Analysis of Air Quality in the Agbada Flow Station Gas Flare Stack Environment, Aluu Niger Delta, Nigeria

Ojukwu, C. K and Somerville, J.M

Institute of Petroleum Engineering, Heriot-Watt University Edinburgh, UK.

Abstract

Analysis of air quality around a gas flare stack environment was conducted for CO, SO_2, NO_2, VOC and SPM_5 for one day (morning, afternoon, evening) at three locations of 50m, 100m and 150m away from the gas flare stack. The ANOVA statistics and Pearson Product Moment correlation were used in the analysis. The result showed that only SO_2 was not within the WHO acceptable limits for air quality. However, the validated hypothesis stated that there is no statistically significant difference between the air quality in the study area and the WHO standard, hence indicating that the result is attributed to chance. The study also discovered that there is a strong negative linear relationship between SO_2, CO and the distance away from the flare stack. This meant pollutants concentration decreases with increasing distance away from the flare stack, thus suggesting it is safer to reside further away from a known gas flare stack. The study therefore concluded that extended periods of field data measurement is required for the validation of air quality status in the study area. The study further recommended that oil companies should continue to keep up with the high standards of operation while working with the regulators to plan out other gas utilization projects. A conscious periodic inventory of air quality in the flow station and its environs should be done due to the developmental projects that are beginning to spring up in the area. This is to monitor and track the concentration level of pollutants in order to avert spread of diseases arising from high pollutant concentration.

Keywords: Air Quality, Gas flare, Stack, flow station.

Introduction

The petroleum industry is the mainstay of the Nigerian economy, contributing more than 70% of the revenue and over 8% of the GDP (National Bureau of Statistics, 2017). The Niger Delta region accounts for almost all oil production in Nigeria and consequently is challenged with many of the issues in the industry.

ISSN 2229-5518

Environmental degradation is one of the key problems associated with the Niger Delta region. Standards have been set by several organizations including the World Health Organization (WHO), Nigeria Federal Ministry of Environment (FMEnv) on limits for certain toxic pollutants. Air pollution is a key area in environmental management and therefore requires that organizations and industries maintain the highest standards in its management.

Air quality can be said to be the degree to which the surrounding air is clean. When the degree to which the surrounding air is not within the acceptable set standards, the air in that environment is then said to be polluted. The World Health Organization defines air pollution as the "contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere". The sources of air pollution include; bush burning, vehicle emissions, industrial emissions and gas flaring. Some pollutants are SO2, CO, NO2, O3, SPM, and VOCs.

Nwakire (2014) in the study "The impact of gas flaring on air quality: a case study of Izombe in Eastern Nigeria" sampled for NO_2, SO_2, H_2S, CO, Volatile Organic Compounds (VOC) and SPM against the Federal Environmental Protection Agency (FEPA) standard. The method used was based on collecting samples 100m, 200m and 300m away from the flare stack. The study concluded that the mean concentrations for NO2, SO2, H2S, VOC, CO and SPM with 0.83ppm, 1.91ppm, 0.95ppm, 2.96ppm, 1.61ppm, and 7.11ppm respectively all exceeded the FEPA standard.

Ojeh (2012), in the study "Sustainable Development and Gas Flaring Activities: A Case Study of Ebedei Area of Ikwuani LGA, Delta State, Nigeria." Sampled parameters were NO_2, SO_2, CO, Methane (CH_4) and temperature. The method used was collecting samples from eight points, 50m, 150m, 250m, 250m, 450m, 550m, 650m and a control at 1700m away from the flare bond wall. The study observed that all the pollutant mean values decreased with increasing distance away from the flare bond wall. The hypothesis testing therefore showed there is a significant relationship between the pollutants and temperature.

Flare limits must be strictly adhered to by oil companies operating in the Niger Delta to continue to enhance environmental sustainability. Several studies have been conducted detailing the implication of gas flaring on air quality amongst them are the works of Ojeh, (2012), Gobo et al (2009), Akpan (2016) Nwakire, (2014) and its attendant effect on the environment and the people Adienbo, et al (2010), Orimogunje et al (2010) and Weli (2014). Therefore these raises questions that needs to be answered like what is the air quality around flare sites? Is it within set limits? What is the spread of the pollutants to the environment if any?

This study therefore focuses on analyzing air quality in the Agbada flow station gas flare stack in Aluu, Rivers State. It is aimed at determining the air quality of the study area in line with the WHO standard and the pollutants concentration in relation to distance away from the flare stack

Research Hypothesis

1. Ho = There is no statistically significant difference in the air quality of each location (50m, 100m, 150m) in the study area and WHO standards for air quality.

2. Ho: There is no statistically significant correlation between thedifferentair pollutants concentration in the different sampled locations and the distance to the flare stack.

