11.20 | 0.30 | 0.36 | 0.42 | 0.23 | 0.30 | 0.35 | 33.00 | 40.00 | 38.00 | 0.10 | ND | ND | ND | ND | ND |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **22** | 7.80 | 9.80 | 10.40 | 0.65 | 0.70 | 0.75 | 0.15 | 0.27 | 0.32 | 21.00 | 35.00 | 40.00 | 0.20 | 0.10 | 0.10 | ND | ND | ND |
| **23** | 5.20 | 9.20 | 8.70 | 0.40 | 0.48 | 0.56 | 0.23 | 0.27 | 0.34 | 26.00 | 32.00 | 38.00 | 0.10 | 0.10 | 0.10 | ND | ND | ND |
| **24** | 4.20 | 6.50 | 6.20 | 0.34 | 0.42 | 0.50 | 0.46 | 0.50 | 0.57 | 38.00 | 40.00 | 41.00 | 0.20 | ND | ND | ND | ND | ND |
| **TOTAL** | 132.50 | 158.60 | 159.83 | 11.41 | 12.14 | 16.54 | 5.74 | 7.66 | 8.09 | 839.00 | 972.00 | 991.00 | 10.70 | 6.40 | 4.40 | 0.04 | 0.01 | 0.00 |
| **MEAN** | 5.52 | 6.61 | 6.66 | 0.48 | 0.51 | 0.69 | 0.24 | 0.32 | 0.34 | 34.96 | 40.50 | 41.29 | 0.45 | 0.36 | 0.24 | 0.00 | 0.00 | 0.00 |
| **MIN** | 2.60 | 3.50 | 3.20 | 0.10 | 0.20 | 0.12 | 0.06 | 0.20 | 0.17 | 21.00 | 25.00 | 30.00 | 0.10 | 0.10 | 0.10 | 0.01 | 0.00 | 0.00 |
| **MAX** | 9.80 | 10.30 | 11.20 | 0.85 | 0.81 | 4.30 | 0.46 | 0.50 | 0.57 | 50.00 | 47.00 | 48.00 | 1.20 | 0.90 | 0.80 | 0.02 | 0.01 | 0.00 |
| **SD** | 3.62 | 3.40 | 4.01 | 0.38 | 0.31 | 2.27 | 0.20 | 0.15 | 0.20 | 14.50 | 11.30 | 9.10 | 0.31 | 0.25 | 0.20 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT IHUBE**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 4.60 | 3.50 | 2.50 | 0.45 | 0.30 | 0.30 | 0.05 | 0.20 | 0.04 | 36.00 | 37.00 | 44.00 | 1.20 | 0.80 | 0.50 | ND | ND | ND |
| **2** | 3.20 | 3.00 | 2.30 | 0.35 | 0.30 | 0.27 | 0.13 | 0.19 | 0.16 | 33.00 | 35.00 | 40.00 | 1.10 | ND | 0.30 | ND | ND | ND |
| **3** | 4.20 | 4.00 | 3.10 | 0.32 | 0.35 | 0.25 | 0.10 | 0.15 | 0.21 | 35.00 | 35.00 | 40.00 | 0.80 | 0.60 | 0.50 | 0.002 | ND | ND |
| **4** | 3.20 | 3.60 | 3.10 | 0.08 | 0.13 | 0.10 | 0.16 | 0.18 | 0.15 | 24.00 | 27.00 | 20.00 | 1.00 | 0.70 | ND | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5** | 3.40 | 4.20 | 3.60 | 0.30 | 0.35 | 0.30 | 0.15 | 0.25 | 0.20 | 32.00 | 35.00 | 40.00 | 0.70 | 0.60 | 0.40 | 0.004 | ND | ND |
| **6** | 2.50 | 3.20 | 2.80 | 0.30 | 0.25 | 0.36 | 0.10 | 0.15 | 0.13 | 30.00 | 28.00 | 32.00 | 1.00 | 0.80 | 0.50 | ND | ND | ND |
| **7** | 3.10 | 3.50 | 2.80 | 0.25 | 0.40 | 0.30 | 0.20 | 0.30 | 0.26 | 33.00 | 30.00 | 28.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **8** | 8.20 | 9.50 | 9.10 | 0.03 | 0.15 | 0.08 | 0.13 | 0.15 | 0.12 | 30.00 | 35.00 | 38.00 | 0.90 | 0.80 | 0.60 | ND | ND | ND |
| **9** | 7.50 | 8.60 | 7.80 | 0.35 | 0.30 | 0.28 | 0.20 | 0.35 | 0.30 | 33.00 | 38.00 | 40.00 | 0.70 | 0.50 | 0.20 | 0.001 | ND | ND |
| **10** | 6.90 | 7.40 | 6.80 | 0.30 | 0.40 | 0.38 | 0.09 | 0.20 | 0.17 | 40.00 | 42.00 | 36.00 | 1.40 | 1.10 | 0.70 | ND | ND | ND |
| **11** | 5.50 | 4.40 | 4.70 | 0.28 | 0.30 | 0.25 | 0.13 | 0.26 | 0.20 | 17.00 | 25.00 | 35.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **12** | 1.70 | 3.40 | 2.70 | 0.36 | 0.25 | 0.30 | 0.20 | 0.17 | 0.24 | 37.00 | 40.00 | 38.00 | 1.10 | 0.70 | 0.60 | ND | ND | ND |
| **13** | 2.60 | 3.85 | 4.20 | 0.48 | 0.52 | 0.50 | 0.17 | 0.21 | 0.30 | 35.00 | 39.00 | 37.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **14** | 3.40 | 4.30 | 5.60 | 0.64 | 0.70 | 0.73 | 0.14 | 0.24 | 0.35 | 32.00 | 38.00 | 36.00 | 0.70 | 0.40 | 0.30 | ND | ND | ND |
| **15** | 4.30 | 5.60 | 5.90 | 0.50 | 0.60 | 0.65 | 0.20 | 0.23 | 0.19 | 27.00 | 34.00 | 41.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **16** | 5.20 | 6.80 | 6.50 | 0.42 | 0.45 | 0.50 | 0.34 | 0.36 | 0.30 | 25.00 | 31.00 | 39.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |
| **17** | 3.70 | 5.20 | 7.20 | 0.35 | 0.40 | 0.46 | 0.08 | 0.17 | 0.45 | 32.00 | 35.00 | 33.00 | 0.30 | 0.10 | 0.10 | 0.001 | ND | ND |
| **18** | 4.00 | 6.10 | 5.30 | 0.40 | 0.54 | 0.50 | 0.20 | 0.23 | 0.25 | 19.00 | 24.00 | 30.00 | 0.50 | 0.20 | 0.20 | ND | ND | ND |
| **19** | 6.40 | 7.30 | 8.10 | 0.30 | 0.35 | 0.36 | 0.32 | 0.35 | 0.30 | 34.00 | 38.00 | 40.00 | 0.30 | 0.40 | 0.20 | 0.001 | ND | ND |
| **20** | 5.10 | 6.20 | 7.40 | 0.28 | 0.38 | 0.40 | 0.18 | 0.25 | 0.20 | 32.00 | 39.00 | 41.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **21** | 1.90 | 4.60 | 5.40 | 0.53 | 0.60 | 0.65 | 0.09 | 0.16 | 0.20 | 41.00 | 46.00 | 38.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **22** | 2.90 | 5.90 | 6.80 | 0.72 | 0.80 | 0.63 | 0.20 | 0.35 | 0.30 | 26.00 | 38.00 | 45.00 | 0.80 | 0.70 | 0.50 | 0.001 | ND | ND |
| **23** | 3.70 | 4.70 | 5.20 | 0.45 | 0.40 | 0.37 | 0.15 | 0.25 | 0.20 | 30.00 | 37.00 | 32.00 | 0.70 | 0.60 | 0.40 | ND | ND | ND |
| **24** | 4.20 | 5.10 | 6.30 | 0.36 | 0.43 | 0.35 | 0.27 | 0.32 | 0.35 | 22.00 | 36.00 | 41.00 | 0.60 | 0.20 | 0.10 | ND | ND | ND |
| **TOTAL** | 101.40 | 123.95 | 125.20 | 8.80 | 9.65 | 9.27 | 3.98 | 5.67 | 5.57 | 735.00 | 842.00 | 884.00 | 17.90 | 12.10 | 8.10 | 0.01 | 0.00 | 0.00 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEAN** | 4.23 | 5.16 | 5.22 | 0.37 | 0.40 | 0.39 | 0.17 | 0.24 | 0.23 | 30.63 | 35.08 | 36.83 | 0.75 | 0.53 | 0.35 | 0.00 | 0.00 | 0.00 |
| **MIN** | 1.70 | 3.00 | 2.30 | 0.03 | 0.13 | 0.08 | 0.05 | 0.15 | 0.04 | 17.00 | 24.00 | 20.00 | 0.30 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 8.20 | 9.50 | 9.10 | 0.72 | 0.80 | 0.73 | 0.34 | 0.36 | 0.45 | 41.00 | 46.00 | 45.00 | 1.40 | 1.10 | 0.70 | 0.00 | 0.00 | 0.00 |
| **SD** | 3.28 | 3.30 | 3.41 | 0.35 | 0.34 | 0.33 | 0.15 | 0.11 | 0.21 | 12.03 | 11.00 | 12.75 | 0.31 | 0.26 | 0.19 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

