COMPARATIVE ANALYSIS OF AMBIENT AIR QUALITY STATUS IN RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SETTLEMENTS IN BAYELSA STATE, NIGERIA.

[1]Ubuoh, E.A. [2]Kanu, C. [3]Ikwa, L. O.
[1&2]Department of Environmental Management and Toxicology (EMT),
Michael Okpara University of Agriculture, Umudike (MOUAU), P.M.B. 7267.
[3]Department of Forestry and Environmental Management (FOREM),
Michael Okpara University of Agriculture, Umudike
Corresponding author: E-mail:*ubuohemmanuel@yahoo.com*. Tel: +2348037639777

Abstract
This work focused on the assessment of ambient air quality in Yenogoa, Bayelsa State, Nigeria. The study area was divided into three zones viz: Residential , Commercial and Industrial and Areas with sub-locations for air quality sampling .Ambient air quality is affected adversely by the emission of gaseous pollutants, which include: Oxides of Carbon (COx), Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx) and Particulate matter alongside temperature and relative humidity. The respective zones were measured at standard atmospheric pressure (1 atmosphere) and recorded. The collected data were statistically analysed using statistical tools such as: Mean (X), standard deviation (SD) and coefficient of variance (CV). The calculated values were correlated to the Environmental Protection Agency (EPA) Air Quality Index (AQI) to ascertain humans' health implication of each of the pollutants. Apart from the mean value of 64 μgm^{-3} NO_2that was below AQI, all other parameters affected human health in the area. Using DOE threshold , results of $PM_{2.5}$, SO_2 and NO_2Residential, commercial and industrial were in order of - $PM_{2.5}>SO_2>NO_2$, with $PM_{2.5}$ (94.5%), SO_2 4.3% and NO_2 recording 1.2%.Based on the results, it is recommended that existing environmental laws and regulations by enforced for compliance in the area by an authorized bodies and gas flared should be revolutionized .

Keywords: Ambient air Quality, settlements, gas flaring, health.

1.0 Introduction

Urban agglomerations are places of increased emissions of anthropogenic pollutants into the atmosphere. Concentrations of air pollutants are not only governed by various physical, chemical, or biological processes within the atmosphere, but also by anthropogenic actions. The dependency of air quality on economic development is also reflected in a typical temporal sequence of air pollutant levels (Fenger 1999). Air quality issues sometimes represent challenging environmental problems currently faced by societies as more and more studies suggest impacts of atmospheric pollution on human health and environment as a whole (Desauziers, 2004).Poor air quality most notably occurs in urban areas where some (or all) of the following factors exist (Kindzierski and Scotten, 2004): numerous sources emitting air pollutants (e.g. automobile, industrial and commercial activities), meteorology (e.g. poor mixing conditions in the atmosphere), irregular topographic features, and large populations. It is reported that over 70-80% of air pollution in mega cities in developing nations is attributed to vehicular emissions caused by a large number of older vehicles coupled with poor vehicle maintenance, inadequate road infrastructure and low fuel quality (Gulia*et al*, 2015).

Evidences from various governmental organizations and international bodies have proven that air pollution is a major risk to the environment, quality of life, and health of the population (Colbeck and Nasir, 2010; WHO,2000a;2004a,b,2007).

Economic development, urbanization, energy consumption, transportation/motorization and rapid population growth are major driving forces of air pollution (Colbeck and Lazaridis, 2010). In Nigeria, growing cities, increasing traffic, rapid economic development and higher levels of energy consumption lead to the pollution of air.The predominant industrial activities that are going on in areas, especially the upstream and downstream sectors, as well as others anthropogenically related activities including biomass combustion, refuse burning, gas flaring and traffic emissions release a barrage of substance like volatile organic compounds, oxides of nitrogen, oxides of sulphur, particulate matter and methane at levels that most times exceed both national and international limits(Ana, 2015). Based on these, there is needto monitor the ambient air quality of residential, commercial and industrial areas of Bayelsa where incessant gas flaring and other anthropogenic activities are the order of the day for environmental sustainability.