Study Area

The Niger delta region is located in the southern part of Nigeria consisting of 9 states namely; Abia, AkwaIbom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers States. The states are also known as oil producing states in Nigeria. The Niger Delta area covers 70,000km^2 which is about 7.5% of Nigeria's total land mass with the largest wetland in Africa Tawari et al (2012). The population of the region is over 20 million

ISSN 2229-5518

with several ethnic groups. The Niger delta consists of four (4) major ecological zones which are: Mangrove swamp forest, fresh water swamps, coastal barrier islands and lowland forest. The people are predominantly fishermen and farmers. Aluu is located in Rivers State with coordinates of 4^{o}55′30″N and 6^{o}57′0E as seen in figure 1.0 below. The Agbada field where the flare stack is located is in Aluu. Figure 1.0 shows the map of study area.

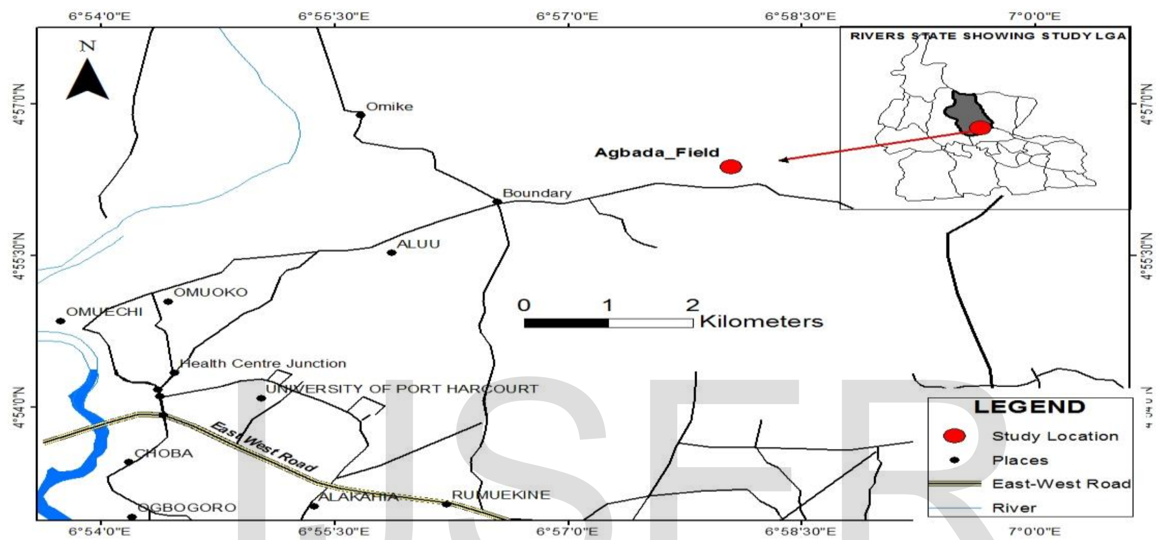

Figure 1: Study area, showing Rivers State (Inset)
Source: Author field report (2017)

Material and Methods

This study adopted the experimental research design. Montgomery, (2012) defined experimental design as the process of planning a study to meet specified objectives. Both primary and secondary sources of data were used for this study. The primary data for this study comprised mainly of in-situ air quality measurement and meteorological data. The secondary sources were books, internet materials, articles and journals

The flow station is located in Aluu community, Rivers State, Nigeria. Samples were obtained in-situ, 50m, 100m and 150m away from the flare site. This is in order to effectively determine the extent to which gas flaring emissions affect air quality in Aluu.

This is in agreement with the work done by Nwakire (2014), Ojeh (2012), Ozabor and Obisesan (2015) and Gobo et al (2015). One term monitoring was employed as sampling was carried out only for one day within duration of 12 hours; this is in line with Nwakire (2014).

In order to achieve the objectives of the study, air quality monitoring equipment were used to ascertain the concentration of different air pollutant in the different sampling locations. This was done three times for one day; from 6am to 7.30am (Morning hours), 12.00noon -1.30pm (Noon) and 5.00pm -6.30pm (Evening) in July 2017 (wet Season) and thereafter the mean was calculated and used for the analysis. The parameters measured were, SO_2, NO_2, CO, VOCs, PM_5, Wind speed, Relative Humidity and temperature.

Aeroqual Series 500 portable air quality monitor together with the various sensor heads for the different gases was used in the measurement. The instrument was powered on and held at breathing zone in the direction of the prevailing wind. Gas concentration readings were then recorded from the instrument's monitor.