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**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UMUAKA JUNCTION**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.50 | 7.60 | 6.90 | 0.60 | 0.50 | 0.50 | 0.41 | 0.45 | 0.80 | 52.00 | 46.00 | 46.00 | 1.30 | 1.20 | 1.20 | 0.001 | ND | ND |
| **2** | 4.80 | 8.50 | 7.80 | 0.50 | 0.55 | 0.55 | 0.35 | 0.66 | 0.68 | 55.00 | 48.00 | 45.00 | 1.40 | 1.30 | 0.90 | ND | ND | ND |
| **3** | 5.05 | 6.40 | 7.20 | 0.65 | 0.48 | 0.48 | 0.47 | 0.75 | 0.50 | 50.00 | 40.00 | 50.00 | 0.90 | 1.00 | 0.80 | 0.003 | ND | ND |
| **4** | 6.20 | 5.20 | 5.60 | 0.56 | 0.40 | 0.60 | 0.33 | 0.30 | 0.40 | 43.00 | 48.00 | 45.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5** | 6.40 | 8.60 | 7.30 | 0.46 | 0.60 | 0.55 | 0.35 | 0.55 | 0.50 | 40.00 | 45.00 | 42.00 | 0.80 | 0.70 | 0.50 | ND | ND | ND |
| **6** | 5.30 | 7.60 | 6.90 | 0.50 | 0.75 | 0.60 | 0.30 | 0.60 | 0.57 | 46.00 | 48.00 | 47.00 | 0.90 | 0.50 | 0.60 | ND | ND | ND |
| **7** | 7.40 | 9.20 | 8.60 | 0.40 | 0.43 | 0.45 | 0.50 | 0.60 | 0.55 | 40.00 | 48.00 | 45.00 | 1.20 | 0.80 | 0.70 | 0.02 | 0.006 | ND |
| **8** | 9.05 | 11.40 | 10.50 | 0.50 | 0.55 | 0.60 | 0.17 | 0.30 | 0.30 | 46.00 | 48.00 | 50.00 | 1.30 | 0.90 | 0.60 | ND | ND | ND |
| **9** | 8.40 | 10.80 | 9.70 | 0.46 | 0.55 | 0.48 | 0.52 | 0.60 | 0.30 | 40.00 | 45.00 | 42.00 | 1.00 | 0.80 | 0.50 | 0.01 | ND | ND |
| **10** | 7.20 | 9.40 | 7.60 | 0.38 | 0.42 | 0.40 | 0.18 | 0.30 | 0.27 | 45.00 | 38.00 | 40.00 | 0.70 | 0.60 | 0.60 | ND | ND | ND |
| **11** | 4.60 | 8.40 | 10.20 | 0.45 | 0.55 | 0.50 | 0.60 | 0.58 | 0.35 | 40.00 | 45.00 | 50.00 | 1.20 | 0.90 | 0.70 | 0.001 | ND | ND |
| **12** | 5.70 | 10.30 | 9.10 | 0.40 | 0.50 | 0.52 | 0.40 | 0.35 | 0.30 | 45.00 | 40.00 | 48.00 | 0.80 | 0.70 | 0.50 | ND | ND | ND |
| **13** | 4.70 | 8.40 | 8.20 | 0.49 | 0.60 | 0.58 | 0.50 | 0.52 | 0.45 | 39.00 | 41.00 | 47.00 | 0.70 | 0.40 | 0.20 | ND | ND | ND |
| **14** | 3.60 | 6.50 | 7.20 | 0.57 | 0.67 | 0.65 | 0.63 | 0.65 | 0.60 | 38.00 | 42.00 | 46.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **15** | 4.80 | 7.30 | 6.80 | 0.50 | 0.60 | 0.55 | 0.35 | 0.40 | 0.45 | 40.00 | 47.00 | 45.00 | 0.40 | 0.30 | 0.20 | ND | ND | ND |
| **16** | 3.90 | 5.20 | 5.40 | 0.45 | 0.48 | 0.50 | 0.47 | 0.65 | 0.50 | 35.00 | 38.00 | 40.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **17** | 4.30 | 5.10 | 6.20 | 0.50 | 0.54 | 0.55 | 0.44 | 0.52 | 0.50 | 41.00 | 47.00 | 44.00 | 0.60 | 0.40 | 0.10 | 0.001 | ND | ND |
| **18** | 6.20 | 6.40 | 5.80 | 0.43 | 0.50 | 0.55 | 0.35 | 0.50 | 0.46 | 27.00 | 38.00 | 41.00 | 0.50 | 0.40 | 0.20 | ND | ND | ND |
| **19** | 7.20 | 8.20 | 6.70 | 0.37 | 0.45 | 0.52 | 0.70 | 0.75 | 0.60 | 35.00 | 41.00 | 46.00 | 0.30 | 0.10 | 0.10 | ND | ND | ND |
| **20** | 3.70 | 4.30 | 5.10 | 0.40 | 0.50 | 0.45 | 0.50 | 0.60 | 0.57 | 40.00 | 50.00 | 52.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **21** | 4.10 | 7.30 | 6.50 | 0.30 | 0.43 | 0.55 | 0.36 | 0.40 | 0.45 | 37.00 | 45.00 | 49.00 | 0.60 | 0.30 | 0.10 | ND | ND | ND |
| **22** | 6.40 | 9.20 | 10.10 | 0.45 | 0.50 | 0.48 | 0.42 | 0.53 | 0.45 | 26.00 | 34.00 | 43.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **23** | 2.60 | 4.60 | 5.20 | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 | 0.60 | 35.00 | 40.00 | 42.00 | 0.20 | 0.20 | 0.10 | 0.001 | ND | ND |
| **24** | 4.50 | 5.40 | 7.60 | 0.50 | 0.60 | 0.63 | 0.46 | 0.53 | 0.55 | 22.00 | 38.00 | 46.00 | 0.30 | 0.20 | 0.30 | ND | ND | ND |
| **TOTAL** | 131.60 | 181.30 | 178.20 | 11.17 | 12.55 | 12.69 | 10.26 | 12.64 | 11.70 | 957.00 | 1040.00 | 1091.00 | 18.10 | 13.80 | 10.30 | 0.04 | 0.01 | 0.00 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEAN** | 5.48 | 7.55 | 7.43 | 0.47 | 0.52 | 0.53 | 0.43 | 0.53 | 0.49 | 39.88 | 43.33 | 45.46 | 0.75 | 0.58 | 0.43 | 0.01 | 0.01 | 0.00 |
| **MIN** | 2.60 | 4.30 | 5.10 | 0.30 | 0.40 | 0.40 | 0.17 | 0.30 | 0.27 | 22.00 | 34.00 | 40.00 | 0.20 | 0.10 | 0.10 | 0.00 | 0.01 | 0.00 |
| **MAX** | 9.05 | 11.40 | 10.50 | 0.65 | 0.75 | 0.65 | 0.70 | 0.75 | 0.80 | 55.00 | 50.00 | 52.00 | 1.40 | 1.30 | 1.20 | 0.02 | 0.01 | 0.00 |
| **SD** | 3.23 | 3.55 | 2.71 | 0.18 | 0.18 | 0.13 | 0.27 | 0.23 | 0.27 | 16.52 | 8.04 | 6.01 | 0.37 | 0.34 | 0.31 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT BANANA JUNCTION**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 8.20 | 7.80 | 6.50 | 0.70 | 0.60 | 0.50 | 0.62 | 0.62 | 0.63 | 45.00 | 40.00 | 32.00 | 1.00 | 0.80 | 0.90 | ND | ND | ND |
| **2** | 7.10 | 6.70 | 7.60 | 0.60 | 0.67 | 0.60 | 0.65 | 0.74 | 0.80 | 48.00 | 45.00 | 47.00 | 1.10 | 0.70 | 0.60 | 0.001 | ND | ND |
| **3** | 9.40 | 6.10 | 8.50 | 0.72 | 0.55 | 0.65 | 0.50 | 0.57 | 0.30 | 54.00 | 51.00 | 46.00 | 0.50 | 0.40 | 0.70 | 0.004 | ND | ND |
| **4** | 8.50 | 8.90 | 9.20 | 0.60 | 0.58 | 0.55 | 0.40 | 0.45 | 0.47 | 48.00 | 45.00 | 55.00 | 0.70 | 0.80 | 0.50 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **5** | 7.70 | 9.20 | 9.50 | 0.50 | 0.70 | 0.64 | 0.43 | 0.70 | 0.60 | 42.00 | 36.00 | 31.00 | 0.90 | 0.70 | 0.40 | 0.01 | ND | ND |
| **6** | 6.50 | 8.80 | 8.30 | 0.55 | 0.70 | 0.50 | 0.55 | 0.80 | 0.75 | 45.00 | 50.00 | 46.00 | 1.30 | 1.10 | 0.80 | ND | ND | ND |
| **7** | 9.80 | 10.70 | 10.20 | 0.50 | 0.60 | 0.50 | 0.60 | 0.65 | 0.50 | 47.00 | 50.00 | 48.00 | 1.20 | 0.80 | 0.60 | ND | ND | ND |
| **8** | 10.40 | 10.50 | 9.30 | 0.65 | 0.70 | 0.55 | 0.40 | 0.50 | 0.45 | 50.00 | 52.00 | 51.00 | 1.40 | 0.90 | 1.00 | 0.02 | ND | ND |
| **9** | 9.60 | 12.10 | 12.60 | 0.65 | 0.50 | 0.40 | 0.34 | 0.28 | 0.40 | 45.00 | 48.00 | 37.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **10** | 8.10 | 9.50 | 9.03 | 0.53 | 0.65 | 0.57 | 0.40 | 0.45 | 0.30 | 40.00 | 42.00 | 37.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **11** | 5.10 | 6.60 | 7.30 | 0.67 | 0.60 | 0.46 | 0.72 | 0.80 | 0.60 | 43.00 | 47.00 | 38.00 | 1.04 | 0.90 | 0.80 | 0.002 | ND | ND |
| **12** | 9.50 | 7.50 | 8.70 | 0.50 | 0.63 | 0.58 | 0.47 | 0.45 | 0.40 | 55.00 | 48.00 | 45.00 | 1.20 | 1.00 | 0.70 | ND | ND | ND |
| **13** | 7.30 | 7.60 | 9.00 | 0.55 | 0.65 | 0.58 | 0.54 | 0.58 | 0.60 | 42.00 | 44.00 | 45.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **14** | 5.20 | 7.60 | 9.30 | 0.60 | 0.67 | 0.57 | 0.60 | 0.70 | 0.80 | 30.00 | 40.00 | 43.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **15** | 7.10 | 8.40 | 7.80 | 0.45 | 0.50 | 0.60 | 0.83 | 0.78 | 0.72 | 28.00 | 37.00 | 41.00 | 0.30 | 0.20 | 0.20 | ND | ND | ND |
| **16** | 6.30 | 7.50 | 9.50 | 0.50 | 0.60 | 0.65 | 0.64 | 0.60 | 0.50 | 31.00 | 36.00 | 38.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **17** | 7.70 | 9.10 | 10.30 | 0.38 | 0.56 | 0.60 | 0.32 | 0.54 | 0.60 | 23.00 | 30.00 | 36.00 | 0.50 | 0.30 | 0.10 | ND | ND | ND |
| **18** | 6.40 | 8.60 | 7.40 | 0.40 | 0.50 | 0.55 | 0.52 | 0.65 | 0.70 | 38.00 | 42.00 | 43.00 | 0.70 | 0.60 | 0.20 | ND | ND | ND |
| **19** | 8.20 | 11.05 | 10.90 | 0.35 | 0.40 | 0.45 | 0.60 | 0.65 | 0.73 | 22.00 | 28.00 | 34.00 | 0.50 | 0.40 | 0.20 | ND | ND | ND |
| **20** | 4.70 | 7.30 | 9.50 | 0.54 | 0.67 | 0.60 | 0.76 | 0.82 | 0.94 | 35.00 | 37.00 | 40.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **21** | 5.30 | 9.20 | 12.60 | 0.60 | 0.65 | 0.70 | 0.87 | 0.98 | 1.10 | 40.00 | 43.00 | 38.00 | 0.90 | 0.40 | 0.30 | ND | ND | ND |
| **22** | 8.10 | 9.00 | 10.30 | 0.40 | 0.50 | 0.57 | 0.45 | 0.52 | 0.68 | 24.00 | 33.00 | 39.00 | 0.80 | 0.70 | 0.40 | ND | ND | ND |
| **23** | 3.90 | 6.70 | 8.10 | 0.25 | 0.38 | 0.46 | 0.75 | 0.95 | 0.87 | 38.00 | 40.00 | 42.00 | 1.00 | 0.80 | 0.70 | ND | ND | ND |
| **24** | 4.50 | 7.40 | 9.30 | 0.45 | 0.50 | 0.58 | 0.47 | 0.45 | 0.40 | 36.00 | 38.00 | 45.00 | 0.60 | 0.50 | 0.20 | ND | ND | ND |
| **TOTAL** | 174.60 | 203.85 | 220.73 | 12.64 | 14.06 | 13.41 | 13.43 | 15.23 | 14.84 | 949.00 | 1002.00 | 997.00 | 19.64 | 14.70 | 11.10 | 0.04 | 0.00 | 0.00 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEAN** | 7.28 | 8.49 | 9.20 | 0.53 | 0.59 | 0.56 | 0.56 | 0.63 | 0.62 | 39.54 | 41.75 | 41.54 | 0.82 | 0.61 | 0.46 | 0.01 | 0.00 | 0.00 |
| **MIN** | 3.90 | 6.10 | 6.50 | 0.25 | 0.38 | 0.40 | 0.32 | 0.28 | 0.30 | 22.00 | 28.00 | 31.00 | 0.30 | 0.20 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 10.40 | 12.10 | 12.60 | 0.72 | 0.70 | 0.70 | 0.87 | 0.98 | 1.10 | 55.00 | 52.00 | 55.00 | 1.40 | 1.10 | 1.00 | 0.02 | 0.00 | 0.00 |
| **SD** | 3.25 | 3.02 | 3.06 | 0.24 | 0.16 | 0.15 | 0.28 | 0.35 | 0.40 | 16.51 | 12.04 | 12.03 | 0.30 | 0.25 | 0.27 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UMUNA JUNCTION ORLU**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 9.20 | 8.20 | 10.40 | 0.90 | 0.60 | 0.50 | 0.76 | 0.76 | 0.72 | 47.00 | 45.00 | 33.00 | 1.00 | 0.50 | 0.60 | ND | ND | ND |
| **2** | 8.40 | 8.80 | 9.60 | 0.80 | 0.62 | 0.55 | 0.66 | 0.76 | 0.70 | 50.00 | 47.00 | 45.00 | 0.90 | 0.70 | 0.40 | 0.002 | ND | ND |
| **3** | 10.90 | 9.40 | 9.60 | 0.80 | 0.60 | 0.70 | 0.62 | 0.68 | 0.65 | 51.00 | 48.00 | 35.00 | 1.10 | 0.90 | 0.80 | ND | ND | ND |
| **4** | 9.20 | 9.40 | 10.40 | 0.55 | 0.40 | 0.65 | 0.50 | 0.40 | 0.55 | 50.00 | 54.00 | 47.00 | 1.00 | 1.10 | 0.70 | 0.001 | ND | ND |
| **5** | 8.90 | 10.60 | 9.80 | 0.55 | 0.68 | 0.60 | 0.45 | 0.75 | 0.70 | 45.00 | 40.00 | 48.00 | 1.20 | 1.00 | 0.90 | 0.01 | ND | ND |
| **6** | 9.20 | 11.60 | 10.80 | 0.45 | 0.78 | 0.70 | 0.50 | 0.65 | 0.70 | 42.00 | 51.00 | 43.00 | 1.30 | 0.80 | 0.70 | ND | ND | ND |
| **7** | 10.20 | 12.60 | 11.80 | 0.70 | 0.80 | 0.60 | 0.70 | 0.80 | 0.70 | 50.00 | 48.00 | 50.00 | 1.20 | 0.90 | 0.60 | 0.01 | ND | 0.001 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8** | 10.70 | 11.80 | 10.60 | 0.50 | 0.60 | 0.64 | 0.60 | 0.70 | 0.65 | 48.00 | 50.00 | 56.00 | 1.40 | 1.30 | 1.00 | ND | ND | ND |
| **9** | 10.20 | 10.80 | 9.70 | 0.50 | 0.70 | 0.60 | 0.60 | 0.73 | 0.50 | 51.00 | 44.00 | 46.00 | 1.10 | 0.80 | 0.70 | 0.01 | ND | ND |
| **10** | 9.80 | 8.40 | 7.60 | 0.75 | 0.60 | 0.64 | 0.55 | 0.40 | 0.53 | 36.00 | 40.00 | 48.00 | 0.90 | 1.00 | 0.80 | ND | ND | 0.002 |
| **11** | 7.40 | 7.80 | 8.50 | 0.62 | 0.57 | 0.70 | 0.70 | 0.65 | 0.56 | 47.00 | 50.00 | 45.00 | 1.20 | 0.70 | 0.60 | 0.001 | ND | ND |
| **12** | 9.40 | 10.80 | 9.01 | 0.65 | 0.55 | 0.50 | 0.55 | 0.40 | 0.50 | 48.00 | 50.00 | 52.00 | 1.40 | 1.10 | 1.00 | ND | ND | ND |
| **13** | 8.30 | 9.60 | 9.50 | 0.61 | 0.58 | 0.53 | 0.63 | 0.56 | 0.59 | 39.00 | 42.00 | 45.00 | 0.90 | 0.70 | 0.40 | ND | ND | ND |
| **14** | 7.20 | 8.30 | 10.05 | 0.56 | 0.60 | 0.55 | 0.70 | 0.72 | 0.68 | 29.00 | 34.00 | 38.00 | 0.50 | 0.40 | 0.30 | ND | ND | ND |
| **15** | 8.40 | 9.70 | 10.50 | 0.40 | 0.50 | 0.50 | 0.60 | 0.65 | 0.60 | 32.00 | 36.00 | 40.00 | 0.60 | 0.40 | 0.20 | 0.02 | ND | ND |
| **16** | 6.70 | 9.40 | 9.70 | 0.70 | 0.75 | 0.78 | 0.81 | 0.95 | 1.10 | 40.00 | 42.00 | 46.00 | 1.10 | 0.90 | 0.60 | ND | ND | ND |
| **17** | 5.80 | 7.80 | 6.40 | 0.30 | 0.36 | 0.40 | 0.56 | 0.58 | 0.60 | 23.00 | 35.00 | 39.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **18** | 4.50 | 6.70 | 9.80 | 0.55 | 0.60 | 0.73 | 0.40 | 0.53 | 0.55 | 41.00 | 45.00 | 46.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **19** | 7.60 | 9.20 | 10.80 | 0.82 | 0.75 | 0.70 | 0.50 | 0.60 | 0.75 | 19.00 | 26.00 | 31.00 | 0.70 | 0.50 | 0.30 | 0.01 | ND | ND |
| **20** | 5.60 | 7.30 | 6.90 | 0.28 | 0.37 | 0.46 | 0.46 | 0.50 | 0.57 | 28.00 | 35.00 | 43.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **21** | 8.20 | 10.30 | 9.60 | 0.50 | 0.50 | 0.65 | 0.60 | 0.74 | 0.65 | 33.00 | 34.00 | 42.00 | 1.30 | 1.00 | 0.90 | 0.01 | ND | ND |
| **22** | 3.90 | 5.30 | 7.10 | 0.35 | 0.43 | 0.40 | 0.45 | 0.50 | 0.50 | 43.00 | 44.00 | 46.00 | 1.20 | 0.80 | 0.60 | ND | ND | ND |
| **23** | 5.70 | 7.80 | 6.50 | 0.46 | 0.50 | 0.57 | 0.37 | 0.40 | 0.50 | 36.00 | 40.00 | 48.00 | 0.80 | 0.50 | 0.40 | ND | ND | ND |
| **24** | 6.30 | 6.90 | 8.20 | 0.52 | 0.45 | 0.50 | 0.50 | 0.60 | 0.65 | 31.00 | 40.00 | 43.00 | 1.00 | 0.70 | 0.30 | ND | ND | ND |
| **TOTAL** | 191.70 | 218.50 | 222.86 | 13.82 | 13.89 | 14.15 | 13.77 | 15.01 | 15.20 | 959.00 | 1020.00 | 1055.00 | 23.50 | 17.60 | 13.30 | 0.07 | 0.00 | 0.00 |
| **MEAN** | 7.99 | 9.10 | 9.29 | 0.58 | 0.58 | 0.59 | 0.57 | 0.63 | 0.63 | 39.96 | 42.50 | 43.96 | 0.98 | 0.73 | 0.55 | 0.01 | 0.00 | 0.00 |
| **MIN** | 3.90 | 5.30 | 6.40 | 0.28 | 0.36 | 0.40 | 0.37 | 0.40 | 0.50 | 19.00 | 26.00 | 31.00 | 0.40 | 0.20 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 10.90 | 12.60 | 11.80 | 0.90 | 0.80 | 0.78 | 0.81 | 0.95 | 1.10 | 51.00 | 54.00 | 56.00 | 1.40 | 1.30 | 1.00 | 0.02 | 0.00 | 0.00 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SD** | 3.52 | 3.65 | 2.70 | 0.31 | 0.22 | 0.19 | 0.22 | 0.28 | 0.31 | 16.25 | 14.07 | 12.50 | 0.29 | 0.29 | 0.27 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season result where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT OGBOKO JUNCTION**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 4.70 | 8.50 | 7.10 | 0.40 | 0.45 | 0.45 | 0.36 | 0.36 | 0.61 | 47.00 | 56.00 | 51.00 | 1.20 | 1.10 | 0.90 | ND | ND | ND |
| **2** | 5.20 | 8.40 | 8.30 | 0.40 | 0.46 | 0.50 | 0.40 | 0.65 | 0.45 | 40.00 | 38.00 | 43.00 | 0.90 | 0.80 | 0.50 | 0.02 | ND | ND |
| **3** | 4.20 | 5.60 | 6.20 | 0.35 | 0.40 | 0.40 | 0.40 | 0.56 | 0.35 | 42.00 | 40.00 | 48.00 | 1.00 | 1.20 | 0.90 | ND | 0.003 | ND |
| **4** | 5.10 | 4.30 | 4.80 | 0.25 | 0.20 | 0.17 | 0.26 | 0.25 | 0.30 | 35.00 | 28.00 | 38.00 | 1.10 | 0.90 | 0.70 | ND | ND | ND |
| **5** | 5.20 | 9.30 | 8.60 | 0.30 | 0.40 | 0.35 | 0.30 | 0.50 | 0.45 | 40.00 | 45.00 | 42.00 | 0.80 | 0.60 | 0.40 | 0.001 | ND | ND |
| **6** | 6.10 | 8.60 | 8.10 | 0.45 | 0.50 | 0.40 | 0.38 | 0.45 | 0.40 | 33.00 | 46.00 | 40.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **7** | 6.10 | 8.60 | 8.10 | 0.45 | 0.50 | 0.40 | 0.38 | 0.45 | 0.40 | 33.00 | 46.00 | 40.00 | 1.10 | 0.70 | 0.60 | 0.01 | ND | ND |
| **8** | 8.30 | 9.60 | 9.10 | 0.20 | 0.25 | 0.20 | 0.30 | 0.25 | 0.30 | 40.00 | 45.00 | 48.00 | 0.90 | 0.60 | 0.50 | ND | ND | ND |
| **9** | 7.60 | 8.30 | 8.40 | 0.40 | 0.35 | 0.30 | 0.25 | 0.36 | 0.32 | 36.00 | 40.00 | 43.00 | 1.30 | 1.20 | 0.80 | ND | ND | ND |
| **10** | 5.60 | 6.20 | 4.50 | 0.38 | 0.30 | 0.46 | 0.60 | 0.56 | 0.50 | 28.00 | 30.00 | 34.00 | 0.70 | 0.60 | 0.40 | 0.001 | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **11** | 4.10 | 6.20 | 5.30 | 0.48 | 0.50 | 0.40 | 0.50 | 0.45 | 0.30 | 36.00 | 40.00 | 47.00 | 1.20 | 1.10 | 0.70 | ND | ND | ND |
| **12** | 4.80 | 5.10 | 4.30 | 0.37 | 0.25 | 0.20 | 0.30 | 0.25 | 0.26 | 38.00 | 36.00 | 28.00 | 0.80 | 0.60 | 0.30 | ND | ND | ND |
| **13** | 4.65 | 6.90 | 6.75 | 0.28 | 0.32 | 0.31 | 0.40 | 0.41 | 0.43 | 37.00 | 38.00 | 36.00 | 0.80 | 0.50 | 0.30 | ND | ND | ND |
| **14** | 4.50 | 8.70 | 9.20 | 0.26 | 0.30 | 0.42 | 0.50 | 0.57 | 0.60 | 37.00 | 40.00 | 43.00 | 0.70 | 0.40 | 0.20 | ND | ND | 0.001 |
| **15** | 5.00 | 7.40 | 8.30 | 0.30 | 0.35 | 0.40 | 0.45 | 0.50 | 0.55 | 40.00 | 45.00 | 47.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **16** | 3.10 | 5.70 | 6.30 | 0.35 | 0.45 | 0.50 | 0.70 | 0.75 | 0.80 | 26.00 | 35.00 | 41.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |
| **17** | 6.04 | 8.50 | 7.60 | 0.42 | 0.56 | 0.55 | 0.60 | 0.64 | 0.73 | 35.00 | 39.00 | 40.00 | 0.30 | 0.40 | 0.10 | ND | ND | ND |
| **18** | 5.10 | 9.20 | 9.40 | 0.37 | 0.40 | 0.38 | 0.40 | 0.50 | 0.56 | 24.00 | 37.00 | 35.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **19** | 2.80 | 4.80 | 6.50 | 0.40 | 0.45 | 0.50 | 0.37 | 0.48 | 0.52 | 32.00 | 46.00 | 43.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **20** | 4.30 | 5.70 | 5.60 | 0.50 | 0.55 | 0.60 | 0.29 | 0.37 | 0.41 | 30.00 | 37.00 | 40.00 | 0.70 | 0.60 | 0.30 | ND | ND | ND |
| **21** | 5.20 | 6.50 | 7.10 | 0.30 | 0.36 | 0.40 | 0.32 | 0.46 | 0.50 | 23.00 | 35.00 | 39.00 | 0.40 | 0.20 | 0.10 | ND | ND | ND |
| **22** | 3.90 | 5.60 | 4.70 | 0.46 | 0.35 | 0.45 | 0.53 | 0.62 | 0.65 | 35.00 | 42.00 | 44.00 | 1.10 | 0.50 | 0.60 | ND | ND | ND |
| **23** | 4.20 | 6.07 | 5.80 | 0.32 | 0.40 | 0.50 | 0.48 | 0.50 | 0.72 | 25.00 | 28.00 | 36.00 | 0.70 | 0.30 | 0.40 | 0.01 | ND | ND |
| **24** | 2.80 | 5.50 | 7.40 | 0.40 | 0.50 | 0.45 | 0.32 | 0.40 | 0.46 | 33.00 | 37.00 | 40.00 | 0.30 | 0.20 | 0.10 | ND | ND | ND |
| **TOTAL** | 118.59 | 169.27 | 167.45 | 8.79 | 9.55 | 9.69 | 9.79 | 11.29 | 11.57 | 825.00 | 949.00 | 986.00 | 19.80 | 15.10 | 10.70 | 0.04 | 0.00 | 0.00 |
| **MEAN** | 4.94 | 7.05 | 6.98 | 0.37 | 0.40 | 0.40 | 0.41 | 0.47 | 0.48 | 34.38 | 39.54 | 41.08 | 0.83 | 0.63 | 0.45 | 0.01 | 0.00 | 0.00 |
| **MIN** | 2.80 | 4.30 | 4.30 | 0.20 | 0.20 | 0.17 | 0.25 | 0.25 | 0.26 | 23.00 | 28.00 | 28.00 | 0.30 | 0.20 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 8.30 | 9.60 | 9.40 | 0.50 | 0.56 | 0.60 | 0.70 | 0.75 | 0.80 | 47.00 | 56.00 | 51.00 | 1.30 | 1.20 | 0.90 | 0.02 | 0.00 | 0.00 |
| **SD** | 2.77 | 2.65 | 2.55 | 0.15 | 0.18 | 0.22 | 0.23 | 0.25 | 0.27 | 12.00 | 14.07 | 11.54 | 0.29 | 0.31 | 0.25 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UMUAGO URUALLA**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 3.80 | 3.00 | 3.40 | 0.30 | 0.30 | 0.20 | 0.12 | 0.12 | 0.16 | 32.00 | 45.00 | 42.00 | 1.40 | 1.30 | 0.90 | ND | ND | ND |
| **2** | 3.20 | 3.30 | 3.35 | 0.25 | 0.28 | 0.23 | 0.14 | 0.18 | 0.23 | 34.00 | 36.00 | 32.00 | 1.10 | 0.80 | 0.70 | ND | ND | ND |
| **3** | 3.00 | 3.50 | 4.10 | 0.28 | 0.23 | 0.25 | 0.21 | 0.20 | 0.18 | 30.00 | 35.00 | 40.00 | 0.80 | 0.55 | 0.60 | 0.001 | ND | ND |
| **4** | 2.70 | 2.30 | 2.50 | 0.20 | 0.10 | 0.14 | 0.19 | 0.15 | 0.23 | 25.00 | 24.00 | 29.00 | 1.30 | 0.90 | 0.70 | ND | ND | ND |
| **5** | 4.50 | 5.30 | 5.60 | 0.20 | 0.30 | 0.30 | 0.17 | 0.20 | 0.15 | 30.00 | 38.00 | 33.00 | 1.20 | 0.80 | 0.50 | 0.004 | ND | ND |
| **6** | 5.10 | 6.30 | 5.80 | 0.25 | 0.30 | 0.26 | 0.30 | 0.20 | 0.20 | 30.00 | 40.00 | 38.00 | 0.97 | 0.70 | 0.60 | ND | ND | ND |
| **7** | 3.80 | 4.70 | 4.20 | 0.20 | 0.20 | 0.30 | 0.30 | 0.35 | 0.20 | 32.00 | 38.00 | 43.00 | 1.20 | 0.90 | 0.43 | 0.02 | ND | ND |
| **8** | 5.50 | 6.80 | 6.40 | 0.20 | 0.15 | 0.25 | 0.25 | 0.30 | 0.23 | 30.00 | 34.00 | 40.00 | 1.05 | 0.70 | 0.50 | ND | ND | ND |
| **9** | 4.80 | 4.50 | 3.60 | 0.30 | 0.28 | 0.20 | 0.16 | 0.24 | 0.19 | 30.00 | 43.00 | 35.00 | 0.80 | 0.60 | 0.42 | ND | ND | ND |
| **10** | 4.80 | 4.20 | 3.40 | 0.15 | 0.27 | 0.31 | 0.20 | 0.14 | 0.25 | 30.00 | 28.00 | 35.00 | 1.00 | 0.80 | 0.65 | 0.001 | ND | ND |
| **11** | 3.40 | 2.70 | 2.50 | 0.26 | 0.20 | 0.25 | 0.18 | 0.24 | 0.14 | 36.00 | 32.00 | 30.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **12** | 2.60 | 2.80 | 2.20 | 0.14 | 0.20 | 0.10 | 0.23 | 0.15 | 0.13 | 28.00 | 25.00 | 24.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **13** | 2.50 | 3.70 | 4.80 | 0.30 | 0.35 | 0.34 | 0.37 | 0.38 | 0.39 | 30.00 | 33.00 | 34.00 | 0.60 | 0.50 | 0.30 | ND | ND | ND |
| **14** | 2.40 | 4.60 | 5.30 | 0.45 | 0.50 | 0.57 | 0.50 | 0.60 | 0.65 | 33.00 | 40.00 | 42.00 | 0.80 | 0.40 | 0.20 | ND | ND | ND |
| **15** | 3.20 | 3.80 | 6.50 | 0.35 | 0.40 | 0.40 | 0.61 | 0.67 | 0.70 | 21.00 | 30.00 | 36.00 | 0.90 | 0.70 | 0.50 | 0.003 | ND | ND |
| **16** | 4.30 | 5.70 | 5.50 | 0.25 | 0.30 | 0.45 | 0.46 | 0.53 | 0.60 | 30.00 | 35.00 | 40.00 | 0.50 | 0.20 | 0.10 | ND | ND | ND |
| **17** | 3.10 | 3.60 | 4.80 | 0.50 | 0.55 | 0.53 | 0.87 | 0.96 | 1.00 | 33.00 | 36.00 | 40.00 | 0.70 | 0.60 | 0.40 | ND | ND | ND |
| **18** | 5.60 | 6.30 | 7.40 | 0.17 | 0.23 | 0.25 | 0.23 | 0.28 | 0.30 | 31.00 | 37.00 | 42.00 | 0.30 | 0.10 | 0.20 | ND | ND | ND |
| **19** | 4.80 | 5.60 | 7.10 | 0.25 | 0.30 | 0.36 | 0.40 | 0.47 | 0.52 | 18.00 | 23.00 | 28.00 | 0.40 | 0.50 | 0.30 | ND | ND | ND |
| **20** | 2.60 | 3.50 | 5.40 | 0.09 | 0.18 | 0.24 | 0.14 | 0.24 | 0.30 | 24.00 | 30.00 | 37.00 | 0.70 | 0.60 | 0.20 | ND | ND | ND |
| **21** | 3.50 | 5.09 | 6.10 | 0.30 | 0.38 | 0.36 | 0.20 | 0.28 | 0.35 | 30.00 | 38.00 | 44.00 | 0.60 | 0.40 | 0.10 | 0.001 | ND | ND |
| **22** | 3.10 | 5.30 | 5.80 | 0.24 | 0.28 | 0.30 | 0.19 | 0.25 | 0.24 | 25.00 | 32.00 | 39.00 | 0.40 | 0.30 | 0.10 | ND | ND | ND |
| **23** | 2.70 | 4.90 | 5.80 | 0.42 | 0.45 | 0.40 | 0.42 | 0.48 | 0.50 | 23.00 | 27.00 | 34.00 | 0.60 | 0.40 | 0.30 | ND | ND | ND |
| **24** | 2.80 | 3.60 | 5.20 | 0.35 | 0.40 | 0.47 | 0.25 | 0.31 | 0.43 | 30.00 | 34.00 | 41.00 | 0.50 | 0.30 | 0.20 | ND | ND | ND |
| **TOTAL** | 87.80 | 105.09 | 116.75 | 6.40 | 7.13 | 7.46 | 7.09 | 7.92 | 8.27 | 695.00 | 813.00 | 878.00 | 19.92 | 14.65 | 10.10 | 0.03 | 0.00 | 0.00 |
| **MEAN** | 3.66 | 4.38 | 4.86 | 0.27 | 0.30 | 0.31 | 0.30 | 0.33 | 0.34 | 28.96 | 33.88 | 36.58 | 0.83 | 0.61 | 0.42 | 0.00 | 0.00 | 0.00 |
| **MIN** | 2.40 | 2.30 | 2.20 | 0.09 | 0.10 | 0.10 | 0.12 | 0.12 | 0.13 | 18.00 | 23.00 | 24.00 | 0.30 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 |
| **MAX** | 5.60 | 6.80 | 7.40 | 0.50 | 0.55 | 0.57 | 0.87 | 0.96 | 1.00 | 36.00 | 45.00 | 44.00 | 1.40 | 1.30 | 0.90 | 0.02 | 0.00 | 0.00 |
| **SD** | 1.612 | 2.25 | 2.60 | 0.21 | 0.23 | 0.24 | 0.39 | 0.44 | 0.45 | 9.07 | 11.00 | 10.11 | 0.31 | 0.27 | 0.22 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**EGBEMA**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UMUORJI**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 6.50 | 8.30 | 7.50 | 0.50 | 0.70 | 0.55 | 0.20 | 0.40 | 0.75 | 47.00 | 42.00 | 45.00 | 1.50 | 1.40 | 1.20 | ND | ND | ND |
| **2** | 5.90 | 7.40 | 6.70 | 0.45 | 0.57 | 0.50 | 0.30 | 0.45 | 0.50 | 40.00 | 38.00 | 50.00 | 1.40 | 1.10 | 1.00 | 0.10 | 0.002 | ND |
| **3** | 5.30 | 6.20 | 5.80 | 0.50 | 0.60 | 0.52 | 0.25 | 0.40 | 0.70 | 45.00 | 40.00 | 51.00 | 1.90 | 1.60 | 1.30 | 0.002 | ND | ND |
| **4** | 7.10 | 7.52 | 6.70 | 0.40 | 0.45 | 0.38 | 0.50 | 0.30 | 0.45 | 40.00 | 47.00 | 54.00 | 1.50 | 1.30 | 1.10 | ND | ND | ND |
| **5** | 8.40 | 9.80 | 10.20 | 0.50 | 0.60 | 0.50 | 0.50 | 0.70 | 0.55 | 43.00 | 44.00 | 47.00 | 1.30 | 1.40 | 1.20 | ND | ND | ND |
| **6** | 8.90 | 10.10 | 9.70 | 0.48 | 0.60 | 0.55 | 0.78 | 1.03 | 0.90 | 48.00 | 50.00 | 53.00 | 1.70 | 1.50 | 1.10 | 0.10 | ND | ND |
| **7** | 7.40 | 9.50 | 8.60 | 0.35 | 0.40 | 0.68 | 0.60 | 0.70 | 0.65 | 43.00 | 50.00 | 47.00 | 1.30 | 1.20 | 1.00 | ND | ND | ND |
| **8** | 9.20 | 10.70 | 9.80 | 0.30 | 0.45 | 0.35 | 0.54 | 0.60 | 0.65 | 40.00 | 48.00 | 52.00 | 1.30 | 0.90 | 0.70 | 0.001 | ND | ND |
| **9** | 5.60 | 7.33 | 6.50 | 0.56 | 0.60 | 0.57 | 0.40 | 0.75 | 0.90 | 45.00 | 47.00 | 52.00 | 1.40 | 1.20 | 1.30 | ND | ND | ND |
| **10** | 7.30 | 9.21 | 7.96 | 0.60 | 0.80 | 0.50 | 0.82 | 0.23 | 1.12 | 51.00 | 43.00 | 49.00 | 1.60 | 1.40 | 1.30 | 0.01 | ND | ND |
| **11** | 6.30 | 6.42 | 5.84 | 0.60 | 0.52 | 0.45 | 0.65 | 0.50 | 0.47 | 42.00 | 45.00 | 48.00 | 2.10 | 1.70 | 1.20 | ND | ND | ND |
| **12** | 5.70 | 7.31 | 6.30 | 0.50 | 0.38 | 0.40 | 0.40 | 0.50 | 0.35 | 38.00 | 44.00 | 51.00 | 1.40 | 1.10 | 1.00 | ND | ND | ND |
| **13** | 5.45 | 7.06 | 6.90 | 0.57 | 0.54 | 0.53 | 0.38 | 0.46 | 0.45 | 29.00 | 36.00 | 43.00 | 0.90 | 0.60 | 0.50 | ND | ND | ND |
| **14** | 5.20 | 6.80 | 7.60 | 0.63 | 0.70 | 0.65 | 0.36 | 0.42 | 0.54 | 21.00 | 28.00 | 34.00 | 0.70 | 0.50 | 0.40 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | 6.30 | 7.50 | 8.30 | 0.53 | 0.58 | 0.60 | 0.45 | 0.53 | 0.58 | 33.00 | 37.00 | 41.00 | 1.20 | 0.70 | 0.60 | ND | ND | ND |
| **16** | 4.50 | 6.50 | 6.20 | 0.45 | 0.52 | 0.50 | 0.64 | 0.78 | 0.74 | 42.00 | 44.00 | 46.00 | 1.40 | 1.30 | 0.90 | ND | ND | ND |
| **17** | 7.20 | 9.40 | 8.60 | 0.37 | 0.40 | 0.45 | 0.50 | 0.58 | 0.53 | 25.00 | 36.00 | 45.00 | 1.10 | 0.80 | 0.50 | ND | ND | ND |
| **18** | 5.30 | 9.80 | 8.70 | 0.73 | 0.78 | 0.84 | 0.86 | 0.97 | 1.00 | 34.00 | 39.00 | 40.00 | 0.90 | 0.70 | 0.40 | ND | ND | ND |
| **19** | 7.50 | 9.30 | 9.10 | 0.63 | 0.65 | 0.75 | 0.77 | 1.03 | 0.96 | 15.00 | 27.00 | 35.00 | 0.80 | 0.50 | 0.60 | 0.02 | ND | ND |
| **20** | 4.50 | 8.30 | 7.80 | 0.30 | 0.45 | 0.42 | 0.56 | 0.62 | 0.67 | 20.00 | 25.00 | 38.00 | 1.20 | 0.70 | 0.50 | ND | ND | ND |
| **21** | 3.90 | 7.20 | 8.50 | 0.41 | 0.40 | 0.38 | 0.32 | 0.55 | 0.60 | 26.00 | 39.00 | 36.00 | 1.30 | 1.20 | 0.90 | 0.001 | ND | ND |
| **22** | 5.60 | 6.09 | 7.20 | 0.36 | 0.57 | 0.60 | 0.42 | 0.53 | 0.51 | 33.00 | 41.00 | 44.00 | 1.00 | 0.80 | 0.60 | ND | ND | ND |
| **23** | 4.70 | 6.20 | 7.96 | 0.45 | 0.50 | 0.58 | 0.27 | 0.31 | 0.48 | 35.00 | 38.00 | 40.00 | 1.30 | 0.90 | 0.70 | ND | ND | ND |
| **24** | 5.10 | 6.50 | 6.30 | 0.31 | 0.46 | 0.53 | 0.45 | 0.51 | 0.63 | 22.00 | 31.00 | 39.00 | 1.20 | 1.00 | 0.80 | ND | ND | ND |
| **TOTAL** | 148.85 | 190.44 | 184.76 | 11.48 | 13.22 | 12.78 | 11.92 | 13.85 | 15.68 | 857.00 | 959.00 | 1080.00 | 31.40 | 25.50 | 20.80 | 0.23 | 0.00 | 0.00 |
| **MEAN** | 6.20 | 7.94 | 7.70 | 0.48 | 0.55 | 0.53 | 0.50 | 0.58 | 0.65 | 35.71 | 39.96 | 45.00 | 1.31 | 1.06 | 0.87 | 0.03 | 0.00 | 0.00 |
| **MIN** | 3.90 | 6.09 | 5.80 | 0.30 | 0.38 | 0.35 | 0.20 | 0.23 | 0.35 | 15.00 | 25.00 | 34.00 | 0.70 | 0.50 | 0.40 | 0.00 | 0.00 | 0.00 |
| **MAX** | 9.20 | 10.70 | 10.20 | 0.73 | 0.80 | 0.84 | 0.86 | 1.03 | 1.12 | 51.00 | 50.00 | 54.00 | 2.10 | 1.70 | 1.30 | 0.10 | 0.00 | 0.00 |
| **SD** | 2.66 | 2.32 | 2.21 | 0.22 | 0.21 | 0.25 | 0.33 | 0.40 | 0.39 | 18.07 | 12.58 | 10.02 | 0.33 | 0.35 | 0.31 | 0.05 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UKWUGBA 1**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 7.10 | 7.60 | 8.20 | 0.55 | 0.60 | 0.50 | 0.40 | 0.60 | 0.55 | 50.00 | 45.00 | 51.00 | 1.30 | 1.00 | 0.90 | ND | ND | ND |
| **2** | 6.50 | 8.30 | 7.60 | 0.50 | 0.70 | 0.60 | 0.45 | 0.50 | 0.47 | 48.00 | 43.00 | 50.00 | 1.60 | 1.40 | 1.10 | 0.02 | ND | 0.001 |
| **3** | 7.20 | 7.60 | 6.70 | 0.40 | 0.54 | 0.50 | 0.50 | 0.48 | 1.20 | 50.00 | 48.00 | 53.00 | 0.90 | 0.80 | 1.20 | 0.001 | ND | ND |
| **4** | 7.65 | 8.50 | 8.20 | 0.45 | 0.60 | 0.55 | 0.45 | 0.50 | 0.70 | 50.00 | 45.00 | 52.00 | 1.40 | 1.20 | 1.00 | ND | ND | ND |
| **5** | 9.10 | 10.30 | 10.70 | 0.55 | 0.60 | 0.50 | 0.60 | 0.80 | 0.70 | 48.00 | 50.00 | 55.00 | 1.10 | 0.80 | 0.90 | 0.01 | ND | ND |
| **6** | 9.50 | 11.30 | 10.60 | 0.60 | 0.80 | 0.74 | 0.60 | 0.86 | 0.70 | 50.00 | 52.00 | 54.00 | 1.70 | 1.30 | 1.20 | ND | ND | 0.01 |
| **7** | 8.10 | 10.40 | 9.30 | 0.50 | 0.70 | 0.60 | 0.70 | 0.95 | 0.90 | 46.00 | 50.00 | 50.00 | 1.40 | 1.20 | 1.10 | 0.03 | ND | ND |
| **8** | 10.30 | 11.10 | 11.20 | 0.40 | 0.55 | 0.50 | 0.70 | 1.30 | 0.97 | 50.00 | 51.00 | 50.00 | 2.20 | 1.70 | 1.20 | ND | ND | ND |
| **9** | 7.52 | 7.20 | 6.20 | 0.45 | 0.67 | 0.45 | 0.60 | 0.50 | 0.40 | 51.00 | 48.00 | 50.00 | 1.20 | 0.80 | 0.70 | 0.01 | ND | ND |
| **10** | 7.41 | 7.61 | 8.16 | 0.55 | 0.50 | 0.50 | 0.70 | 0.20 | 1.38 | 55.00 | 48.00 | 51.00 | 1.40 | 1.00 | 0.80 | ND | ND | ND |
| **11** | 7.52 | 6.70 | 7.22 | 0.75 | 0.50 | 0.44 | 0.58 | 0.50 | 0.46 | 53.00 | 50.00 | 47.00 | 1.30 | 1.20 | 0.90 | 0.001 | ND | ND |
| **12** | 6.27 | 7.60 | 5.40 | 0.75 | 0.50 | 0.60 | 0.75 | 0.40 | 0.50 | 52.00 | 48.00 | 50.00 | 1.50 | 1.30 | 1.00 | ND | ND | ND |
| **13** | 5.30 | 6.90 | 5.60 | 0.59 | 0.69 | 0.65 | 0.45 | 0.60 | 0.53 | 36.00 | 38.00 | 42.00 | 1.10 | 0.70 | 0.50 | ND | ND | ND |
| **14** | 4.30 | 6.20 | 5.80 | 0.63 | 0.68 | 0.70 | 0.45 | 0.50 | 0.55 | 20.00 | 28.00 | 33.00 | 0.80 | 0.70 | 0.40 | 0.002 | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15** | 5.40 | 7.20 | 6.50 | 0.55 | 0.64 | 0.60 | 0.50 | 0.60 | 0.65 | 19.00 | 36.00 | 40.00 | 0.70 | 0.50 | 0.30 | ND | 0.01 | ND |
| **16** | 6.20 | 8.10 | 8.60 | 0.82 | 0.92 | 1.00 | 0.67 | 0.70 | 1.00 | 27.00 | 34.00 | 42.00 | 1.40 | 1.20 | 1.30 | ND | ND | ND |
| **17** | 3.70 | 4.80 | 5.30 | 0.47 | 0.56 | 0.60 | 0.46 | 0.50 | 0.67 | 15.00 | 28.00 | 38.00 | 0.70 | 0.50 | 0.30 | 0.01 | ND | ND |
| **18** | 6.50 | 9.60 | 8.40 | 0.55 | 0.60 | 0.57 | 0.53 | 0.60 | 0.68 | 33.00 | 40.00 | 43.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **19** | 2.60 | 4.10 | 5.30 | 0.63 | 0.70 | 0.76 | 0.76 | 0.86 | 0.94 | 22.00 | 27.00 | 36.00 | 1.10 | 0.80 | 0.50 | 0.001 | ND | ND |
| **20** | 5.20 | 6.30 | 7.60 | 0.50 | 0.66 | 0.70 | 0.60 | 0.74 | 0.82 | 31.00 | 42.00 | 45.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **21** | 3.50 | 5.50 | 6.30 | 0.45 | 0.55 | 0.63 | 0.40 | 0.55 | 0.63 | 25.00 | 29.00 | 36.00 | 1.30 | 1.20 | 0.10 | ND | ND | ND |
| **22** | 4.06 | 4.90 | 5.60 | 0.47 | 0.56 | 0.60 | 0.60 | 0.67 | 0.74 | 34.00 | 43.00 | 46.00 | 0.90 | 0.70 | 0.50 | ND | ND | ND |
| **23** | 3.70 | 5.30 | 6.10 | 0.51 | 0.55 | 0.65 | 0.46 | 0.50 | 0.59 | 28.00 | 33.00 | 41.00 | 1.20 | 0.90 | 0.60 | 0.001 | ND | ND |
| **24** | 4.60 | 6.70 | 5.80 | 0.40 | 0.53 | 0.46 | 0.40 | 0.55 | 0.43 | 23.00 | 39.00 | 44.00 | 1.30 | 0.10 | 0.90 | ND | ND | ND |
| **TOTAL** | 149.23 | 179.81 | 176.38 | 13.02 | 14.90 | 14.40 | 13.31 | 14.96 | 17.16 | 916.00 | 995.00 | 1099.00 | 29.50 | 22.50 | 18.50 | 0.09 | 0.01 | 0.01 |
| **MEAN** | 6.22 | 7.49 | 7.35 | 0.54 | 0.62 | 0.60 | 0.55 | 0.62 | 0.72 | 38.17 | 41.46 | 45.79 | 1.23 | 0.94 | 0.77 | 0.01 | 0.01 | 0.00 |
| **MIN** | 2.60 | 4.10 | 5.30 | 0.40 | 0.50 | 0.44 | 0.40 | 0.20 | 0.40 | 15.00 | 27.00 | 33.00 | 0.70 | 0.10 | 0.10 | 0.00 | 0.01 | 0.00 |
| **MAX** | 10.30 | 11.30 | 11.20 | 0.82 | 0.92 | 1.00 | 0.76 | 1.30 | 1.38 | 55.00 | 52.00 | 55.00 | 2.20 | 1.70 | 1.30 | 0.03 | 0.01 | 0.01 |
| **SD** | 3.85 | 3.60 | 2.99 | 0.21 | 0.22 | 0.29 | 0.18 | 0.55 | 0.50 | 20.08 | 12.55 | 11.05 | 0.34 | 0.35 | 0.34 | 0.01 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT UKWUGBA 2**

