ESTIMATION OF PRIMARY AIR POLLUTANTS' EMISSIONS FROM NIGER-DELTA FLOWSTATIONS BY LONG TERM CONTINUOUS MONITORING

E.O. ObaniJesu* and O.A. Okelana

Chemical Engineering Department,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria

* Correspondence author

ABSTRACT

This study was carried out to evaluate the air quality of upstream petroleum operations in Nigerian oilfields. SOx, NOx, VOC and COx concentrations were measured at six flow-stations within Niger-Delta region of Nigeria at 60, 200, and 500m respectively away from the point sources for eighteen months using Testo 350 Gas Analyzer. Statistical analyses of the obtained data were carried out using ANOVA and Scheffe Post Hoc tests to determine the significance level of each pollutant at each field and to determine any reduction level from the previous study.

SO_x concentration was discovered to be alarmingly high at all distances in all the fields while CO_x posed no threat, except for oilfield 3 where it was a little bit above the standard at 200m away from the flare. NOx emission at oilfield 4, 5 and 6 were a threat to the environment while its values at fields 1, 2 and 3 fluctuated. High concentration of VOC was also recorded for sites 1, 2 and 4 but not significant at sites 3, 5 and 6. Development of Air Quality Index (AQI) and other control and abatement techniques were recommended.

Keywords: Air quality, Primary Air Pollutants, Upstream Petroleum Operations, Niger-Delta

INTRODUCTION

Air as the prime resource for sustenance of life (BIAQI, 2005) is a mixture of nitrogen, oxygen, carbon dioxide and some inert gases (Table 1). It also contains water vapor of varying quantity. Man needs the atmospheric oxygen (O_2) for respiration and releases carbon-dioxide (CO_2), while the reverse is the case for plants. Through this; normal composition of air is maintained. However, different human activities ranging from agricultural and domestic to industrial distort this balance; petroleum production is one of these industrial activities.

Through many conducted studies, petroleum industry has been confirmed as a major source of air pollution in Nigeria. The country has over 31.4 billion barrel ultimate reserve of crude oil (Erinne, 1999) and projection of 40 billion barrels by 2010 (Obanijesu et al, 2005). Also, the OPEC allowable production rate of 2 million barrels per day with projection of 5 million barrels per day by 2010 has currently placed her as the sixth largest producer of petroleum in the world (Klein, 1999). Nigeria crude oil reserves have gravities ranging from 21^{O} API to 45^{O} API. Her main export crude blends are Bonny light (37^{O} API) and Forcados (31^{O} API) while almost 65% of her crude is light (35^{O} API or higher) and sweet (low sulfur content). The majority of the oil which lies in about 250 small fields with at least, 200 others existing and containing undisclosed reserves (NIGC, 2001) are found in relatively simple geographical structures along the coastal Niger River Delta.

The Niger-Delta region which is described as one of the largest wetlands in the world covers an area of over 70000 square kilometers (Groundwork, 2003) with a number of ecological zones that range from sandy coastal ridge barriers, brackish or saline mangrove, freshwater, permanent and seasonal swamps, forests to lowland rain forests. The region is served by the River Niger and its numerous tributaries. Its hydrology is determined by tides of the Atlantic Ocean and the flood regime of the River Niger. The ecosystem is particularly sensitive to changes in water quality, such as salinity or pollution and to changes in hydrology. The total population is estimated at 20 million people in long settled community spreading through nine states of the Nigerian federation. Fishing, hunting and subsistence agriculture are the major occupation of the people while the oil industry is the major industrial sector.

The crude is basically produced from the reservoir rock through exploration, drilling and production techniques. Drilling activities basically include the operation of a rig, a drilling mud system and drill string to make hole. The drilling rig is used to handle the drill pipe and bits to the set casing to complete the well. The hole is drilled to the various existing pay zones and the richest two are completed at a location using dual completion method.

Production, which is the operation of bringing the well fluids to the surface and preparing the fluids for transportation to refineries, jetty, etc. basically includes well completion(bringing the fluid to the surface) and separation (separating the reservoir fluid to its oil, associated gas and produced water components at flowstation). During separation process, crude oil flow and pressure at the flowstation inlet are set manually at the inlet manifold by means of chokes. Valve work is provided to direct flow to header (High Pressure (HP), Low Pressure (LP), Extra High Pressure (XXHP) or Test Headers (TH)). The headers on each skid are connected to the corresponding header on the adjacent skid to separate the oil and gas (Fig 1). The oil flows to the surge vessel which stores and stabilizes the crude as well as provide the needed Net Positive Suction Head (NPSH) for the pumps. The gas goes to the flare via the Flare Liquid Knockout Vessel (FLKO). The gases leaving the HP/LP separator and surge vessels are sent to the FLKO to knock off the entrained liquid in the gas present in FLKO. This separation is aided by impingement and pressure differentials. The removed liquid is returned to the surge vessel where flow lines with the aid of centrifugal pumps are used to move the separated oil to treatment and storage facilities or to the terminal for export. The gas produced from the process trains of which is presently of low economy value in Nigeria except that utilized for instrument, power and fuel gas systems is sent to flare at a site remotely located about 300 meters away from the station for flaring.