Particulate Matter (PM) was collected in the study area using the Met One Model GT-321 Particle Counter for 5.0 micron size range. The monitor was hand held around the breathing zone and the measured concentration was read directly on the screen after particle capturing. Particulate matter concentrations were obtained for particulate matter with diameter of 5.0 micrometer (PM_5). PM_5 is within the range of particles for PM_{10} as specified in the WHO guideline which is for particle size diameter of between 10micrometer and 2.5micrometer. Therefore the PM_{10} guideline was used to evaluate the PM_5 particulates captured in this study. The Met One GT-321 particle counter does not measure beyond the PM_5 particulates.

Data for Temperature, Relative humidity and Wind speed were obtained using the Extech Model 45170 meter. The Instrument was hand held in the direction of the wind which turned the vane airflow sensor after which the wind value was displayed and recorded in m/s. Temperature was measured in ^0C while the Relative humidity was also recorded.

The data collected for this study was presented using tables and charts. Hypothesis one was validated using the ANOVA statistics. This is a parametric test which shows the difference between the mean two or more samples. The essence is to identify if the air quality in Aluu has significant difference with W.H.O standard for air quality.

The second hypothesis was validated using the Pearson Product Moment Correlation (PPMC) statistical tool. This is to determine the relationship between the pollutants concentration and the distance away from the flare stack. This is in agreement with work done by Ojeh (2012). PPMC critical value table was used to validate the correlation.

Results

Air quality data for the study area were collected from three different sampled locations of 50m, 100m and 150m respectively, therefore the results are presented in the light of the above.

Mean Air Quality Data for Location 1(50 Meters away from the flare stack)

This section shows the mean values of the air quality data in location 1 of the sampling points which is 50 m away from the gas flare stack as against the world health organization standard for air quality in the study location. This is as shown in the figure below.

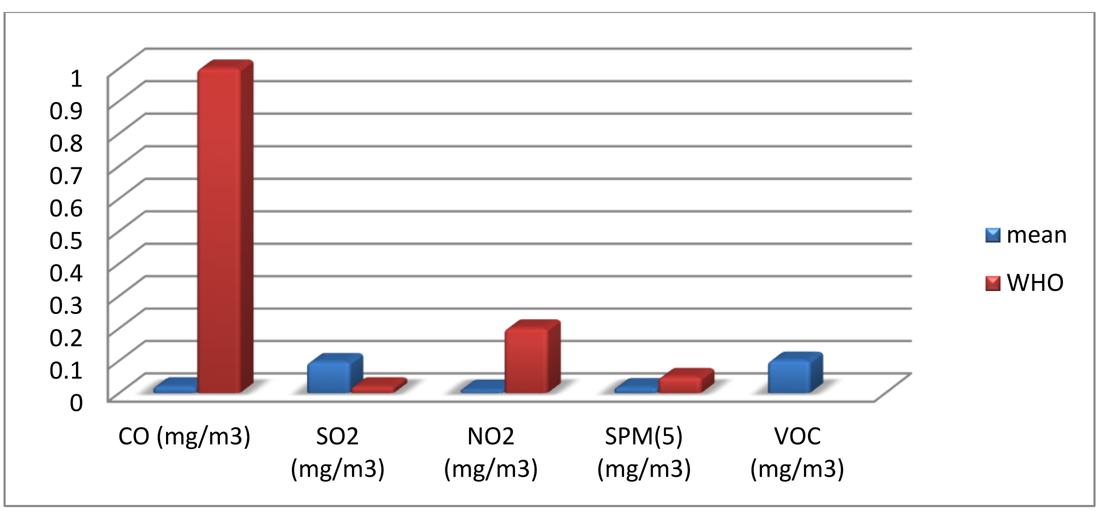

Figure 2: Graphical representation of mean air quality data for location 1 (50m away from the flare stack)
Source: Author field report (2017)

The figure 2 above shows the mean values for the sampled parameters at 50m location against the WHO standards. SPM_5, CO and NO_2 are within the WHO standards with 0.017mg/m3, 0.0201mg/m3 and 0.011mg/m3 respectively against WHO standards of 0.05mg/m3, 1.0mg/m3 and 0.2mg/m3 respectively. SO_2 is above the WHO standard with 0.096mg/m3 against a WHO standard of 0.02mg/m3. Therefore SO_2 is not within the acceptable limits at the 50m location.

Mean Air Quality Data for Location 1(100 Meters away from the flare stack)

This section shows the mean values of the air quality data in location 2 of the sampling points which is 100 m away from the gas flare stack as against the World Health Organization standard for air quality in the study location. This is as shown in the figure below.