| | | $PM_{10}$ ($mg/m^3$) | | | $NO_2$ (ppm) | | | $SO_2$ (ppm) | | | CO (ppm) | | | VOC ($mg/m^3$) | | | $H_2S$ (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 5.10 | 8.50 | 7.40 | 0.60 | 0.56 | 0.40 | 0.23 | 0.48 | 0.55 | 51.00 | 46.00 | 50.00 | 1.20 | 0.90 | 1.00 | ND | ND | ND |
| **2** | 6.10 | 7.80 | 7.10 | 0.55 | 0.50 | 0.70 | 0.35 | 0.45 | 0.50 | 50.00 | 40.00 | 52.00 | 1.10 | 1.20 | 0.80 | 0.001 | ND | ND |
| **3** | 5.10 | 5.90 | 6.40 | 0.30 | 0.40 | 0.35 | 0.40 | 0.60 | 0.55 | 48.00 | 46.00 | 50.00 | 1.50 | 1.20 | 1.00 | ND | ND | ND |
| **4** | 6.80 | 7.30 | 7.24 | 0.38 | 0.40 | 0.35 | 0.50 | 1.10 | 0.80 | 47.00 | 45.00 | 51.00 | 1.20 | 1.30 | 0.90 | ND | ND | ND |
| **5** | 7.50 | 9.40 | 8.60 | 0.70 | 0.75 | 0.60 | 0.40 | 0.60 | 0.50 | 50.00 | 48.00 | 51.00 | 1.00 | 1.20 | 8.00 | 0.01 | ND | ND |
| **6** | 8.20 | 10.70 | 10.40 | 0.50 | 0.70 | 0.60 | 0.50 | 0.80 | 0.65 | 49.00 | 50.00 | 50.00 | 1.30 | 0.70 | 1.00 | ND | ND | ND |
| **7** | 7.70 | 9.20 | 9.07 | 0.55 | 0.50 | 0.70 | 0.80 | 1.25 | 1.10 | 45.00 | 48.00 | 46.00 | 1.20 | 1.40 | 1.10 | 0.003 | ND | ND |
| **8** | 9.70 | 10.40 | 10.00 | 0.35 | 0.40 | 0.30 | 0.65 | 0.90 | 0.85 | 48.00 | 53.00 | 52.00 | 1.20 | 0.80 | 0.70 | ND | ND | ND |
| **9** | 6.10 | 8.30 | 7.63 | 0.56 | 0.50 | 0.40 | 0.48 | 0.55 | 0.23 | 53.00 | 51.00 | 49.00 | 1.00 | 0.90 | 0.80 | ND | ND | ND |
| **10** | 5.39 | 11.39 | 7.70 | 0.70 | 0.60 | 0.45 | 0.45 | 0.21 | 0.89 | 52.00 | 45.00 | 51.00 | 1.40 | 1.20 | 1.10 | 0.001 | ND | ND |
| **11** | 5.90 | 6.40 | 5.10 | 0.40 | 0.35 | 0.30 | 0.60 | 0.34 | 0.50 | 43.00 | 48.00 | 50.00 | 0.90 | 1.20 | 0.70 | ND | ND | ND |
| **12** | 7.64 | 6.20 | 6.81 | 0.80 | 0.30 | 0.55 | 0.67 | 0.50 | 0.70 | 46.00 | 53.00 | 45.00 | 1.20 | 0.80 | 0.75 | ND | ND | ND |
| **13** | 5.90 | 6.20 | 6.56 | 0.52 | 0.68 | 0.70 | 0.60 | 0.67 | 0.65 | 32.00 | 40.00 | 42.00 | 1.40 | 1.20 | 0.90 | ND | ND | ND |
| **14** | 4.80 | 5.70 | 6.30 | 0.56 | 0.73 | 0.80 | 0.66 | 0.70 | 0.60 | 17.00 | 26.00 | 38.00 | 0.70 | 0.80 | 0.50 | ND | ND | ND |
| **15** | 5.30 | 6.50 | 7.30 | 0.50 | 0.55 | 0.61 | 0.47 | 0.58 | 0.50 | 31.00 | 37.00 | 42.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **16** | 6.40 | 5.80 | 6.70 | 0.47 | 0.56 | 0.60 | 0.40 | 0.62 | 0.60 | 22.00 | 35.00 | 36.00 | 0.80 | 0.60 | 0.40 | ND | ND | ND |
| **17** | 4.50 | 7.30 | 8.30 | 0.93 | 1.06 | 0.98 | 0.45 | 0.56 | 0.82 | 33.00 | 40.00 | 43.00 | 0.70 | 0.50 | 0.30 | 0.002 | ND | ND |
| **18** | 3.80 | 5.10 | 6.40 | 0.72 | 0.75 | 0.70 | 0.70 | 0.72 | 0.67 | 24.00 | 34.00 | 38.00 | 1.10 | 0.70 | 0.50 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **19** | 5.60 | 8.50 | 9.20 | 0.40 | 0.46 | 0.53 | 0.43 | 0.65 | 0.73 | 19.00 | 25.00 | 37.00 | 0.90 | 0.80 | 0.30 | ND | ND | ND |
| **20** | 6.30 | 9.80 | 10.20 | 0.55 | 0.60 | 0.68 | 0.85 | 1.00 | 0.94 | 35.00 | 37.00 | 40.00 | 1.30 | 0.80 | 0.60 | ND | ND | ND |
| **21** | 4.70 | 8.40 | 9.70 | 0.39 | 0.47 | 0.53 | 0.60 | 0.72 | 0.66 | 27.00 | 31.00 | 39.00 | 1.10 | 0.70 | 0.50 | ND | ND | ND |
| **22** | 5.70 | 7.60 | 8.30 | 0.45 | 0.52 | 0.64 | 0.45 | 0.50 | 0.53 | 15.00 | 34.00 | 49.00 | 0.95 | 0.80 | 0.60 | 0.001 | ND | ND |
| **23** | 3.50 | 6.20 | 5.40 | 0.53 | 0.68 | 0.60 | 0.36 | 0.50 | | 28.00 | 35.00 | 41.00 | 1.30 | 1.10 | 0.90 | ND | ND | ND |
| **24** | 4.60 | 6.20 | 6.07 | 0.46 | 0.50 | 0.65 | 0.48 | 0.63 | 0.55 | 26.00 | 32.00 | 38.00 | 1.20 | 0.90 | 0.70 | ND | ND | ND |
| **TOTAL** | 142.33 | 184.79 | 183.88 | 12.87 | 13.52 | 13.72 | 12.48 | 15.63 | 15.07 | 891.00 | 979.00 | 1080.00 | 26.85 | 22.60 | 24.75 | 0.02 | 0.00 | 0.00 |
| **MEAN** | 5.93 | 7.70 | 7.66 | 0.54 | 0.56 | 0.57 | 0.52 | 0.65 | 0.66 | 37.13 | 40.79 | 45.00 | 1.12 | 0.94 | 1.03 | 0.00 | 0.00 | 0.00 |
| **MIN** | 3.50 | 5.10 | 5.10 | 0.30 | 0.30 | 0.30 | 0.23 | 0.21 | 0.23 | 15.00 | 25.00 | 36.00 | 0.70 | 0.50 | 0.30 | 0.00 | 0.00 | 0.00 |
| **MAX** | 9.70 | 11.39 | 10.40 | 0.93 | 1.06 | 0.98 | 0.85 | 1.25 | 1.10 | 53.00 | 53.00 | 52.00 | 1.50 | 1.40 | 8.00 | 0.01 | 0.00 | 0.00 |
| **SD** | 3.12 | 3.16 | 2.65 | 0.32 | 0.39 | 0.34 | 0.31 | 0.52 | 0.43 | 19.08 | 14.04 | 8.02 | 0.21 | 0.24 | 1.50 | 0.00 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

**CONCENTRATIONS OF AIR POLLUTANTS MEASURED DURING DRY AND WET SEASON AT OPUOMA**

| | | **$PM_{10}$ ($mg/m^3$)** | | | **$NO_2$ (ppm)** | | | **$SO_2$ (ppm)** | | | **CO (ppm)** | | | **VOC ($mg/m^3$)** | | | **$H_2S$ (ppm)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WEEK** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** | **M** | **A** | **E** |
| **1** | 8.20 | 6.80 | 8.50 | 0.50 | 0.45 | 0.48 | 0.19 | 0.27 | 0.28 | 48.00 | 40.00 | 50.00 | 1.20 | 1.10 | 0.90 | 0.01 | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2** | 7.50 | 7.20 | 6.80 | 0.40 | 0.47 | 0.45 | 0.20 | 0.25 | 0.22 | 40.00 | 35.00 | 48.00 | 1.40 | 1.30 | 1.20 | 0.01 | 0.002 | ND |
| **3** | 6.40 | 5.80 | 7.30 | 0.35 | 0.40 | 0.50 | 0.30 | 0.45 | 0.47 | 45.00 | 40.00 | 46.00 | 1.30 | 0.90 | 0.80 | ND | ND | ND |
| **4** | 8.20 | 9.50 | 8.60 | 0.25 | 0.30 | 0.40 | 0.25 | 0.40 | 0.50 | 40.00 | 38.00 | 45.00 | 0.90 | 0.80 | 0.90 | ND | ND | ND |
| **5** | 8.90 | 9.60 | 9.30 | 0.45 | 0.60 | 0.55 | 0.30 | 0.35 | 0.40 | 45.00 | 50.00 | 46.00 | 1.10 | 0.90 | 0.95 | ND | ND | ND |
| **6** | 9.10 | 10.20 | 8.60 | 0.45 | 0.47 | 0.40 | 0.45 | 0.50 | 0.60 | 42.00 | 48.00 | 45.00 | 1.40 | 1.20 | 1.10 | 0.01 | 0.001 | ND |
| **7** | 6.80 | 8.50 | 8.40 | 0.40 | 0.40 | 0.55 | 0.20 | 0.40 | 0.30 | 48.00 | 50.00 | 50.00 | 0.90 | 1.20 | 1.00 | 0.01 | ND | ND |
| **8** | 10.50 | 10.30 | 9.60 | 0.20 | 0.35 | 0.25 | 0.30 | 0.50 | 0.45 | 43.00 | 47.00 | 46.00 | 1.40 | 1.10 | 1.00 | 0.10 | 0.01 | ND |
| **9** | 8.40 | 6.70 | 5.81 | 0.50 | 0.40 | 0.45 | 0.27 | 0.28 | 0.19 | 51.00 | 45.00 | 48.00 | 1.20 | 0.90 | 0.80 | ND | ND | ND |
| **10** | 9.62 | 7.64 | 8.60 | 0.60 | 0.50 | 0.55 | 0.30 | 0.31 | 0.29 | 50.00 | 47.00 | 50.00 | 0.90 | 0.70 | 1.00 | 0.001 | ND | ND |
| **11** | 8.23 | 7.36 | 6.40 | 0.45 | 0.50 | 0.35 | 0.40 | 0.45 | 0.30 | 48.00 | 40.00 | 46.00 | 1.00 | 0.90 | 0.80 | ND | ND | ND |
| **12** | 5.40 | 7.20 | 5.79 | 0.56 | 0.70 | 0.50 | 0.50 | 0.45 | 0.40 | 45.00 | 50.00 | 48.00 | 1.30 | 1.10 | 0.90 | ND | ND | ND |
| **13** | 4.60 | 6.80 | 7.60 | 0.60 | 0.69 | 0.60 | 0.41 | 0.46 | 0.45 | 43.00 | 48.00 | 45.00 | 1.20 | 0.90 | 1.00 | ND | ND | ND |
| **14** | 3.80 | 7.20 | 9.40 | 0.63 | 0.68 | 0.70 | 0.32 | 0.47 | 0.50 | 40.00 | 46.00 | 42.00 | 0.90 | 1.10 | 0.80 | ND | ND | ND |
| **15** | 5.80 | 7.30 | 6.40 | 0.45 | 0.50 | 0.56 | 0.20 | 0.30 | 0.40 | 18.00 | 32.00 | 40.00 | 1.40 | 1.10 | 1.20 | ND | ND | ND |
| **16** | 4.60 | 6.50 | 7.80 | 0.40 | 0.60 | 0.65 | 0.50 | 0.64 | 0.55 | 20.00 | 37.00 | 39.00 | 1.30 | 1.10 | 0.90 | 0.02 | ND | ND |
| **17** | 5.20 | 8.40 | 9.10 | 0.53 | 0.67 | 0.72 | 0.43 | 0.45 | 0.30 | 15.00 | 35.00 | 41.00 | 0.80 | 0.60 | 0.50 | ND | ND | ND |
| **18** | 5.06 | 10.40 | 8.96 | 0.35 | 0.46 | 0.55 | 0.30 | 0.40 | 0.36 | 23.00 | 33.00 | 36.00 | 0.90 | 0.40 | 0.30 | ND | ND | ND |
| **19** | 2.70 | 4.90 | 7.03 | 0.45 | 0.50 | 0.74 | 0.47 | 0.58 | 0.60 | 19.00 | 26.00 | 38.00 | 1.10 | 0.90 | 0.70 | 0.001 | ND | ND |
| **20** | 5.82 | 8.40 | 6.70 | 0.60 | 0.50 | 0.55 | 0.20 | 0.36 | 0.31 | 30.00 | 40.00 | 42.00 | 1.00 | 0.70 | 0.60 | ND | ND | ND |
| **21** | 3.50 | 6.20 | 7.60 | 0.50 | 0.57 | 0.60 | 0.33 | 0.50 | 0.26 | 26.00 | 32.00 | 37.00 | 1.10 | 0.80 | 0.50 | 0.001 | ND | ND |
| **22** | 4.50 | 7.30 | 6.40 | 0.48 | 0.50 | 0.58 | 0.35 | 0.40 | 0.46 | 22.00 | 40.00 | 38.00 | 1.20 | 0.70 | 0.60 | ND | ND | ND |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **23** | 5.10 | 7.02 | 7.80 | 0.30 | 0.38 | 0.46 | 0.40 | 0.46 | 0.50 | 34.00 | 37.00 | 40.00 | 0.90 | 0.60 | 0.30 | ND | ND | ND |
| **24** | 3.70 | 5.80 | 6.20 | 0.43 | 0.52 | 0.54 | 0.25 | 0.35 | 0.20 | 21.00 | 34.00 | 36.00 | 0.80 | 0.50 | 0.40 | ND | ND | ND |
| **TOTAL** | 151.63 | 183.02 | 184.69 | 10.83 | 12.11 | 12.68 | 7.82 | 9.98 | 9.29 | 856.00 | 970.00 | 1042.00 | 26.60 | 21.50 | 19.15 | 0.16 | 0.01 | 0.00 |
| **MEAN** | 6.32 | 7.63 | 7.70 | 0.45 | 0.50 | 0.53 | 0.33 | 0.42 | 0.39 | 35.67 | 40.42 | 43.42 | 1.11 | 0.90 | 0.80 | 0.02 | 0.00 | 0.00 |
| **MIN** | 2.70 | 4.90 | 5.79 | 0.20 | 0.30 | 0.25 | 0.19 | 0.25 | 0.19 | 15.00 | 26.00 | 36.00 | 0.80 | 0.40 | 0.30 | 0.00 | 0.00 | 0.00 |
| **MAX** | 10.50 | 10.40 | 9.60 | 0.63 | 0.70 | 0.74 | 0.50 | 0.64 | 0.60 | 51.00 | 50.00 | 50.00 | 1.40 | 1.30 | 1.20 | 0.10 | 0.01 | 0.00 |
| **SD** | 3.90 | 2.75 | 1.90 | 0.22 | 0.20 | 0.25 | 0.15 | 0.19 | 0.21 | 18.07 | 12.08 | 7.00 | 0.20 | 0.24 | 0.26 | 0.03 | 0.00 | 0.00 |

**Note ; Week 1-12 : dry season results, week 13 – 24 wet season results, where M = morning, A = afternoon, E = evening, MIN = minimum value, MAX = maximuu value, SD =standard deviation**

## APPENDIX 11

**VALUES OF METEOROLOGICAL PARAMETERS MEASURED IN OWERRI STUDY AREA**

**METEOROLOGICAL PARAMETERS MEASURED AT IMSU JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed | Ambient Temp. | R.H(%) | Air flow m^3/min | Wind Direction | Wave Height | Wind Speed | Ambient Temp | R.H (%) | Air flow $m^3$/mi | Wind Direction | Wave Height | Wind Speed | Ambient Temp. | R.H(%) | Air flow m^3/min | Wind Direction | Wave Height (m) |