Flaring which is a common method of disposal of flammable waste gases in the upstream oil, gas, downstream refining and chemical processing industries (Akeredolu and Sonibare, 2004) is an open-air flame, usually at the tip of a long stack. The flame is exposed to the weather elements, particularly winds and for air pollution regulatory purposes classified as a stationary combustion source (Ritter et al, 2002). Gas flares are chosen as the disposal option for handling waste hydrocarbon gases because of their ability to burn efficiently (Strosher, 1996). Complete combustion must occur within the available short residence time making flame temperature a primary variable in the combustion process (Roe et al, 1998). The pollutants of concern for this study COx, NOx, SOx, and VOC were generated during the combustion process of flaring and booming (booming is the direct discharge of the gaseous emissions into the atmosphere).

All high-temperature processes produce NO (Vesilind et al, 1997). The nitric oxide formed by the thermal fixation of atmospheric nitrogen (for the reaction is strongly temperature dependent) is then oxidized further to nitrogen dioxide (NO_2) in the ambient air.

$$N_2 + O_2 \rightarrow 2NO$$
$$2NO + O_2 \rightarrow 2NO_2$$

The associated gas made up of nitrogen, sulfur and carbon containing hydrocarbon compounds is also oxidized through the combustion process to form NOx, SOx, VOC and COx. The ozone which is a secondary pollutant is formed through photochemical smog (Vesilind et al, 1997).

These air pollutants have severe negative impacts on human, flora, fauna and the entire environment. CO is poisonous to human health. It reduces the oxygen-carrying capacity of the blood of man by combining with the hemoglobin to form carboxy-hemoglobin, which at 60% concentration results to death from lack of oxygen. Furthermore, elevated CO air problem episodes can be experienced due to climate influences, particularly during cold, dry, stagnant winter mornings and evenings (Morris et al, 2003). During these periods, CO emissions are trapped near the ground where they build-up in direct response to hourly variation (Sound Track, 2005). CO_2 contributes to greenhouse effects by absorbing some of the heat the earth normally radiates into the space and re-radiates that heat back to the earth surface. This in effect increases the earth temperature which over time may result to melting the polar ice cap leading to flooding amongst others (Discovery, 2005). NO oxidizes to NO_2 in addition to the existing NO_2 to become the major component in the formation of photochemical smog. NO_2 can cause respiratory symptoms such as coughing, wheezing, and shortness of breath in children and adults who have respiratory diseases such as asthma. NO_2 plays a significant role in the formation of ozone, particle pollution, haze and acid rain. The ozone (O_3) formed is highly reactive and causes damage to vegetation and properties. It can irritate the respiratory organ; cause coughing, throat irritation and sensation in the chest. It reduces lung functioning, and makes it difficult to breathe deeply. People who are active in outdoor activities are at high risk because during physical activities, ozone penetrates deeper into the parts of the lungs that are more vulnerable to injury (Morris et al, 2003). SOx cause damage to vegetation, properties and health. Additionally, CO_2, NO_2, SO_2 and SO_3 are soluble in water at different ratios. In the atmosphere, they dissolved in the available water vapor to form H_2CO_3, HNO_3, H_2SO_3 and H_2SO_4 respectively. These acids are highly corrosive in nature and come back to the earth as acid rain. Acid rain having pH of about 2.6 destroys vegetation, lakes, rivers, roof tops amongst others.

In recognition of the problems these pollutants could create, different studies are being carried out globally in order to predict and control their impact on environment. With technological advancements, the vast amount of data about ambient air is generated to know the quality of air environment and administer the appropriate corrective actions wherever necessary.

Gaseous emission monitoring study is part of environmental performance monitoring of production operations aimed at achieving continuous performance improvement with the ultimate goal of minimizing negative impacts on the environment arising from production operations. In Canada, regulatory approaches on sulfur emissions from Alberta petroleum production and processing operations address both environmental protection in the form of ambient air quality guidelines and pollution protection through sulfur recovery and flaring guidelines (Table 2). In Nigeria, Federal Environmental Protection Agency, **FEPA** (now Federal Ministry of Environment, **FME**) roled out environmental standards in 1991 as presented in Tables 3, 4 and 5. These standards are closely monitored within the Petroleum Industry in the country by Department of Petroleum Resources (DPR) for strict compliance.

This work was carried out to study the quality of these pollutants emitted into the Nigeria airshed by petroleum production operation. Similar study was carried out by Obanijesu et al, 2006 for four months in 2004 (May and August), however, this study is more comprehensive for it spanned through eighteen months (March, 2005 – August, 2006), thereby extensively covering a whole period of dry and wet seasons. This work also study the enrichment factors of the pollutants throughout the study period.