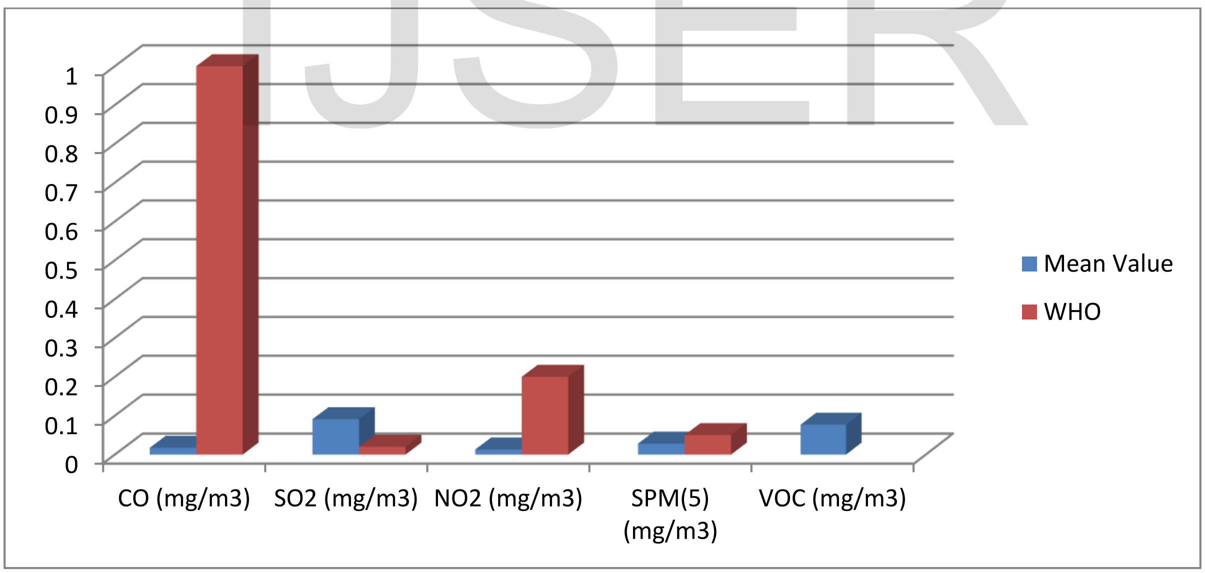

Figure 3: Graphical representation of mean air quality data for location 2 (100m away from the flare stack)
Source: Author field report (2017)

The figure 3 above shows the mean values for the sampled parameters at 100m location against the WHO standards. SPM_5, CO and NO_2 are within the WHO standards with

0.028mg/m3, 0.0174mg/m3 and 0.0131mg/m3 respectively against WHO standards of 0.05mg/m3, 1.0mg/m3 and 0.2mg/m3 respectively. SO_2 is above the WHO standard with 0.091mg/m3 against a WHO standard of 0.02mg/m3. Therefore SO_2 is not within the acceptable limits at the 100m location.

Mean Air Quality Data for Location 1(150 Meters away from the flare stack)

This section shows the mean values of the air quality data in location 2 of the sampling points which is 150 m away from the gas flare stack as against the World Health Organization standard for air quality in the study location. This is as shown in the figure below;

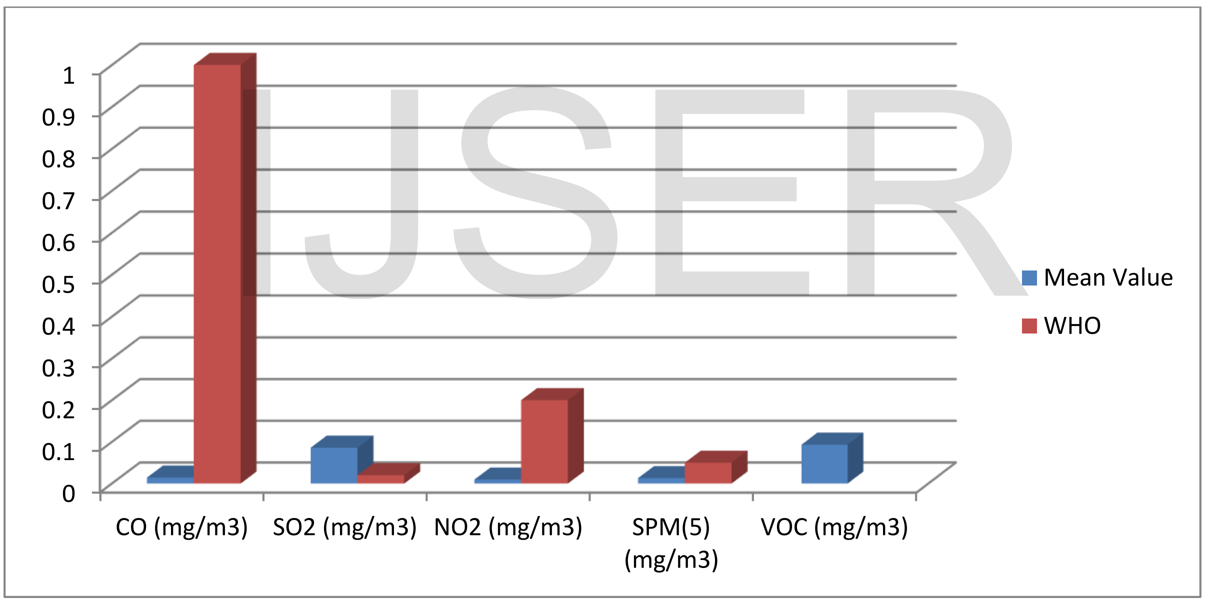

Figure 4: Graphical representation of mean air quality data for location 1 (50m away from the flare stack)
Source: Author field report (2017)