| | (m/s) | (°C) | | | (°) | (m) | (m/s) | (°C) | | n | (°) | (m) | (m/s) | (°C) | | | (°) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.20 | 30.50 | 73.00 | 24.20 | 337.50 NW | 0.10 | 1.30 | 35.00 | 69.00 | 136.20 | 340.50 SE | 0.10 | 0.70 | 31.20 | 74.00 | 47.60 | 135.00 SES | 0.10 |
| 2 | 1.70 | 27.50 | 86.00 | 47.50 | 227.00NWN | 0.20 | 1.40 | 35.20 | 76.00 | 145.00 | 230.00 NE | 0.20 | 1.20 | 32.00 | 78.00 | 45.80 | 138.00 SW | 0.10 |
| 3 | 1.50 | 28.50 | 80.00 | 63.00 | 207.10 NWN | 0.20 | 2.10 | 34.10 | 78.00 | 70.50 | 260.00 SEE | 0.20 | 0.60 | 30.50 | 79.00 | 51.20 | 146.20 SE | 0.10 |
| 4 | 3.10 | 29.50 | 87.00 | 145.00 | 38.60 SW | 0.30 | 2.30 | 34.30 | 68.00 | 108.30 | 92.50 NW | 0.20 | 1.40 | 35.30 | 69.00 | 53.60 | 326.20 NE | 0.10 |
| 5 | 2.30 | 31.80 | 70.00 | 136.40 | 245.50 NE | 0.20 | 1.50 | 36.20 | 69.00 | 118.60 | 320.00 NW | 0.20 | 0.90 | 34.60 | 69.00 | 48.60 | 126.00 SE | 0.10 |
| 6 | 1.30 | 28.20 | 74.00 | 106.50 | 37.00 SE | 0.20 | 0.50 | 37.80 | 69.00 | 42.30 | 72.00 NEE | 0.10 | 2.30 | 40.20 | 65.00 | 168.40 | 328.00 NW | 0.20 |
| 7 | 2.70 | 29.60 | 76.00 | 162.70 | 273.00 SE | 0.20 | 1.80 | 35.20 | 78.00 | 118.50 | 230.00 NE | 0.20 | 0.70 | 34.70 | 79.00 | 78.00 | 37.00 NW | 0.10 |
| 8 | 3.20 | 26.50 | 92.00 | 134.40 | 235.80 NE | 0.30 | 2.60 | 29.50 | 77.00 | 128.70 | 326.00 NW | 0.20 | 2.10 | 27.60 | 85.00 | 120.40 | 62.00 NEE | 0.20 |
| 9 | 2.80 | 26.60 | 73.00 | 127.20 | 103.00 NE | 0.20 | 3.40 | 28.40 | 78.00 | 168.70 | 214.20 NW | 0.30 | 1.90 | 32.20 | 74.00 | 68.10 | 103.60 NEE | 0.20 |
| 10 | 2.60 | 25.30 | 77.00 | 141.90 | 63.50 NW | 0.20 | 2.20 | 31.20 | 72.00 | 75.60 | 136.00 NEE | 0.20 | 1.60 | 32.30 | 79.00 | 139.50 | 65.30 NW | 0.10 |
| 11 | 3.30 | 27.30 | 85.00 | 186.00 | 246.00 NW | 0.30 | 2.20 | 32.40 | 73.00 | 136.20 | 217.00 SW | 0.20 | 2.60 | 30.40 | 81.00 | 174.60 | 115.00 NWN | 0.20 |
| 12 | 1.70 | 28.70 | 80.00 | 115.00 | 86.60 NW | 0.10 | 1.20 | 36.30 | 67.00 | 138.20 | 292.50 SW | 0.10 | 0.60 | 34.80 | 69.00 | 63.60 | 226.20 NEE | 0.10 |
| 13 | 1.60 | 31.40 | 71.00 | 96.00 | 45. 00 NE | 0.20 | 2.80 | 39.40 | 64.00 | 169.00 | 45.00 NE | 0.20 | 1.30 | 30.90 | 86.00 | 80.10 | 247.50SWW | 0.10 |
| 14 | 2.40 | 28.00 | 84.00 | 146.50 | 73.00 NW | 0.20 | 0.70 | 36.50 | 72.00 | 67.50 | 56.50 NEE | 0.10 | 1.10 | 28.70 | 82.00 | 76.30 | 46.00 NW | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 0.80 | 27.10 | 86.00 | 56.40 | 145.50NEE | 0.10 | 1.30 | 34.60 | 79.00 | 106.80 | 103.00 SW | 0.10 | 2.30 | 30.30 | 80.00 | 152.50 | 240.00 NW | 0.20 |
| 16 | 1.50 | 29.40 | 93.00 | 87.00 | 203.00 SW | 0.10 | 2.10 | 31.80 | 88.00 | 142.30 | 93.50 NWN | 0.20 | 0.90 | 27.80 | 93.00 | 56.30 | 310.50 NE | 0.10 |
| 17 | 3.10 | 27.90 | 81.00 | 200.50 | 57.50 NE | 0.30 | 0.60 | 33.50 | 77.00 | 58.00 | 247.00 SW | 0.10 | 1.20 | 31.20 | 93.00 | 107.30 | 58.00 SW | 0.20 |
| 18 | 1.80 | 28.30 | 86.00 | 124.00 | 78.00 SEE | 0.20 | 1.60 | 35.70 | 81.00 | 123.60 | 68.00 NE | 0.20 | 2.70 | 32.70 | 94.00 | 182.70 | 72.60 SWW | 0.30 |
| 19 | 2.06 | 30.10 | 79.00 | 131.40 | 101.50NWN | 0.20 | 2.20 | 34.90 | 80.00 | 109.00 | 204.50 NW | 0.20 | 1.40 | 31.30 | 86.00 | 110.20 | 107.00 NW | 0.10 |
| 20 | 1.20 | 27.70 | 90.00 | 65.00 | 47.40NE | 0.10 | 0.80 | 31.40 | 93.00 | 73.50 | 67.00 SW | 0.10 | 1.50 | 30.50 | 92.00 | 142.50 | 220.50 SW | 0.10 |
| 21 | 1.40 | 28.60 | 96.00 | 172.30 | 324.50 SE | 0.10 | 3.20 | 30.60 | 93.00 | 183.00 | 26.50 NE | 0.30 | 1.80 | 28.60 | 93.00 | 153.10 | 76.00 NW | 0.20 |
| 22 | 3.50 | 29.10 | 88.00 | 240.50 | 125.00 NE | 0.30 | 0.40 | 32.30 | 84.00 | 37.50 | 45.00 NEW | 0.10 | 2.20 | 30.50 | 93.00 | 163.30 | 35.50 SW | 0.20 |
| 23 | 2.30 | 26.90 | 92.00 | 136.20 | 103.50 NW | 0.20 | 3.10 | 29.80 | 92.00 | 167.40 | 72.00 SW | 0.30 | 0.60 | 27.90 | 93.00 | 48.80 | 89.00 SW | 0.10 |
| 24 | 1.60 | 29.60 | 93.00 | 102.10 | 46.00 NE | 0.20 | 1.40 | 32.50 | 86.00 | 135.80 | 318.00 NW | 0.10 | 2.40 | 30.10 | 93.00 | 173.40 | 45.50 SEE | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT ASSUMPTA ROUND ABOUT**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 0.50 | 32.50 | 80.00 | 26.40 | 157.50 SE | 0.10 | 2.10 | 37.00 | 68.00 | 40.50 | 147.00 NW | 0.10 | 0.60 | 35.90 | 69.00 | 92.90 | 315.00 NWN | 0.10 |
| 2 | 2.00 | 30.50 | 80.00 | 63.70 | 103.5 SES | 0.10 | 2.10 | 36.30 | 70.00 | 62.00 | 138.50 NWN | 0.10 | 0.80 | 34.50 | 75.00 | 95.80 | 308.00 NW | 0.20 |
| 3 | 1.20 | 29.30 | 86.00 | 40.50 | 210.20 SEE | 0.20 | 1.80 | 35.80 | 86.00 | 50.20 | 120.00 NW | 0.10 | 1.20 | 36.10 | 75.00 | 87.30 | 240.70 NWN | 0.20 |
| 4 | 1.70 | 25.30 | 92.00 | 72.40 | 67.20 NE | 0.10 | 1.70 | 34.70 | 80.00 | 62.30 | 67.00 SE | 0.10 | 1.90 | 35.10 | 70.00 | 39.40 | 217.00 SE | 0.20 |
| 5 | 0.80 | 27.50 | 85.00 | 63.20 | 75.00 SW | 0.10 | 2.00 | 36.80 | 77.00 | 124.00 | 308.50 SES | 0.20 | 1.20 | 34.90 | 81.00 | 84.70 | 57.50 NEE | 0.20 |
| 6 | 2.10 | 28.70 | 79.00 | 231.30 | 207.50 NW | 0.20 | 1.30 | 38.60 | 85.00 | 102.50 | 120.50 NW | 0.20 | 1.80 | 39.60 | 83.00 | 145.70 | 260.50 NE | 0.20 |
| 7 | 1.60 | 30.20 | 80.00 | 132.40 | 65.30 NW | 0.20 | 0.50 | 35.80 | 84.00 | 62.40 | 332.00 SEE | 0.10 | 1.40 | 33.50 | 81.00 | 56.40 | 51.00 SW | 0.10 |
| 8 | 2.40 | 24.60 | 84.00 | 153.00 | 42.00 NW | 0.20 | 1.50 | 29.80 | 86.00 | 83.40 | 285.00 NE | 0.10 | 2.80 | 28.10 | 78.00 | 132.80 | 153.60 NE | 0.20 |
| 9 | 3.20 | 24.70 | 84.00 | 171.60 | 45.30 NW | 0.30 | 2.70 | 27.30 | 85.00 | 153.40 | 104.50 NEE | 0.20 | 2.30 | 31.40 | 86.00 | 104.60 | 274.00 NW | 0.20 |
| 10 | 2.80 | 25.80 | 85.00 | 164.80 | 208.00 NE | 0.20 | 2.30 | 31.50 | 91.00 | 175.20 | 325.50 NWN | 0.20 | 2.70 | 33.40 | 81.00 | 132.80 | 47.50 NE | 0.20 |
| 11 | 2.80 | 27.80 | 85.00 | 158.60 | 103.45 NE | 0.20 | 1.60 | 32.60 | 90.00 | 75.10 | 328.50 NEE | 0.10 | 2.30 | 29.80 | 86.00 | 147.30 | 214.00 NE | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 2.40 | 29.30 | 79.00 | 142.40 | 103.20 NEE | 0.20 | 1.60 | 37.70 | 93.00 | 92.30 | 162.00 NE | 0.20 | 1.60 | 34.30 | 75.00 | 139.40 | 317.00 SW | 0.10 |
| 13 | 1.20 | 31.50 | 80.00 | 73.80 | 247.5 NW | 0.20 | 3.90 | 34.00 | 86.00 | 231.50 | 135.00 SE | 0.30 | 2.40 | 31.60 | 80.00 | 153.20 | 135.00 SW | 0.20 |
| 14 | 0.70 | 30.30 | 80.00 | 39.50 | 28.00.NW | 0.10 | 1.10 | 31.00 | 85.00 | 39.50 | 107.50 SW | 0.10 | 0.90 | 30.40 | 80.00 | 49.60 | 206.00 NW | 0.10 |
| 15 | 2.40 | 28.70 | 94.00 | 143.00 | 72.50 SW | 0.20 | 2.20 | 33.40 | 86.00 | 123.70 | 203.00SWN | 0.20 | 1.30 | 33.10 | 81.00 | 86.40 | 116.50 NWN | 0.10 |
| 16 | 1.30 | 31.80 | 87.00 | 54.60 | 103.00 NW | 0.10 | 1.50 | 30.70 | 94.00 | 104.20 | 86.00 SW | 0.10 | 2.20 | 31.50 | 80.00 | 134.50 | 324.00 SW | 0.20 |
| 17 | 0.50 | 30.40 | 93.00 | 38.30 | 231.70 SE | 0.10 | 2.30 | 32.00 | 87.00 | 146.50 | 118.50 NW | 0.20 | 3.40 | 30.70 | 80.00 | 183.20 | 127.00 NW | 0.30 |
| 18 | 0.80 | 27.90 | 93.00 | 42.00 | 245.00 SW | 0.10 | 1.20 | 31.80 | 89.00 | 112.60 | 272.00SWW | 0.10 | 0.70 | 31.30 | 86.00 | 62.30 | 312.00 SW | 0.10 |
| 19 | 2.50 | 30.60 | 80.00 | 162.50 | 132.50 SEE | 0.20 | 0.70 | 30.60 | 90.00 | 47.30 | 306.50 NW | 0.10 | 1.40 | 29.60 | 93.00 | 102.50 | 78.00 NW | 0.10 |
| 20 | 3.10 | 27.30 | 85.00 | 175.20 | 341.00 SW | 0.30 | 2.10 | 32.90 | 83.00 | 138.50 | 234.00 SW | 0.20 | 2.10 | 32.40 | 87.00 | 157.60 | 236.00 NE | 0.20 |
| 21 | 0.40 | 26.80 | 92.00 | 32.00 | 108.00 SE | 0.10 | 1.30 | 31.70 | 93.00 | 124.40 | 124.50 NW | 0.10 | 0.50 | 30.80 | 93.00 | 58.40 | 68.50 NWN | 0.10 |
| 22 | 2.30 | 29.30 | 93.00 | 146.10 | 65.50 NW | 0.20 | 0.60 | 30.50 | 92.00 | 36.20 | 89.00 NE | 0.10 | 1.60 | 31.20 | 93.00 | 142.60 | 109.30 SW | 0.20 |
| 23 | 1.60 | 27.70 | 93.00 | 128.50 | 46.00 SW | 0.20 | 2.40 | 32.60 | 93.00 | 157.07 | 317.00 SW | 0.20 | 0.80 | 29.70 | 93.00 | 67.50 | 254.00 NW | 0.10 |
| 24 | 1.80 | 28.50 | 93.00 | 147.20 | 53.50 NW | 0.20 | 1.90 | 33.30 | 85.00 | 123.60 | 68.50 NW | 0.20 | 1.50 | 32.30 | 87.00 | 123.00 | 132.50 SW | 1.00 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT EMMANUEL COLLEGE ROUNDABOUT**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/ min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.20 | 34.90 | 75.00 | 161.70 | 315.00 NWN | 0.20 | 0.80 | 37.80 | 75.00 | 71.00 | 135.50 SES | 0.20 | 2.70 | 33.10 | 86.00 | 171.70 | 128.50 SE | 0.20 |
| 2 | 2.40 | 31.70 | 80.00 | 140.30 | 313.00 NW | 0.20 | 1.00 | 37.50 | 75.00 | 83.00 | 145.00 SEE | 0.10 | 1.60 | 33.70 | 87.00 | 168.5 | 130.50 SE | 0.10 |
| 3 | 0.70 | 32.10 | 80.00 | 54.90 | 305.00 NW | 0.10 | 1.20 | 38.50 | 69.00 | 68.30 | 155.50 SEE | 0.20 | 2.30 | 34.20 | 81.00 | 142.50 | 138.50 SEE | 0.20 |
| 4 | 1.40 | 27.20 | 93.00 | 112.40 | 72.80 SE | 0.10 | 2.80 | 38.10 | 69.00 | 48.50 | 127.00 NE | 0.20 | 0.60 | 32.20 | 87.00 | 58.30 | 306.00 NEE | 0.10 |
| 5 | 1.60 | 29.30 | 86.00 | 95.70 | 102.50 NEE | 0.20 | 0.70 | 38.60 | 74.00 | 68.50 | 62.00 NEE | 0.10 | 0.80 | 32.70 | 80.00 | 69.60 | 136.00 SW | 0.10 |
| 6 | 1.20 | 30.30 | 86.00 | 95.20 | 320.00 NWN | 0.10 | 0.70 | 39.50 | 77.00 | 68.30 | 95.00 SE | 0.10 | 1.20 | 36.40 | 78.00 | 102.30 | 85.00 SES | 0.10 |
| 7 | 0.70 | 31.70 | 80.00 | 47.10 | 47.50 NE | 0.10 | 1.30 | 38.10 | 75.00 | 86.30 | 67.50 NW | 0.10 | 1.60 | 31.70 | 81.00 | 132.40 | 146.50 NE | 0.20 |
| 8 | 2.90 | 25.70 | 85.00 | 127.80 | 205.50 NEE | 0.20 | 3.60 | 32.60 | 80.00 | 178.30 | 234.50 NW | 0.10 | 2.30 | 26.50 | 85.00 | 123.40 | 237.00 SW | 0.20 |
| 9 | 3.40 | 25.40 | 85.00 | 184.10 | 230.10 NEE | 0.30 | 2.70 | 29.20 | 86.00 | 158.30 | 65.00 NWN | 0.20 | 2.80 | 30.50 | 80.00 | 145.50 | 128.50 NE | 0.20 |
| 10 | 2.20 | 28.50 | 79.00 | 108.60 | 47.60 NEE | 0.20 | 3.20 | 32.40 | 74.00 | 163.80 | 148.00 SW | 0.20 | 1.90 | 30.60 | 80.00 | 124.6 | 221.00 NWN | 0.10 |
| 11 | 3.10 | 29.70 | 86.00 | 165.30 | 46.00 NE | 0.30 | 2.70 | 32.70 | 80.00 | 161.50 | 127.00 NW | 0.20 | 1.50 | 30.60 | 80.00 | 123.70 | 180.00 NW | 0.10 |
| 12 | 1.50 | 31.20 | 80.00 | 98.20 | 234.80 SW | 0.10 | 0.60 | 38.10 | 69.00 | 39.50 | 137.00 NW | 0.10 | 0.80 | 32.40 | 87.00 | 68.30 | 346.50 NE | 0.10 |
| 13 | 2.30 | 32.40 | 80.00 | 166.40 | 337.5 NWN | 0.20 | 0.50 | 37.10 | 69.00 | 29.30 | 337.5 NWN | 0.10 | 1.20 | 30.90 | 80.00 | 71.30 | 225.00SW | 0.20 |
| 14 | 1.60 | 28.90 | 79.00 | 107.30 | 126.50 NW | 0.10 | 1.30 | 34.50 | 75.00 | 78.40 | 220.00 SW | 0.10 | 2.40 | 28.90 | 93.00 | 176.30 | 68.50 SW | 0.20 |
| 15 | 0.50 | 30.50 | 78.00 | 49.70 | 72.00 SW | 0.10 | 0.70 | 36.10 | 69.00 | 53.60 | 67.50 NW | 0.10 | 1.30 | 30.40 | 90.00 | 142.40 | 132.00 NW | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 2.10 | 29.60 | 86.00 | 158.60 | 136.50 NE | 0.20 | 2.40 | 35.20 | 81.00 | 168.30 | 85.50 SW | 0.20 | 0.70 | 33.20 | 87.00 | 125.20 | 46.00 SWN | 0.10 |
| 17 | 0.90 | 30.70 | 93.00 | 75.30 | 45.00 NW | 0.10 | 1.60 | 34.80 | 87.00 | 142.50 | 132.00 NE | 0.20 | 1.40 | 29.80 | 94.00 | 134.50 | 69.50 NW | 0.10 |
| 18 | 1.40 | 29.20 | 93.00 | 98.20 | 240.00 SW | 0.10 | 0.80 | 35.60 | 81.00 | 67.10 | 45.50 NWN | 0.10 | 2.20 | 32.60 | 90.00 | 146.10 | 52.50 NW | 0.20 |
| 19 | 3.20 | 28.80 | 93.00 | 187.40 | 315.50 NWN | 0.30 | 3.10 | 36.40 | 69.00 | 185.20 | 245.00 SW | 0.30 | 3.30 | 33.70 | 86.00 | 185.30 | 76.50 SE | 0.30 |
| 20 | 0.60 | 30.30 | 86.00 | 71.60 | 153.00 NW | 0.10 | 2.20 | 34.70 | 87.00 | 161.50 | 323.00 NW | 0.20 | 1.50 | 32.50 | 87.00 | 136.90 | 108.00 SW | 0.20 |
| 21 | 1.30 | 31.60 | 86.00 | 112.30 | 84.00 SW | 0.10 | 0.90 | 33.80 | 88.00 | 65.60 | 124.50 SW | 0.10 | 2.10 | 28.70 | 95.00 | 142.80 | 125.50 NW | 0.20 |
| 22 | 0.80 | 29.70 | 93.00 | 53.50 | 127.50 NW | 0.10 | 1.40 | 35.40 | 75.00 | 86.30 | 46.00NWW | 0.10 | 0.50 | 30.10 | 88.00 | 46.30 | 235.00 SW | 0.10 |
| 23 | 2.70 | 30.80 | 86.00 | 142.10 | 58.00 NWW | 0.20 | 2.10 | 34.80 | 87.00 | 152.70 | 163.50 SW | 0.20 | 1.70 | 30.70 | 93.00 | 137.80 | 338.00 NW | 0.20 |
| 24 | 1.20 | 28.60 | 93.00 | 93.20 | 228.00 NW | 0.10 | 1.70 | 33.90 | 80.00 | 102.50 | 237.0 NW | 0.10 | 0.90 | 31.40 | 86.00 | 72.10 | 246.50 SW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT FIRE SERVICE ROUNDABOUT**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.20 | 35.30 | 75.00 | 131.60 | 225.00 SW | 0.20 | 2.00 | 39.00 | 69.00 | 140.30 | 45.00 NEE | 0.10 | 1.20 | 32.60 | 80.00 | 154.10 | 305.00 NW | 0.20 |
| 2 | 2.00 | 33.50 | 81.00 | 120.40 | 105.00 SES | 0.20 | 2.20 | 38.00 | 75.00 | 130.50 | 70.00 SES | 0.20 | 2.50 | 33.80 | 74.00 | 157.20 | 320.00 NW | 0.20 |
| 3 | 1.40 | 32.40 | 80.00 | 97.40 | 201.50 SWN | 0.20 | 2.50 | 38.60 | 75.00 | 105.40 | 60.00 NE | 0.20 | 0.90 | 34.30 | 69.00 | 136.40 | 250.20 SW | 0.10 |
| 4 | 2.00 | 27.60 | 85.00 | 121.50 | 45.70 NE | 0.20 | 1.30 | 28.60 | 79.00 | 72.00 | 214.50 SW | 0.10 | 2.20 | 31.50 | 80.00 | 73.20 | 118.00 NW | 0.20 |
| 5 | 2.80 | 30.10 | 80.00 | 174.00 | 326.00 SW | 0.20 | 1.40 | 39.30 | 69.00 | 137.40 | 164.00 NW | 0.10 | 2.10 | 32.50 | 82.00 | 132.50 | 204.50 NE | 0.20 |
| 6 | 1.70 | 30.80 | 80.00 | 118.60 | 214.50 NE | 0.20 | 1.10 | 39.70 | 69.00 | 115.10 | 236.50 NE | 0.10 | 2.50 | 34.80 | 69.00 | 174.60 | 120.60 NEE | 0.20 |
| 7 | 2.60 | 30.90 | 86.00 | 154.00 | 321.00NWN | 0.20 | 2.10 | 37.60 | 75.00 | 136.00 | 227.00 NW | 0.20 | 2.50 | 30.60 | 74.00 | 146.00 | 46.60 NEW | 0.20 |
| 8 | 3.80 | 25.30 | 93.00 | 145.60 | 102.00 NEE | 1.00 | 2.30 | 31.80 | 80.00 | 133.20 | 86.00 NEE | 0.20 | 2.70 | 25.70 | 85.00 | 72.30 | 302.60 NW | 0.20 |
| 9 | 2.60 | 25.70 | 93.00 | 149.30 | 202.50 NW | 0.10 | 3.50 | 30.50 | 80.00 | 173.90 | 310.60 NE | 1.00 | 3.20 | 30.70 | 80.00 | 175.60 | 74.80 NW | 0.30 |
| 10 | 3.60 | 28.90 | 86.00 | 196.40 | 326.00 SW | 1.00 | 2.00 | 32.70 | 80.00 | 108.3 | 227.40 NW | 0.20 | 2.50 | 30.20 | 79.00 | 164.30 | 237.00 NW | 0.20 |
| 11 | 2.70 | 30.20 | 86.00 | 136.20 | 122.50 SE | 0.20 | 1.50 | 33.30 | 85.00 | 89.60 | 241.50 SWN | 0.10 | 1.80 | 30.20 | 80.00 | 136.30 | 321.50 NEE | 0.10 |
| 12 | 1.90 | 31.80 | 80.00 | 131.50 | 46.70 NWN | 0.10 | 2.30 | 38.60 | 75.00 | 162.00 | 334.50 SE | 0.20 | 1.20 | 31.40 | 74.00 | 103.20 | 108.00 NW | 0.10 |
| 13 | 1.80 | 32.90 | 80.00 | 129.10 | 222.50SWS | 0.20 | 1.50 | 36.50 | 87.00 | 92.50 | 315.00 NW | 0.10 | 2.30 | 30.80 | 70.00 | 139.00 | 45.00 NE | 0.20 |
| 14 | 2.10 | 29.80 | 80.00 | 142.50 | 135.00 SW | 0.20 | 0.90 | 34.60 | 90.00 | 123.60 | 75.00 SWN | 0.10 | 1.40 | 28.50 | 80.00 | 124.20 | 312.00 NW | 0.10 |
| 15 | 1.50 | 30.30 | 86.00 | 126.20 | 56.50 SWW | 0.10 | 2.40 | 35.70 | 93.00 | 167.20 | 102.50 SE | 0.20 | 1.90 | 30.70 | 80.00 | 143.50 | 276.50 SW | 0.20 |
| 16 | 0.60 | 28.90 | 86.00 | 46.70 | 93.00 SWN | 0.10 | 1.60 | 34.90 | 78.00 | 138.40 | 241.00 SW | 0.10 | 2.60 | 32.40 | 87.00 | 174.50 | 67.50 NW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 1.30 | 31.20 | 82.00 | 124.50 | 107.50 NW | 0.10 | 1.70 | 33.80 | 87.00 | 145.40 | 327.00 NW | 0.20 | 3.20 | 29.60 | 93.00 | 185.30 | 59.00 NE | 0.30 |
| 18 | 2.50 | 30.50 | 86.00 | 163.50 | 45.50 SW | 0.20 | 2.60 | 34.50 | 84.00 | 153.00 | 58.50 NWN | 0.20 | 0.80 | 31.30 | 80.00 | 73.60 | 28.50NWN | 0.10 |
| 19 | 0.70 | 28.70 | 93.00 | 57.30 | 36.00 SWW | 0.10 | 0.80 | 35.60 | 69.00 | 57.40 | 37.50 SW | 0.10 | 2.40 | 30.50 | 86.00 | 146.90 | 85.00 SW | 0.20 |
| 20 | 1.60 | 31.60 | 93.00 | 132.50 | 217.00 SWN | 0.20 | 1.90 | 33.90 | 81.00 | 152.70 | 260.00 NW | 0.20 | 3.10 | 30.80 | 90.00 | 186.30 | 93.50 NW | 0.30 |
| 21 | 0.80 | 30.30 | 86.00 | 58.90 | 67.50 SW | 0.10 | 0.70 | 34.70 | 75.00 | 43.60 | 180.00 SW | 0.10 | 1.70 | 28.70 | 86.00 | 134.60 | 124.50 NE | 0.20 |
| 22 | 2.30 | 29.60 | 93.00 | 163.40 | 49.00 SWN | 0.20 | 1.20 | 35.50 | 69.00 | 84.50 | 274.00 NW | 0.10 | 1.10 | 30.60 | 78.00 | 107.40 | 257.00 SW | 0.10 |
| 23 | 1.90 | 30.40 | 91.00 | 145.30 | 134.00 SW | 0.20 | 2.50 | 34.80 | 75.00 | 163.50 | 47.50 NW | 0.20 | 0.70 | 27.90 | 93.00 | 64.70 | 245.00 NW | 0.10 |
| 24 | 1.10 | 29.50 | 86.00 | 94.30 | 63.70 NW | 0.10 | 1.80 | 32.90 | 80.00 | 123.50 | 84.00 SWN | 0.20 | 1.60 | 32.30 | 80.00 | 128.50 | 76.50 NWN | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT WORLD BANK MARKET JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.10 | 34.20 | 75.00 | 104.50 | 135.00 SE | 0.10 | 2.30 | 38.50 | 68.00 | 97.20 | 167.00 NE | 0.20 | 0.80 | 36.00 | 69.00 | 140.20 | 245.00 NWN | 0.20 |
| 2 | 2.30 | 36.00 | 75.00 | 95.30 | 126.00 NE | 0.20 | 1.80 | 37.70 | 69.00 | 86.00 | 105.00 NEE | 0.10 | 0.90 | 33.50 | 75.00 | 83.60 | 116.70 NW | 0.10 |
| 3 | 2.60 | 31.20 | 80.00 | 135.10 | 35.70 SEE | 0.20 | 2.60 | 36.80 | 75.00 | 132.00 | 320.50 NWN | 0.10 | 1.20 | 35.20 | 69.00 | 150.30 | 215.00 NWN | 0.10 |
| 4 | 0.90 | 26.70 | 92.00 | 47.30 | 216.00 NEE | 0.10 | 1.60 | 35.60 | 75.00 | 82.40 | 47.00 NWN | 0.10 | 1.70 | 34.20 | 75.00 | 104.60 | 168.00 SES | 0.20 |
| 5 | 1.50 | 27.80 | 93.00 | 107.50 | 216.00 NE | 0.10 | 0.50 | 37.40 | 69.00 | 48.30 | 136.00 SW | 0.10 | 0.70 | 33.80 | 75.00 | 42.50 | 328.00 NWN | 0.10 |
| 6 | 0.60 | 29.20 | 93.00 | 45.20 | 67.50 NW | 0.10 | 0.80 | 39.10 | 68.00 | 73.40 | 47.40 SES | 0.10 | 2.10 | 38.70 | 64.00 | 153.10 | 232.00 SE | 0.20 |
| 7 | 1.50 | 30.60 | 86.00 | 126.30 | 203.00 NEE | 0.10 | 0.60 | 36.30 | 75.00 | 70.60 | 105.00 SES | 0.10 | 1.50 | 33.20 | 81.00 | 153.50 | 163.00 NEE | 0.20 |
| 8 | 4.10 | 24.40 | 92.00 | 192.70 | 51.60 NW | 1.00 | 1.80 | 30.40 | 73.00 | 86.30 | 226.70 NW | 0.10 | 1.40 | 26.60 | 85.00 | 58.60 | 128.50 NEE | 0.10 |
| 9 | 2.90 | 24.60 | 92.00 | 135.40 | 345.00 NE | 0.30 | 2.50 | 28.70 | 79.00 | 85.70 | 207.00 NWN | 0.20 | 2.70 | 31.60 | 79.00 | 132.80 | 248.00 NWN | 0.20 |
| 10 | 2.50 | 27.40 | 93.00 | 86.20 | 215.00 NWN | 0.20 | 1.80 | 31.80 | 80.00 | 56.40 | 103.50 SE | 0.20 | 1.50 | 31.50 | 80.00 | 104.70 | 250.00 NEE | 0.10 |
| 11 | 1.90 | 28.50 | 93.00 | 157.60 | 347.00 NWN | 0.10 | 2.30 | 33.10 | 81.00 | 147.30 | 37.60 SEE | 0.20 | 1.20 | 30.30 | 80.00 | 60.40 | 240.70 NWN | 0.10 |
| 12 | 1.40 | 29.80 | 86.00 | 65.00 | 316.00 NE | 0.10 | 1.70 | 36.60 | 75.00 | 123.40 | 56.00 NWN | 0.20 | 1.20 | 31.80 | 80.00 | 103.20 | 68.00 SE | 0.10 |
| 13 | 1.30 | 34.00 | 81.00 | 79.00 | 247.50SWW | 0.10 | 2.80 | 34.50 | 75.00 | 166.30 | 45.00 NE | 0.20 | 1.20 | 31.50 | 80.00 | 74.20 | 135.0 SE | 0.10 |
| 14 | 2.40 | 30.20 | 86.00 | 153.50 | 45.50 NW | 0.20 | 0.40 | 32.60 | 80.00 | 36.40 | 236.00 NW | 0.10 | 2.30 | 30.30 | 86.00 | 159.70 | 251.00 SE | 0.20 |
| 15 | 1.60 | 29.50 | 93.00 | 124.30 | 214.00 SW | 0.20 | 2.20 | 33.40 | 81.00 | 153.60 | 48.50 SW | 0.20 | 0.50 | 31.70 | 80.00 | 46.20 | 57.00 NW | 0.10 |
| 16 | 0.70 | 31.30 | 86.00 | 54.00 | 325.00 NW | 0.10 | 1.30 | 35.20 | 75.00 | 122.80 | 162.00 NEE | 0.10 | 1.80 | 30.20 | 86.00 | 132.30 | 64.50 NE | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 1.40 | 30.60 | 86.00 | 124.50 | 78.30 SW | 0.10 | 2.80 | 34.60 | 75.00 | 174.50 | 126.50 NW | 0.20 | 2.40 | 32.10 | 80.00 | 164.30 | 227.00 SW | 0.20 |
| 18 | 2.10 | 28.90 | 93.00 | 167.00 | 64.00 NW | 0.20 | 0.50 | 33.70 | 81.00 | 48.10 | 67.00 NE | 0.10 | 1.30 | 30.80 | 86.00 | 108.50 | 104.00 SE | 0.10 |
| 19 | 1.60 | 31.20 | 86.00 | 147.00 | 208.00 SW | 0.10 | 3.20 | 31.80 | 80.00 | 187.30 | 312.00 NW | 0.30 | 1.60 | 29.40 | 86.00 | 137.20 | 248.00 NW | 0.10 |
| 20 | 0.80 | 30.70 | 86.00 | 73.40 | 49.50 NE | 0.10 | 1.10 | 32.60 | 80.00 | 115.20 | 94.50 SW | 0.10 | 2.20 | 30.30 | 80.00 | 160.40 | 47.50 NE | 0.20 |
| 21 | 1.70 | 32.30 | 80.00 | 153.50 | 75.00 NW | 0.20 | 2.30 | 34.20 | 75.00 | 168.40 | 74.00 NW | 0.20 | 1.80 | 31.50 | 88.00 | 143.60 | 129.00 SE | 0.20 |
| 22 | 0.60 | 30.50 | 86.00 | 47.70 | 58.00 SW | 0.10 | 1.60 | 30.70 | 86.00 | 137.60 | 86.50 NE | 0.20 | 0.60 | 29.80 | 86.00 | 48.20 | 336.00 SW | 0.10 |
| 23 | 1.10 | 29.70 | 93.00 | 109.20 | 83.50 NW | 0.10 | 2.40 | 32.90 | 80.00 | 152.30 | 265.00 NW | 0.20 | 3.10 | 30.60 | 86.00 | 193.80 | 53.50 NE | 0.30 |
| 24 | 1.80 | 30.80 | 80.00 | 153.00 | 234.00 SW | 0.20 | 0.90 | 29.80 | 86.00 | 53.70 | 83.50 SW | 0.10 | 2.50 | 30.40 | 86.00 | 167.40 | 83.00 SE | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT INDUSTRIAL LAYOUT IRRETE**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/ min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.50 | 34.70 | 74.00 | 67.70 | 202.00 NW | 0.20 | 1.50 | 39.00 | 63.00 | 87.50 | 140.00 NWN | 0.20 | 1.40 | 35.70 | 75.00 | 138.50 | 280.00 NW | 0.10 |
| 2 | 1.80 | 37.20 | 69.00 | 105.60 | 325.00 | 0.10 | 2.00 | 38.70 | 63.00 | 107.00 | 144.50 NW | 0.30 | 1.20 | 33.20 | 81.00 | 102.70 | 158.00 NEE | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | NWN | | | | | | | | | | | | | |
| 3 | 2.30 | 32.40 | 80.00 | 72.30 | 151.10 NWN | 0.10 | 0.80 | 37.40 | 69.00 | 73.60 | 136.00 NW | 0.20 | 2.50 | 35.50 | 75.00 | 142.10 | 314.00 NE | 0.20 |
| 4 | 1.80 | 26.40 | 92.00 | 91.50 | 105.50 NE | 0.10 | 2.20 | 37.80 | 64.00 | 54.70 | 252.50 SEE | 0.20 | 0.80 | 32.60 | 80.00 | 146.40 | 143.00 NW | 0.10 |
| 5 | 2.40 | 28.70 | 93.00 | 152.80 | 305.00 NW | 0.20 | 1.80 | 38.30 | 64.00 | 162.10 | 27.50 NWN | 0.20 | 1.40 | 33.20 | 75.00 | 108.40 | 26.50 SEE | 0.20 |
| 6 | 1.80 | 29.60 | 93.00 | 145.10 | 123.00 NEE | 0.20 | 2.20 | 40.10 | 63.00 | 156.20 | 328.50 NWN | 0.20 | 1.70 | 37.50 | 69.00 | 132.70 | 123.00 NWN | 0.20 |
| 7 | 2.20 | 31.30 | 86.00 | 117.80 | 203.00 NEE | 0.20 | 2.70 | 37.50 | 69.00 | 163.80 | 47.50 SW | 0.20 | 1.20 | 32.60 | 80.00 | 84.00 | 37.30 SES | 0.10 |
| 8 | 3.40 | 24.80 | 92.00 | 143.00 | 51.60 NW | 0.30 | 2.20 | 31.70 | 74.00 | 162.00 | 48.50 NE | 0.20 | 2.60 | 27.70 | 85.00 | 104.60 | 74.80 NW | 0.20 |
| 9 | 3.30 | 24.80 | 92.00 | 178.80 | 123.50 NWN | 0.30 | 3.30 | 27.90 | 78.00 | 162.00 | 337.00 NE | 0.30 | 3.00 | 29.30 | 86.00 | 163.40 | 67.30 NW | 0.30 |
| 10 | 2.70 | 28.20 | 93.00 | 155.60 | 183.50 SE | 0.20 | 2.10 | 32.30 | 74.00 | 124.60 | 313.00 NW | 0.20 | 1.20 | 31.20 | 80.00 | 47.20 | 242.00 SE | 0.10 |
| 11 | 2.50 | 29.10 | 86.00 | 129.40 | 125.00 NW | 0.20 | 1.80 | 32.80 | 75.00 | 109.40 | 145.10 NE | 0.10 | 2.50 | 31.10 | 80.00 | 168.20 | 127.50 SEE | 0.20 |
| 12 | 2.60 | 30.40 | 86.00 | 161.50 | 204.50 NE | 0.20 | 1.40 | 37.20 | 69.00 | 106.70 | 212.50 NE | 0.10 | 1.30 | 33.10 | 75.00 | 126.40 | 133.00 NWN | 0.10 |
| 13 | 1.50 | 34.00 | 75.00 | 89.90 | 157.50 SES | 0.10 | 2.40 | 37.30 | 69.00 | 165.60 | 315.0 NWN | 0.20 | 1.30 | 31.20 | 76.00 | 80.30 | 135.0 SE | 0.10 |
| 14 | 2.10 | 29.60 | 86.00 | 138.50 | 243.00 SE | 0.20 | 0.90 | 35.20 | 75.00 | 58.30 | 69.50 NW | 0.10 | 2.20 | 30.90 | 86.00 | 162.20 | 293.00 NE | 0.20 |
| 15 | 1.60 | 30.60 | 86.00 | 123.30 | 89.00 SW | 0.20 | 2.30 | 34.60 | 75.00 | 147.10 | 242.00 NW | 0.20 | 1.50 | 29.80 | 86.00 | 138.40 | 236.00 NW | 0.10 |
| 16 | 0.70 | 31.30 | 80.00 | 64.60 | 75.50 NW | 0.10 | 1.50 | 33.70 | 81.00 | 132.30 | 316.00 NWN | 0.10 | 1.60 | 32.30 | 80.00 | 152.60 | 78.30 SW | 0.10 |
| 17 | 2.40 | 30.20 | 90.00 | 156.00 | 326.00 SES | 0.20 | 1.70 | 36.20 | 69.00 | 141.50 | 274.00 SW | 0.20 | 0.90 | 30.60 | 86.00 | 63.90 | 281.50 NE | 0.10 |
| 18 | 1.80 | 28.90 | 86.00 | 128.40 | 146.00 SE | 0.20 | 0.80 | 35.80 | 75.00 | 53.70 | 95.00 NE | 0.10 | 1.40 | 31.40 | 86.00 | 132.70 | 108.00 NW | 0.10 |
| 19 | 2.60 | 30.50 | 80.00 | 163.10 | 48.50 SW | 0.30 | 1.20 | 36.30 | 69.00 | 129.60 | 76.50 NW | 0.10 | 1.80 | 29.50 | 86.00 | 147.80 | 216.50 SEE | 0.20 |
| 20 | 3.10 | 29.40 | 86.00 | 184.30 | 152.00 SE | 0.30 | 3.10 | 34.60 | 75.00 | 187.40 | 284.00 NE | 0.30 | 2.30 | 30.30 | 86.00 | 172.50 | 274.00 SE | 0.20 |
| 21 | 0.80 | 30.60 | 80.00 | 68.50 | 96.50 SW | 0.10 | 1.40 | 33.90 | 81.00 | 147.30 | 46.50 NW | 0.10 | 2.40 | 32.10 | 80.00 | 175.20 | 328.00 NE | 0.20 |
| 22 | 2.70 | 29.80 | 93.00 | 164.46 | 173.00 NEE | 0.30 | 0.70 | 34.50 | 75.00 | 60.10 | 63.00 NE | 0.10 | 1.90 | 29.60 | 86.00 | 146.80 | 247.00 NW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 1.30 | 27.90 | 93.00 | 128.50 | 64.00 SE | 0.10 | 1.60 | 35.70 | 75.00 | 148.30 | 93.50 NW | 0.10 | 0.70 | 28.50 | 86.00 | 48.70 | 156.00 NE | 0.10 |
| 24 | 1.20 | 29.70 | 93.00 | 120.90 | 263.50 SW | 0.10 | 2.10 | 34.80 | 75.00 | 146.50 | 275.00 NW | 0.20 | 1.30 | 27.80 | 93.00 | 127.50 | 239.00 SE | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT EGBU - URATTA RING ROAD**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.40 | 32.70 | 81.00 | 120.00 | 157.50 SES | 0.20 | 0.60 | 40.00 | 64.00 | 125.00 | 126.50 SEE | 0.10 | 2.30 | 32.00 | 81.00 | 137.20 | 142.00 SE | 0.20 |
| 2 | 2.20 | 36.70 | 74.00 | 130.00 | 148.00 SW | 0.10 | 0.80 | 39.60 | 69.00 | 145.00 | 126.50 SEE | 0.10 | 2.60 | 30.00 | 80.00 | 145.30 | 135.00 SE | 0.20 |
| 3 | 1.10 | 33.20 | 75.00 | 140.00 | 312.40 SW | 0.10 | 1.40 | 39.80 | 65.00 | 115.20 | 106.00 SE | 0.20 | 0.70 | 31.60 | 78.00 | 126.40 | 150.00 NW | 0.10 |
| 4 | 1.50 | 28.70 | 93.00 | 82.60 | 52.40 NW | 0.10 | 1.80 | 38.70 | 73.00 | 68.50 | 107.00 NW | 0.10 | 1.30 | 31.60 | 80.00 | 142.00 | 247.00 SWN | 2.00 |
| 5 | 2.60 | 30.60 | 86.00 | 166.50 | 134.00 SE | 0.20 | 0.40 | 39.70 | 69.00 | 35.50 | 206.00 SE | 0.10 | 0.60 | 31.90 | 86.00 | 36.70 | 218.00 NW | 0.10 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 1.60 | 31.40 | 86.00 | 128.60 | 78.00 SES | 0.20 | 0.60 | 39.30 | 69.00 | 32.80 | 310.00 SE | 0.10 | 1.40 | 32.40 | 86.00 | 74.30 | 153.50 NW | 0.10 |
| 7 | 1.80 | 32.10 | 87.00 | 63.20 | 83.50 SES | 0.10 | 1.40 | 39.70 | 72.00 | 104.90 | 134.00 NEW | 0.20 | 0.50 | 29.80 | 81.00 | 35.80 | 104.00 NWN | 0.10 |
| 8 | 2.70 | 26.80 | 92.00 | 103.10 | 74.00 NWN | 0.20 | 1.60 | 30.50 | 81.00 | 103.10 | 79.00 SW | 0.10 | 2.20 | 25.40 | 86.00 | 115.50 | 248.00 NWN | 0.20 |
| 9 | 2.50 | 26.30 | 92.00 | 120.00 | 114.30 NEE | 0.20 | 2.80 | 31.70 | 80.00 | 103.50 | 74.50 NW | 0.20 | 2.50 | 30.40 | 79.00 | 165.40 | 208.00 NE | 0.20 |
| 10 | 3.20 | 29.50 | 93.00 | 182.50 | 238.10 NW | 0.30 | 2.40 | 33.60 | 81.00 | 142.50 | 102.50 SES | 0.20 | 2.60 | 29.70 | 86.00 | 148.80 | 68.50 NW | 0.20 |
| 11 | 1.70 | 30.60 | 93.00 | 108.10 | 107.50 SE | 0.10 | 2.50 | 33.20 | 81.00 | 154.70 | 332.00 SW | 0.20 | 1.40 | 29.50 | 86.00 | 55.60 | 340.20 SW | 0.10 |
| 12 | 1.30 | 32.70 | 93.00 | 82.60 | 62.40 SE | 0.10 | 0.90 | 38.70 | 69.00 | 58.50 | 117.00NWW | 0.10 | 0.70 | 30.50 | 80.00 | 42.40 | 47.00 SES | 0.10 |
| 13 | 1.20 | 34.20 | 87.00 | 125.00 | 135.05 SE | 0.20 | 1.80 | 36.80 | 68.00 | 117.60 | 135.0 SE | 0.20 | 0.40 | 30.90 | 80.00 | 26.00 | 225.00 SW | 0.10 |
| 14 | 0.90 | 31.10 | 93.00 | 54.20 | 252.50 SEE | 0.10 | 2.10 | 34.60 | 75.00 | 155.30 | 140.00 NWN | 0.20 | 1.20 | 31.40 | 80.00 | 107.20 | 96.00 SEE | 0.10 |
| 15 | 1.30 | 30.20 | 93.00 | 109.60 | 27.50 NWN | 0.10 | 1.30 | 33.80 | 81.00 | 128.10 | 144.50 NW | 0.10 | 2.30 | 30.70 | 79.00 | 162.70 | 240.50 NEE | 0.20 |
| 16 | 0.70 | 29.50 | 93.00 | 48.90 | 105.50 NE | 0.10 | 1.50 | 35.40 | 75.00 | 142.30 | 136.00 NW | 0.10 | 1.50 | 28.80 | 86.00 | 133.50 | 237.00 NWN | 0.10 |
| 17 | 1.90 | 28.90 | 93.00 | 142.10 | 305.00 NW | 0.20 | 0.70 | 36.10 | 68.00 | 47.80 | 252.50 SEE | 0.10 | 0.80 | 29.60 | 86.00 | 48.30 | 240.50 NW | 0.10 |
| 18 | 2.30 | 30.30 | 93.00 | 173.50 | 280.00 NW | 0.10 | 2.40 | 34.80 | 75.00 | 157.70 | 27.50 NWN | 0.20 | 1.70 | 30.60 | 80.00 | 146.10 | 217.00 NW | 0.20 |
| 19 | 1.40 | 30.50 | 92.00 | 126.80 | 158.00 NEE | 0.10 | 1.20 | 33.90 | 81.00 | 107.80 | 293.00 NE | 0.10 | 2.10 | 28.90 | 86.00 | 167.40 | 312.00 NW | 0.20 |
| 20 | 1.60 | 27.80 | 93.00 | 136.50 | 314.00 NE | 0.20 | 0.50 | 34.50 | 75.00 | 49.30 | 236.00 NE | 0.10 | 2.20 | 30.10 | 80.00 | 158.50 | 276.50 SW | 0.20 |
| 21 | 2.10 | 28.40 | 93.00 | 164.30 | 315.0 NWN | 0.20 | 1.60 | 33.60 | 81.00 | 126.50 | 78.30 SW | 0.20 | 0.90 | 29.70 | 93.00 | 51.30 | 67.50 NW | 0.10 |
| 22 | 0.80 | 30.30 | 86.00 | 52.10 | 69.50 NW | 0.10 | 2.30 | 34.70 | 75.00 | 172.60 | 140.00 NW | 0.20 | 1.80 | 30.80 | 86.00 | 139.40 | 135.0 SE | 0.20 |
| 23 | 2.40 | 29.80 | 86.00 | 168.70 | 242.00 NW | 0.10 | 1.40 | 33.80 | 81.00 | 122.40 | 126.20 SW | 0.10 | 2.40 | 29.20 | 87.00 | 165.70 | 251.00 SE | 0.20 |
| 24 | 2.20 | 28.60 | 93.00 | 171.60 | 63.50 SE | 0.20 | 1.60 | 32.70 | 87.00 | 130.10 | 142.00 SEE | 0.10 | 2.00 | 29.60 | 86.00 | 161.40 | 57.00 NW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**VALUES OF METEOROLOGICAL PARAMETERS MEASURED IN THE STUDY AREAS**