METHODOLOGY

Six flowstations located at Niger-Delta region of the country were studied for this work. The first site (oilfield1) was located in 1979 in a swamp and salt-water region. It is mounted on a concrete barge capable of producing about 45000 bpd and designed to be unmanned. It has a provision for accommodation with a houseboat as a support. It operates on electronic instrumentation, electric drive and a massive power generation that serves both the facility and the community. The second station, discovered in 1989, was a sand filled three process train facility with production capacity of 135000 bpd. The third field is a double bank station with a design capacity of about 80000bpd. It consists of a flowstation, an offshore Development Platform and 17 clusters. The facilities are unmanned, fully automatic and failsafe. The operations crew visits the station on daily basis from a terminal logistic base. The fourth is based on 30000bpd flowstation design. It supplies stabilized crude along with produced water to a terminal about 3km away via a 12" delivery line. The fifth site which is a swamp piled, three-bank flowstation with each having 45000 b/d capacities. The station is supported on piled structure with a single deck. The station is built on a piled area of about 50m by 100m. The sixth field that covers about 16km^2 is located at about 65km SSW in the swamp and salt-Water region of Warri. The field was discovered in 1973 with 17 hydrocarbon bearing reservoirs. Presently, 21 producing wells are tied in to the station.

A Testo 350 Flue Gas Analyzer (instrumental equipment for automatic analysis of ambient air through the use of physical properties and giving cyclic or continuous output signed) was used to measure the emissions. Sampling points were 60m, 200m and 500m from the flare point source. Measurements were taken in the morning between 8am and 11:59am when activities were going on within the facilities and at afternoon between 4pm and 5pm when the staff were supposed to be resting.

Air sample was continuously extracted from the atmosphere and a portion of the sample sent to the analyzer to determine the pollutant of interest. The control unit which is a portable measuring instrument for spot checks and measurements on site is equipped with a probe socket and an integrated differential pressure probe. The comprehensive range of probes makes it possible for accurate measurement of temperature, pressure, humidity, velocity, current and voltage. The measured data were statistically analyzed using Analysis of Variance (ANOVA) package and the obtained results were double checked with Scheffe Post Hoc Test as given by Shutler (2002).

RESULTS AND DISCUSSION

Figures 2 to 25 present the daily measured average concentrations ($\mu g/m^3$) of the pollutants at each distance (m) while Table 6 presents the significance level of each pollutant per field as determined by ANOVA.

SO_x measured for both morning and afternoon (Figs 2 - 7) at all fields are seriously higher than the maximum expected ambient air quality standard for the gaseous emission (Table 4). The concentrations were even greater than the emission limit for SO_x from stationary sources (Table 5), this reveals a serious problem with the discharge system. This simply identifies SO_x as a major pollutant in all the sites as confirmed by the ANOVA analyses (Table 6). It was also observed that at some instances, the afternoon readings at a specific field may be higher than that of the morning. This could be due to variation in the quality of the emission or change in wind direction.

NO_x values at oilfields 1, 2 and 3 generally fell within the limit but were threats at fields 4, 5 and 6 (Figs 8 - 13). Emissions at field 1 and 2 were dangerous however in the morning time while the emissions were considerable at other distances. Fields 4, 5 and 6 also have a sort of fluctuation in their emission values thereby falling within and without but mostly without, making the emission significant as recorded in Table 6. At oilfield 3, NO_x emission was perfectly within the environmental limit throughout the study period.

From Fig 14 – 19, it is observed that there is a high concentration of VOC at sites 1, 2 and 4 but at the other fields, the values fall within the limit. Also, Figs 20 – 25 show that CO is within the specified environmental limit in all the fields.

In Table 6, any emissions with a value lower than 0.05 is of significant emission level in that particular field. Collectively, the SO_2 is a threat in all fields studied as shown in the charts (Figs 2 – 7) and confirmed by the statistical tool employed (Table 6) to determine the significance level. This trend was observed and reported in the previous study (Obanijesu et al, 2006b), thus confirming that the company has done little or nothing in reducing this particular pollutant and therefore, there is dire need to critical solve this problem. A lot of work has been done by the company in reducing CO from the initial significant level to insignificant level, while a little improvement were recorded for NOx and VOCs.

Finally, Fields 1 and 4 are the most affected areas while Field 3 is the least (Table 6); however, none of the areas is free from acid rain which is a persistent occurrence within the region. This makes the region susceptible to consistent environmental degradation till a lasting solution is found.

Proposed Control Measures

Due to the excessive discharge of SOx, NOx and VOC in all/some of the fields, there is a need to recover these gases for commercial use before sending the rest to flare or boom. Processes such as Flue Gas Desulfurization, Wet scrubbing and adsorption could be applied.