The figure 4 above show the mean values for the sampled parameters at 150m location against the WHO standards. SPM_5, CO and NO_2 are within the WHO standards with 0.013mg/m3, 0.0143mg/m3 and 0.0095mg/m3 respectively against WHO standards of 0.05mg/m3, 1.0mg/m3 and 0.2mg/m3 respectively. SO_2 is above the WHO standard with 0.086mg/m3 against a WHO standard of 0.02mg/m3. Therefore SO_2 is not within the acceptable limits at the 150m location.

Report of Meteorological Parameters in the different Locations

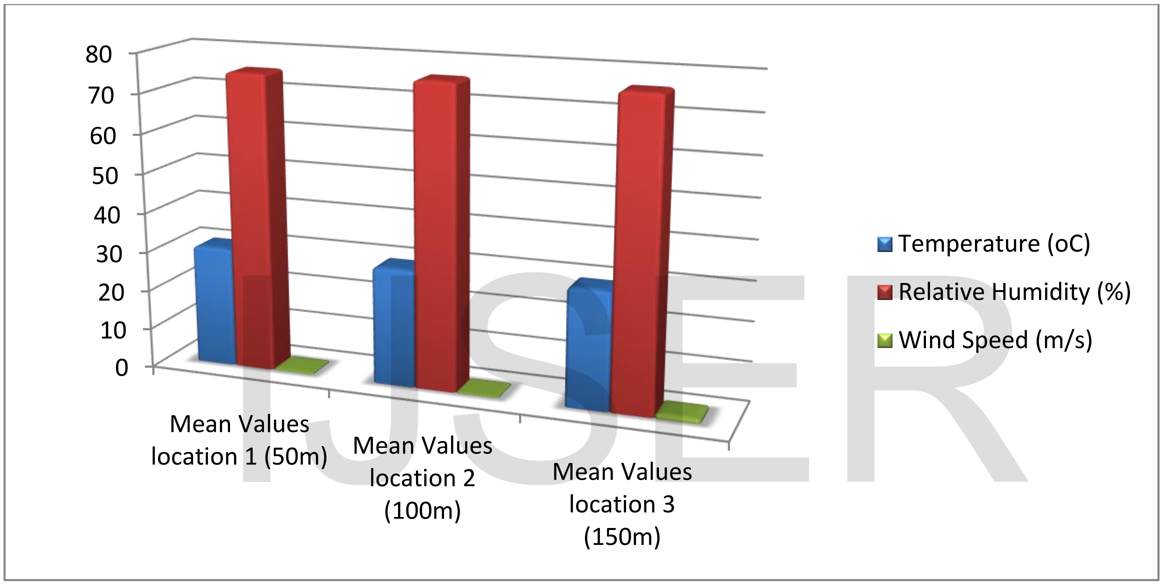

Figure 5: Mean Values for Meteorological parameters in the different locations
Source: Author field report (2017)

The mean wind speed for the three locations was 0.4m/s, 0.3m/s and 1.14m/s respectively.

Temperature in the area showed a mean of 30.53 ^{0}C, 29.7^{0}C and 29.63^{0}C respectively for the three locations. Relative humidity also revealed that at a distance of 50m away from the stack, a value of 75.37% was obtained while 76.1% and 76.33 were recorded for 100m and 150m locations respectively.

Hypothesis Testing

The hypothesis of the study were validated with ANOVA statistic tool for hypothesis one and the Pearson product moment correlation statistics for hypothesis two.

In the analysis of hypothesis one, each location at the study was compared with the WHO standard to validate the difference.

Hence, the null hypothesis Ho: states that there is no statistically significant differences between the 50m, 100 and 150m locations and the WHO standard for air quality.

Table 1: Result of ANOVA for difference in air quality parameters in distance of 50m, 100m 150m and WHO Standard Limits for air quality.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1042.817	3	347.6056	0.619113	0.608471	2.946685
Within Groups	15720.8	28	561.4571			
Total	16763.62	31				

The ANOVA table above reveals that calculated F statistic value for the analysis is 0.619113while the critical value is 2.9466585. Therefore, since the calculated F statistic value of 0.619113is less than the critical value of 2.9466585 $F^{3}{}_{31}$ degree of freedom, hence the null hypothesis H_0 of no significant variation is accepted and the alternate hypothesis H_1 is rejected. From the result the study has revealed that there is no statistically significant difference between the 50m, 100 and 150m locations and the WHO standard for air quality in the study.