2.0 Materials and Methods

2.1 Study Area: Yenagoa which is the capital of Bayelsa State, is situated in the Southern part of Nigeria. It covers 21,100 sq. kilometers and it is geographically located within latitude 04^0 15'N, 05^0 22' N and 60^0 45' E. According to 2006 population census (NPC, 2006). Yenagoa has a population of over two million (2,000, 000). The main monthly temperature is between 26^0C

to 28^{0}C. Annual rainfalls areheavy, between 3,000mm to 3,500mm. Therelative humidity in the area ranged between 80% to85%.The study area is predominantly oil exploration and exploitation with incessant gas flaring (Nwachukwu and Ugwuanyi, 2010; Osuji and Avwiri, 2005; Ugwuanyi and Obi, 2002; Oyekunle, 1999).

2.2 Air Sampling Techniques: The study was conducted at nine randomly selected stations in residential, commercial and industrial areas, and sampling was done for 6 months . Study locations were further subdivided into three points each based on the activities prevalence in the area:

2.2.1 Commercial Settlement (CS): Point 1(Pt1)- Amarata (AM), Point 2(Pt2)- Swali (SW) and Point 3(Pt3) Onopa (ON) were selected to get representative air quality samples. These areas are highly populated, businesses in the area are very intense and because of that, the amount of vehicular movement in these areas is quite high.

2.2.2 Industrial Settlement (IS): Point 1(Pt1)- Oloibiri (OL), Point 2(Pt2)Imiringa (IM), Point 3(Pt3) - Gbarain (GB) were selected to get representative air quality samples. These areas are highly industrialized areas where gas is incessantly flared.

2.2.3 Residential Settlement (RS): Point 1(Pt1)Kpansia (KP), Point 2(Pt2), Biogbolo (BI) Point 3(Pt3), with indiscriminate dumping and burning of refuse which pollutes the acid as observed.Monitoring of air quality and climatic variables (Table 1) were done in the ambient air during dry season (January-March). Triplicate sample collection was carried out in each study station during the study seasons and the average values for each parameter was determined. The weather characteristics (temperature, relative humidity). The air sampling (8 hourly basis) was carried out between the months of Jan-March in all the selected stations during day time using equipment in Table 1:

Table 1: Methods used in determining the Gaseous Emissions and Meteorological Variables

Parameters	**Air Monitors**	**Range**	**Alarm**
CO (μgm^{-3})	CO monitor Gasman model 1925H	0-50ppm	50ppm
NO_2 (μgm^{-3})	NO_2 Gas monitor Gasman model 1983N	0-10ppm	3.0ppm
SO_2 (μgm^{-3})	SO_2 Gas monitor Gasman model 19648H	0-10ppm	2.0ppm
PM_{10} (μgm^{-3})	Haz-Dust TM particulate monitor	0.1-200	+1.0
Temp (Oc)	Thermometer	10 – 50◦C	-
R. Humidity (%)	Multi -purpose Hydro. model	(20-100%	-

The collected air quality data were then compared to the Ambient Air Quality Standard (prescribed limit) set by the Environmental Protection 1995(Table 2) to determine health effects on the people as follows**:**

Table: 2 Air Quality Index (A.Q.I): Health implication

Air Quality index (AQI) Values When the AQI is in this range	**Levels of Health Concern Air quality conditions are:**	**Colours As symbolized by this color**
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very unhealthy	Purple
301 to 500	Hazardous	Maroon

Environmental Protection Agency (EPA), 1991

Apart from above index, measured air quality data were then compared to the Ambient Air Quality Standard (prescribed limit) set by the Department of Environment (DOE) in 1995 (Table 3) to determine the level of pollution in residential, commercial and industrial environments:

Table 3. Recommended Pollutant Threshold Level (Prescribed Limit) for the different Zones set by the Department of Environment

Threshold Level/Study location	Concentration in microgram per cubic meter ((μgm^{-3})		
	SPM	**SO_2**	**NO_2**
Residential	500	120	120
Commercial	400	100	100
Industrial	200	80	80

Source: Department of Environment (DOE)1995

2.3 Data Analysis: Air qualities measured were presented in tables, graphs, percent , mean and percentage. Also description of the result in words was used for the presentation. Standard deviation, Co-efficient of variation and mean were also used to test if there was any significant variation in the perception of environmental impacts among residents in the different zones in the study area.

