International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 4 Issue 6 ǁ June. 2016 ǁ PP. 37-42

Approaches to Air Quality Assessment: A Tool for Advancement of Air Quality Policy

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Abstract: Air pollution issues remain a serious threat to environmental health in many cities of the world. High concentration levels of air pollutants have been shown to have wide-rangingnegativeeffects on human health and the environment. This paper reviews studies done on air quality with both spatial and regression analysis approach as well as studies done in areas around gas flaring in the Niger delta. Gas production and utilization in Nigeria has increased by 121.04% and 556.87% respectively while gas flaring has reduced by 63.88%. The benefits of the research are reduction of public health risks, protection of the environment, proposal of new policies that will help to reflect how action can be taken to help mitigate and abate the effects of climate change, promotion of good environment for economic activities, reduction of community agitations, ensures good climatic conditions for crops and other bio-entities to thrive and ensures sustainable development.

Keywords– Air quality, geo-regression, Kriging, Nigeria,Policy

I. INTRODUCTION

A large number of air quality studies have been carried out over the years particularly in exposure assessment. The importance of such studies has gained wide recognition in various parts of the world. Man has always sort to have significant control over his exposure to environmental components that have the potential to impart on his health. Air pollution issue remains a serious threat to environmental health in many cities of the world [1 2]. Air quality in particular has attained its seriousness as an issue because there is an extent which is usually small to which one can control what one breathes in compared to the extent of control to what one eats, touches or drinks. What one breathes in, in terms of the quality of the air is largely a function of one's location at a particular period of time except if moving around with gas masks proves favourable. This therefore necessitates knowledge of air quality in such locations. High concentration levels of air pollutants have been shown to have general adverse effects on human health [3-5]. The pollutants of interest in this study include sulphur IV oxide (SO_2), carbon II oxide (CO), nitrogen IV oxide (NO_2), particulate matter (PM), ozone (O_3) and lead (Pb). These pollutants are referred to as criteria air pollutants because their health implications have been well established and documented. There are numerous human activities, which result in the release of potential toxic substances into the atmosphere [6-7]. 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 and boilers and furnaces of industries, plants and homes [8]. Air quality around a location may be impacted by activities such as burning of fossil fuel by waste gas flaring from oil production facilities, burning of fuel in the operation of high capacity power generators for long periods and emissions from vehicles [9].

Various air quality assessments have been done around the world using various approaches. However, these approaches have their strengths and weaknesses. The major aim of these assessment studies is to ascertain the exposure levels of receptors to these pollutants especially humans. One approach to investigating these relationships is to collect environmental data coincidentally with health data so that the environmental data can directly support analysis of health outcomes [10]. There are however issues of cost hence most assessment studies are done in small areas or locations. Availability of air quality data base could prove useful in this respect. Air quality data base especially in Nigeria is readily unavailable. In this regard, spatial analysis becomes necessary as spatial interpolation can predict ambient concentrations in unmonitored locations. It was asserted [11] that a spatial distribution map can give city planners a much more effective visual perspective of the spatial variations in city air quality than can tabular data from point samples, and this can lead to faster decision making about which areas represent the greatest risks and are therefore most in need of intervention measures.

This study aims to present a critical review of air quality assessments using spatial analysis and regression approach as well as air quality studies done around flow station where there is gas flaring.

II. MATERIALS AND METHODS

This review is motivated by an ongoing research to assess and investigate the level of exposure to the air quality in an oil operating area in the Niger Delta of Nigeria. Data required are meteorological data, air quality data (criteria air pollutants), population data and hospital records. Kriging interpolation, inverse distance weighting interpolation, land use regression and multiple regression analysis will be done to comparative model performance. Principal correspondence and factor analysis will be done to determine the major sources contributing to the air pollution in the area. Material required are ArcGIS software, XLSTAT for statistical analysis, ENERAC multigas analyzer, combined wind vane and digital Anemometer, Pyranometer equipped with an automatic logging system. (Skye Data Hog 2). To this end, a thorough literature review was done.