Hypothesis one for this study is confirmed that there is no statistically significant difference between the air quality in the study area and the WHO standards for air quality.

The Pearson Product Moment Correlation (PPMC) was used in the correlation analysis of the various air pollutants studied. Thereafter, table for PPMC critical values was used to validate the hypothesis for the individual pollutants.

A line graph was initially adopted to present the correlation between the pollutants concentration and distance to the flare. The choice of a line graph instead of a scatter plot was due to the limited number of data. Figure 3.4 and table 3.3 below show the result of the analysis.

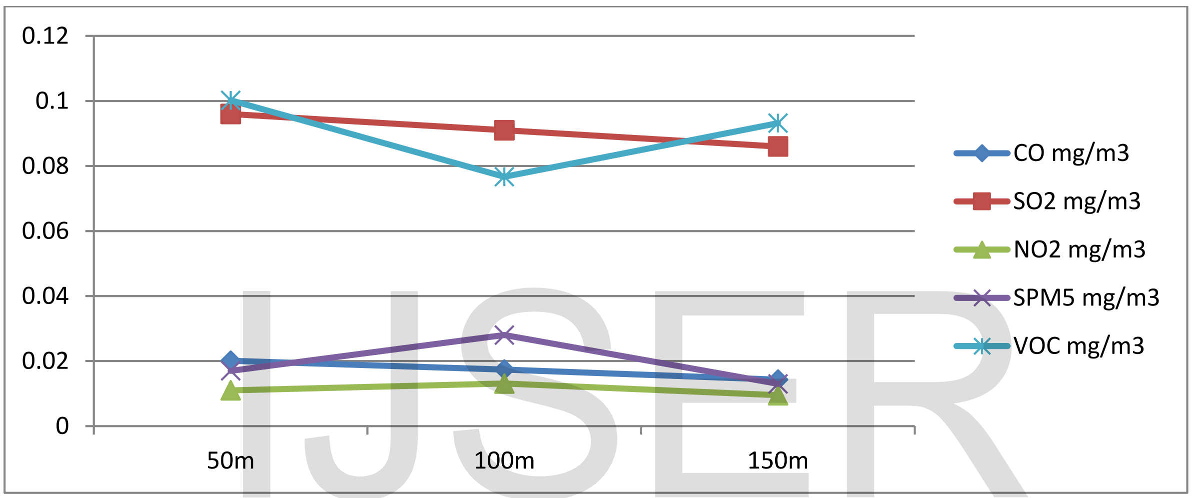

Figure 6: Relationship between mean pollutant concentration and distance to flare stack.
Source: Author field report (2017)

Figure 6 above suggest a negative linear relationship exists between the pollutants concentration CO, SO_2 and the distance to the flare stack. It also shows that as the distance from the flare stack increases, the pollutants concentration decreases for CO and SO_2. This is however a simple relationship since only two variables are involved. Therefore, in determining the strength of the relationship, the PPMC was used for each of the pollutants against the distance to the flare stack. The table 2.0 below shows the correllation coefficient of the various pollutants studied.

International Journal of Scientific & Engineering Research Volume 11, Issue 12, December-2020
ISSN 2229-5518

Table 2: Correlation Coeficients Result for Sampled Pollutants

CO			**SO_2**		
	Column 1	*Column 2*		*Column 1*	*Column 2*
Column 1	1		Column 1	1	
Column 2	**-0.99921**	1	Column 2	**-1**	1
SPM5			**$N0_2$**		
	Column 1	*Column 2*		*Column 1*	*Column 2*
Column 1	1		Column 1	1	
Column 2	**-0.25748**	1	Column 2	**-0.41475**	1
VOC					
	Column 1	*Column 2*			
Column 1	1				
Column 2	**-0.29008**	1			

The Table 2, suggests a strong negative linear relationship exists between CO, SO_2 and the distance to the flare stack based on their correlation coefficients of -0.99921 and -1 respectively. However it also suggests a weak nagative linear relationship for SPM_5, NO_2 and VOC based on their correlation coefficents of -0.25748, -0.41475 and -0.29008 respectively.

The hypothesis was therefore validated for each pollutant using their correlation coefficients at a probability level of 95%, and 1 degree of freedom.