In Washington DC, all regional significant projects must be analyzed for regional air quality emission (WSDOT, 2003). An area is monitored for a period of years, measuring particular air pollutants called "Critical pollutants". These pollutants are basically CO, SO_2, particular matters (PM), ground level ozone, lead and NO_2. Once a non-attainment area achieves compliance with the National Ambient Air Quality Standards (NAAQS), it is considered an air quality "maintenance" area until the standard has been maintained for ten years. Nigeria can equally adopt such method or develop a similar principle.

Study from Ozone Transport Assessment Group (OTAG) have concluded that regional NOx controls are one of the most effective control strategies for reducing regional ozone concentration in the eastern United States (Morris et al, 2003). Also, the 1-hour ozone NAAQS has a threshold of 0.12ppm that is not to be exceeded more than once per year within three consecutive years (Morris et al, 2003). Therefore, the industry in Nigeria should encourage researches on effective control of NOx from various oilfields. DPR should also closely monitor the producing zones for conformity with guidelines. DPR documents should include a statement of the attainment status of the area in which such project is located whereas, if the area is in non-attainment or maintenance for any of the four pollutants, the document should state the pollutants causing such classification.

Oil producing companies in Niger-Delta region of the country should develop a Company Implementation Plan (CIP) explaining how it will comply with the Clean Air Act as specified by USEPA final conformity of Nov. 24, 1993. A CIP is a collection of the regulations a company will use to clean up polluted area. The document, which should be made available to the public on request should include and discuss the results of quantitative local COx, SOx, VOC, NOx and Ozone. It should contain planning portion based on the estimates of current and future population and employment, travels and congestion; as well as Hot-Spot analysis portion based on consistency with regional emission. Hot –Spot analysis is an estimate of the likely future localized pollutants' concentrations and a comparison of those concentrations to the FEPA standards.

The management of the operating companies within the region should create systems to educate, train and support workers (all personnel, employed or contracted for any length of time), this will enable them to incorporate HSE information into their routines and conduct day-to-day tasks in a safe manner while protecting the environment (SHARE, 2002). Workers should immediately report any incident or situation which is or could potentially become unsafe or cause damage to the environment and should be free to refuse to perform unsafe work practices.

A study on air quality index for the city of Kanpur, India, Sharma et al (2003) reported that air quality worsens (very poor to severe) in winter months and also during the early summer months (March, April and part of May) and generally improves in monsoon and post-monsoon periods (good to moderate) as rain washes out the pollutants. Air Quality Index (AQI) should also be developed for Nigeria and the values published daily while forecast for the next day should be made. Those forecasts will help local residents protect their health by alerting them to plan their strenuous activities for a time when air quality is better. It will effectively allow vulnerable people reduce their risk of exposure to unhealthy air quality levels by reducing prolonged or cutting back on heavy exertion. Prolonged exertion is an activity that occurs over several hours and makes you breathe slightly harder than normal while heavy exertion is that activity that makes one to breathe hard.

CONCLUSION

This study has discovered that Niger-Delta region of Nigeria is still subjected to severe environmental degradation through unsafe gas management practices. It is therefore necessary to earnestly develop pragmatic remediation techniques to safe the environment from prolong destruction while a standard air quality index should equally be developed for the region

Table 1: The percentage of gases found in sea-level air

Element or Gas	Chemical Symbol	Percentage of Air
Nitrogen	N_2	78.084 %
Oxygen	O_2	20.9476 %
Argon	Ar	0.934 %
Carbon Dioxide	CO_2	0.0314 %
Neon	Ne	0.001818 %
Helium	He	0.000524 %
Methane	CH_4	0.0002 %
Krypton	Kr	0.000114 %
Hydrogen	H_2	0.00005 %
Xenon	Xe	0.0000087 %

Source: Pub (2005)

Table 2: Alberta Ambient Air Quality Guidelines Related to Sulfur Emission

Parameter	Guideline
SO_2	450 μg/m³ as a 1-hour average
	150 μg/m³ as a 24-hour average
	30 μg/m³ as an annual average
H_2S	14 μg/m³ as a 1-hour average
	4 μg/m³ as a 1-hour average
Static Total Sulphation	0.5mg SO_3 equivalent/day/100cm² as a 1-month accumulated average
Static H_2S	0.1mg SO_3 equivalent/day/100cm² as a 1-month accumulated average

Source: Brian (2005)

Table 3: Tolerance Limit for the Ambient Air Pollutants in Nigeria.

Pollutant	Long-term (mg/m³)	Limit (hours)	Short-term (mg/m³)	Limit (min)
CO	1.0	24	5.0	30
SO_2	0.05	24	0.5	30
Ozone	0.1	24	0.2	30
NOx	0.004	24	0.1	30
NO	0.4	12	0.8	30
NO_2	0.085	24	0.085	30
Hydrocarbon (Total)	2.0	24	5.0	30
Benzene	0.8	24	1.5	30
Toluene	0.6	24	0.6	30
Xylene	0.2	24	0.2	30

Source: FEPA (1991)

Table 4: Nigerian Ambient Air Quality Standard

Pollutant	Time of Average	Limit (μg/m³)
SOx	Daily average of hourly values; 1 hour	26 260
Non-methane Hydrocarbon	Daily average of 3 hourly values	160
CO	Daily average of hourly values; 8-hourly average	11.4 22.8
NOx (NO_2)	Daily average of hourly values (range)	75.0-113
Photochemical Oxidant	Hourly values	0.06 ppm

Source: FEPA (1991)

Table 5: Emission Limits for Specific Pollutants from Stationary Sources.