III. REVIEW OF AIR QUALITY STUDIES APPROACHES

3.1. Using Spatial and Geo-Regression Approachreview

Spatial interpolation modeling has been applied as a procedure for pollutants concentration estimation at unmonitored locations within a study area. This is done based on proximity of monitored observation in that area. It was mentioned [12]that the justification underlying spatial interpolation is the assumption that points closer together in space are more likely to have similar values than points more distant. Several interpolation methods have been used such as inverse distance weighting, kriging, nearest neighbor, spatial averaging and linear regressions. The inverse distance weighting method involves the assigning of more weights to averaged data points close to the point to be estimated. It is a deterministic mathematical interpolation approach. It was stated that [13] to predict values at unsampled locations, distance weighting assigns more weight to nearby points than to distant points making inverse distance-weighting (IDW) popular form of spatial interpolation method. Kriging however is a regression-based technique that estimates values at unsampled locations using weights reflecting the correlation between data at two sample locations or between a sample location and the location to be estimated [13]. It was argued that distance-weighting and kriging typically are not suitable for air pollution mapping in most metropolitan areas due to relative paucity of air quality monitors and the likely poor spatial distribution of those monitors [14]. Distance-weighting requires a dense network of uniformly spaced, spatially-autocorrelated observations [13]. Kriging is a more advanced type of interpolation method that can be used to predict values for unmonitored points and their standard errors in other words it can also estimate measures of uncertainty. Kriging models exploit spatial dependence in the data to develop smoothed surfaces. The spatial dependence can be divided roughly into two broad categories. First-order effects measure broad trends in all the data points such as the global mean, whereas second-order effects measure local variations at shorter distances between the points [15-16]. Kriging models are considered optimal interpolators because they supply the best linear unbiased estimate of the variable's value at any point in the study area [16].

Linear regression method was used [14] for spatial analysis of ground-level ozone concentrations in the Tucson, Arizona, region. A large range of temporal variability is used to compensate for sparse spatial observations due to few ozone monitors. Cross-validation of the pooled models revealed an overall R^2 of 0.90 and approximately 7% error. The composite ozone maps predict that the highest ozone concentrations occur in a monitor-less area on the eastern edge of Tucson. The maps also reveal the need for ozone monitors in industrialized areas and in rural, forested areas. In a spatial interpolation comparative study, they [10]applied both inverse distance weighting method for spatial exposure analysis. Monitor data of PM_{10} and O_3 within a 250km search window (radius) were used. Other smaller windows (60km and 100km) were also tested. The weight used was $\lambda_1=1/d_1$ where d_1 is the distance between sets of data points to be predicted. The result found through cross validation was that the accuracy of interpolation was not too sensitive to the window size. They further argued that spatial variation of measured air pollution is complex but that it is not generally unstructured and that it is to an extent always spatially dependent on some scale. This dependence they referred to as autocorrelation. This was supported by [15]. In light of the above argument, kriging interpolation method was used on the same data since the structure may be overlain by random local variation which can be summarized by a variogram. Nearest neighbor and spatial averaging methods were also used. They found that the distribution of the range for O_3 in the counties where all four methods were applied was not significantly different. Interpolated values were plotted and regressed with actual measured value. The R^2 and coefficients showed that of the four methods, kriging performed poorest. Lack of even distribution of monitors in urban and rural locations and lack of prior determination of spatial relationship of the data before applying kriging method could have influenced the result.