3.0 Results and Discussion

Table 4-7 represent the results of ambient air pollutants , climatic variables the Mean (x), Standard Deviation (S.D) and Coefficient of Variance (C.V) in the selected residential, Commercial and industrial zonesin the study areas.Table 4 represents the characterization of three selected monitoring sites for ambient air quality with Point 1- Kpansia , Point 2- Yenizue–egene and Point 3- Biogbolo in the Residential Area; Table 5 showing Commercial Area with the study locations viz: Point 1- Amarata , Point 2- Swali and Point 3- Onopa , and Table 6 showing industrial area with study locations viz: Point 1- Oloibiri (OP), Point 2- Imiringa, Point 3 - Gbarain and Table 7.

Table 4: Air Pollutants in Residential Area and Mean (x), Standard Deviation (S.D) and Coefficient of Variance in selected Residential Areas.

Parameters	*Pt 1	*Pt 2	*Pt 3	X	S.D	C.V
CO (µgm^{-3})	15600	15600	15500	15567	47.1	0.00303
CO_2 (µgm^{-3})	1080000	1150000	1190000	1140000	45460	0.0399
NO_2 (µgm^{-3})	70.1	52.4	69.6	64	8.23	0.129
SO_2 (µgm^{-3})	255	254	304	271	23.3	0.0860
$PM_{2.5}$ (µgm^{-3})	15360	17180	16110	11383	4891	0.4297
Temp (oC)	35.8	36.8	30.8	36.9	21.1	0.00688
R. Humidity (%)	63.8	63.5	55.4	60.9	3.89	0.0639

Source: Fieldwork, 2015.

Table 5: Air Pollutants and the Mean (x), Standard Deviation (S.D) and Coefficient of Variance (C.V) in the Commercial Area.

Air Quality	*Pt 1	*Pt 2	* Pt 3	(X)	S.D	C.V
CO (μgm^{-3})	20200	16800	17800	18267	1427	0.0781
CO_2 (μgm^{-3})	11600	11400	12400	11800	432	0.0366
NO_2 (μgm^{-3})	111	147	237	165	53	0.321
SO_2 (μgm^{-3})	205	718	483	469	210	0.448
$PM_{2.5}$ (μgm^{-3})	19670	19770	23170	20890	1627	0.0780
Temp (^{o}C)	30.8	30.3	31..9	31	1.39	0.00456
R. Humidity (%)	81.3	74.8	64.3	73.5	7	0.0952

Source: Fieldwork, 2015.

3.1 Comparison of Recommended Pollutant Threshold Level for the different Zones with the selected Study locations.

Comparison of $PM_{2.5}$, SO_2 and NO_2 the three Settlements to the DOE (1995) Threshold Limits are shown below:

3.1.1 **Residential Settlement (RS):** From Table 7, among the three study locations in the residential zone, particulate matter recorded the mean value of 11382µgm^{-3} above the PM 500(µgm-3), prescribed limit of DOE (1995), sulphur dioxide recorded the mean value of 271 µgm^{-3}, above the 120 µgm^{-3}prescribed limit of DOE (1995), with nitrogen dioxide recording the mean value of 64 µgm-^{3}, below the 120 µgm-^{3}, prescribed limit of DOE (1995). The results in the residential zone shows that particulate matter is the dominant factor:>$PM_{2.5}$>SO_2>NO_2. High concentrations of pm and SO_2 were suspected to be caused by indiscriminate open air burning of waste, vehicular traffic etc. The result conformed with the findings of Avnish and Pawar (2010) who observed the same results in residential area in India .