Table 3: Correlation Hypothesis Testing Result

Parameters	correlation coefficient r	critical value	DF	Probability Level
CO (mg/m3)	-0.999	0.997	1	0.05
SO2 (mg/m3)	-1	0.997	1	0.05
NO2 (mg/m3)	-0.414	0.997	1	0.05
SPM(5) (mg/m3)	-0.257	0.997	1	0.05
VOC (mg/m3)	-0.29	0.997	1	0.05

Therefore from table 3 above, the null hypothesis is rejected for pollutants CO and SO_2, hence the alternate hypothesis is accepted which states that there is a statistically significant correlation of theair pollutants concentration for CO and SO_2 in the different sampled locations and the distance to the flare stack.

While the null hypothesis is not rejected for pollutants NO_2, SPM_5 and VOC which states that there is no statistically significant correlation of theair pollutants concentration for NO_2, SPM_5 and VOC in the different sampled locations and the distance to the flare stack.

Discussions

The findings of the study revealed that CO, NO_2 and SPM_5 mean concentrations of 0.0201mg/m3, 0.0174mg/m3, 0.0143mg/m3; 0.011mg/m3, 0.0131mg/m3, 0.0095mg/m3 and 0.017mg/m3, 0.028mg/m3, 0.013mg/m3 respectively for the three locations (50m, 100m, 150m) were within acceptable limits of the WHO standard. This is in agreement with the study of Gobo et al (2009) where all the parameters studied were within regulatory limits. However, SO_2 with mean concentrations of 0.096mg/m3, 0.091mg/m3 and 0.086mg/m3 for the three locations of 50m, 100m and 150m respectively were not within the WHO acceptable limits. This is also in agreement with Ojeh (2012) and Nwakire (2014) where measured SO_2 data failed to meet the regulatory limit. VOC which was not paired with WHO standard in this study had a mean value of 0.1002mg/m3, 0.0767mg/m3 and 0.0932mg/m3 for the three sampled locations of 50m, 100m and 150m respectively. SO_2 reacts with rain water to cause acid rain which is harmful to the environment, Otti et al (2014).

However, the study revealed that there is no statistically significant difference between the study area air quality and the WHO standards. This suggests that the results are more probably attributed to chance; therefore they have a low probability to be true. Small sample size was a common observation in the study. However, winter (2013) confirmed that the use of very small sample size is adequate for student's t test.

Figure 5 showed the temperature decreasing with increasing distance away from the flare stack. This was the phenomenon observed in the study of Ojeh (2012) and Ozabor and Obisesan (2015). The authors reported that temperature not only influences the pollutants but also affect agricultural produce around the heat source, Ozabor&Obisean (2015). This study also observed that the relative humidity increased as the temperature decreased with increasing distance away from the flare stack this agrees with Weli (2014). The study showed that lower values of SPM were reported in the wet season than in the dry season. This was in agreement with the study conducted by Gobo A. E et al (2009) and AkpanAnyanime O. where lower values of NO2, SO2, CO, Total

Suspended Particles (TSP) and SPM were reported in the wet season. This is suspected to be the case in this study since it is conducted in the wet season.

The study also discovered that there is a strong negative linear relationship between the pollutants concentration of CO and SO_2 in the different sampled locations and the distance to the flare stack at the study area. This suggests that it is safer to reside further away from the flare stack than too close to avoid air pollution.

Bluman (2006), mentioned that there are possibilities for relationships between two variables to be strong which can be due to several outlined factors, one of which is a third unknown variable referred to as a lurking variable.

Several variables could be termed lurking, like the period or season when the samples were taken. Weli (2014) showed that both wet and dry seasons influence the spread of air pollutants. Air pollutants spread more and further in the dry season than the wet season. The position of the flare stack is another factor that was not considered. According to Akeredolu and Shonibare (2004), elevated flare stacks have the ability of better dispersing the combustion products and pollutants away from its area. A ground flare was used at the study area which could have contributed to the higher concentration of pollutants around the flare stack. Other anthropogenic activities could impact the result. However, the study area was largely non-residential with very few human activities.

The strong negative linear relationship between pollutants concentration and distance to flare stack discovered in the study are also in agreement with the studies conducted by Ojeh (2012) and Nwakire (2014). While Ojeh (2012) determined the correlation between the temperature of the flare and the distance, Nwakire (2014) used descriptive method to ascertain the relationship between distance and the pollutants concentration. Both methods of analysis were different from the methods used in this study.

Conclusion and Recommendations

The result showed that only SO_2 was not within the WHO acceptable limits for air quality. However, the validated hypothesis stated that there is no statistically significant difference between the air quality in the study area and the WHO standard, hence indicating that the result is attributed to chance. It is therefore concluded that extended periods of field data measurement is required for the validation of air quality status in the study area.

However, the study also observed a strong negative relationship between SO_2, CO and the distance to the flare stack. This means that the concentration of the pollutants decreases with increasing distance away from the flare stack, suggesting that it is safer to reside further away from the flare stack than closer to it.