3.2. The Use of Geographically Weighted Regression (GWR) Model

Tao*et al* (2008) reported in their work the spatial and temporal changes of air particulate concentrations in Beijing. The spatial relations of air particulate pollution concentrations and the occurrences of residential respiratory diseases in 2008 were also studied applying the geographically weighted regression (GWR) model in GIS environment. GIS map algebra allowed them to quantitatively visualize the local changes across the space in the study area. GWR analysis showed that spatial concentrations of PM had positive coefficients or impacts on occurrences of residential respiratory diseases. A study which [17] examined the spatial distribution of air pollution in response to recent air quality regulations was done in Delhi, India. Air pollution was monitored at 113 sites spread across Delhi and its surrounding areas analysis was based on proximity analysis for data integration, spatial interpolation of air pollution surfaces and regression modelling. ArcGIS Ver 9.x was used to compute proximity to road and industrial cluster which were the sources using spatial join in which computed the Cartesian distance of all sample sites to their closest sources. He applied kriging method for interpolation. The optimal parameters, such as distance range, distance exponent, were computed by minimizing variance between actual and estimated values at the sample sites. For regression, two different sets of models were used. In the first set, air pollution at a sample site was modelled as a function of the selected covariates which included proximity to the major roads, industrial clusters, frequency of buses and other heavy vehicles per minute, using an Ordinary Least Square (OLS) regression model. In the second set, Spatial Autoregressive Models (SAM) was used because the error term observed a statistically significant spatial autocorrelation, which could not be handled by the OLS models. The result obtained from the study showed that air pollution levels in Delhi and its surroundings were significantly higher than that recommended by the World Health Organization (WHO), air quality regulations in the city adversely affected the air quality of the areas surrounding Delhi and industries and trucks were identified as the major contributors of both fine and coarse particles [17]. A study investigated the intra-urban distribution of SO_2, NOx, NO_2, Benzene, Toluene, and Xylenes in one of the world's most polluted cities, Lanzhou, China. The locations were classified according to the proximity to relevant point emission sources. The result suggests that the spatial distribution of urban air pollution in Lanzhou can be significantly described in terms of diffusion of emission sources in space, when the measurement averaging time is sufficiently long. This might be important to establish a relationship between air quality measurement representativeness and human exposure assessment. An attempt was made [19] to map the polluted areas of Agra and predict the pollution at unsampled locations. Thirty places in Agra were selected for collecting air samples. Geographic Information System (GIS) and Kriging (Ordinary Kriging) approach was used to show the polluted and unpolluted areas in Agra (Dayalbagh) region. A semivariogram was plotted to show the relationship between lag distance and semivariance. The Ordinary Kriging filled the map with different colors. Each color corresponds to different values of air pollution. Spatial Analysis and Decision Assistance (SADA) GIS software was used in the work for the prediction of the pollution level at the location where samples were not taken. ArcGISwas used in a study [20] to identify spatial variation of air quality status in the vicinity of the landfill site in Rumuolumeni in Niger Delta of Nigeria. Air quality and meteorological parameters were collected with respect to distance from the center of the dumpsite. The spatial coverage of levels of concentration of each air quality parameters was calculated in hectares (ha) in ArcGIS 9.3 environment. The GIS analysis showed that the spatial coverage of the entire study area was 1.128 sq km. Result indicates that concentrations of pollutants in the study area varied spatially.

3.3. Air Quality Assessment Around Oil Operating Areas in Nigeria

The oil and gas industry through several researches have be implicated in significant impact to ambient air quality most especially through gas flaring (Table 1 and Figure 2). In this paper, a review is made on modeling and assessment studies done in area around gas flaring in Nigeria especially in the Niger Delta.

Table 1: A 17 years gas production, utilization and flaring volumes for Nigeria.