Joshi *et al*., 2006; Chauhan and Joshi, 2010 found that the concentration of gaseous pollutants viz: NOx was under the permissible limits as per CPCB in the residential area which the present study is in line.

3.1.2 **Commercial Settlement (CS):**The result in Table 6 indicates that particulate matter recorded the mean value of 20890 μgm^{-3}, above the PM 500 μgm^{-3}, prescribed limit of DOE (1995), sulphur dioxide recorded the mean value of 469 μgm^{-3}, above the 120 μgm^{-3} prescribed limit of DOE (1995), with nitrogen dioxide recording the mean value of 165 μgm-^{3}, above the 120 μgm^{-3}, prescribed limit of DOE (1995). The result in the commercial zone shows that particulate matter override other pollutants viz: $>PM_{2.5}>SO_2>NO_2$.

The high concentration of pm is suspected to be from manmade sources such automobile exhaust and other anthropogenic activities. The result is in consonant with the observation that the diesel engine produces high level of very small particles (Gupta, 1999). Sandhu *et al.*, (2004) reported that the high concentration of RSPM in all commercial site due to plying of diesel vehicles. Motor vehicles also generate a range of particulate matter through the dust produced from brakes, clutch plates, tires and indirectly through the re-suspension of particulates on road surfaces through vehicles–generate turbulence (Watkins, 1991). Jain *et al*., (2004), Rajasekhar *et al*., (1999) reported that the higher concentration of SPM exceeds the permissible limits, this may be attributed of automobile pollution in commercial environment.

3.1.3 **Industrial Settlement (IS):** The result in Table 6 indicates that particulate matter recorded the mean value of 21510 μgm^{-3}, above the $PM_{2.5}$ 500 μgm-^{3}, prescribed limit of DOE (1995), sulphur dioxide recorded the mean value of 1702 μgm-$_{3}$, above the 120 μgm-^{3} prescribed limit of DOE (1995), with nitrogen dioxide recording the mean value of 423 μgm-^{3}, above the 120 μgm-^{3}, prescribed limit of DOE (1995) :$>PM_{2.5}>SO_2>NO_2$. These were suspected to be caused by the oil and non-oil related industries including refinery, petrochemical, liquefied natural gas, chemical fertilizer, aluminum smelter, paper, cement, flour, wood, battery and textile industries etc which emit various kinds of air pollutants . The pollution from these industries adds to the burden of gaseous and particulate pollutants in the air. In this study information regarding air pollution from three of these industries namely the chemical fertilizer plant, petroleum refinery plant and the petrochemical complex would be reported (Ana, 2015). Then air pollution is termed as „the price of Industrialization" (Gias *et al*, 2006).

The overall result shows that $PM_{2.5}$ is the dominant factor in the study area with residential having 21.16%, commercial recorded 38.84% and the industrial zone with the highest percentage of 40%, in residential SO2 recorded 11.09%, NO_2 recorded 9.68% accordingly, in commercial SO2 recorded 19.20% , NO_2 24.96% and in industrial zone SO_2, NO_2 recorded 69.69%,65.35% being the highest in the study area above the DOE (1995) air quality standards (Fig.1). This results are in line with the findings of Oluwole et al.(1996) in a typical air quality assessment of the Niger Delta showed that the levels of volatile oxides of carbon, nitrogen and sulphur and total particulates exceed existing Federal Environmental Protection Agency's (FEPA,1991) standards leading to moderate to hazardous health effects (Table 2), Table 4-5.