Substance	Limits (μg/m³)
CO_2	10% by Vol.
SO_2	30-300
Organic Compounds	50
SO_3	100-200
NOx	100-300

Source: FEPA (1991)

Table 6: ANOVA results showing the significant gas (es) per field

Location	SOx	NOx	CO	VOC	Significant gases
Oilfield 1	0.037	0.042	0.329	0.049	SOx, NOx and VOC
Oilfield 2	0.001	0.830	0.204	0.032	SOx and VOC
Oilfield 3	0.004	0.140	0.300	0.135	Sox
Oilfield 4	0.023	0.041	0.230	0.038	SOx, NOx andVOC
Oilfield 5	0.046	0.048	0.601	0.230	SOx and NOx
Oilfield 6	0.001	0.044	0.561	0.436	SOx and NOx

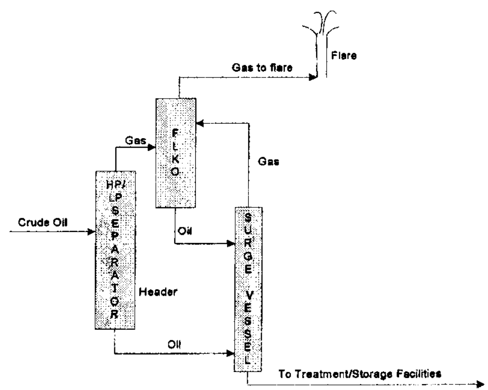

Fig 1: Oil and gas separation process before flaring/booming

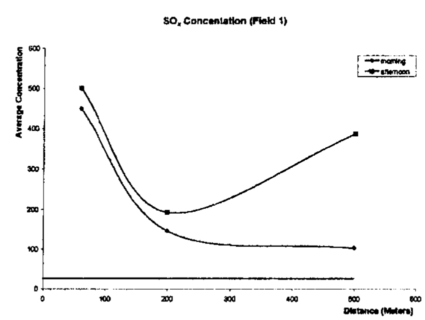

Fig 2: SOx Daily Average Concentration per distance for oilfield 1

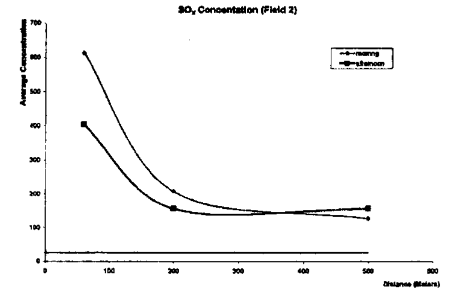

Fig 3: SOx Daily Average Concentration per distance for oilfield 2

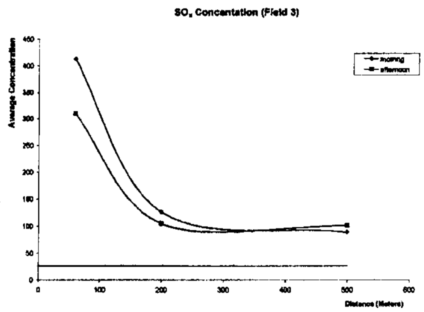

Fig 4: SOx Daily Average Concentration per distance for oilfield 3

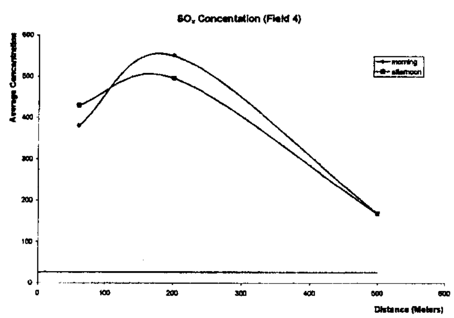

Fig 5: SOx Daily Average Concentration per distance for oilfield 4

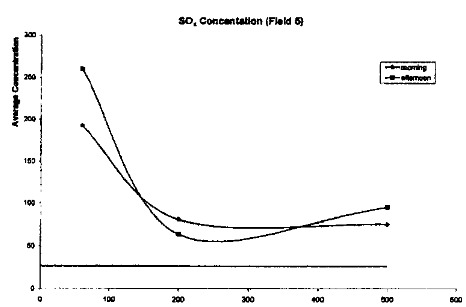

Fig 6: SOx Daily Average Concentration per distance for oilfield 5