Year	Total volume of gas produced (bscf)‡	Total volume of gas utilized† (bscf)	Total volume of gas flared (bscf)	% volume of gas utilized (bscf)	% volume of gas flared (bscf)
1997	1142.00	340.20	801.80	29.79	70.21
1998	1308.00	473.85	834.15	36.23	63.77
1999	1328.00	529.58	798.42	39.88	60.12
2000	1599.00	716.24	882.76	44.79	55.21
2001	1823.00	902.65	920.35	49.51	50.49
2002	1652.00	877.89	774.11	53.14	46.86
2003	1828.54	982.53	846.01	53.73	46.27
2004	2082.28	1196.52	885.76	57.46	42.54
2005	2093.63	1281.30	812.33	61.20	38.80
2006	2196.04	1383.09	812.95	62.98	37.02
2007	2426.67	1626.61	800.06	67.03	32.97
2008	2282.44	1664.82	617.62	72.94	27.06
2009	1837.28	1327.93	509.35	72.28	27.72
2010	2392.84	1811.27	581.57	75.70	24.30
2011	2400.40	1781.37	619.03	74.21	25.79
2012	2580.17	1991.50	588.67	77.18	22.82
2013	2325.14	1915.83	409.31	82.40	17.60
2014	2524.27	2234.67	289.60	88.53	11.47

Source: NNPC annual statistical bulletin (2015) with modification

†utilized here means that it waseither sold, re-injected, as feedstock to LNG, LPG, NGL, as fuel for operations and plants. (LNG is liquefied natural gas, LPG is liquefied petroleum gas, and NGL is natural gas liquid)
‡ Bscf is billion standard cubic feet

A seventeen-year gas flaring data[21] presented Figure 1and shows that gas production has increased from 1142 bscf in 1997 to 2524.27bscf in 2014 (121.04%) gas utilization increased from 340.2 bscf in 1997 to 2234.67bscf in 2014 (556.87%). However, gas flaring has reduced from 801.8bscf in 1997 to 289.60bscf in 2014 (63.88%). This shows that there has been a significant progress in reducing the amount of gas flared and this translates to reduce air pollution by the oil and gas sector.

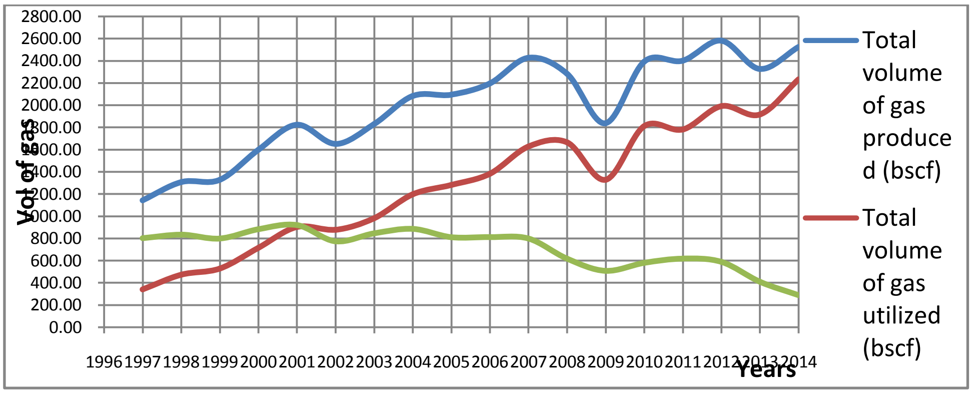

Figure 1A chart showing A 17 year's gas production, utilization and flaring in Nigeria (Ploted with data from Table 1