High concentration of particulate matter in the atmosphere is responsible for Stress on the heart, bronchial constriction, impairment of lung elasticity and gaseous exchange efficient, silicosis (a form of pneumoconiosis caused by inhalation of dust particles), respiratory tract disease systematic toxicity (Pelucchi *et al.* 2009)., and altered immune defense (WHO, 2004a; Obi and Ugwuanyi, 2002, Kappos *et al.* 2004). Gulia *et al*, 2014). sulfur dioxide irritates the skin and mucous membranes of the eyes, nose, throat, and lungs. High concentrations of SO_2 can cause inflammation and irritation of the respiratory system, particularly during heavy physical activity. The resulting symptoms may include pain when taking a deep breath, coughing, throat irritation, and breathing difficulties. High concentrations of SO_2 can affect lung function, worsen asthma attacks, and aggravate existing heart disease in sensitive groups. This gas can also react with other chemicals in the air and convert to a small particle that can lodge in the lungs and cause similar health effects. Nitrogen dioxide causes the reddish-brown haze in city air, which contributes to heart and lung problems and may be carcinogenic (Gulia *et al*, 2014) Comparison of $PM_{2.5}$, SO_2 and NO_2 the three Settlements to the DOE (1995) Threshold Limits. These are shown below: The overall result shows that $PM_{2.5}$ is the dominant factor in the study area with residential having 21.16%, commercial recorded 38.84% and the industrial zone with the highest percentage of 40%, in residential SO_2 recorded 11.09%, NO_2 recorded 9.68% accordingly, in commercial SO_2 recorded 19.20% , NO_2 24.96% and in industrial zone SO_2, NO_2 recorded 69.69%,65.35% being the highest in the study area above the DOE (1995) air quality standards (. This results are in line with the findings of Oluwole *et al*.(1996) in a typical air quality assessment of the Niger Delta showed that the levels of volatile oxides of carbon, nitrogen and sulphur and total particulates exceed existing Federal Environmental Protection Agency's (FEPA,1991) standards leading to moderate to hazardous health effects (Table 2). High concentration of particulate matter in the atmosphere is responsible for Stress on the heart, bronchial constriction, impairment of lung elasticity and gaseous exchange efficient, silicosis (a form of pneumoconiosis caused by inhalation of dust particles), respiratory tract disease systematic toxicity (Pelucchi *et al.* 2009)., and altered immune defense (WHO, 2004a; Obi and Ugwuanyi, 2002, Kappos *et al*. 2004). Gulia*et al*, 2014). sulfur dioxide irritates the skin and mucous membranes of the eyes, nose, throat, and lungs. High concentrations of SO_2 can cause inflammation and irritation of the respiratory system, particularly during heavy physical activity. The resulting symptoms may include pain when taking a deep breath, coughing, throat irritation, and breathing difficulties. High concentrations of SO_2 can affect lung function, worsen asthma attacks, and aggravate existing heart disease in sensitive groups. This gas can also react with other chemicals in the air and convert to a small particle that can lodge in the lungs and cause similar health effects.Nitrogen dioxide causes the reddish-brown haze in city air, which contributes to heart and lung problems and may be carcinogenic Gulia*et al*, 2014

Table 6: Air Pollutants and the Mean (x), Standard Deviation (S.D) and Coefficient of Variance (C.V) in the Industrial Zone

Parameters	*Pt 1	*Pt 2	*Pt 3	X	S.D	C.V
CO (μgm^{-3})	16600	16700	16700	16667	35.6	0.00214
CO_2 (μgm^{-3})	1110000	1080000	1150000	1113333	28674	0.0258
NO_2 (μgm^{-3})	419	566	311	432	105	0.243
SO_2 (μgm^{-3})	482	2565	2060	1702	887	0.5212
$PM_{2.5}$(μgm^{-3})	24110	17910	22510	21510	2628	0.122
Temp (K)	307.5	307.1	306.6	307	0.374	0.00122
R. Humidity (%)	60.3	60.4	66.5	62.4	3.90	0.0625

Table 7: Comparison of Recommended Pollutant Threshold Level for the different Zones with the selected Study locations