Based on the result of the study, it is recommended that the oil companies should continue to keep up with the high standards of operation while working with the regulators to plan out other gas utilization projects. It also recommends a timely and conscious periodic inventory of air quality of the flow station owing to the developmental projects that are beginning to spring up in the area so as to understand the nature, characteristics and concentration level of pollutants to avert spread of diseases arising from high pollutants concentration in the area.

References

Adienbo O. M, Nwafor A. (2010): Effect of prolonged exposure to gas flaring on some haemological parameters of humans in the Niger Delta region of Nigeria. Journal of Applied Science and Environmental management. Vol. 14(1) 13 – 15.

Akeredolu F. A and Sonibare J. A (2004): A review of the usefulness of gas flares in pollution control. Journal of management of Environmental quality.Research Library.Pg 574

Akpan A.O (2016): Environmental sustainability: Assessing the impact of air pollutants due to gas flaring – QueIboe Estuary case. World Journal of Environmental Engineering.Vol. 4. No. 1 1 – 5.

Ana, G. R, Sridhar E.E, Mynepalli K.C and Asuzu M.C (2010): Environmental risks factors and hospital based cancers in two Nigeria cities. Journal of Public health and Epidemiology. 2(8) 216 – 223.

Bluman, A.G. (2006): Elementary Statistics: A brief Version. A step by step approach.McGraw Hill.Third Edition. ISBN 0-07-297621-7 pg. 1 – 612

Freeman, E.R. (1984): Strategic Management-The Stakeholder Approach. Boston: pitman

Gobo A. E, Richard G., Ubong I. U (2009): Health Impact of gas flares on Igwuruta / Umuechem communities in Rivers State. Journal of Applied science and environmental manangement. Vol. 13(3) 27 – 33

Ite, A.E, Udo, J.I, Magaret, U.I, Sunday W.P (2013): Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigerian Niger Delta. American journal of environmental protection.Vol 1 Issue 4

Montgomery D. C (2012): Design and Analysis of experiments. John wiley& sons Inc. Isbn 9781118146927. 8th Edition.pg 5 750

Nachmias C. F and Nachmias D (2009): Research methods in the social sciences. Hodder Education.5th edition. ISBN: 978-0-340-66226-7 pg. 1 - 547

National bureau of statistics (NBS) Nigerian GDP report for Q1 2017.
www.nigerianstat.gov.ng/

Nwakire, C (2014): The impact of gas flaring on the air quality: A case study of Izombe in Eastern Nigeria. International journal of Engineering research and reviews. Vol. 2 issue 3 PP 61 – 71

Ojeh, V.N (2012): Sustainable development and gas flaring activities: A case study of Ebedei Area of Ukwuani LGA, Delta State, Nigeria. Journal of Resources and environment. 2(4) – 174

Orimoogunje O. O. I, Ayanlade A., Akinkuolie T. A, Odiong A.U (2010): Perception on effect of gas flaring on the environment. Research journal of environmental health and earth sciences. ISSN; 2041-0492

Otti, V.I and Ogbuagu, F. U (2014): Environmental health effects of exposure to air pollution in Industrialised Areas. Journal of civil and engineering research. ISSN 2224 – 5790

Oyegun C.U (2003): Essentials of social and environmental research. University of Port Harcourt press limited 1st edition..ISBN: 978-2321-94-X Pg. 1 – 239

Ozabor. F and Obisesan, A (2015): Gas flaring: Impacts on temperature, Agriculture and the people of Ebedei in Delta State, Nigeria. Journal of sustanaible society.Vol 4. No. 2, 2015, 5 – 12.

Mmom, P.C and Ubokobong, E (2014): Spatio-temporal variations in Urban vehicular emission in Uyo city, AkwaIbom State, Nigeria. Journal of sustainable development. ISSN: 1913-9063

Tawari C.C and Abowei, J.F.N (2012): Air pollution in the Niger delta area of Nigeria. International journal of fisheries and aquatic sciences. ISSN: 2049-8411

Weli, V.E. (2014): Spatial and seasonal influence of meteorological parameters on the concentration of suspended particulate matter in an industrial city of Port Harcourt, Nigeria. Journal of developing country studies. ISSN: 2224-607X

Winter, J D. (2013): Using the student's t- test with extremely small sample sizes. Research gate publishers.Practical assessment, research and evaluation. ISSN: 1531-7714

Zagha, O and Nwaogazie, I.L (2015): Roadside air pollution assessment in Port Harcourt Nigeria. Standard scientific research and essays. ISSN 2310-7502
http://web.anglia.ac.uk/numbers/biostatistics/pearson/local_folder/critical_values.html. accessed on august 27, 2017.