Gas flaring and accompanying environmental issues have necessitated air quality researches. A study to predict gaseous emission [22] was done based on possible individual combustion types anticipated in flare operations. They found out that natural gas composition was observed to be a prominent factor out of the seven factors they considered in the determination of non-methane gaseous emission characteristics and that it determines the chemical composition per volume of air required for combustion. An evaluation [23] of ground level concentration of CO_2, SO_2, NO_2 and total hydrocarbon (THC), which are products of gas flaring was done using several records of monitored air parameters from flow stations in oil producing areas in the Niger Delta area of Nigeria. The data collected from the oil companies' records. Results obtained from the simulation model developed which was based on the principles of gaseous dispersion by Gaussian had a good agreement with dispersion pattern. He concluded that factors influencing pollutants at ground level are the volume of gas flared, wind speed, discharge or exit velocity and proximity to the source of flaring. A study in the same year [24] which was experimental on gas flares to ascertain the level to which the petroleum refinery industry pollutes the atmosphere was carried out. Gases that were of concern in the study were NO, CO, SO_2 and total volatile hydrocarbon. Modeling was done for the pollutant concentration from the flare point using visual basic based on Gaussian plume modeling technique. The result obtained showed a good agreement with the experimental results. MATLAB was used [25] to model of a typical gas flare from a gas flare in Petroleum Company in Nigeria. The results of the modeling were compared by way of model evaluation with experimental data. Flare height and atmospheric conditions were studied as parameters that have effects on the dispersion pattern of pollutants. A predictive dispersion model which was based on the principle of Gaussian distribution was applied [26] to quantify the extent of dispersion of air pollutants from gas flaring. They recorded the volume and condition of the gas flare along with concentration which was experimental data. The results showed the effect of flare volume change and dispersion pattern of pollutants. They also studied the effects of stack efficiency, wind speed and atmospheric stability on the concentrations of pollutants from gas flaring. To further understand the formation mechanism of secondary pollutants, he [27] did a review on the significance of gaseous emissions in the forming secondary air pollutants in the atmosphere. He reviewed three air pollutants formed in the atmosphere due to the presence of precursor air pollutants from gas flares along with their environmental impacts and formation mechanisms.

A research was conducted to evaluate the possible environmental characteristics of atmospheric contaminants.They[28] carried out a study to determine the level and distribution of CO_2 and other associated potential contaminants at some flare sites in the Niger Delta. Agbada 1 and 2 flow stations of Shell Petroleum Development Corporation were monitored. A control which was Eneka village with no history of gas flaring was used for comparison for a period of three months. They reported that CO_2, CO and associated air pollutants provided significant concentrations at the choice sites relative to the Control site. Similarly, a study on the extent of air pollution around various gas flaring sites in the Niger delta was carried out. Different samples at various proximities from the gas flare locations were taken and measured. Experimentations were also meticulously carried out. The result obtained in their [29] research showed a marked trend as all the parameters considered showed anincline away from the flare point in all the flow stations. A study [30]assessed the challenges of gas flaring, spatial spread of gaseous discharges and atmospheric conditions that affect the spread of air pollutants from gas flares using the IduObosi flowstation in the Niger Delta of Nigeria as a case study. The AirWare Model was used to determine the distribution. The results showed that at higher wind speeds emission concentrations increases at closer distances and decreases at increased distances. While at lower wind speeds high concentrations are experienced. They concluded that meteorological factors such as atmospheric stability class, wind velocity and wind direction determines the behavior of pollutants in the atmosphere.

An investigation the influence [31] of gas flaring on available soil quality parameters, near oil flow stations in Eket and Izombe in the Niger DeltaNigeria was done. Soil samples were collected from depths 0 – 30 cm and 30 – 60 cm at 50 m, 150 m and 250 m distance from flare location. Control area was also sampled. These result values for the measured soil parameters showed a reverse trend by increasing with distance. Relative to the control parameters, they observed that gas flaring had deleterious effects on soil qualities in the study areas. A study [32] to investigate the impact of gas flaring on the air quality in Izombe in the Niger Delta was conducted using chemical air pollutants. The result of analysis all exceeded Federal Environmental Protection Agency (FEPA) stipulated Standard. The adoption of current reliable and efficient technologies for emission control was recommended.

IV. CONCLUSION

Studies in areas of air quality are essential hence over the years and the years to come there will be continuous research. Environmental awareness is necessary on the part of individuals and government. Adequate information about air quality is useful in policy formulation, town planning, provision of mitigation and abatement measure, setting and reviewing of air quality standards and assessing performance air pollution control measures. As reviewed, gas flaring is a major contributor to poor air quality. However, in Nigeria the amount of flared gas is reducing. Air quality studies that has been done in Nigeria has been in point locations which may not give the extent to which people are exposed to air pollutant hence it is necessary to perform spatial analysis and present results in a thematic map which will help in future town planning. Interpolation methods and other spatial analysis are becoming more popular. An ongoing research by same authors aims to perform a thorough assessment of air quality in selected oil operating areas showing the extent of exposure producing thematic maps for different land use types using various spatial interpolation techniques.