**OKIGWE**

**METEOROLOGICAL PARAMETERS MEASURED AT ANARA JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 0.60 | 28.60 | 86.00 | 29.50 | 250.00 NEW | 0.10 | 0.50 | 35.40 | 74.00 | 27.70 | 135.00 NWN | 0.10 | 1.20 | 34.60 | 75.00 | 130.00 | 146.00 NE | 0.10 |
| 2 | 0.70 | 29.70 | 79.00 | 28.70 | 230.00 NW | 0.10 | 0.90 | 34.10 | 78.00 | 25.20 | 140.00 NW | 0.10 | 1.20 | 32.20 | 80.00 | 32.00 | 210.00 NW | 0.10 |
| 3 | 1.20 | 30.10 | 74.00 | 45.20 | 183.00 NW | 0.10 | 0.80 | 37.60 | 71.00 | 35.20 | 126.20 SW | 0.10 | 1.70 | 35.30 | 73.00 | 42.00 | 127.20 NW | 0.20 |
| 4 | 2.30 | 28.20 | 80.00 | 60.60 | 146.00 NE | 0.20 | 1.30 | 38.60 | 68.00 | 62.30 | 142.00 SW | 0.30 | 2.40 | 32.50 | 84.00 | 167.00 | 263.00 NW | 0.20 |
| 5 | 1.60 | 27.30 | 93.00 | 93.50 | 230.00 NE | 0.20 | 1.40 | 40.60 | 65.00 | 73.40 | 163.00 NEW | 0.10 | 1.20 | 30.70 | 85.00 | 82.60 | 57.00 SW | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 2.80 | 30.10 | 73.00 | 165.30 | 307.00 NE | 0.20 | 1.30 | 39.20 | 67.00 | 85.30 | 72.50 SW | 0.10 | 1.70 | 35.30 | 68.00 | 97.80 | 48.00 NEE | 0.20 |
| 7 | 2.40 | 27.50 | 93.00 | 174.00 | 335.50 NEW | 0.20 | 0.80 | 38.40 | 76.00 | 45.70 | 62.30 NE | 0.10 | 1.30 | 33.70 | 70.00 | 85.30 | 96.00 SEE | 0.10 |
| 8 | 2.90 | 28.50 | 93.00 | 102.70 | 96.00 NE | 0.20 | 3.40 | 28.20 | 80.00 | 136.40 | 271.50 NW | 0.60 | 3.10 | 28.90 | 86.00 | 133.80 | 240.50 NEE | 0.30 |
| 9 | 3.20 | 25.40 | 92.00 | 159.00 | 326.50 NW | 0.30 | 1.80 | 31.70 | 76.00 | 126.70 | 120.00 NE | 0.10 | 2.30 | 27.50 | 89.00 | 155.30 | 237.00 NWN | 0.20 |
| 10 | 1.90 | 32.30 | 80.00 | 108.10 | 140.50 NW | 0.10 | 2.40 | 32.30 | 81.00 | 106.50 | 126.00 NE | 0.20 | 1.80 | 29.60 | 87.00 | 126.70 | 240.50 NW | 0.10 |
| 11 | 1.20 | 33.50 | 75.00 | 73.80 | 143.00 NE | 0.10 | 2.50 | 37.20 | 68.00 | 143.20 | 173.50 NE | 0.20 | 1.40 | 29.60 | 86.00 | 112.60 | 217.00 NW | 0.10 |
| 12 | 1.50 | 29.90 | 86.00 | 124.50 | 82.00 NE | 0.10 | 2.30 | 36.20 | 70.00 | 148.70 | 150.50 NW | 0.20 | 1.30 | 31.20 | 78.00 | 83.70 | 243.00 SW | 0.10 |
| 13 | 2.00 | 30.40 | 86.00 | 121.10 | 292.5 NWW | 0.20 | 0.80 | 34.50 | 73.00 | 63.60 | 125.0 SW | 0.10 | 2.50 | 32.90 | 88.00 | 155.50 | 22.5 NEN | 0.20 |
| 14 | 1.30 | 32.50 | 87.00 | 127.30 | 64.00 NW | 0.20 | 1.00 | 35.30 | 78.00 | 97.20 | 321.50 NEE | 0.10 | 1.80 | 32.60 | 89.00 | 152.40 | 246.00 NW | 0.20 |
| 15 | 2.50 | 31.09 | 80.00 | 173.10 | 47.00 NW | 0.10 | 1.20 | 33.80 | 87.00 | 104.80 | 128.00 NE | 0.10 | 3.20 | 27.70 | 93.00 | 187.30 | 314.50 NW | 0.30 |
| 16 | 0.80 | 30.60 | 80.00 | 48.20 | 248.50 NE | 0.10 | 2.80 | 34.30 | 86.00 | 174.10 | 45.00 NE | 0.20 | 2.80 | 29.30 | 93.00 | 164.60 | 145.00 NEE | 0.30 |
| 17 | 2.40 | 29.50 | 93.00 | 163.50 | 316.00 NEE | 0.20 | 0.70 | 35.20 | 79.00 | 58.40 | 212.00 NW | 0.10 | 2.10 | 30.20 | 90.00 | 158.50 | 327.00 SW | 0.20 |
| 18 | 1.70 | 30.10 | 73.00 | 147.20 | 107.00 NW | 0.20 | 0.50 | 33.90 | 86.00 | 43.60 | 48.50NWN | 0.10 | 1.30 | 31.10 | 90.00 | 127.30 | 272.50 SW | 0.10 |
| 19 | 1.40 | 28.70 | 93.00 | 134.50 | 43.00 NE | 0.10 | 1.30 | 35.70 | 78.00 | 124.50 | 87.00 SW | 0.10 | 1.50 | 33.10 | 87.00 | 142.60 | 225.00 NEE | 0.10 |
| 20 | 0.90 | 30.20 | 86.00 | 57.30 | 224.50 NW | 0.10 | 3.10 | 35.40 | 78.00 | 187.30 | 73.50 NW | 0.30 | 2.40 | 29.80 | 87.00 | 163.08 | 70.00 NW | 0.20 |
| 21 | 2.60 | 29.30 | 93.00 | 172.20 | 128.50 NWW | 0.20 | 2.70 | 33.60 | 90.00 | 168.40 | 134.50 NE | 0.30 | 0.60 | 31.30 | 86.00 | 41.50 | 205.00 NEE | 0.10 |
| 22 | 1.10 | 31.60 | 85.00 | 86.50 | 221.00 NWN | 0.10 | 3.20 | 34.70 | 86.00 | 193.60 | 202.60 NW | 0.30 | 2.50 | 30.60 | 86.00 | 165.30 | 143.00 NW | 0.20 |
| 23 | 1.80 | 28.80 | 93.00 | 132.60 | 182.00 NW | 0.20 | 2.20 | 35.20 | 83.00 | 152.70 | 64.50 NW | 0.20 | 1.60 | 29.50 | 87.00 | 137.10 | 136.50 NEN | 0.10 |
| 24 | 2.20 | 29.40 | 93.00 | 143.70 | 246.50 NW | 0.20 | 0.60 | 35.80 | 80.00 | 48.30 | 247.00 NW | 0.10 | 0.80 | 28.70 | 93.00 | 53.60 | 250.00 NW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT UMUNA JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/ min | Wind Direction (°) | Wave Height (m) |
| 1 | 0.80 | 27.70 | 93.00 | 35.10 | 335.00 NWN | 0.10 | 1.00 | 37.60 | 64.00 | 60.20 | 225.00 SWW | 0.10 | 1.50 | 36.00 | 69.00 | 91.00 | 135.00 SES | 0.10 |
| 2 | 1.00 | 28.50 | 93.00 | 33.60 | 327.00 NWS | 0.10 | 1.20 | 36.20 | 73.00 | 65.70 | 230.00 SW | 0.20 | 1.60 | 36.60 | 72.00 | 98.60 | 308.00 NW | 0.20 |
| 3 | 2.40 | 28.20 | 92.00 | 162.70 | 305.00 NEW | 0.20 | 1.60 | 38.20 | 64.00 | 76.50 | 315.00 SE | 0.10 | 1.30 | 36.20 | 69.00 | 82.00 | 240.70 NWN | 0.10 |
| 4 | 1.80 | 29.80 | 90.00 | 133.20 | 313.00 SW | 0.10 | 0.70 | 37.30 | 69.00 | 34.80 | 317.00 NWN | 0.10 | 1.80 | 31.60 | 80.00 | 118.70 | 217.00 SE | 0.20 |
| 5 | 1.20 | 28.10 | 92.00 | 68.10 | 68.00 SE | 0.20 | 2.50 | 39.80 | 64.00 | 163.60 | 207.30 NW | 0.20 | 2.10 | 32.50 | 80.00 | 157.90 | 57.50 NEE | 0.20 |
| 6 | 1.60 | 27.40 | 90.00 | 118.40 | 227.00 SW | 0.20 | 2.20 | 38.80 | 68.00 | 142.80 | 257.00 NW | 0.20 | 1.40 | 35.70 | 75.00 | 103.50 | 260.50 NE | 0.20 |
| 7 | 1.60 | 30.70 | 83.00 | 72.30 | 48.00 SWE | 0.10 | 2.30 | 38.60 | 64.00 | 115.90 | 243.00 NW | 0.20 | 0.70 | 35.40 | 75.00 | 43.90 | 51.00 SW | 0.10 |
| 8 | 3.50 | 24.50 | 92.00 | 170.90 | 236.70 NW | 0.70 | 2.70 | 40.80 | 59.00 | 172.00 | 142.00 NEE | 0.20 | 3.30 | 24.30 | 86.00 | 165.70 | 153.60 NE | 0.30 |
| 9 | 2.90 | 30.30 | 86.00 | 163.40 | 255.00 NEE | 0.20 | 2.10 | 30.30 | 85.00 | 108.30 | 247.00 NW | 0.20 | 1.60 | 28.50 | 84.00 | 63.60 | 274.00 NW | 0.10 |
| 10 | 2.20 | 32.10 | 80.00 | 116.00 | 223.50 NEW | 0.20 | 1.50 | 31.40 | 80.00 | 124.00 | 346.00 NW | 0.10 | 1.70 | 30.20 | 80.00 | 103.60 | 47.50 NE | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 1.50 | 31.60 | 86.00 | 108.10 | 104.00 SE | 0.10 | 1.40 | 35.70 | 67.00 | 123.60 | 223.00 NW | 0.10 | 0.90 | 30.30 | 80.00 | 87.30 | 214.00 NE | 0.10 |
| 12 | 2.30 | 28.40 | 93.00 | 135.20 | 127.00 SE | 0.20 | 1.60 | 37.80 | 65.00 | 127.10 | 136.00 SW | 0.10 | 0.50 | 33.60 | 79.00 | 50.50 | 317.00 SW | 0.10 |
| 13 | 1.00 | 29.50 | 93.00 | 66.20 | 202.5 SWS | 0.10 | 0.60 | 33.50 | 87.00 | 34.60 | 45.0 NE | 0.10 | 2.20 | 34.00 | 79.00 | 144.30 | 157.5 SES | 0.20 |
| 14 | 1.70 | 31.40 | 85.00 | 148.40 | 138.00 SW | 0.20 | 2.50 | 34.90 | 83.00 | 162.20 | 82.00 NE | 0.20 | 2.40 | 32.10 | 87.00 | 152.50 | 105.00 NEE | 0.20 |
| 15 | 0.80 | 28.00 | 93.00 | 54.90 | 225.50 NW | 0.10 | 1.30 | 34.50 | 81.00 | 128.10 | 224.50 NW | 0.10 | 2.50 | 30.80 | 80.00 | 161.20 | 52.00 SWW | 0.20 |
| 16 | 2.10 | 30.20 | 86.00 | 169.00 | 335.00 SW | 0.20 | 1.40 | 33.60 | 90.00 | 136.80 | 74.00 NE | 0.1 | 0.90 | 29.40 | 86.00 | 64.30 | 127.00 NW | 0.10 |
| 17 | 1.60 | 29.40 | 93.00 | 128.00 | 232.00 NW | 0.10 | 1.80 | 34.70 | 81.00 | 153.20 | 57.00 NW | 0.20 | 1.80 | 30.30 | 80.00 | 138.40 | 246.00 SE | 0.20 |
| 18 | 2.40 | 31.80 | 86.00 | 167.20 | 126.50 SW | 0.20 | 0.60 | 32.40 | 90.00 | 43.90 | 146.00 NE | 0.10 | 2.10 | 31.50 | 80.00 | 159.60 | 326.00 NW | 0.20 |
| 19 | 1.30 | 28.20 | 95.00 | 127.40 | 56.00 SWN | 0.10 | 0.80 | 35.10 | 79.00 | 53.30 | 230.00 NE | 0.10 | 1.40 | 29.80 | 86.00 | 137.20 | 109.00 NE | 0.10 |
| 20 | 1.20 | 30.60 | 86.00 | 113.60 | 79.50 NWS | 0.10 | 1.90 | 34.80 | 81.00 | 156.40 | 307.00 NE | 0.20 | 1.80 | 30.60 | 80.00 | 143.10 | 125.00 SEE | 0.20 |
| 21 | 0.70 | 28.70 | 93.00 | 48.20 | 152.50 NW | 0.10 | 1.80 | 34.70 | 83.00 | 151.70 | 35.50 NEW | 0.20 | 0.40 | 30.40 | 80.00 | 37.50 | 147.00 SE | 0.10 |
| 22 | 3.20 | 30.10 | 86.00 | 176.20 | 66.50 NEE | 0.30 | 1.30 | 33.80 | 87.00 | 124.10 | 226.50 NW | 0.10 | 0.60 | 29.70 | 93.00 | 43.60 | 127.00 NE | 0.10 |
| 23 | 2.80 | 29.70 | 93.00 | 153.50 | 215.00SW | 0.20 | 1.70 | 34.60 | 76.00 | 142.30 | 140.50 NW | 0.20 | 1.60 | 30.30 | 86.00 | 135.30 | 54.00 NWW | 0.10 |
| 24 | 1.70 | 30.20 | 86.00 | 143.60 | 162.50 SW | 0.20 | 2.30 | 33.80 | 86.00 | 163.50 | 123.00 NE | 0.20 | 2.80 | 29.60 | 93.00 | 164.20 | 65.00 NWW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT OKIGWE EXPRESS JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.20 | 30.30 | 86.00 | 72.00 | 45.00 NEE | 0.10 | 1.60 | 39.00 | 64.00 | 45.00 NE | 27.90 | 0.10 | 2.60 | 37.00 | 69.00 | 155.10 | 157.00 SES | 0.20 |
| 2 | 1.30 | 27.70 | 86.00 | 80.00 | 52.00 NE | 0.20 | 1.40 | 38.00 | 69.00 | 48.00 NEE | 26.30 | 0.10 | 2.80 | 37.00 | 70.00 | 148.40 | 143.00 SWE | 0.10 |
| 3 | 2.00 | 29.20 | 85.00 | 80.30 | 60.00 NWN | 0.10 | 2.30 | 38.40 | 64.00 | 63.00 NW | 43.10 | 0.10 | 2.80 | 37.10 | 74.00 | 201.20 | 308.00 SEE | 0.10 |
| 4 | 2.60 | 26.50 | 93.00 | 96.50 | 47.00 NW | 2.00 | 1.60 | 36.70 | 70.00 | 201.00 NEE | 95.00 | 0.10 | 2.30 | 32.20 | 80.00 | 147.10 | 320.00 NWN | 0.20 |
| 5 | 2.40 | 28.70 | 86.00 | 137.60 | 249.50 NEW | 0.50 | 1.70 | 39.10 | 64.00 | 318.00 NE | 146.30 | 0.20 | 1.50 | 33.00 | 92.00 | 106.30 | 75.50 NW | 0.20 |
| 6 | 2.30 | 28.50 | 86.00 | 148.50 | 316.00 NEE | 0.20 | 1.50 | 39.20 | 69.00 | 106.40 NE | 114.60 | 0.20 | 0.50 | 36.80 | 67.00 | 42.70 | 39.00 SW | 0.10 |
| 7 | 1.70 | 29.10 | 87.00 | 58.20 | 107.00 NW | 0.10 | 2.70 | 39.10 | 69.00 | 319.50 SES | 132.60 | 0.20 | 1.50 | 36.30 | 69.00 | 103.60 | 115.50 NW | 0.20 |
| 8 | 4.20 | 25.20 | 88.00 | 196.30 | 45.50 NE | 0.90 | 3.40 | 27.50 | 88.00 | 336.50 NE | 140.50 | 0.70 | 3.00 | 28.70 | 88.00 | 117.00 | 34l.60 NE | 0.30 |
| 9 | 3.40 | 27.30 | 87.00 | 162.30 | 234.50 NWN | 0.30 | 2.30 | 29.60 | 86.00 | 328.50 NWN | 142.40 | 0.20 | 1.90 | 29.80 | 89.00 | 112.20 | 106.00 NEE | 0.10 |
| 10 | 2.80 | 28.40 | 86.00 | 163.20 | 348.00 NE | 0.20 | 1.80 | 32.70 | 80.00 | 65.50 NEE | 57.50 | 0.10 | 2.10 | 29.70 | 90.00 | 1460.00 | 148.00 NE | 0.20 |
| 11 | 2.60 | 29.30 | 86.00 | 147.50 | 342.50 NEW | 0.20 | 1.70 | 35.40 | 75.00 | 108.00 NEE | 116.30 | 0.10 | 2.10 | 31.80 | 86.00 | 136.30 | 86.50 NW | 0.20 |
| 12 | 1.40 | 30.20 | 80.00 | 95.60 | 163.50 NE | 0.10 | 1.30 | 39.20 | 65.00 | 243.00 NEE | 117.30 | 0.10 | 1.80 | 33.40 | 84.00 | 131.00 | 220.00 NEW | 0.10 |
| 13 | 1.40 | 28.80 | 79.00 | 86.70 | 120.50 NW | 0.10 | 2.50 | 36.60 | 70.00 | 225.0 SW | 148.00 | 0.20 | 1.10 | 34.00 | 78.00 | 28.10 | 135.0 SES | 0.10 |
| 14 | 1.70 | 29.50 | 91.00 | 143.10 | 135.0 SW | 0.20 | 0.50 | 35.70 | 74.00 | 307.00 NW | 47.50 | 0.10 | 1.60 | 30.20 | 87.00 | 147.30 | 226.00 SW | 0.10 |
| 15 | 2.10 | 30.10 | 86.00 | 156.00 | 221.50 SEE | 0.20 | 0.80 | 35.40 | 75.00 | 53.00 NE | 53.10 | 0.10 | 2.20 | 31.10 | 90.00 | 168.40 | 214.50 NW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 1.00 | 28.70 | 93.00 | 74.20 | 218.00 NW | 0.10 | 2.50 | 33.70 | 80.00 | 124.50 SW | 152.60 | 0.20 | 1.20 | 33.10 | 89.00 | 124.20 | 125.00 SEE | 0.10 |
| 17 | 2.40 | 30.20 | 80.00 | 165.30 | 45.00 NW | 0.20 | 3.10 | 34.70 | 78.00 | 87.00 NW | 187.20 | 0.30 | 1.70 | 32.90 | 85.00 | 153.70 | 97.00 SW | 0.20 |
| 18 | 2.50 | 29.30 | 86.00 | 168.60 | 242.00 NW | 0.20 | 0.40 | 35.20 | 76.00 | 348.50 SE | 36.10 | 0.10 | 1.30 | 32.60 | 90.00 | 128.10 | 262.50 SW | 0.10 |
| 19 | 2.80 | 30.40 | 80.00 | 172.30 | 78.50NWN | 0.20 | 2.40 | 33.80 | 80.00 | 216.00 NE | 148.70 | 0.20 | 3.10 | 27.70 | 96.00 | 192.30 | 236.00 SES | 0.30 |
| 20 | 2.20 | 32.50 | 87.00 | 158.60 | 47.00 NW | 0.20 | 1.20 | 34.30 | 80.00 | 120.50 NW | 136.20 | 0.10 | 2.30 | 29.30 | 95.00 | 158.20 | 47.00 SW | 0.20 |
| 21 | 2.00 | 31.09 | 86.00 | 147.30 | 93.50 NW | 0.20 | 0.70 | 36.20 | 72.00 | 133.00 NE | 47.30 | 0.10 | 2.40 | 30.60 | 91.00 | 164.50 | 126.50 NE | 0.20 |
| 22 | 1.80 | 28.50 | 93.00 | 138.50 | 234.50 NE | 0.10 | 2.40 | 33.20 | 87.00 | 82.00 NE | 145.80 | 0.20 | 1.90 | 29.50 | 92.00 | 146.30 | 280.00 SW | 0.20 |
| 23 | 3.30 | 28.40 | 93.00 | 186.30 | 237.00 NW | 0.30 | 1.30 | 34.50 | 86.00 | 92.50 SWW | 126.30 | 0.10 | 1.50 | 28.70 | 93.00 | 134.20 | 143.00 SW | 0.10 |
| 24 | 2.20 | 30.30 | 86.00 | 146.80 | 147.5 NW | 0.20 | 2.20 | 35.30 | 76.00 | 74.00 NW | 141.80 | 0.20 | 1.40 | 29.80 | 94.00 | 128.70 | 72.5 SE | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT ST. MARY'S JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H(%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.40 | 32.00 | 85.00 | 143.50 | 135.00 SEE | 0.20 | 2.00 | 37.30 | 72.00 | 117.60 | 157.70 SES | 0.20 | 1.30 | 37.30 | 67.00 | 102.20 | 337.50NWN | 0.20 |
| 2 | 2.40 | 28.50 | 88.00 | 150.50 | 137.00 SE | 0.20 | 2.30 | 36.30 | 76.00 | 114.20 | 160.70 SWE | 0.20 | 1.40 | 37.80 | 69.00 | 117.50 | 328.70 NW | 0.20 |
| 3 | 1.60 | 30.10 | 78.00 | 105.10 | 126.00 NE | 0.10 | 2.60 | 38.10 | 64.00 | 126.40 | 163.20 SW | 0.10 | 0.80 | 38.00 | 59.00 | 135.00 | 329.00 NW | 0.10 |
| 4 | 1.50 | 27.10 | 93.00 | 72.10 | 105.00 NEE | 0.10 | 1.20 | 35.20 | 72.00 | 57.00 | 67.50 SE | 0.20 | 1.70 | 33.40 | 85.00 | 83.60 | 76.50 NEE | 0.10 |
| 5 | 0.80 | 28.60 | 90.00 | 44.00 | 52.00 NWW | 0.10 | 1.30 | 38.60 | 69.00 | 119.30 | 224.50 SE | 0.10 | 1.70 | 33.10 | 86.00 | 135.20 | 106.00 NEE | 0.20 |
| 6 | 1.70 | 28.80 | 86.00 | 120.00 | 117.00 NW | 0.20 | 0.60 | 38.50 | 68.00 | 37.60 | 37.00 NE | 0.10 | 1.20 | 37.10 | 67.00 | 84.30 | 314.50 NE | 0.10 |
| 7 | 2.50 | 29.80 | 86.00 | 178.70 | 246.00 SE | 0.20 | 0.60 | 38.70 | 70.00 | 26.80 | 53.00 SW | 0.10 | 2.10 | 36.70 | 70.00 | 146.20 | 267.00 NEW | 0.20 |
| 8 | 3.10 | 25.80 | 88.00 | 152.60 | 336.00 NWN | 0.30 | 2.70 | 26.30 | 86.00 | 119.00 | 267.00 NE | 0.20 | 3.40 | 25.30 | 85.00 | 157.30 | 320.00 SW | 0.60 |
| 9 | 2.60 | 27.80 | 87.00 | 136.40 | 109.00 NE | 0.20 | 1.60 | 31.40 | 80.00 | 62.70 | 210.50 NEE | 0.10 | 2.20 | 30.10 | 80.00 | 130.50 | 317.00 NW | 0.20 |
| 10 | 2.30 | 28.70 | 93.00 | 126.40 | 54.00 NW | 0.20 | 1.20 | 32.50 | 80.00 | 122.70 | 237.00 NWN | 0.10 | 2.50 | 29.20 | 86.00 | 160.50 | 337.50 SE | 0.20 |
| 11 | 1.80 | 29.80 | 87.00 | 63.60 | 65.00 NW | 0.10 | 0.70 | 35.20 | 78.00 | 39.30 | 321.50 SE | 0.10 | 1.30 | 31.40 | 81.00 | 105.20 | 326.00 NE | 0.10 |
| 12 | 0.80 | 32.60 | 83.00 | 56.30 | 42.00 NEW | 0.10 | 1.50 | 38.60 | 69.00 | 136.50 | 114.70 SWE | 0.10 | 1.40 | 34.80 | 74.00 | 117.50 | 44.80 NEE | 0.10 |
| 13 | 0.40 | 30.40 | 81.00 | 26.30 | 247.5 SWW | 0.10 | 1.30 | 33.20 | 81.00 | 77.20 | 92.50 NW | 0.10 | 1.20 | 32.90 | 78.00 | 108.40 | 22.5 NEE | 0.20 |
| 14 | 2.80 | 31.09 | 80.00 | 164.20 | 58.00 SW | 0.20 | 1.40 | 33.90 | 84.00 | 119.30 | 237.00 NW | 0.10 | 1.80 | 31.10 | 81.00 | 142.40 | 154.00 NW | 0.20 |
| 15 | 2.10 | 30.60 | 81.00 | 157.60 | 327.00 NW | 0.20 | 2.80 | 35.70 | 78.00 | 159.20 | 155.0 SW | 0.20 | 2.40 | 30.80 | 80.00 | 157.30 | 265.00 NW | 0.20 |
| 16 | 1.30 | 29.50 | 95.00 | 126.10 | 146.00 SE | 0.10 | 0.70 | 34.40 | 80.00 | 47.80 | 90.00 NWN | 0.10 | 2.50 | 29.40 | 87.00 | 161.00 | 272.00 NEW | 0.2 |
| 17 | 1.50 | 30.10 | 86.00 | 132.70 | 226.00 NW | 0.10 | 0.50 | 33.60 | 85.00 | 36.40 | 76.50 NW | 0.10 | 2.30 | 30.30 | 81.00 | 156.20 | 147.5 SWW | 0.20 |
| 18 | 2.40 | 28.70 | 93.00 | 148.40 | 139.00 SW | 0.20 | 1.60 | 34.70 | 83.00 | 132.50 | 48.00 SE | 0.20 | 0.80 | 31.50 | 80.00 | 52.30 | 318.00 NW | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 0.60 | 30.20 | 89.00 | 43.90 | 75.00 SE | 0.10 | 3.10 | 36.20 | 78.00 | 185.30 | 216.00 NEE | 0.30 | 1.50 | 28.50 | 88.00 | 125.40 | 127.00 NW | 0.10 |
| 20 | 2.50 | 29.90 | 93.00 | 152.10 | 127.00 SE | 0.20 | 0.80 | 34.50 | 79.00 | 53.70 | 210.00 NE | 0.10 | 1.20 | 30.20 | 81.00 | 117.30 | 146.00 SEE | 0.10 |
| 21 | 1.30 | 30.40 | 81.00 | 128.20 | 163.00 SWN | 0.10 | 2.30 | 35.30 | 80.00 | 154.20 | 154.00 SW | 0.20 | 2.80 | 30.30 | 80.00 | 163.80 | 326.00 NW | 0.30 |
| 22 | 2.20 | 31.50 | 80.00 | 143.80 | 217.00 SW | 0.20 | 1.80 | 35.80 | 83.00 | 135.90 | 89.00 NW | 0.20 | 0.70 | 31.60 | 83.00 | 47.20 | 134.00 SW | 0.10 |
| 23 | 1.70 | 29.30 | 93.00 | 138.70 | 187.5 SES | 0.20 | 2.40 | 34.30 | 87.00 | 162.40 | 66.50 NW | 0.20 | 1.40 | 30.30 | 84.00 | 124.10 | 136.00 NWN | 0.10 |
| 24 | 1.20 | 28.80 | 93.00 | 125.30 | 125.00 SW | 0.10 | 2.20 | 35.20 | 79.00 | 157.60 | 152.50 NW | 0.20 | 1.30 | 29.60 | 86.00 | 119.80 | 127.00 NE | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT OKIGWE LGA HQ**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed | Ambient Temp. | R.H | Air flow | Wind Direction | Wave Height | Wind Speed | Ambient Temp | R.H | Air flow | Wind Direction | Wave Height | Wind Speed | Ambient Temp. | R.H | Air flow m^3/min | Wind Direction | Wave Height |