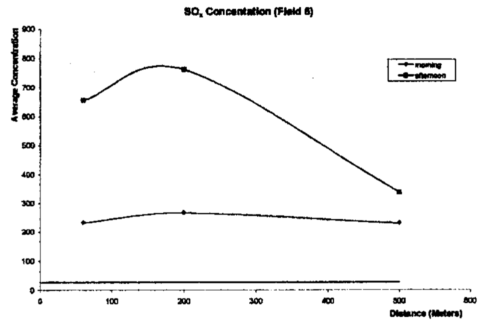

Fig 7: SOx Daily Average Concentration per distance for oilfield 6

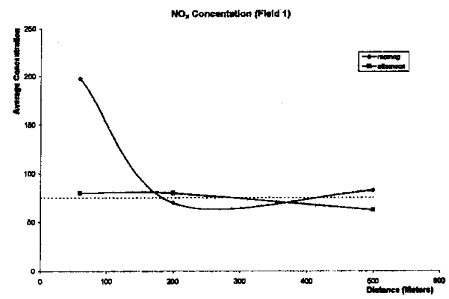

Fig 8: NOx Daily Average Concentration per distance for oilfield 1

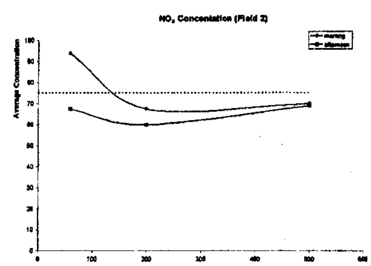

Fig 9: NOx Daily Average Concentration per distance for oilfield 2

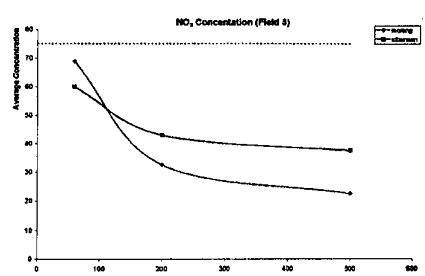

Fig 10: NOx Daily Average Concentration per distance for oilfield 3

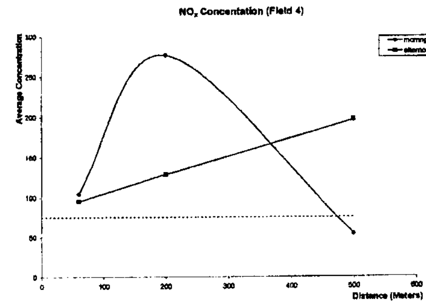

Fig 11: NOx Daily Average Concentration per distance for oilfield 4

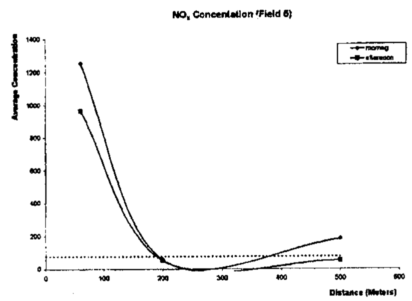

Fig 12: NOx Daily Average Concentration per distance for oilfield 5

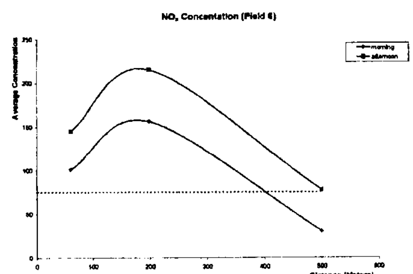

Fig 13: NOx Daily Average Concentration per distance for oilfield 6

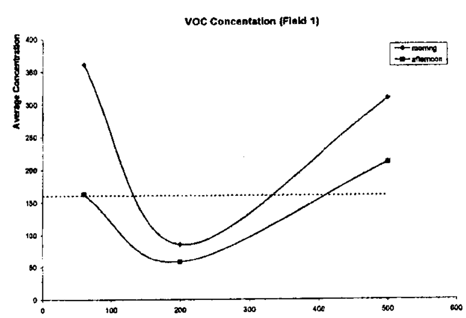

Fig 14: VOC Daily Average Concentration per distance for oilfield 1

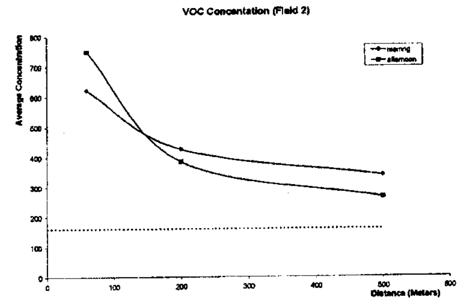

Fig 15: VOC Daily Average Concentration per distance for oilfield 2

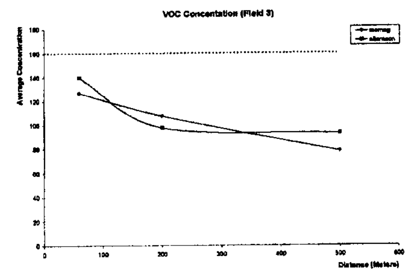

Fig 16: VOC Daily Average Concentration per distance for oilfield 3

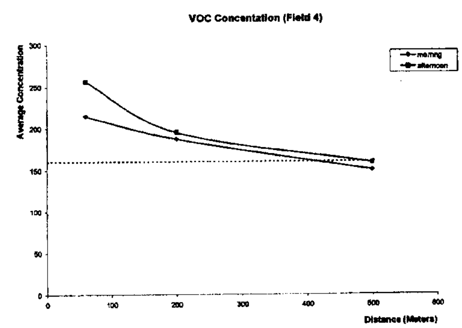