Threshold Level/Study location	**Concentration in microgram per cubic meter (μgm^{-3})**		
	PM2.5	**SO_2**	**NO_2**
Residential (Standard)	**500**	**120**	**120**
Study Location (Residential)	X: 11382 (21.16%)	X:271 (11.09%)	X:64 (9.68%)
Commercial (Standard)	**400**	**100**	**100**
Study Location(Commercial)	X: 20890(38.84%)	X:469(19.20%)	X:165 (24.96%)
Industrial (Standard)	**200**	**80**	**80**
Study Location (Industrial)	X:21510 (40%)	X:1702 (69.69%)	X:432 (65.35%)
Mean/percentage	**53782 (94.5%)**	**2442 (4.3%)**	**661(1.2%)**

Temperature and relative humidity are driving force in chemical reactions while lower wind speed may promote buildup of chemicals in the atmosphere since there will be less dispersive force to dilution effect. According to Seinfeld *et al* (1998) , Bailey *et al* (2005) observed that sulfur dioxide and nitric oxides will readily react to form new compounds in ambient air . They are converted into sulfuric acid and nitric acid (CAA,1998): In the gas phase sulfur dioxide is oxidized by reaction with the hydroxyl radical via an intermolecular reaction (Seinfeld *et al* (1998) :

$SO_2 + OH\cdot \rightarrow HOSO_2\cdot$ Equ. (1)

which is followed by:

$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3$ Equ. (2)

In the presence of water, sulfur trioxide (SO_3) is converted rapidly to sulfuric acid:

$SO_3 (g) + H_2O (l) \rightarrow H_2SO_4 (aq)$ Equ. (3)

Nitrogen dioxide reacts with OH to form nitric acid:

$NO_2 + OH\cdot \rightarrow HNO_3$ Equ. (4)

When clouds are present, the loss rate of SO_2 is faster than can be explained by gas phase chemistry alone. This is due to reactions in the liquid water droplets. Sulfur dioxide dissolves in water and then, like carbon dioxide, hydrolyses in a series of equilibrium reactions (Lefohn *et al*, 1999) :

$SO_2 (g) + H_2O \rightleftharpoons SO_2\cdot H_2O$ Equ. (5)

$SO_2\cdot H_2O \rightleftharpoons H^+ + HSO_3^-$ Equ. (6)

$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$ Equ. (7)

Acid rain can damage buildings, historic monuments, and statues, especially those made of rocks, such as limestone and marble, that contain large amounts of calcium carbonate. Acids in the rain react with the calcium compounds in the stones to create gypsum, which then flakes off:

$CaCO_3 (s) + H_2SO_4 (aq) \rightleftharpoons CaSO_4 (s) + CO_2 (g) + H_2O$ Equ. (8)

The effects of this are commonly seen on old gravestones, where acid rain can cause the inscriptions to become completely illegible. Acid rain also increases the corrosion rate of galvanized iron roofing sheet (Ubuoh, 2010). For instance Ana (2015) observed that , the presence of acidified rain water in the environment increases the corrosion rate of roofing sheets, monuments and other economic structures. In the Niger delta area there is glaring evidence of the impacts of corrosion on several building structures and arts work and these cases have been observed to deteriorate at rather alarming rates.

3.2 Conclusion: From the results of the atmospheric compositions in the study area, it is observed that air quality such as CO, CO_2, NO_2, SO_2 and $PM_{2.5}$ varied based on anthropogenic activities. These variations are caused by the influence of atmospheric temperature and relative humidity respectively. The overall results show that apart from low NO_2 in residential area, particulate matter, sculpture dioxide and nitrogen dioxide were above the prescribe air quality threshold limits in the three zones chosen that affect man and his environment. These air quality parameters are emitted to the atmosphere by incessant gas flaring and allied industries, vehicular emission and indiscriminate waste burning in the area. The result also show that $PM_{2.5}$ is the dominant factor in the atmosphere , sculpture dioxide ranking second and nitrogen dioxide being the third, with industrial area recording the highest percentage of the three special pollutants followed by commercial and the residential being the lowest percentage. The result further indicated SO_2 and NO_2 asacid precursors, reacting with water vapour and sulfurous acid (H_2SO_3) through oxidation to form H_2SO_4 and nitric acid together leading to formation of acid rain in the atmosphere (Ubuoh *et al*,2010; Ubuoh, 2012b).Based on the results it is recommended that, in order to improve on the current air quality in the State, there is need to embark on the following:

- Industries, especially those present in the Niger Delta area of Nigeria should improve on their technology and find a way of minimizing air pollutants rather than emitting to the atmosphere.
- Government and NGO should stop playing politics with " gas flaring", that the existing environmental laws and regulations should be implemented and compliance enforced for environmental sustainability.
- There should be a focus on the reduction of pollution levels from vehicles, industry, to permissible levels as defined in national and international standards.
- Above all, gas flared should be revolutionized for better economy.

REFERENCES

Ana, G. R (2015 **):** Air Pollution in the Niger Delta Area: Scope, Challenges and RemediesDepartment of Environmental Health Sciences, Faculty of Public Health, University of Ibadan,*Nigeria.www.intechopen.com, PP1-19.*

Avnish, C. and Mayank, P. (2010): Assessment Of Ambient Air Quality Status In Urbanization, Industrialization And Commercial Centers Of Uttarakhand (India). *New York Science Journal;3(7):85-94.*

Bailey R. A, Clark J. P. Krause, S, and Strong, R. L. (2005): Chemistry of the environment. 2nd Edition. *Elsevier (Singapore) Pte Ltd, Singapore, Malaysia.*

CAA (1998):*Clean Air Act Reduces Acid Rain In Eastern United States, ScienceDaily, September 28, 1998*

Colbeck, I and Lazaridis, M. (2010). Aerosol and Environmental Pollution. *Biomed. Life Sci. 97:117-131.*

Colbeck, I. Nasir Z. A. and Ali, Z (2010): The state of ambient air quality in Pakistan- a review. *Environ. Sci. Pollut. Res. 17:49-63.*

Desauziers, V. (2004): Traceability of Pollutant Measurements for Ambient Air Monitoring. *Trends in Analytical Chemistry, 23(3):252-260*

FEPA (1991) *(Federal Environmental Protection Agency): National Policy on the Environment, The Presidency, Abuja, Nigeria.*

Fenger, J., (1999): Urban air quality. *Atmospheric Environment 33, 4877-4900.*

Gias, U. A, Kazi, M. M. and Mohammed S. A. (2006): Status of Ambient Air Quality in the Urban and Rural Areas of Chittagong, Bangladesh. *ECO Services International*

Gulia, S. Shiva N. S.M., Mukesh, Kh, , ,and Isha, K. (2015):Urban air quality management-A review.*Atmospheric Pollution ResearchVolume 6, Issue 2*, March 2015, Pages 286–304.

Gupta A. B. (1999): Vehicular air pollution and asthma.*Asthma Sanjeevani 1999; 5(2); 3-5.*

Harald B. (2010):Approaches in modeling the impact of air pollution-induced material degradation" *(PDF). Retrieved 2010-11-18.*

Iyorakpo, J. (2015): Impact of rapid urbanization on environmental quality in Genagoa Metropolis, Bayelsa State-Nigeria. *European Scientific Journal August 2015 edition vol.11, No.23 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431.*

Jain R, Dwivedi , D. K, and Gupta, A.B. (2004): Status of air quality at selected traffic junctions of Jaipur city.*Nature Environment and Pollution Technology 2004; 3 (4): 435-442.*

Kappos, A.D., Bruckmann, P., Eikmann, T., Englert, N., Heinrich, U., Hoppe, P., Koch, E., Krause, G.H.M., Kreyling, W.G., Rauchfuss, K., Rombout, P., Schulz-Klemp, V., Thiel, W. R., and Wichmann, H.E.(2004): Health effects of particles in ambient air. *International Journal of Hygiene and Environmental Health* 207, 399-407.