| | (m/s) | (°C) | (%) | m^3/ min | (°) | (m) | (m/s) | (°C) | (%) | $m^3$/min | (°) | (m) | (m/s) | (°C) | (%) | | (°) | (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.40 | 32.10 | 80.00 | 125.50 | 22.50 NE | 0.20 | 1.80 | 36.00 | 74.00 | 108.50 | 337.50 NWW | 0.20 | 1.80 | 38.50 | 78.00 | 97.00 | 315.00 NW | 0.10 |
| 2 | 2.50 | 30.20 | 86.00 | 131.00 | 25.50 NEE | 0.10 | 1.60 | 37.60 | 69.00 | 103.80 | 325.50 NEW | 0.10 | 1.70 | 38.20 | 76.00 | 87.80 | 320.00 NEW | 0.10 |
| 3 | 2.80 | 30.70 | 81.00 | 142.50 | 56.00 SE | 0.20 | 2.80 | 37.80 | 71.00 | 157.20 | 258.00 NE | 0.20 | 2.30 | 38.30 | 74.00 | 102.00 | 205.00 NE | 0.20 |
| 4 | 2.20 | 27.70 | 88.00 | 107.50 | 137.00 SE | 0.20 | 0.80 | 33.60 | 78.00 | 35.00 | 45.00 NEW | 0.10 | 0.60 | 34.80 | 75.00 | 47.80 | 57.00 SW | 0.10 |
| 5 | 2.00 | 29.40 | 86.00 | 123.60 | 34.00 NEE | 0.20 | 1.50 | 38.20 | 69.00 | 95.40 | 52.00 NW | 0.20 | 0.80 | 34.50 | 78.00 | 48.50 | 48.70 SE | 0.10 |
| 6 | 1.80 | 29.60 | 90.00 | 107.60 | 134.50 NEW | 0.10 | 2.30 | 40.70 | 65.00 | 154.00 | 112.50 SE | 0.20 | 1.30 | 38.60 | 68.00 | 132.10 | 231.00 NW | 0.20 |
| 7 | 3.00 | 30.20 | 80.00 | 197.50 | 74.00 NWS | 0.20 | 2.20 | 41.50 | 64.00 | 84.50 | 271.30 NW | 0.20 | 1.80 | 37.80 | 72.00 | 126.40 | 163.40 NEE | 0.20 |
| 8 | 4.60 | 26.10 | 93.00 | 198.10 | 275.00 NEE | 1.00 | 4.30 | 25.70 | 87.00 | 182.30 | 325.00 NEE | 0.80 | 4.70 | 25.20 | 85.00 | 198.20 | 257.00 NEE | 1.00 |
| 9 | 3.70 | 27.20 | 90.00 | 178.60 | 232.30 NW | 1.00 | 1.70 | 29.80 | 86.00 | 150.50 | 60.00 NW | 0.20 | 1.30 | 30.50 | 93.00 | 84.00 | 246.50 NE | 0.10 |
| 10 | 1.70 | 29.20 | 93.00 | 65.70 | 130.50 SE | 0.10 | 2.60 | 30.90 | 80.00 | 43.50 | 205.00 NEE | 0.20 | 1.60 | 30.70 | 84.00 | 71.00 | 36.50 NEE | 0.10 |
| 11 | 2.10 | 30.40 | 81.00 | 126.10 | 341.50 NEE | 0.20 | 1.50 | 34.80 | 75.00 | 74.40 | 87.00 NW | 0.10 | 1.80 | 32.80 | 79.00 | 128.50 | 58.00 SEE | 0.10 |
| 12 | 1.00 | 33.30 | 75.00 | 104.20 | 75.00 NW | 0.10 | 1.70 | 39.70 | 68.00 | 98.40 | 327.50 NEW | 0.10 | 2.20 | 35.70 | 76.00 | 145.80 | 312.00 NE | 0.20 |
| 13 | 1.50 | 31.20 | 81.00 | 87.20 | 225.0 SWW | 0.10 | 2.80 | 34.50 | 75.00 | 168.70 | 67.5 NEE | 0.30 | 2.30 | 33.60 | 80.00 | 154.20 | 67.5 NEE | 0.20 |
| 14 | 2.40 | 29.50 | 86.00 | 158.00 | 74.00 NW | 0.20 | 1.50 | 33.60 | 80.00 | 142.10 | 23.00 NEE | 0.10 | 1.40 | 31.10 | 82.00 | 85.00 | 136.50 NE | 0.10 |
| 15 | 2.50 | 30.60 | 81.00 | 162.30 | 68.50 NE | 0.20 | 1.30 | 34.70 | 78.00 | 98.90 | 66.00 NE | 0.10 | 1.60 | 33.10 | 80.00 | 104.30 | 125.00 NEE | 0.20 |
| 16 | 2.30 | 32.70 | 73.00 | 147.60 | 234.00 NE | 0.20 | 1.40 | 32.40 | 80.00 | 124.50 | 147.00 SE | 0.10 | 0.60 | 29.80 | 86.00 | 32.50 | 149.00 SW | 0.10 |
| 17 | 0.80 | 30.80 | 80.00 | 53.20 | 97.00 SW | 0.10 | 2.80 | 37.10 | 72.00 | 136.30 | 84.00 NEE | 0.30 | 2.50 | 31.30 | 81.00 | 152.40 | 97.00 NW | 0.20 |
| 18 | 1.00 | 31.10 | 78.00 | 103.50 | 36.50 SE | 0.10 | 0.70 | 34.80 | 78.00 | 43.20 | 124.50 NEW | 0.10 | 1.30 | 30.60 | 83.00 | 78.30 | 174.00 NW | 0.10 |
| 19 | 1.20 | 30.20 | 80.00 | 118.40 | 145.00 NEE | 0.10 | 0.50 | 35.70 | 76.00 | 32.80 | 174.00 NWS | 0.10 | 1.50 | 32.90 | 80.00 | 122.40 | 268.50 NE | 0.10 |
| 20 | 2.80 | 29.50 | 93.00 | 156.60 | 322.00 SW | 0.20 | 1.60 | 36.80 | 74.00 | 125.10 | 27.00 NE | 0.20 | 2.30 | 27.50 | 93.00 | 148.20 | 214.00 NE | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 0.70 | 28.90 | 93.00 | 48.40 | 27.00 NW | 0.10 | 3.10 | 34.60 | 78.00 | 176.30 | 92.00 NW | 0.30 | 2.70 | 29.60 | 86.00 | 158.00 | 56.00 NEE | 0.30 |
| 22 | 0.50 | 30.30 | 81.00 | 37.30 | 243.00 SW | 0.10 | 2.70 | 33.80 | 78.00 | 152.70 | 120.50 NE | 0.30 | 2.10 | 27.70 | 93.00 | 126.50 | 48.50 NEE | 0.20 |
| 23 | 1.30 | 30.50 | 78.00 | 123.30 | 126.00 NW | 0.10 | 1.60 | 35.70 | 77.00 | 132.50 | 48.00 NEE | 0.20 | 0.70 | 29.30 | 93.00 | 35.30 | 85.00 NW | 0.10 |
| 24 | 2.20 | 27.80 | 93.00 | 143.60 | 42.00 NE | 0.20 | 1.20 | 33.80 | 80.00 | 108.60 | 106.50 NW | 0.10 | 1.20 | 30.20 | 81.00 | 102.30 | 205.0 SW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT IHUBE**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 0.50 | 33.10 | 75.00 | 29.50 | 45.00 NEE | 0.10 | 1.30 | 36.20 | 72.00 | 77.60 | 157.00 SES | 0.20 | 0.60 | 40.70 | 59.00 | 37.50 | 67.50 NEE | 0.10 |
| 2 | 0.60 | 32.60 | 81.00 | 27.50 | 48.00 NEW | 0.10 | 1.30 | 36.70 | 70.00 | 80.20 | 148.40 SEE | 0.10 | 0.80 | 39.60 | 64.00 | 48.50 | 54.80 NE | 0.20 |
| 3 | 2.50 | 32.20 | 80.00 | 34.20 | 71.00 SW | 0.10 | 1.60 | 37.30 | 69.00 | 81.60 | 143.20 SW | 0.10 | 0.50 | 38.50 | 69.00 | 46.50 | 92.00 NW | 0.10 |
| 4 | 1.70 | 28.20 | 86.00 | 48.70 | 58.00 SW | 0.10 | 2.50 | 32.40 | 78.00 | 182.60 | 136.00 NW | 0.20 | 1.20 | 34.50 | 72.00 | 93.60 | 125.00 NW | 0.20 |
| 5 | 0.70 | 29.50 | 88.00 | 32.70 | 36.50 NE | 0.10 | 2.30 | 37.50 | 75.00 | 154.80 | 103.00 SW | 0.20 | 2.40 | 35.20 | 70.00 | 163.10 | 176.00 NW | 0.20 |
| 6 | 1.40 | 30.10 | 80.00 | 72.30 | 76.00 NWN | 0.10 | 2.70 | 40.10 | 65.00 | 170.50 | 334.00 NWN | 0.20 | 0.80 | 39.20 | 63.00 | 28.90 | 52.60 SE | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 1.90 | 30.60 | 78.00 | 143.60 | 324.00 NE | 0.20 | 2.40 | 38.30 | 69.00 | 103.00 | 325.00 NEE | 0.20 | 2.60 | 38.20 | 76.00 | 157.80 | 323.50 SW | 0.20 |
| 8 | 3.60 | 26.60 | 93.00 | 175.40 | 234.50 NW | 0.80 | 2.80 | 26.30 | 85.00 | 127.90 | 105.40 NW | 0.20 | 3.70 | 26.50 | 78.00 | 174.60 | 310.50NWN | 0.60 |
| 9 | 2.80 | 27.70 | 87.00 | 120.50 | 65.00 NE | 0.20 | 1.40 | 30.60 | 80.00 | 89.30 | 14I.60 NE | 0.20 | 1.70 | 31.70 | 81.00 | 47.50 | 86.00 NWN | 0.10 |
| 10 | 2.10 | 30.10 | 81.00 | 128.60 | 78.00 NEE | 0.20 | 1.40 | 31.40 | 77.00 | 110.60 | 134.50 NW | 0.10 | 2.80 | 30.20 | 78.00 | 87.50 | 148.00 SW | 0.20 |
| 11 | 1.30 | 30.70 | 80.00 | 82.30 | 86.70 NE | 0.10 | 2.30 | 33.40 | 76.00 | 124.80 | 126.00 SEE | 0.20 | 1.70 | 32.20 | 75.00 | 97.80 | 136.00 NWN | 0.10 |
| 12 | 1.30 | 34.00 | 69.00 | 118.00 | 237.50 SW | 0.10 | 1.20 | 38.40 | 67.00 | 67.80 | 80.50 SEE | 0.10 | 0.80 | 36.40 | 65.00 | 76.40 | 38.70 NWN | 0.10 |
| 13 | 2.40 | 31.20 | 78.00 | 142.40 | 315.00 NW | 0.20 | 3.10 | 36.20 | 78.00 | 184.10 | 247.5 SWW | 0.20 | 3.00 | 37.20 | 65.00 | 178.10 | 22.50 NW | 0.20 |
| 14 | 1.80 | 32.70 | 80.00 | 121.50 | 27.50 NWW | 0.20 | 1.30 | 35.10 | 74.00 | 97.80 | 152.00 NE | 0.10 | 0.90 | 34.60 | 75.00 | 52.60 | 123.00 NW | 0.10 |
| 15 | 1.50 | 33.20 | 75.00 | 118.00 | 226.50 NW | 0.10 | 1.90 | 34.80 | 75.00 | 124.30 | 145.50 SE | 0.20 | 1.80 | 34.00 | 78.00 | 136.70 | 164.50 SW | 0.20 |
| 16 | 1.10 | 31.10 | 78.00 | 79.30 | 158.00 NE | 0.10 | 1.20 | 35.70 | 73.00 | 89.60 | 236.50 NEE | 0.10 | 2.10 | 33.10 | 80.00 | 148.20 | 325.00 SE | 0.20 |
| 17 | 1.20 | 30.20 | 80.00 | 87.50 | 242.00 NW | 0.10 | 2.70 | 34.80 | 75.00 | 153.70 | 218.00 SEE | 0.30 | 1.30 | 35.30 | 73.00 | 107.80 | 140.50 SW | 0.10 |
| 18 | 2.50 | 29.50 | 93.00 | 146.30 | 72.00 NW | 0.20 | 2.30 | 36.40 | 69.00 | 146.10 | 262.00 NE | 0.20 | 2.40 | 32.80 | 80.00 | 165.40 | 77.50SWW | 0.20 |
| 19 | 0.60 | 29.90 | 93.00 | 38.20 | 212.50 SW | 0.10 | 1.60 | 35.70 | 75.00 | 124.50 | 167.5 SWN | 0.20 | 2.50 | 30.60 | 81.00 | 168.90 | 162.00 NW | 0.20 |
| 20 | 1.20 | 33.30 | 76.00 | 84.90 | 272.50 NW | 0.10 | 2.40 | 33.60 | 78.00 | 148.30 | 126.00 SW | 0.20 | 1.50 | 34.40 | 78.00 | 134.40 | 135.50 NW | 0.10 |
| 21 | 0.50 | 30.50 | 80.00 | 32.70 | 125.00 NEE | 0.10 | 0.90 | 34.70 | 81.00 | 57.10 | 325.00 NE | 0.10 | 2.30 | 33.90 | 81.00 | 156.20 | 336.50 NE | 0.20 |
| 22 | 1.40 | 29.80 | 94.00 | 116.30 | 48.00 NW | 0.10 | 1.80 | 35.40 | 74.00 | 104.60 | 132.00 SW | 0.20 | 0.70 | 33.80 | 80.00 | 47.60 | 28.00 SE | 0.10 |
| 23 | 2.80 | 30.60 | 80.00 | 153.50 | 215.00 NEE | 0.30 | 2.20 | 36.80 | 72.00 | 142.40 | 217.50 NW | 0.20 | 1.40 | 34.70 | 78.00 | 126.40 | 293.00 NE | 0.10 |
| 24 | 1.70 | 30.30 | 81.00 | 128.40 | 137.00 NW | 0.20 | 1.50 | 34.90 | 78.00 | 121.60 | 36.00 SW | 0.10 | 2.20 | 32.50 | 80.00 | 154.50 | 183.50NW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**VALUES OF METEOROLOGICAL PARAMETERS MEASURED IN THE STUDY AREAS**