Fig 17: VOC Daily Average Concentration per distance for oilfield 4

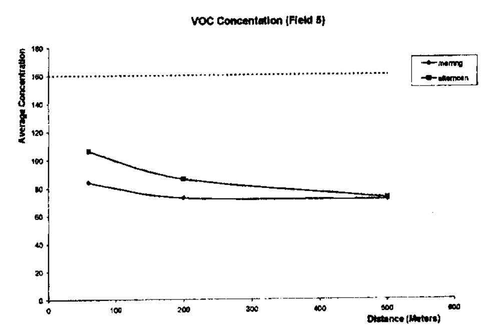

Fig 18: VOC Daily Average Concentration per distance for oilfield 5

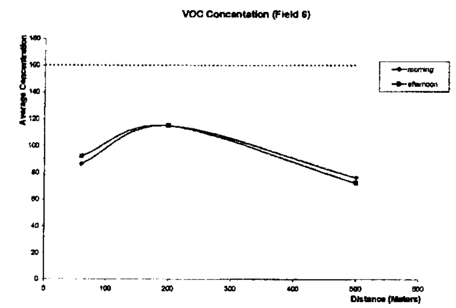

Fig 19: VOC Daily Average Concentration per distance for oilfield 6

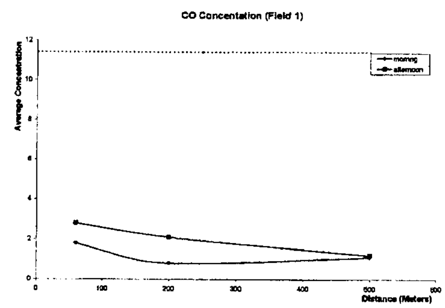

Fig 20: CO Daily Average Concentration per distance for oilfield 1

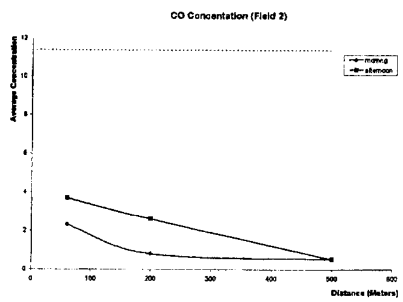

Fig 21: CO Daily Average Concentration per distance for oilfield 2

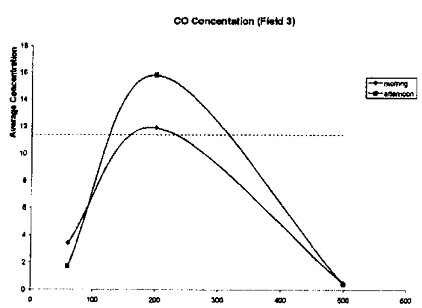

Fig 22: CO Daily Average Concentration per distance for oilfield 3

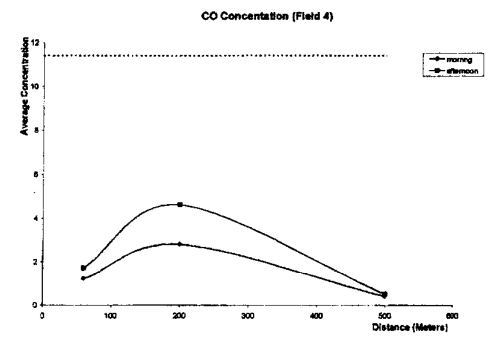

Fig 23: CO Daily Average Concentration per distance for oilfield 4

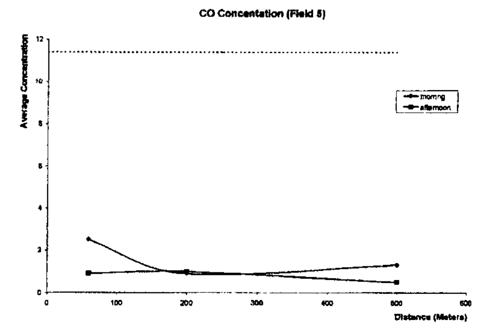

Fig 24: CO Daily Average Concentration per distance for oilfield 5

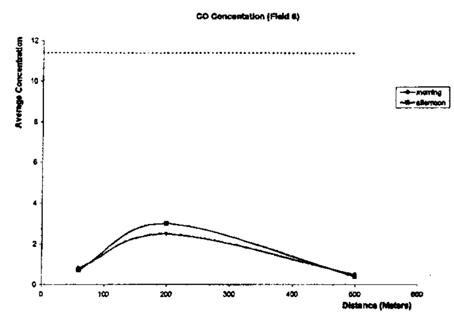

Fig 25: CO Daily Average Concentration per distance for oilfield 6

REFERENCES

Akeredolu, F.A. and Sonibare, J.A. (2004), "A Review of the Usefulness of Gas Flares in Air Pollution Control", Management of Environmental Quality: An International Journal, Vol. 15, No 6.