ACKNOWLEDGEMENT

The authors wish to express special thanks to World Bank for offer of Ph.D. scholarship at World Bank African Centre of Excellence, Institute of Petroleum Studies, University of Port Harcourt.

REFERENCES

[1]. Kan H., Chen B., Hong C. (2009): Health impact of outdoor air pollution in China: current knowledge and future research needs. Environ Health Perspect 117(5):A187
[2]. McCarthy M.C., Hafner H.R., Chinkin L.R., Charrier J.G. (2007): Temporal variability of selected air toxics in the United States. Atmos Environ 41:7180-7194
[3]. Allen R.W., Criqui M.H., Diez Roux A.V., Allison M., and Shea S. (2009): Fine particulate air pollution, proximity to traffic, and aortic atherosclerosis: the multiethnic study of Atherosclerosis. Epidemiology 20(2): 254-264.
[4]. Hulguin, F., Flores S., Ross Z., Cortex, M., Molina M., Molina L. (2007): Traffic related exposures, airway function, inflammation and respiratory symptoms in children, Am J RespirCrit Care Med 176:1236-1246
[5]. Moshammer H., Hutter H. P., Hauck H., Neuberger M. (2006): Low levels of air pollution induced changes of lung fuction in a panel of school children. EurRespir J. 27:1138-1143
[6]. Aas, W., Hjellbrekke, A.G., Semb, A. and Scaug, J. Data quality 1997, Quality assurance and field comparisons. Lillestrom.Chemical coordinating center, NORWEGIAN Institute for Air Research, EMEP / CCC6 / 99. 1999
[7]. Campbell, G.W., Stedman, J.R. and Stevenson, K. (1994): A Survey of Nitrogen dioxide concentration in the United Kingdom using diffusion tubes. Atmos. Environ. 28:477-486.
[8]. Park, K. (2005): Preventive and Social Medicine (18th ed). Journal Pur, India: M / S BanarsidasBhanot publishers.
[9]. Akuro, A. (2012): Air Quality Survey of some locations in the Niger Delta Area J. Appl. Sci. Environ. Manage. Vol. 16 (1) 125 – 134
[10]. David, W. W., Lester, Y. and Susan A. P. (2004): Comparison of spatial interpolation methods for the