Kindzierski, W.B., and Scotten, B. (2004): Airshed Management: The Future of Ambient Air QualityMonitoring in Canada. *Canadian Civil Engineering*, 20(4): 22-24.

Lefohn, A.S., Husar, J.D. and Husar, R.B. (1999): *Global Sulfur Emissions Database, United States:* A.S.L. & Associates

Nwachukwu, A.N, and Ugwuanyi, J. U (2010): Air pollution and its possible health effects on rural dwellers in Rivers State, Nigeria. *Afr. J. Phys*. 3:217-240.

Oluwole, A.F. Olaniyi, H.B. Akeredolu, F.A. Ogunsola, O.J. and Obioh, I.B. (1996): Impact of the Petroleum Industry on Air Quality in Nigeria, *Presented at the 8th Biennial International Seminar on the Petroleum Industry and the Nigerian Environment, Port Harcourt, 17-21* November.

Oyekunle LO (1999): Effects of gas flaring in Niger-Delta area. Nigeria Society of Chemical Engineer, *Proceedings of 29th Annual Conference, Port Harcourt, Nigeria, p. 105.*

Osuji L. C, and Avwiri G. O (2005): Flared Gases and Other Pollutants Associated with Air Quality in Industrial Areas of Nigeria: An Overview. *Chem. Biodivers. 2:1-8.*

Pelucchi, C. Negri, E. Gallus, S. Boffetta, P. Tramacere, I. and La Vecchia, C., (2009): Long-term particulate matter exposure and mortality: *A review of European epidemiological studies, BMC Public Health, 8 pages..*

Rajasekhar R. V. J. Samy I. K. Sridhar, M. and Muthusubramanian, P.(1999): Estimation of suspended particulate matter in the ambient air of Madurai city by sedimentation and filtration methods. *IJEP* 1999; 21(8): 673-676.

Sandhu, P. S, Patel U, and Gupta A. B. (2004): Exposure to airborne particles and their physical characterization in ambient environment of Jaipur city. *Nature Environment and Pollution Technology* ; 3 (4): 509-514.

Seinfeld, J. Pandis, H. and Spyros N. (1998): *Atmospheric Chemistry and Physics — From Air Pollution to Climate Change.* John Wiley and Sons, Inc

Ubuoh, E. A. Akande, S.O. Anyadike, R.N.C. Akhionbare, W.N. Igbojionu,D.O., Njoku,J.D. and AkhionbareS.M.O. (2010):"Atmospheric Corrosion of Roofs in Selected Parts of AkwaIbom State, Nigeria". *Global Journal of Engineering and technology (GJET*) Calcutta, India , Vol.3, Number 2, pp. 317 – 324.

Ubuoh, E. A. (2012b): "Spatial and Temporal variations of Acid Rain Formation in Selected Oil Producing Communities in AkwaIbom State, Nigeria". *Canadian Journal on Scientific and Industrial Research*. Vol. 3 No. 4, Pages: 193-207.

Ugwuanyi, J. U. and Obi, F. C (2002): A survey of Health Effects of Air Pollution on Peasant Farmers in Benue State, Nigeria. *Int. J. environ. Stud.* Vol. 59. Gordon and Breach Sci. Publishers, U.K,P.

Watkins L. H. (1991*): Air pollution from road vehicles. Transport and Road Research Laboratory, London,* U.K, 1991.

WHO (2000a):Evaluation and use of epidemiological evidence for environmental health risk assessment. *World Health Organization, Regional Office for Europe, Copenhagen 2000 (e68940).*

WHO (2004a): Health aspects of air pollution. Results from WHO project "Systematic review of health aspects of air pollution in Europe". *World Health Organization Regional Office for Europe 2004*.http//www.euro.who.int/document/E83080.pdf

WHO (2004b): Comparative quantification of health risks: *global andregional burden of diseases attributable to selected major risk*

WHO (2007): Global estimates of burden of diseases caused by the environmental and occupational health risks.