**ORLU**

**METEOROLOGICAL PARAMETERS MEASURED AT UMUAKA JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/ min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/ Min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.30 | 29.90 | 86.00 | 78.60 | 202.50 SWS | 0.20 | 5.00 | 38.20 | 67.00 | 197.60 | 157.50 SES | 0.10 | 0.60 | 35.80 | 78.00 | 34.00 | 67.50 NEE | 0.10 |
| 2 | 1.50 | 30.40 | 78.00 | 75.10 | 214.60 SW | 0.10 | 3.00 | 37.60 | 74.00 | 56.50 | 152.00 SEE | 0.20 | 1.20 | 33.50 | 85.00 | 42.00 | 46.00 NE | 0.10 |
| 3 | 1.70 | 28.60 | 87.00 | 68.20 | 198.60 SW | 0.20 | 2.70 | 39.70 | 59.00 | 57.20 | 162.30 SW | 0.20 | 2.30 | 34.70 | 80.00 | 43.00 | 115.00 NE | 0.20 |
| 4 | 2.50 | 29.50 | 89.00 | 163.50 | 238.00 NW | 0.20 | 0.90 | 37.60 | 69.00 | 86.00 | 83.00 NEE | 0.20 | 1.30 | 34.30 | 82.00 | 67.30 | 205.60 NE | 0.10 |
| 5 | 1.20 | 26.60 | 84.00 | 95.30 | 103.50 SW | 0.10 | 1.70 | 39.60 | 64.00 | 145.40 | 102.50 SE | 0.10 | 1.60 | 32.80 | 85.00 | 103.00 | 102.00 NW | 0.10 |
| 6 | 0.90 | 28.20 | 90.00 | 52.30 | 68.40 NE | 0.10 | 2.60 | 38.60 | 70.00 | 162.30 | 165.80 NW | 0.20 | 1.20 | 32.70 | 87.00 | 83.60 | 235.00 SWN | 0.10 |
| 7 | 2.80 | 25.60 | 92.00 | 163.80 | 310.00 SEE | 0.20 | 1.40 | 39.60 | 67.00 | 142.90 | 67.00 SW | 0.10 | 1.70 | 33.40 | 80.00 | 91.70 | 84.00 NE | 0.10 |
| 8 | 3.10 | 30.70 | 78.00 | 127.80 | 235.80 NE | 0.30 | 3.40 | 34.70 | 72.00 | 118.20 | 253.50 NE | 0.30 | 2.70 | 25.50 | 93.00 | 97.30 | 98.50 NW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 3.20 | 29.70 | 90.00 | 118.20 | 156.00 NEE | 0.30 | 2.40 | 33.30 | 75.00 | 126.80 | 133.50 NW | 0.20 | 1.90 | 25.40 | 92.00 | 115.40 | 127.60 NE | 0.10 |
| 10 | 2.60 | 27.50 | 87.00 | 123.80 | 146.20 NE | 0.20 | 1.80 | 31.20 | 78.00 | 122.90 | 175.00 NW | 0.10 | 1.20 | 27.40 | 86.00 | 115.50 | 78.00 NE | 0.10 |
| 11 | 1.80 | 28.30 | 86.00 | 143.20 | 224.30 NE | 0.10 | 1.40 | 39.60 | 64.00 | 122.30 | 237.00 NW | 0.10 | 0.70 | 33.60 | 89.00 | 57.60 | 47.00 NE | 0.10 |
| 12 | 1.60 | 28.80 | 79.00 | 137.30 | 235.50 NEE | 0.20 | 1.30 | 40.30 | 59.00 | 112.40 | 53.40 NEE | 0.10 | 0.60 | 35.60 | 78.00 | 64.50 | 84.00 NWN | 0.10 |
| 13 | 1.70 | 29.70 | 86.00 | 114.00 | 67.50 NEE | 0.20 | 1.30 | 39.30 | 65.00 | 80.30 | 315.00NW | 0.20 | 2.60 | 36.60 | 74.00 | 155.70 | 292.50NWN | 0.20 |
| 14 | 2.50 | 28.50 | 93.00 | 164.20 | 132.00 NE | 0.20 | 1.50 | 35.20 | 74.00 | 103.10 | 146.00 NEE | 0.10 | 2.20 | 34.70 | 78.00 | 143.10 | 135.00 NW | 0.20 |
| 15 | 0.50 | 30.20 | 80.00 | 36.50 | 152.50 NW | 0.10 | 1.80 | 34.80 | 78.00 | 142.70 | 215.00 NE | 0.20 | 2.30 | 32.30 | 80.00 | 146.00 | 236.00 NE | 0.20 |
| 16 | 0.80 | 30.30 | 86.00 | 48.50 | 283.00 NE | 0.10 | 0.40 | 34.30 | 79.00 | 28.60 | 305.50 NW | 0.10 | 0.60 | 33.50 | 81.00 | 47.20 | 26.00 NW | 0.10 |
| 17 | 2.30 | 30.80 | 74.00 | 154.30 | 125.50 SE | 0.20 | 2.40 | 36.20 | 67.00 | 154.80 | 122.00 NW | 0.20 | 2.50 | 31.60 | 85.00 | 154.60 | 164.00 NE | 0.20 |
| 18 | 3.10 | 29.40 | 81.00 | 183.50 | 75.00 NW | 0.30 | 1.20 | 33.20 | 80.00 | 110.20 | 245.00 SW | 0.10 | 1.30 | 29.60 | 86.00 | 121.50 | 265.50 NE | 0.10 |
| 19; | 1.70 | 30.30 | 80.00 | 138.70 | 217.00 SW | 0.20 | 0.70 | 34.50 | 78.00 | 46.20 | 134.00 NE | 0.10 | 1.50 | 30.40 | 81.00 | 132.40 | 81.50 NWN | 0.10 |
| 20 | 1.30 | 29.70 | 86.00 | 123.50 | 153.50 NW | 0.10 | 2.20 | 35.30 | 81.00 | 151.90 | 298.00 NW | 0.20 | 1.30 | 32.80 | 78.00 | 118.60 | 39.00 NW | 0.10 |
| 21 | 2.70 | 28.60 | 93.00 | 172.60 | 103.00 NE | 0.20 | 1.60 | 36.60 | 65.00 | 123.50 | 327.50 NE | 0.20 | 1.40 | 30.90 | 93.00 | 107.00 | 172.00 NW | 0.10 |
| 22 | 3.40 | 29.60 | 93.00 | 185.30 | 165.50 NW | 0.30 | 1.20 | 35.70 | 68.00 | 103.10 | 178.00 NW | 0.10 | 1.80 | 31.50 | 89.00 | 130.40 | 236.00 NW | 0.20 |
| 23 | 2.30 | 30.20 | 81.00 | 157.20 | 326.00 NW | 0.20 | 1.90 | 32.40 | 80.00 | 128.30 | 241.00 NE | 0.20 | 0.70 | 34.20 | 75.00 | 51.40 | 325.00 SW | 0.70 |
| 24 | 1.90 | 29.80 | 93.00 | 139.80 | 43.50 NEE | 0.20 | 1.70 | 34.90 | 78.00 | 120.90 | 67.00 NWN | 0.20 | 1.20 | 30.10 | 81.00 | 116.30 | 142.00 NW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT BANANA JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow m^3/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.90 | 31.50 | 80.00 | 182.30 | 135.00SEE | 0.20 | 1.40 | 38.70 | 65.00 | 93.00 | 135.00 SE | 0.20 | 0.50 | 36.40 | 65.00 | 31.70 | 315.00 N | 0.10 |
| 2 | 2.80 | 28.60 | 85.00 | 176.20 | 141.00 NE | 0.20 | 2.40 | 39.80 | 71.00 | 87.40 | 142.00 SW | 0.20 | 0.60 | 35.20 | 70.00 | 37.80 | 274.00 NW | 0.10 |
| 3 | 2.30 | 29.10 | 86.00 | 151.40 | 146.00 SE | 0.20 | 1.80 | 40.10 | 64.00 | 83.00 | 143.00 SEE | 0.10 | 0.70 | 36.70 | 66.00 | 38.00 | 164.00 NW | 0.20 |
| 4 | 1.80 | 29.80 | 93.00 | 92.80 | 102.50 NE | 0.20 | 1.20 | 38.20 | 73.00 | 103.50 | 45.00 NW | 0.10 | 0.80 | 35.80 | 70.00 | 35.20 | 63.00 SW | 0.10 |
| 5 | 1.50 | 30.20 | 80.00 | 106.10 | 240.60SWN | 0.10 | 1.10 | 40.30 | 66.00 | 56.70 | 56.00 NE | 0.10 | 2.40 | 36.50 | 68.00 | 156.20 | 276.00 SWS | 0.20 |
| 6 | 1.50 | 31.40 | 78.00 | 93.80 | 128.00 NW | 0.10 | 1.00 | 39.80 | 68.00 | 54.50 | 120.50 NE | 0.10 | 2.60 | 36.20 | 72.00 | 145.50 | 347.50 E | 0.20 |
| 7 | 0.60 | 27.40 | 87.00 | 48.20 | 53.20 SE | 0.10 | 2.20 | 40.80 | 65.00 | 43.60 | 324.50 NE | 0.20 | 2.00 | 34.70 | 71.00 | 126.40 | 150.60 NEE | 0.20 |
| 8 | 2.80 | 30.80 | 81.00 | 145.6 | 342.00 NW | 0.20 | 3.60 | 28.40 | 78.00 | 163.00 | 305.00 NW | 3.00 | 3.10 | 28.70 | 93.00 | 137.60 | 102.00 NEE | 0.30 |
| 9 | 3.50 | 30.60 | 80.00 | 163.20 | 340.50 NW | 0.30 | 1.80 | 28.70 | 80.00 | 96.20 | 256.20 SWN | 0.10 | 1.70 | 26.80 | 94.00 | 86.70 | 145.00 NW | 0.10 |
| 10 | 1.50 | 28.80 | 86.00 | 117.20 | 103.60 NW | 0.10 | 2.20 | 32.80 | 78.00 | 143.60 | 80.50 NEE | 0.20 | 2.70 | 28.60 | 91.00 | 138.30 | 228.00 NW | 0.20 |
| 11 | 1.30 | 30.40 | 83.00 | 68.30 | 316.00 SE | 0.10 | 0.50 | 40.30 | 67.00 | 38.60 | 57.50 NEE | 0.10 | 1.10 | 33.20 | 78.00 | 63.50 | 124.30 NW | 0.10 |
| 12 | 1.40 | 29.30 | 89.00 | 105.60 | 205.00 NW | 0.10 | 2.30 | 40.80 | 64.00 | 143.30 | 144.70 NW | 0.20 | 1.20 | 36.20 | 76.00 | 103.70 | 325.00 NEE | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 2.80 | 31.30 | 85.00 | 169.20 | 202.50SWS | 0.20 | 2.40 | 38.30 | 73.00 | 146.10 | 315.0 NEN | 0.20 | 0.50 | 36.10 | 74.00 | 28.80 | 135.0 SE | 0.10 |
| 14 | 1.70 | 29.40 | 83.00 | 132.50 | 73.00 SW | 0.10 | 1.30 | 36.50 | 88.00 | 109.20 | 56.00 NE | 0.10 | 2.70 | 34.00 | 78.00 | 164.10 | 124.00 SEE | 0.20 |
| 15 | 1.10 | 30.30 | 89.00 | 87.10 | 132.00 NE | 0.10 | 1.80 | 34.60 | 89.00 | 123.40 | 237.00 NW | 0.10 | 2.10 | 30.50 | 90.00 | 156.50 | 57.50 NW | 0.20 |
| 16 | 0.80 | 29.50 | 87.00 | 54.30 | 151.40 SW | 0.10 | 1.40 | 35.40 | 80.00 | 113.50 | 72.50 NW | 0.10 | 0.70 | 31.60 | 88.00 | 46.30 | 231.00 SW | 0.10 |
| 17 | 2.10 | 30.10 | 81.00 | 158.20 | 65.00 NW | 0.20 | 1.90 | 33.70 | 89.00 | 124.30 | 323.00 NE | 0.20 | 1.40 | 30.20 | 91.00 | 89.50 | 240.00 SE | 0.10 |
| 18 | 1.60 | 28.70 | 86.00 | 136.40 | 246.00 SW | 0.10 | 1.70 | 35.60 | 86.00 | 97.60 | 124.50 NW | 0.10 | 1.60 | 32.50 | 89.00 | 124.10 | 160.00 SW | 0.10 |
| 19 | 2.40 | 30.20 | 80.00 | 160.50 | 25.00 SWS | 0.20 | 1.50 | 34.70 | 89.00 | 110.30 | 155.00 NEN | 0.10 | 2.30 | 30.70 | 90.00 | 153.80 | 134.00 SE | 0.20 |
| 20 | 1.30 | 29.30 | 85.00 | 123.60 | 84.50 NW | 0.10 | 2.70 | 33.80 | 88.00 | 162.10 | 240.50 SW | 0.20 | 0.60 | 29.80 | 95.00 | 42.20 | 67.00 NE | 0.10 |
| 21 | 0.70 | 28.80 | 93.00 | 46.00 | 322.00 NW | 0.10 | 0.60 | 35.20 | 78.00 | 38.60 | 27.50 SW | 0.10 | 1.30 | 31.70 | 89.00 | 104.60 | 231.50 NW | 0.10 |
| 22 | 2.20 | 31.09 | 89.00 | 153.80 | 45.00 NW | 0.20 | 1.80 | 33.90 | 87.00 | 120.40 | 312.00 NW | 0.10 | 2.20 | 32.30 | 87.00 | 148.30 | 146.00 NW | 0.20 |
| 23 | 1.90 | 29.80 | 93.00 | 132.70 | 213.00 SW | 0.20 | 2.60 | 34.50 | 80.00 | 153.40 | 165.0 NE | 0.20 | 2.50 | 30.10 | 90.00 | 151.80 | 221.50 NW | 0.20 |
| 24 | 1.20 | 30.40 | 88.00 | 107.40 | 98.50 NW | 0.10 | 2.30 | 34.30 | 81.00 | 148.30 | 46.50 NEE | 0.20 | 1.00 | 29.90 | 94.00 | 76.40 | 137.00 SE | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT UMUNA JUNCTION**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.60 | 33.20 | 80.00 | 93.20 | 247.50 SWW | 0.20 | 1.20 | 38.30 | 64.00 | 103.70 | 315.00 NW | 0.20 | 1.40 | 37.60 | 69.00 | 81.00 | 135.00 SE | 0.10 |
| 2 | 1.60 | 29.80 | 86.00 | 87.70 | 235.00 SW | 0.10 | 1.80 | 39.70 | 59.00 | 116.20 | 217.00 NWN | 0.10 | 2.50 | 37.30 | 70.00 | 91.50 | 128.30 SE | 0.20 |
| 3 | 1.40 | 30.30 | 90.00 | 106.20 | 224.70 SEE | 0.10 | 2.10 | 40.50 | 54.00 | 152.30 | 270.00 SW | 0.20 | 0.80 | 36.20 | 67.00 | 74.00 | 145.00 NE | 0.10 |
| 4 | 1.20 | 28.60 | 95.00 | 62.00 | 83.60 SW | 0.10 | 0.60 | 39.30 | 69.00 | 53.20 | 32.00 SW | 0.10 | 1.60 | 35.20 | 74.00 | 94.50 | 128.00 NEE | 0.20 |
| 5 | 0.70 | 28.70 | 95.00 | 54.00 | 54.00 NW | 0.10 | 2.20 | 39.80 | 70.00 | 152.00 | 256.70 SEE | 0.20 | 1.80 | 37.70 | 64.00 | 132.50 | 240.50 NEE | 0.10 |
| 6 | 2.50 | 29.40 | 88.00 | 137.20 | 184.10SWN | 0.20 | 1.20 | 41.30 | 64.00 | 87.20 | 203.00 SW | 0.10 | 2.10 | 37.40 | 69.00 | 138.30 | 123.70 NW | 0.20 |
| 7 | 1.70 | 28.20 | 93.00 | 124.00 | 113.50 NE | 0.10 | 1.20 | 38.50 | 72.00 | 96.10 | 116.00 SEE | 0.10 | 1.80 | 36.50 | 71.00 | 117.50 | 73.20 SW | 0.10 |
| 8 | 3.30 | 25.10 | 94.00 | 182.70 | 205.50 NEE | 0.30 | 3.50 | 28.60 | 83.00 | 136.80 | 217.30 NE | 0.80 | 3.00 | 25.60 | 92.00 | 117.50 | 251.60 N | 0.30 |
| 9 | 2.80 | 25.30 | 95.00 | 105.40 | 57.00 NW | 0.20 | 2.30 | 29.60 | 78.00 | 112.50 | 324.00 NW | 0.20 | 3.10 | 27.20 | 90.00 | 165.30 | 225.50 NEE | 0.30 |
| 10 | 2.70 | 29.70 | 87.00 | 134.30 | 230.50 SW | 0.20 | 1.60 | 31.70 | 75.00 | 103.10 | 243.00 SW | 0.10 | 1.60 | 29.50 | 68.00 | 72.30 | 120.50 NEE | 0.10 |
| 11 | 0.80 | 30.20 | 94.00 | 37.60 | 74.50 SW | 0.10 | 2.10 | 37.80 | 63.00 | 136.10 | 324.20 SW | 0.20 | 1.30 | 34.70 | 77.00 | 106.10 | 116.00 SEE | 0.20 |
| 12 | 2.50 | 29.70 | 88.00 | 142.20 | 56.50 NEE | 0.20 | 1.00 | 38.00 | 65.00 | 67.20 | 107.00 SE | 0.10 | 1.50 | 36.70 | 74.00 | 123.60 | 187.50 NW | 0.20 |
| 13 | 3.40 | 31.40 | 81.00 | 202.60 | 67.50 NE | 0.20 | 1.20 | 36.50 | 69.00 | 72.20 | 135.0 SE | 0.10 | 1.70 | 36.60 | 68.00 | 104.50 | 135.00 SE | 0.20 |
| 14 | 2.00 | 30.30 | 91.00 | 151.30 | 93.00 NEE | 0.20 | 0.70 | 33.40 | 88.00 | 0.10 | 124.00 SE | 0.10 | 2.20 | 34.70 | 7.00 | 154.20 | 127.00 SW | 0.20 |
| 15 | 1.80 | 31.20 | 90.00 | 138.10 | 45.50 NW | 0.10 | 1.40 | 34.70 | 84.00 | 0.10 | 327.00 SW | 0.10 | 0.60 | 33.40 | 80.00 | 36.50 | 156.00 SEE | 0.10 |
| 16 | 3.30 | 29.20 | 93.00 | 185.40 | 152.00 SW | 0.30 | 1.90 | 35.30 | 78.00 | 0.10 | 82.50 SWS | 0.10 | 2.50 | 32.60 | 81.00 | 162.40 | 223.00 NW | 0.20 |
| 17 | 1.50 | 30.10 | 92.00 | 124.60 | 130.50 NE | 0.10 | 0.50 | 36.20 | 76.00 | 0.10 | 216.00 SW | 0.10 | 1.30 | 34.30 | 75.00 | 100.20 | 271.00 NE | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | 2.30 | 29.20 | 95.00 | 154.70 | 146.00 NE | 0.20 | 1.30 | 35.40 | 77.00 | 0.10 | 325.50 NW | 0.10 | 1.40 | 33.50 | 80.00 | 87.60 | 342.5 SW | 0.10 |
| 19 | 0.80 | 30.40 | 91.00 | 47.30 | 64.00NWN | 0.10 | 2.20 | 33.70 | 83.00 | 0.20 | 136.00 SW | 0.20 | 0.80 | 32.80 | 78.00 | 43.60 | 318.00 NW | 0.10 |
| 20 | 2.20 | 29.50 | 94.00 | 150.30 | 256.00 NE | 0.20 | 0.90 | 34.50 | 85.00 | 0.10 | 243.00 SE | 0.10 | 1.50 | 31.70 | 81.00 | 120.50 | 67.50 SE | 0.10 |
| 21 | 1.90 | 30.30 | 91.00 | 126.80 | 321.00 SE | 0.10 | 2.40 | 36.20 | 78.00 | 0.20 | 126.50 SW | 0.20 | 1.40 | 34.10 | 75.00 | 92.40 | 185.00 SE | 0.10 |
| 22 | 2.10 | 32.20 | 88.00 | 152.40 | 135.00 NE | 0.20 | 1.10 | 33.80 | 87.00 | 0.10 | 147.00 SW | 0.10 | 1.60 | 30.90 | 80.00 | 102.70 | 94.00 NE | 0.10 |
| 23 | 0.40 | 30.50 | 92.00 | 32.80 | 25.00 NW | 0.10 | 1.50 | 32.70 | 89.00 | 0.10 | 68.50 NW | 0.10 | 2.30 | 29.80 | 87.00 | 154.30 | 203.50 SEE | 0.20 |
| 24 | 1.30 | 31.20 | 90.00 | 106.60 | 102.00 NE | 0.10 | 2.00 | 33.60 | 88.00 | 0.20 | 252.50 SW | 0.20 | 2.10 | 31.50 | 89.00 | 148.50 | 53.00 NW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT OGBOKO**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/ | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/ | Wind Direction (°) | Wave Height (m) |

| | | | | | | | | | | Min | | | | | | min | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.30 | 33.80 | 78.00 | 78.50 | 157.50 SES | 0.20 | 1.20 | 38.70 | 63.00 | 74.90 | 45.00 NE | 0.10 | 1.30 | 37.60 | 68.00 | 81.30 | 90.00 E | 0.10 |
| 2 | 1.40 | 32.40 | 80.00 | 93.60 | 161.00 SWN | 0.10 | 2.20 | 39.40 | 59.00 | 82.80 | 68.50 NE | 0.20 | 1.40 | 38.10 | 64.00 | 75.00 | 120.70 NE | 0.10 |
| 3 | 1.50 | 31.40 | 81.00 | 83.40 | 171.30 NW | 0.20 | 2.30 | 39.60 | 70.00 | 87.20 | 62.00 NW | 0.20 | 2.80 | 37.50 | 65.00 | 97.60 | 90.00 NE | 0.20 |
| 4 | 2.10 | 28.80 | 86.00 | 237.50 | 319.00 NEE | 0.20 | 1.40 | 40.20 | 54.00 | 126.00 | 73.50 NE | 0.20 | 1.20 | 36.70 | 70.00 | 58.00 | 73.50 NW | 0.10 |
| 5 | 2.30 | 30.40 | 80.00 | 123.40 | 215.20 NE | 0.20 | 1.80 | 37.90 | 64.00 | 168.30 | 240.50 NW | 0.10 | 1.00 | 38.20 | 59.00 | 63.80 | 36.70 SE | 0.10 |
| 6 | 1.40 | 31.60 | 83.00 | 124.30 | 173.60 NE | 0.10 | 1.70 | 38.90 | 62.00 | 128.30 | 75.30 NEE | 0.10 | 1.50 | 38.30 | 64.00 | 102.00 | 75.30 N | 0.10 |
| 7 | 2.30 | 30.70 | 82.00 | 147.50 | 209.50 NW | 0.20 | 2.70 | 39.20 | 64.00 | 104.50 | 202.50 SWN | 0.20 | 1.30 | 37.20 | 68.00 | 68.30 | 102.40NWN | 0.10 |
| 8 | 4.50 | 25.20 | 86.00 | 214.40 | 309.00 N | 0.40 | 3.80 | 27.80 | 86.00 | 187.60 | 123.70 NEE | 0.30 | 3.20 | 26.40 | 87.00 | 153.90 | 337.00NWN | 0.30 |
| 9 | 3.30 | 26.20 | 86.00 | 125.60 | 124.50 SE | 0.30 | 3.60 | 28.40 | 84.00 | 164.60 | 275.00 SW | 0.30 | 2.50 | 27.70 | 85.00 | 128.30 | 329.00 NE | 0.20 |
| 10 | 1.90 | 30.60 | 81.00 | 108.00 | 85.30 NEE | 0.10 | 1.70 | 30.40 | 78.00 | 64.50 | 124.00 NE | 0.10 | 1.40 | 30.20 | 80.00 | 105.70 | 153.00 SW | 0.10 |
| 11 | 1.20 | 31.40 | 79.00 | 117.50 | 47.00 NW | 0.10 | 1.60 | 38.30 | 64.00 | 124.50 | 112.00 NWN | 0.20 | 0.60 | 35.80 | 75.00 | 49.50 | 62.50 SW | 0.10 |
| 12 | 1.80 | 30.20 | 81.00 | 114.70 | 137.00 NE | 0.20 | 1.50 | 39.70 | 59.00 | 124.50 | 82.20 SW | 0.10 | 0.80 | 37.30 | 67.00 | 53.80 | 42.50 NW | 0.10 |
| 13 | 4.60 | 33.50 | 78.00 | 274.90 | 67.50 NEE | 0.50 | 2.90 | 34.70 | 78.00 | 174.90 | 315.0 NWN | 0.20 | 2.70 | 37.20 | 65.00 | 161.20 | 135.00 SE | 0.20 |
| 14 | 2.20 | 31.80 | 83.00 | 168.20 | 245.50NEE | 0.20 | 2.80 | 32.60 | 78.00 | 163.50 | 68.50 NW | 0.20 | 1.80 | 31.60 | 80.00 | 137.20 | 235.0 SEE | 0.20 |
| 15 | 1.60 | 32.40 | 78.00 | 136.40 | 96.00 SW | 0.10 | 1.90 | 34.80 | 76.00 | 142.10 | 212.00 SW | 0.10 | 1.20 | 32.70 | 82.00 | 94.50 | 153.00 NE | 0.10 |
| 16 | 0.70 | 30.20 | 84.00 | 43.30 | 157.50 NE | 0.10 | 1.50 | 33.70 | 90.00 | 133.60 | 165.50 NW | 0.10 | 1.60 | 34.20 | 75.00 | 123.60 | 230.50 SE | 0.10 |
| 17 | 1.50 | 31.60 | 80.00 | 132.10 | 271.00 NE | 0.10 | 0.80 | 31.60 | 80.00 | 35.00 | 237.00 NW | 0.10 | 2.30 | 30.80 | 80.00 | 152.40 | 172.00 SW | 0.20 |
| 18 | 1.60 | 30.50 | 81.00 | 135.70 | 135.50 NE | 0.10 | 1.20 | 35.20 | 69.00 | 92.50 | 84.00 NWN | 0.10 | 3.30 | 32.60 | 78.00 | 178.30 | 244.50 NE | 0.30 |
| 19 | 2.70 | 31.30 | 80.00 | 163.50 | 203.00 NE | 0.20 | 2.10 | 32.80 | 86.00 | 154.60 | 61.50NWN | 0.20 | 1.50 | 31.50 | 93.00 | 127.60 | 137.00 SE | 0.10 |
| 20 | 2.50 | 32.40 | 78.00 | 158.40 | 263.50 SW | 0.20 | 1.30 | 34.30 | 76.00 | 94.70 | 127.00 NE | 0.10 | 2.10 | 33.20 | 76.00 | 150.80 | 253.00 NW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 2.60 | 30.70 | 81.00 | 167.80 | 147.00 NW | 0.10 | 0.70 | 35.20 | 65.00 | 47.40 | 256.60 NW | 0.10 | 0.50 | 29.60 | 93.00 | 43.80 | 125.50 NW | 0.10 |
| 22 | 0.80 | 32.60 | 78.00 | 41.30 | 122.50NW | 0.10 | 1.60 | 33.20 | 80.00 | 132.60 | 93. 00 NW | 0.10 | 2.20 | 30.50 | 86.00 | 151.60 | 312.00 SW | 0.20 |
| 23 | 3.20 | 29.60 | 93.00 | 183.60 | 48.00 NE | 0.30 | 2.20 | 34.50 | 69.00 | 156.70 | 173.00 NEE | 0.20 | 0.90 | 31.20 | 83.00 | 52.40 | 83.50 SE | 0.10 |
| 24 | 2.40 | 30.10 | 82.00 | 154.80 | 325.50 SE | 0.20 | 2.40 | 33.80 | 78.00 | 167.30 | 218.50 NW | 0.20 | 3.10 | 28.90 | 95.00 | 176.30 | 248.00 NW | 0.30 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT UMUAGO URUALLA**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.00 | 35.00 | 69.00 | 58.30 | 225.00 SW | 0.10 | 1.10 | 39.50 | 59.00 | 65.85 | 202.50 SWS | 0.10 | 0.80 | 38.20 | 67.00 | 46.90 | 90.00 E | 0.10 |
| 2 | 1.20 | 33.70 | 75.00 | 64.50 | 230.00 NW | 0.10 | 1.30 | 38.60 | 64.00 | 76.00 | 200.60 SE | 0.10 | 0.90 | 38.80 | 65.00 | 52.40 | 187.00 SW | 0.10 |
| 3 | 0.80 | 32.10 | 78.00 | 62.50 | 201.00 SEE | 0.10 | 1.60 | 39.80 | 57.00 | 74.50 | 230.50 SE | 0.10 | 1.20 | 37.10 | 75.00 | 63.70 | 82.00 SE | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 1.70 | 29.30 | 78.00 | 146.00 | 206. 00 NWN | 0.10 | 1.60 | 40.30 | 53.00 | 162.00 | 124.00 NW | 0.20 | 1.00 | 36.20 | 74.00 | 46.30 | 107.00 SE | 0.10 |
| 5 | 0.50 | 31.20 | 80.00 | 37.20 | 37.00 SE | 0.10 | 1.30 | 39.20 | 68.00 | 73.20 | 67.00 SW | 0.10 | 1.20 | 37.80 | 71.00 | 93.70 | 203.60 N | 0.10 |
| 6 | 2.30 | 31.80 | 82.00 | 143.70 | 230.50 SW | 0.20 | 2.40 | 39.40 | 64.00 | 142.00 | 256.00 SE | 0.20 | 0.80 | 38.60 | 69.00 | 65.20 | 104.50 SW | 0.10 |
| 7 | 1.50 | 31.30 | 83.00 | 73.60 | 97.00 SW | 0.10 | 1.60 | 39.70 | 57.00 | 125.00 | 102.00 NW | 0.10 | 2.20 | 37.80 | 73.00 | 154.20 | 260.50 NW | 0.20 |
| 8 | 3.70 | 25.80 | 87.00 | 193.00 | 76.50 NW | 1.00 | 4.20 | 27.40 | 85.00 | 208.80 | 104.00 NWN | 1.00 | 3.80 | 25.80 | 91.00 | 176.30 | 312.80 NW | 1.00 |
| 9 | 3.60 | 25.60 | 93.00 | 172.40 | 256.00 NE | 1.00 | 2.50 | 27.80 | 86.00 | 133.70 | 67.00 NEE | 0.20 | 2.30 | 28.30 | 85.00 | 107.30 | 96.50 SW | 0.20 |
| 10 | 2.80 | 31.60 | 80.00 | 152.60 | 356.30 SE | 0.20 | 2.10 | 31.60 | 75.00 | 116.00 | 336.50 NW | 0.20 | 2.20 | 30.80 | 80.00 | 125.00 | 136.50 NWN | 0.20 |
| 11 | 1.50 | 31.80 | 77.00 | 123.40 | 125.50 NEE | 0.20 | 1.20 | 38.70 | 62.00 | 85.30 | 240.50 NE | 0.10 | 1.40 | 36.70 | 76.00 | 126.40 | 142.00 NEE | 0.20 |
| 12 | 0.70 | 30.80 | 80.00 | 63.80 | 322.00 NW | 0.10 | 2.10 | 39.40 | 63.00 | 136.20 | 132.60 NE | 0.20 | 1.10 | 37.80 | 72.00 | 116.30 | 223.00 NE | 0.10 |
| 13 | 1.90 | 34.50 | 74.00 | 114.20 | 247.50 SWW | 0.20 | 0.80 | 35.00 | 76.00 | 50.20 | 22.50 NEN | 0.10 | 0.50 | 38.00 | 64.00 | 27.70 | 135.00 SE | 0.10 |
| 14 | 1.30 | 32.40 | 83.00 | 109.20 | 316.00 SW | 0.10 | 1.50 | 34.60 | 77.00 | 123.40 | 316.50 NE | 0.10 | 1.30 | 34.30 | 77.00 | 106.30 | 214.50 NE | 0.10 |
| 15 | 2.60 | 33.20 | 76.00 | 163.70 | 68.50 NW | 0.20 | 2.30 | 35.20 | 74.00 | 154.60 | 237.00 NEE | 0.20 | 2.50 | 33.60 | 80.00 | 163.40 | 325.00 NE | 0.20 |
| 16 | 1.40 | 30.60 | 80.00 | 135.60 | 234.00 SWW | 0.10 | 0.90 | 33.70 | 78.00 | 57.10 | 196.00 NEN | 0.10 | 0.60 | 35.20 | 78.00 | 43.40 | 124.50 SE | 0.60 |
| 17 | 2.20 | 32.30 | 78.00 | 164.10 | 158.50 NW | 0.10 | 1.70 | 34.50 | 75.00 | 135.30 | 295.00 NW | 0.10 | 2.40 | 32.10 | 80.00 | 152.70 | 65.30 SEE | 0.20 |
| 18 | 1.70 | 31.20 | 81.00 | 137.40 | 264.00 SW | 0.10 | 2.60 | 30.30 | 92.00 | 164.40 | 104.00 NW | 0.20 | 2.10 | 28.70 | 87.00 | 150.70 | 143.00 SW | 0.20 |
| 19 | 2.10 | 30.50 | 80.00 | 167.50 | 136.00 SW | 0.20 | 1.40 | 32.10 | 81.00 | 118.20 | 213.00 NEE | 0.10 | 1.80 | 30.60 | 80.00 | 136.70 | 237.00 NEE | 0.10 |
| 20 | 1.00 | 31.60 | 82.00 | 96.70 | 320.00 NE | 0.10 | 2.80 | 33.40 | 76.00 | 172.50 | 346.00 NW | 0.20 | 4.20 | 31.80 | 79.00 | 204.30 | 127.50 SEE | 0.40 |
| 21 | 2.40 | 29.70 | 93.00 | 172.40 | 142.50 SW | 0.20 | 3.20 | 30.60 | 80.00 | 184.70 | 74.50 SWN | 0.30 | 1.50 | 29.40 | 86.00 | 127.20 | 48.50 NE | 0.10 |
| 22 | 2.50 | 31.80 | 82.00 | 175.30 | 56.00 SWS | 0.20 | 0.50 | 34.20 | 75.00 | 36.80 | 53.00 NEE | 0.10 | 1.70 | 30.30 | 80.00 | 138.20 | 96.00 SW | 0.10 |
| 23 | 2.80 | 29.80 | 91.00 | 178.60 | 28.50 NW | 0.30 | 2.20 | 30.40 | 81.00 | 165.20 | 261.50 SW | 0.10 | 2.80 | 28.60 | 93.00 | 183.50 | 157.50 NE | 0.20 |
| 24 | 2.20 | 30.30 | 85.00 | 166.50 | 107.00 SW | 0.20 | 0.70 | 32.50 | 86.00 | 43.60 | 84.50 NW | 0.10 | 1.50 | 30.20 | 82.00 | 124.60 | 271.00 NE | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season resul