BIAQI (2005), "Basis for Indian Air Quality Index (IND - AQI)", http://home.iitk.ac.in/~mukesh/basis.html. accessed on 26th October, 2006

Brian, K.E. (2005), "Managing Sulphur Emissions in the Petroleum Sector", Alberta Energy and Utility Board, Calgary, Canada

Discovery (2005), "Greenhouse effect", www.crystalinks.com/greenhouseffect.html. Accessed on 20th October, 2006

Environmental components (2004), "Regional Air Pollution", http://greenpack.rec.org/air/types_of_air_pollution/01-04-06.shtml

Erinne, N.J. (1999), "Imperative of Process Engineering in the Midstream Petroleum Industry", Natural Gas: The Energy for the Next Millennium, Proceedings of the 29th Annual Conference, Nigerian Society of Chemical Engineers, Nigeria

FEPA (1991), "Guidelines and Standards for Environmental Pollution Control in Nigeria", Federal Environmental Protection Agency, Nigeria

Groundwork (2003), "Shell International's Legacy of Pollution and Damage", Pietermaritzgurg, South Africa, http://www.groundwork.org.za/Pamphlets/Shell.asp Accessed on 26th october, 2006

Klein, B. (1999), "Topic 3014: Nigeria Gas Line Fire", http://www.ldc.upenn.edu/Projects/TDT3/topic.research/topic3014.html

Morris, R.E., Pollack, A.K., Mansell, G.E., Lindhjem, C., Jia, Y. and Wilson, G. (2003), "Impact of Biodiesel Fuels on Air Quality and Human Health", Summary Report, National Renewable Energy Laboratory, Colorado, U.S.A.

NIGC (2001), "Nigeria", Country Analysis Briefs, Africa, Nigeria, April Publication http://www.nigc.org/eia/nigeria.asp

Obanijesu, E.O., Sonibare, J.A., Bello, O.O., Akeredolu, F.A. and Macaulay, S.R.A. (2006a), "The Impact of Pipeline Failures on the Oil and Gas Industry in Nigeria", Engineering Journal, Qatar. In press.

Obanijesu, E.O, Adebiyi, F.M, Sonibare, J.A and Okelana, O.A (2006b), "Air-Borne SO_2 Pollution Monitoring in the Petroleum Operation Areas of Niger-Delta, Nigeria", Energy Source: Part A, USA, In Press

Pub (2005), "Air Composition", Pub Quiz Help, www.pubquizhelp.34sp.com/sci/air.html.

Ritter, K., Lev-on, M, Nordorrum, S and Shires, T. (2002), "Development of a Consistent Methodology for Estimating Greenhouse Gas Emissions from Oil and Gas Industry Operations", Paper Presented At the 11th Annual Emission Inventory Conference, Emission Inventories- Partnering for the Future, Atlanta, G.A. 16-18, April.

Roe, S., Reisman, J., Strait, R., Albright, E. and Kataoke, K. (1998), "Identification of Point Source Emission Controla and Determination of their Efficiencies and Costs", Pechan Report No 98, 01.001/548, California Air Resources Board and the California Environmental Protection Agency, Sacramento, CA.

Sharma, M., Pandey, R., Maheshwari, M., Sengupta, B., Shukia, B.P., Gupta, N.K. and Johri, S. (2003), "Interpretation of Air Quality Data Using an Air Quality Index for the City of Kanpur, India", J. Environ. Eng. Sci 2 (6), Canada.

SHARE (2002), "Upstream Petroleum Industry's HSE Guide", Safety, Health, and Respect for the Environment, Mackenzie Delta HSE Synergy Group, Canada.

Shutler, J (2002), "One way ANOVA - Analysis of variance", http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/SHUTLER2/node1.html, Accessed on 25 October, 2006

Sound Track (2005), "Air Quality", Regional Transit Long-Range Plan, http://www.soundtransit.org/pdf/projects/seis/Final_6-05/Chapters/4-2_AirQuality.pdf

Strosher, M. (1996), Investigations of Flare Gas Emissions in Alberta", Final Report to Environment Canada, Coservation and Protection, the Alberta Energy and Utilities Board and the Canadian Association of Petroleum Products, Environment Technologies, Canada.

Vesilind, P.A, Peirce, J.J and Weiner, R.F (1993), "Environmental Pollution and Control", 4th Edition, Butterworth-Heinemann, Boston

WSDOT (2003), "Environmental Procedures Manual", Section 424, Washington State Department of Transport, USA.