estimation of air quality data, Journal of Exposure Analysis and Environmental Epidemiology Vol 14, 404–415
[11]. Galcano, C. M. and Kariuki, l. W. Mapping and analysis of air pollution in Nairobi, Kenya, International Conference on Spatial Information for Sustainable Development Nairobi, Kenya 2–5 October 2001
[12]. Shelly, E., Jenise, S., David, H., Bill, C. and Ellen, B. (2004): Developing Spatially Interpolated Surfaces and Estimating Uncertainty, United States Office of Air Quality Planning and Standards Publication No. EPA-454/R-04-004
[13]. Myers, D.E. (1994): Spatial interpolation: an overview. Geoderma 62 (1-3), 17–28.
[14]. Jeremy, E. D. and Andrew, C. C. (2002): Predictive mapping of air pollution involving sparse spatial observations, Environmental Pollution Vol 119, 99–117
[15]. Bailey, T.C. and Gatrell A.C. (1995): “Interactive Spatial Data Analysis”. Longman: London.
[16]. Burrough, P.A. McDonnell, R. and Burrough, P.A. (1998): Principles of Geographical Information Systems; Oxford University Press: Oxford, UK, Volume xiii, p. 333.
[17]. Kumar, N. (2009): Air quality interventions and spatial dynamics of air pollution in Delhi and its surroundings Int. J. Environment and Waste Management, Vol. 4, Nos. 1-2
[18]. Costabile, F., Bertoni, G., De Santis, F., Bellagotti, R., Ciuchini, C., Vichi, F. and Allegrini, I. (2010): Spatial Distribution of Urban Air Pollution in Lanzhou, China the Open Environmental Pollution & Toxicology Journal, 2010, 2, 8-15
[19]. Tyagi, A. and Singh, P. (2013): Applying kriging approach on pollution data using GIS software International Journal of Environmental Engineering and Management. Volume 4, Number 3, pp. 185-190
[20]. Weli, V.E. and Adekunle, O. (2014): Spatial Analysis of Atmospheric Pollutants from Rumuolemeni Landfill, Port Harcourt using GIS, Journal of Environment and Earth Science, Vol.4, No.14
[21]. Nigerian National Petroleum Corporation annual statistical bulletin (2015): http://www.nnpcgroup.com/PublicRelations/OilandGasStatistics/AnnualStatisticsBulletin.aspx
[22]. Sonibare J. A. and Akeredolu, F. A. (2004): A Theoretical Pre-diction of Non-Methane Gaseous Emissions from Natural Gas Combustion, Energy Policy, Vol. 32, No. 14, pp. 1653-1665.
[23]. Abdulkareem, A. S. (2005a). Evaluation of Ground Level Concentration of Pollutant Due to Gas Flaring by Computer Simulation: A Case Study of Niger Delta Area of Nigeria, Leonardo Electronic Journal of Practices and Technologies, Vol. 6, pp. 29-42
[24]. Abdulkareem, A. S. (2005b): Urban Air Pollution Evaluation by Computer Simulation: A Case Study of Petroleum Refining Company, Nigeria, Leonardo Electronic Journal of Practices and Technologies, Vol. 6, pp. 17-28.
[25]. Kahforoshan, D. Fatehifar, E. Babalou, A. A. Ebra-himin, A. R. Elkamel, A. and Ltanmohammadzade, J. S. (2008): Modeling and Evaluation of Air pollution from a Gaseous Flare in an Oil and Gas Processing Area, WSEAS Conferences in Santander, Cantabria, 23-25 September.
[26]. Abdulkareem A. S. and Odigure, J. O. (2006): Deterministic Model for Noise Dispersion from Gas Flaring: A Case Study of Niger Delta Area of Nigeria, Journal of Chemical and Biochemical Engineering, Vol. 20, No. 2, pp. 157-164.
[27]. Sonibare, J. A. (2011): A Critical Review of Natural Gas Flares Induced Secondary Air Pollutants, Global NEST Journal, Vol. 13, No. 1, pp. 74-89.
[28]. Nwaichi, E. O. and Uzazobona, M. A. (2011): Estimation of the CO2 Level Due to Gas Flaring in the Niger Delta, Research Journal of Environmental Sciences, Vol. 5, No. 6, pp. 565-572.
[29]. Ubani, E.C. and Onyejekwe, I.M. (2013): Environmental impact analyses of gas flaring in the Niger delta region of Nigeria, American Journal of Scientific and Industrial Research doi:10.5251/ajsir.2013.4.2.246.252
[30]. Edokpa, D.O, and Ede, P.N. (2013): Challenge of Associated Gas Flaring and Emissions Propagation in Nigeria. Academ Arena 5(3):28-35
[31]. Okeke, P. N and Okpala, C.Q. (2014): Effects of gas flaring on selected arable soil quality indicators in the Niger Delta, Nigeria, Sky Journal of Soil Science and Environmental Management Vol. 3(1), pp. 001 - 005,
[32]. Nwakire, C. (2014): The Impact of Gas Flaring on the Air Quality: A Case Study of Izombe in Earstern Nigeria, International Journal of Engineering Research and Reviews Vol. 2, Issue 3, pp: (61-71)