**VALUES OF METEOROLOGICAL PARAMETERS MEASURED IN THE STUDY AREAS**

**EGBEMA**

**METEOROLOGICAL PARAMETERS MEASURED AT UMUORJI**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 2.10 | 30.20 | 78.00 | 150.10 | 247.00 NW | 0.20 | 2.30 | 38.70 | 54.00 | 172.40 | 306.20 NE | 0.20 | 1.80 | 36.10 | 59.00 | 168.40 | 253.00 SW | 0.20 |
| 2 | 2.30 | 27.80 | 83.00 | 142.30 | 134.00 NW | 0.20 | 1.70 | 36.40 | 69.00 | 117.60 | 226.00 SW | 0.20 | 1.50 | 34.50 | 68.00 | 158.40 | 204.00 NEE | 0.20 |
| 3 | 1.40 | 28.60 | 80.00 | 137.50 | 323.50 NE | 0.10 | 1.40 | 28.60 | 82.00 | 137.50 | 72.50 NW | 0.10 | 1.10 | 37.40 | 56.00 | 67.60 | 213.50 NE | 0.10 |
| 4 | 1.80 | 27.80 | 84.00 | 130.40 | 97.50 NE | 0.20 | 0.70 | 37.40 | 69.00 | 45.30 | 137.00 NW | 0.10 | 1.20 | 34.70 | 70.00 | 167.30 | 68.00 NWN | 0.10 |
| 5 | 1.70 | 29.30 | 80.00 | 134.70 | 203.40 SW | 0.10 | 1.20 | 38.50 | 65.00 | 107.00 | 243.50 NW | 0.10 | 2.50 | 35.00 | 65.00 | 164.90 | 327.30 SW | 0.20 |
| 6 | 1.60 | 27.80 | 78.00 | 75.60 | 109.60 NEE | 0.10 | 2.40 | 39.40 | 59.00 | 145.20 | 27.80 NW | 0.20 | 2.80 | 34.80 | 72.00 | 173.80 | 76.30 SW | 0.20 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 0.80 | 28.50 | 82.00 | 48.30 | 234.50 NWN | 0.10 | 1.60 | 39.70 | 54.00 | 126.80 | 104.40 SW | 0.10 | 1.70 | 36.80 | 64.00 | 126.80 | 205.40 NE | 0.10 |
| 8 | 3.50 | 24.70 | 90.00 | 191.20 | 342.70 NW | 0.70 | 3.20 | 29.40 | 90.00 | 179.00 | 283.50 NE | 0.30 | 3.60 | 24.00 | 85.00 | 192.60 | 146.20 NWN | 1.00 |
| 9 | 2.90 | 27.10 | 88.00 | 124.20 | 128.00 NE | 0.20 | 2.10 | 38.30 | 71.00 | 136.10 | 312.00 NE | 0.20 | 1.60 | 36.50 | 67.00 | 114.60 | 75.00 NE | 0.10 |
| 10 | 2.30 | 31.10 | 77.00 | 152.60 | 315.00 NW | 0.20 | 2.60 | 36.50 | 65.00 | 125.30 | 247.50 SWS | 0.10 | 0.60 | 38.80 | 66.00 | 34.20 | 292.50 NWW | 0.10 |
| 11 | 1.60 | 29.20 | 85.00 | 123.60 | 328.00 NW | 0.10 | 0.90 | 37.80 | 66.00 | 46.50 | 334.50 NWN | 0.10 | 1.20 | 36.40 | 70.00 | 108.20 | 328.00 NWN | 0.10 |
| 12 | 1.60 | 28.60 | 87.00 | 117.90 | 342.70 NWN | 0.10 | 1.20 | 39.50 | 57.00 | 117.00 | 236.50 NW | 0.10 | 0.50 | 34.60 | 76.00 | 42.30 | 75.00 NE | 0.10 |
| 13 | 2.40 | 33.80 | 74.00 | 143.50 | 112.5 SEE | 0.20 | 2.60 | 38.40 | 58.00 | 164.00 | 157.5 SES | 0.20 | 1.40 | 35.40 | 73.00 | 102.10 | 315.00 NW | 0.20 |
| 14 | 2.20 | 33.30 | 76.00 | 151.30 | 263.50 SW | 0.20 | 3.20 | 34.50 | 84.00 | 183.20 | 25.50 SW | 0.30 | 0.90 | 32.80 | 78.00 | 57.60 | 85.00 NWN | 0.10 |
| 15 | 1.10 | 31.20 | 79.00 | 104.60 | 175.00 SEE | 0.10 | 2.80 | 33.40 | 75.00 | 172.00 | 72.50 SE | 0.20 | 2.20 | 34.20 | 69.00 | 154.30 | 57.50 NW | 0.20 |
| 16 | 2.40 | 30.50 | 80.00 | 165.30 | 242.50 NE | 0.20 | 1.40 | 32.70 | 78.00 | 143.00 | 183.00 SW | 0.10 | 1.30 | 33.50 | 75.00 | 124.70 | 234.00 NE | 1.00 |
| 17 | 2.50 | 30.10 | 82.00 | 169.30 | 351.00 SW | 0.20 | 2.20 | 31.30 | 79.00 | 136.40 | 235.00 SE | 0.20 | 2.40 | 29.70 | 87.00 | 162.40 | 126.50 SE | 0.20 |
| 18 | 2.80 | 33.20 | 78.00 | 174.50 | 127.00 NW | 0.30 | 2.00 | 35.60 | 74.00 | 148.20 | 321.50 SEE | 0.20 | 3.20 | 31.40 | 80.00 | 183.20 | 302.00 NE | 0.30 |
| 19 | 1.40 | 30.40 | 80.00 | 132.60 | 272.00 NW | 0.10 | 1.80 | 31.70 | 78.00 | 133.50 | 178.00 SW | 0.10 | 0.60 | 30.30 | 81.00 | 42.50 | 70.50 NW | 0.10 |
| 20 | 1.70 | 29.50 | 93.00 | 138.30 | 125.00 SW | 0.10 | 0.60 | 30.40 | 81.00 | 36.60 | 124.00 SES | 0.10 | 2.10 | 28.90 | 93.00 | 152.70 | 137.00 SW | 0.20 |
| 21 | 2.60 | 30.30 | 81.00 | 156.60 | 74.50 NEE | 0.20 | 1.20 | 31.20 | 80.00 | 108.70 | 27.00 SE | 0.10 | 1.90 | 30.10 | 85.00 | 143.40 | 263.50 NW | 0.20 |
| 22 | 0.80 | 28.20 | 88.00 | 43.70 | 322.00 NW | 0.10 | 1.30 | 29.60 | 87.00 | 125.20 | 284.50 NE | 0.10 | 2.30 | 28.30 | 86.00 | 155.60 | 145.50 NW | 0.20 |
| 23 | 1.20 | 30.20 | 80.00 | 108.20 | 57.00 SE | 0.10 | 2.50 | 31.50 | 80.00 | 151.90 | 128.00 NW | 0.20 | 0.70 | 30.40 | 83.00 | 46.30 | 97.50 NE | 0.10 |
| 24 | 2.10 | 29.70 | 90.00 | 148.20 | 219.50 SEE | 0.20 | 1.80 | 30.70 | 85.00 | 136.30 | 130.50 SW | 0.20 | 2.00 | 29.20 | 92.00 | 150.50 | 263.00 SW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT UKWUGBA 1**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 1.40 | 30.70 | 79.00 | 102.10 | 321.50 SW | 0.10 | 0.90 | 38.30 | 65.00 | 56.00 | 218.00 NWN | 0.10 | 1.30 | 36.50 | 68.00 | 136.20 | 312.50 NW | 0.10 |
| 2 | 0.70 | 28.10 | 76.00 | 64.60 | 56.50 SW | 0.10 | 1.00 | 37.20 | 68.00 | 57.30 | 157.50 NWN | 0.10 | 1.20 | 35.70 | 80.00 | 103.50 | 327.50 NW | 0.20 |
| 3 | 2.60 | 27.60 | 92.00 | 36.20 | 67.00 NWN | 0.20 | 2.30 | 37.30 | 70.00 | 155.20 | 137.00 SW | 0.20 | 1.30 | 38.70 | 69.00 | 82.40 | 93.00 NW | 0.10 |
| 4 | 1.20 | 27.40 | 93.00 | 146.30 | 74.60 SW | 0.10 | 2.20 | 38.20 | 73.00 | 165.60 | 324.50 SW | 0.20 | 1.70 | 35.30 | 76.00 | 146.60 | 158.50 SW | 0.20 |
| 5 | 2.60 | 29.80 | 87.00 | 193.60 | 342.80 NW | 0.20 | 2.80 | 38.70 | 66.00 | 183.40 | 282.00 NE | 0.20 | 2.40 | 34.70 | 73.00 | 145.50 | 123.00 NW | 0.20 |
| 6 | 2.40 | 34.70 | 75.00 | 145.50 | 271.50 NW | 0.20 | 1.70 | 38.80 | 57.00 | 115.00 | 205.00 NE | 0.10 | 1.30 | 33.80 | 76.00 | 51.40 | 53.50 NEE | 0.10 |
| 7 | 1.50 | 29.30 | 86.00 | 109.50 | 49.30 SW | 0.10 | 2.70 | 39.20 | 64.00 | 168.30 | 287.00 SWS | 0.20 | 2.20 | 37.20 | 74.00 | 173.60 | 116.80 NW | 0.20 |
| 8 | 2.90 | 25.30 | 88.00 | 167.10 | 109.00 NE | 0.20 | 3.70 | 30.60 | 81.00 | 186.30 | 123.50 NW | 1.00 | 3.30 | 25.50 | 87.00 | 172.50 | 68.50 NE | 0.30 |
| 9 | 3.50 | 28.60 | 85.00 | 174.60 | 326.10 NWN | 1.00 | 2.40 | 39.40 | 59.00 | 143.40 | 165.60 NWN | 0.20 | 3.10 | 37.80 | 65.00 | 167.50 | 237.50 NWN | 0.30 |
| 10 | 1.60 | 33.10 | 74.00 | 79.10 | 337.00 NWN | 0.20 | 1.70 | 38.20 | 73.00 | 76.20 | 337.50 NWN | 0.10 | 0.80 | 38.10 | 58.00 | 22.70 | 337.50 NWN | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 2.20 | 30.30 | 80.00 | 124.70 | 237.00 SWS | 0.20 | 1.50 | 37.40 | 65.00 | 113.80 | 249.00 SWW | 0.10 | 0.70 | 37.70 | 73.00 | 59.80 | 226.10 NW | 0.10 |
| 12 | 2.30 | 29.80 | 85.00 | 156.30 | 129.00 NE | 0.20 | 0.70 | 38.70 | 66.00 | 56.30 | 323.00 NW | 0.10 | 1.10 | 35.50 | 76.00 | 104.20 | 347.00 SWN | 0.10 |
| 13 | 0.50 | 33.30 | 76.00 | 48.00 | 315.00 NW | 0.10 | 0.90 | 39.20 | 54.00 | 51.20 | 315.00 NW | 0.10 | 0.60 | 36.10 | 69.00 | 65.90 | 225.00 SW | 0.10 |
| 14 | 1.30 | 33.60 | 75.00 | 113.40 | 122.00 NE | 0.10 | 2.40 | 34.50 | 57.00 | 167.50 | 267.00 NW | 0.20 | 2.10 | 32.30 | 78.00 | 158.20 | 162.00 NW | 0.20 |
| 15 | 1.40 | 30.50 | 80.00 | 120.20 | 145.00 SW | 0.10 | 1.60 | 32.80 | 82.00 | 154.30 | 107.50 NE | 0.10 | 2.20 | 30.50 | 80.00 | 161.40 | 247.00 NW | 0.20 |
| 16 | 0.60 | 31.70 | 79.00 | 37.50 | 324.00 NW | 0.10 | 1.80 | 34.60 | 73.00 | 132.40 | 145.00 SW | 0.20 | 2.50 | 33.10 | 77.00 | 164.20 | 342.50 SW | 0.20 |
| 17 | 1.80 | 30.40 | 83.00 | 132.40 | 167.50 NW | 0.20 | 0.60 | 33.80 | 78.00 | 36.70 | 234.00 NW | 0.10 | 0.80 | 32.40 | 81.00 | 46.20 | 152.50 NW | 0.10 |
| 18 | 2.10 | 33.30 | 78.00 | 158.30 | 132.00 NW | 0.20 | 1.20 | 35.30 | 72.00 | 106.20 | 192.50 NW | 0.10 | 1.50 | 32.70 | 84.00 | 132.40 | 37.00 SW | 0.10 |
| 19 | 2.50 | 30.60 | 80.00 | 163.80 | 46.00 NWN | 0.20 | 2.10 | 33.90 | 76.00 | 165.30 | 327.60 NE | 0.20 | 1.60 | 30.80 | 80.00 | 135.20 | 48.00 SWE | 0.10 |
| 20 | 2.30 | 29.20 | 88.00 | 159.70 | 260.00 SE | 0.20 | 2.90 | 32.70 | 80.00 | 176.50 | 73.00 NEE | 0.30 | 1.20 | 31.30 | 79.00 | 114.50 | 126.00 NW | 0.10 |
| 21 | 0.80 | 31.40 | 82.00 | 46.40 | 64.00 NWW | 0.10 | 3.20 | 33.50 | 78.00 | 187.50 | 157.00 NW | 0.30 | 3.20 | 32.50 | 82.00 | 182.60 | 239.00 SWE | 0.30 |
| 22 | 1.20 | 28.60 | 93.00 | 110.00 | 157.00 NW | 0.10 | 2.00 | 29.70 | 85.00 | 167.30 | 178.00 NW | 0.20 | 0.80 | 30.10 | 81.00 | 47.80 | 175.00 NW | 0.10 |
| 23 | 3.30 | 30.70 | 80.00 | 183.50 | 73.50 NW | 0.30 | 1.40 | 34.40 | 70.00 | 128.20 | 260.50 NEE | 0.10 | 1.40 | 31.60 | 80.00 | 124.50 | 225.00 NE | 0.10 |
| 24 | 1.60 | 29.80 | 93.00 | 135.60 | 245.00 NW | 0.10 | 0.50 | 33.60 | 75.00 | 34.50 | 305.00 NW | 0.10 | 1.70 | 32.40 | 78.00 | 136.20 | 63.00 SW | 0.20 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT UKWUBGA 2**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) | Wind Speed (m/s) | Ambient Temp. (°C) | R.H (%) | Air flow $m^3$/min | Wind Direction (°) | Wave Height (m) |
| 1 | 0.80 | 31.30 | 78.00 | 36.60 | 317.00 NWN | 0.10 | 1.20 | 39.00 | 65.00 | 106.30 | 67.50 NW | 0.20 | 1.50 | 35.50 | 72.00 | 97.00 | 293.00 NE | 0.20 |
| 2 | 1.30 | 30.40 | 81.00 | 82.70 | 164.00 NEE | 0.20 | 0.60 | 35.60 | 69.00 | 31.60 | 45.00 NW | 0.10 | 0.80 | 32.40 | 82.00 | 47.30 | 55.00 SW | 0.10 |
| 3 | 1.90 | 29.40 | 85.00 | 73.80 | 278.50 SW | 0.20 | 1.60 | 35.60 | 59.00 | 170.60 | 47.00 NW | 0.10 | 1.50 | 36.30 | 68.00 | 102.10 | 252.50 SWN | 0.20 |
| 4 | 1.60 | 30.50 | 80.00 | 172.80 | 123.00 NW | 0.20 | 1.30 | 38.70 | 57.00 | 93.70 | 236.00 NE | 0.10 | 1.90 | 34.20 | 75.00 | 178.20 | 304.00 NW | 0.20 |
| 5 | 1.50 | 29.70 | 92.00 | 106.80 | 108.00 NE | 0.10 | 0.60 | 39.50 | 54.00 | 48.30 | 74.60 NWN | 0.10 | 1.30 | 36.80 | 69.00 | 106.00 | 45.70 NE | 0.10 |
| 6 | 2.40 | 31.30 | 80.00 | 150.10 | 328.00 SW | 0.20 | 2.60 | 40.20 | 63.00 | 162.40 | 336.50 SW | 0.20 | 2.10 | 35.30 | 76.00 | 152.30 | 124.60 NW | 0.20 |
| 7 | 2.40 | 30.60 | 82.00 | 152.60 | 39.50 NW | 0.20 | 1.20 | 38.40 | 69.00 | 108.50 | 114.50 NE | 0.10 | 1.80 | 35.30 | 74.00 | 142.90 | 108.00 NE | 0.10 |
| 8 | 3.10 | 29.80 | 87.00 | 183.50 | 214.50 NW | 0.30 | 2.80 | 33.80 | 76.00 | 165.20 | 76.00 NW | 0.20 | 3.10 | 28.70 | 89.00 | 167.80 | 218.00 NW | 0.30 |
| 9 | 2.70 | 28.60 | 93.00 | 115.50 | 263.40 SW | 0.20 | 1.80 | 39.40 | 70.00 | 128.20 | 315.00 SW | 0.10 | 2.50 | 35.40 | 77.00 | 136.00 | 320.30 NEE | 0.20 |
| 10 | 1.50 | 35.40 | 74.00 | 71.60 | 337.5 NWN | 0.10 | 1.20 | 37.80 | 64.00 | 96.10 | 315.00 NW | 0.20 | 0.40 | 38.20 | 68.00 | 24.60 | 45.00 NE | 0.20 |
| 11 | 1.70 | 28.90 | 89.00 | 110.50 | 124.50 NEE | 0.20 | 2.30 | 39.70 | 67.00 | 132.50 | 136.50 NW | 0.20 | 1.40 | 35.70 | 72.00 | 123.70 | 273.50 SWW | 0.20 |
| 12 | 1.40 | 27.30 | 86.00 | 91.20 | 234.50 NW | 0.10 | 2.30 | 38.40 | 70.00 | 145.20 | 126.00 NWN | 0.20 | 0.80 | 33.80 | 89.00 | 54.20 | 232.50 NWW | 0.10 |
| 13 | 0.50 | 34.40 | 75.00 | 27.70 | 225.00SWW | 0.10 | 1.70 | 41.40 | 54.00 | 66.50 | 202.50 SWS | 0.20 | 2.50 | 34.20 | 81.00 | 150.80 | 292.50 NW | 0.20 |
| 14 | 1.30 | 30.60 | 82.00 | 120.30 | 170.50 NW | 0.10 | 2.10 | 34.60 | 77.00 | 151.60 | 142.60 NW | 0.20 | 1.50 | 31.40 | 83.00 | 132.40 | 122.00 NW | 0.10 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 2.50 | 31.30 | 80.00 | 162.40 | 127.00 SW | 0.20 | 3.30 | 33.70 | 86.00 | 184.50 | 163.00 SE | 0.30 | 1.10 | 33.20 | 86.00 | 106.20 | 239.00 NE | 0.10 |
| 16 | 0.60 | 29.70 | 93.00 | 34.50 | 63.00 NW | 0.10 | 0.40 | 35.20 | 78.00 | 29.50 | 215.00 SW | 0.10 | 0.60 | 30.90 | 80.00 | 46.70 | 353.50 SWN | 0.10 |
| 17 | 2.50 | 30.50 | 84.00 | 172.40 | 85.50 SWW | 0.20 | 1.50 | 34.20 | 75.00 | 134.60 | 236.50 SWS | 0.10 | 2.80 | 34.50 | 79.00 | 173.60 | 82.50 NW | 0.20 |
| 18 | 1.80 | 31.60 | 80.00 | 136.20 | 36.00 NE | 0.20 | 1.90 | 35.60 | 69.00 | 147.30 | 67.50 SW | 0.10 | 0.70 | 32.70 | 87.00 | 51.20 | 162.00 NW | 0.10 |
| 19 | 0.70 | 32.30 | 86.00 | 43.20 | 28.00 NW | 0.10 | 3.10 | 34.50 | 76.00 | 182.40 | 332.00 SSE | 0.30 | 1.60 | 33.30 | 76.00 | 142.10 | 234.00 SW | 0.10 |
| 20 | 3.20 | 28.80 | 93.00 | 184.50 | 114.00 NW | 0.30 | 1.30 | 33.40 | 78.00 | 118.60 | 124.40 SW | 0.10 | 2.40 | 30.50 | 78.00 | 164.60 | 93.00 SE | 0.20 |
| 21 | 0.90 | 30.60 | 81.00 | 47.20 | 302.00 SW | 0.10 | 0.70 | 33.90 | 70.00 | 43.80 | 235.00 NWN | 0.10 | 1.80 | 32.80 | 81.00 | 138.40 | 253.50 NW | 0.20 |
| 22 | 2.80 | 31.40 | 80.00 | 174.20 | 143.50 SES | 0.30 | 0.80 | 30.30 | 87.00 | 46.50 | 148.00 SW | 0.10 | 1.20 | 29.40 | 92.00 | 117.60 | 60.50 SW | 0.10 |
| 23 | 1.20 | 30.80 | 84.00 | 109.70 | 192.0 NE | 0.20 | 1.40 | 34.80 | 77.00 | 130.40 | 127.00 SWS | 0.10 | 2.20 | 32.10 | 90.00 | 148.30 | 78.00 SW | 0.20 |
| 24 | 2.60 | 31.50 | 82.00 | 153.40 | 287.00 SWE | 0.20 | 2.50 | 34.10 | 80.00 | 146.30 | 65.50 NW | 0.20 | 1.70 | 30.60 | 79.00 | 127.50 | 326.00 NW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results

**METEOROLOGICAL PARAMETERS MEASURED AT OPUOMA**

| | MORNING | | | | | | AFTERNOON | | | | | | EVENING | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Week | Wind Speed | Ambient Temp. | R.H | Air flow | Wind Direction | Wave Height | Wind Speed | Ambient Temp | R.H (%) | Air flow | Wind Direction | Wave Height | Wind Speed | Ambient Temp. | R.H | Air flow | Wind Direction | Wave Height |

| | (m/s) | (°C) | (%) | $m^3$/ min | (°) | (m) | (m/s) | (°C) | | $m^3$/ min | (°) | (m) | (m/s) | (°C) | (%) | $m^3$/ min | (°) | (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.50 | 31.80 | 77.00 | 93.50 | 47.30 NE | 0.20 | 1.30 | 37.50 | 65.00 | 136.60 | 230.40 SW | 0.20 | 1.70 | 37.30 | 69.00 | 128.50 | 183.60 NW | 0.20 |
| 2 | 2.50 | 28.60 | 90.00 | 158.20 | 35.50 NW | 0.20 | 1.80 | 38.10 | 68.00 | 135.70 | 237.50 NE | 0.20 | 1.40 | 36.30 | 70.00 | 86.20 | 86.50 SWW | 0.20 |
| 3 | 2.30 | 30.70 | 78.00 | 276.00 | 146.00 NW | 0.20 | 2.70 | 38.70 | 67.00 | 268.10 | 25.50 NE | 0.20 | 2.30 | 40.10 | 64.00 | 146.50 | 145.00 SW | 0.20 |
| 4 | 2.40 | 28.70 | 86.00 | 176.00 | 217.00 SW | 0.20 | 1.50 | 39.40 | 58.00 | 126.40 | 125.00 NW | 0.20 | 1.10 | 35.80 | 70.00 | 93.50 | 204.50 SW | 0.10 |
| 5 | 2.20 | 30.50 | 78.00 | 172.80 | 256.10 NWN | 0.20 | 2.70 | 38.80 | 65.00 | 165.90 | 315.00 SW | 0.20 | 2.60 | 36.30 | 68.00 | 176.20 | 210.00 NWN | 0.20 |
| 6 | 1.80 | 29.40 | 89.00 | 96.30 | 58.40 NE | 0.10 | 0.50 | 39.60 | 64.00 | 34.70 | 124.00 NWN | 0.10 | 2.00 | 35.70 | 77.00 | 146.70 | 234.00 SWS | 0.20 |
| 7 | 1.70 | 31.20 | 76.00 | 136.40 | 179.00 SWW | 0.10 | 2.30 | 40.30 | 57.00 | 145.90 | 86.30 NW | 0.20 | 2.50 | 38.70 | 67.00 | 192.10 | 267.50 SW | 0.20 |
| 8 | 4.30 | 25.80 | 92.00 | 206.40 | 65.30 NWN | 1.00 | 4.50 | 27.40 | 80.00 | 208.70 | 203.40 NE | 1.00 | 2.80 | 25.40 | 88.00 | 148.20 | 53.60 NE | 0.20 |
| 9 | 3.20 | 29.50 | 89.00 | 153.40 | 322.80 NW | 0.30 | 1.70 | 39.90 | 65.00 | 145.90 | 124.50 NW | 0.10 | 2.80 | 38.40 | 65.00 | 126.20 | 153.00 NW | 0.20 |
| 10 | 3.70 | 35.50 | 75.00 | 222.00 | 247.00 SW | 0.30 | 1.30 | 38.50 | 72.00 | 87.10 | 315.00 NW | 0.10 | 1.60 | 41.30 | 59.00 | 122.30 | 247.30 SWW | 0.10 |
| 11 | 2.40 | 31.60 | 80.00 | 156.30 | 286.30 SW | 0.20 | 1.80 | 41.60 | 59.00 | 127.30 | 273.00 SWN | 0.20 | 0.50 | 38.60 | 64.00 | 38.60 | 228.60 NW | 0.10 |
| 12 | 2.10 | 30.40 | 76.00 | 126.20 | 265.00 NEE | 0.20 | 1.40 | 39.80 | 63.00 | 124.60 | 63.50 NE | 0.10 | 1.50 | 36.70 | 70.00 | 126.60 | 136.50 NWN | 0.20 |
| 13 | 0.90 | 34.30 | 78.00 | 56.90 | 27.00 W | 0.10 | 1.90 | 34.80 | 74.00 | 113.90 | 45.00 NE | 0.20 | 4.10 | 34.00 | 75.00 | 259.50 | 247.50 SWW | 0.40 |
| 14 | 3.30 | 30.80 | 82.00 | 184.50 | 125.0 NW | 0.30 | 1.50 | 33.50 | 78.00 | 134.50 | 123.50 NW | 0.10 | 1.30 | 30.40 | 87.00 | 128.30 | 123.00 NW | 0.10 |
| 15 | 2.30 | 31.50 | 85.00 | 164.30 | 320.50 NE | 0.20 | 0.90 | 34.60 | 75.00 | 51.40 | 236.00 SWW | 0.10 | 2.70 | 32.50 | 78.00 | 174.50 | 216.00 SW | 0.20 |
| 16 | 1.60 | 29.80 | 90.00 | 137.10 | 74.00 SW | 0.10 | 2.20 | 32.30 | 80.00 | 163.60 | 63.50 SEE | 0.20 | 0.90 | 30.70 | 93.00 | 54.60 | 118.40 NW | 0.10 |
| 17 | 0.50 | 31.20 | 86.00 | 29.60 | 283.50 NW | 0.10 | 2.10 | 33.60 | 77.00 | 168.20 | 185.00 NEE | 0.20 | 2.60 | 34.30 | 76.00 | 168.70 | 137.00 | 0.20 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | SWS | |
| 18 | 2.10 | 32.40 | 79.00 | 173.50 | 35.00 SW | 0.20 | 2.50 | 35.20 | 74.00 | 175.30 | 294.00 NE | 0.20 | 3.10 | 33.60 | 78.00 | 183.40 | 262.50 SW | 0.30 |
| 19 | 1.90 | 32.70 | 89.00 | 141.40 | 273.00 NW | 0.20 | 2.60 | 33.70 | 78.00 | 178.50 | 153.70 SW | 0.20 | 0.60 | 31.80 | 80.00 | 47.30 | 86.00 NW | 0.10 |
| 20 | 0.80 | 29.30 | 93.00 | 47.40 | 134.00 NE | 0.10 | 3.20 | 31.80 | 80.00 | 186.20 | 335.00 NE | 0.30 | 2.70 | 30.30 | 82.00 | 167.90 | 73.00 NE | 0.30 |
| 21 | 1.40 | 32.50 | 87.00 | 123.50 | 45.50 NWW | 0.10 | 1.60 | 34.30 | 79.00 | 147.40 | 89.00 NW | 0.10 | 1.80 | 33.70 | 89.00 | 141.60 | 242.50 SW | 0.20 |
| 22 | 1.30 | 31.90 | 90.00 | 116.40 | 271.00 NE | 0.10 | 0.70 | 35.10 | 80.00 | 46.30 | 123 50 SW | 0.10 | 1.20 | 31.50 | 84.00 | 110.80 | 124.60 NW | 0.10 |
| 23 | 2.60 | 31.00 | 86.00 | 162.50 | 142.50SW | 0.20 | 2.40 | 32.50 | 83.00 | 163.60 | 67.00 NWW | 0.20 | 2.20 | 30.60 | 93.00 | 153.20 | 310.00 SW | 0.20 |
| 24 | 1.20 | 32.20 | 80.00 | 105.30 | 98.00 NW | 0.10 | 1.50 | 33.40 | 84.00 | 136.10 | 241.00 NW | 0.10 | 0.80 | 32.20 | 85.00 | 52.40 | 169.00 NW | 0.10 |

Note ; Week 1-12 : dry season results, week 13 – 24 wet season results