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# Effect of Gas Flaring on Buildings in the Oil Producing Rural Communities of River State, Nigeria *(Pp. 90-102)*

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## Abstract

*Many rural communities in the Nigeria Delta Region have been exposed to the flaring of Associated (AG) gas due to increased extraction of petroleum in the area. The study aimed at assessing the effect of gas flaring on the built environment using buildings as the main observed objects. Two rural communities (Obrikom and Omoku) were used for the case-control study. The study, carried out within a period of 11 months, combined modeled and measured estimates, considered emissions inventory and location data and combined expert judgment to assess possible effects of gas flaring on a sample of 106 buildings. Results shows that* $SO_2$*,* $NO_2$ *and* $PM_{10}$ *were the major pollutants that may have acted as causative agents of the observed impacts (corrosion of roof tops, coloration of walls, leakage of roof tops etc), due to their toxic properties. There was high positive correlation between pollution levels and the level of impact on the sampled buildings (OR = 3.2, 95%, C.I. 1.3 – 6.7). The study concluded that epidemiological studies on the communities around gas flaring points have become imperative to determine the health effects from continuous exposure.*

**Key Words:** buildings, degradation, effect, exposure, emissions, gas flaring

## Introduction

Nigeria is the world's biggest flarer of Associated Gas (AG) with more than 1000 gas flaring points that release over 23 billion/$m^3$ of gas per annum (Olukoya, 2008). Due to poor infrastructure and unsustainable practices among oil companies, only 19% of the total gas flared is recovered (Ibhade 2001, Evoh 2002). Recent studies have investigated the impact of gas flaring on micro-climate and vegetation (Odilison 1999, Efe 2003) soil, air and water quality (Ekanem 2001), human health (Obajimi 1998; Oniero and Aboribo 2001) and on national economy (Oghifo 2001). Other studies associated gas flaring with increasing poverty among rural women (Obadina 2000, Gabriel 2004), climate change (Emerole 2008), and increase in political activism in the Niger Delta Region (Akingbade 2001). Although these studies differed in their findings and conclusions, some produced very astonishing results. For example, a study in Bayelsa State in 2005 found that gas flaring caused 49 pre-mature deaths, 120,000 asthma attacks and 8 additional cases of cancer (ERA and CJP 2005). Despite these efforts, studies on the impact of gas flaring on built environment are limited. Increasing concerns about long-term effects due to residential proximity to gas flaring points prompted this research since operations of industrial facilities near human habitations may lead to increased hazards and environmental degradation (Pezzoli *et al* 2007). The aim of this study was to assess the impact of gas flaring on the major components of the built environment, namely, buildings. These structures constitute elements that relate to public health and safety, local economy and cultural heritage (Transande *et al* 2009). Our working hypothesis was that greater exposure of buildings to gas flaring may be associated with their increased degradation.

## Materials and Methods

The study was carried out at Obrikom and Omoku communities in Ogba/Egbema/Ndoni Local Government Area (ONELGA) of Rivers State. Obrikom, (designated Zone A) stretched between 4km to 8km from the flare point while Omoku (Zone B), located between 10km to 15km both from the flare point formed the control area. The overall distance conforms with recommendations from Slama *et al* (2008) on air pollution measurements and exposure assessment. These two contiguous communities have been exposed to gas flaring for the past 40 years when Agip Company started exploiting crude oil in the area. The area has therefore been exposed to air pollutants for quite some time. A questionnaire-based interview was conducted among one out of every four residents in the area to obtain vital information on their buildings (age, specific uses, etc). Other information included those on roofing materials, distance of buildings from flare points, different changes observed on them, and intensity of change. A total of 106 buildings were surveyed with 82 of them located at Obrikom and 24 at Omoku. Most of these buildings were bungalows having between 2 to 5 rooms with block walls and different roofing materials. The Gaussian Plume Dispersion Model was used to predict the time-averaged concentrations of gaseous pollutants downwind from the flare point close to Obrikom (4km) based upon emission data (stack height, efflux velocity, diameter of stack, wind speed, concentration of individual pollutants, etc, obtained from Agip Company) and atmospheric dispersion estimates (See Equation 1) in order to optimize exposure assessment (Jurek et al 2005). This model applies only to a single point source of air pollutants (Masters 2006) which was exactly the case in point. The modeled values were validated by on-the-spot measurements of ambient concentration levels of pollutants at eight sampling points located within the two communities (5 at Obrikom and 3 at Omoku). Air sampling was conducted focusing mainly on three *criteria pollutants*, namely, sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$) and particulate matter ($PM_{10}$) since they constitute more than 60% of total AG emissions from petroleum extraction (CARB 1998; Karbassi *et al* 2007, Soltanali and Shams Hagani 2008) and for the fact that their toxicity can vary according to time, season and location (Hopke et al 2006). Measurements were made using the Multi Gas Analyzer MRU (2002 Model) with electrochemical measuring principles and complete gas conditioning systems. Data were collected between 8.30am and 4.30m on 8-hourly within one-hour and half-hour intervals on daily basis during the 11-month period. This helped to locate the sampling points with the highest and lowest concentration levels of individual pollutants at any given time. The study therefore combined modeled and measured estimates and added expert judgment component to evaluate possible impact of these gases on buildings. The sampling period (November 2007 to September 2008) covered the two seasons of the year (dry and rainy seasons) to enable the assessment of the influence of humidity and dry atmosphere on ground level concentrations of measured pollutants. The pH levels of rain water were equally monitored during the study period. Impacts on the buildings were categorized as weathering of the walls, changes in colour of roofing materials (corrosion) and walls, leakage of roof tops, cracks on walls, and coloring of walls following the approach of Sexton et al (2007). Data were analyzed using mixed-effect models with random subject effects accounting for repeated measures. Covariates were chosen based on previous literature identifying potential risk factors for buildings exposure to air pollution (Cooper and Alley 2002; Smith 1993b, Rahbar and Kaghazchi 2005). In the first level of analyses, linear and logistic models were applied for the three pollutant gases combined to know whether associations exist. Similar models were also applied for all observed changes in the buildings, including all potentials covariates excluding pollution variables, to verify whether associations exist. The three pollution variables were then included into the models to investigate their effects on the buildings. The effect of distance from the source of flare and observed changes were examined to know whether they modified the effects of air pollutants on buildings. For categorical exposure variables, odds-ratios (ORs) and 95% confidence intervals (CIs) were calculated to assess the association between pollutants, observed changes in buildings and adjustments for other potential confounders. Sensitivity analyses were performed to explore the robustness of the models used. Data were analysed using statistical package SAS version 9.1 (SAS Institute Inc, Cary, NC, USA).

## Results and Discussion

There were significant differences in the concentration levels of individual gases at different sampling points compared with Federal Environmental Protection Agency (FEPA) standards. It was observed that the concentration levels of $SO_2$ and $NO_2$ were highly significant ($p<0.05$), especially during the dry season. The diurnal concentration levels of $SO_2$ ranged from 225μg/m$^3$ to 238μg/m$^3$ with an average diurnal value of 232μg/m$^3$; $NO_2$ ranged between 210μg/m$^3$ and 223μg/m$^3$ with an average diurnal value of 217μg/m$^3$, while $PM_{10}$ ranged from 56μg/m$^3$ to 62μg/m$^3$ with an average diurnal value of 59μg/m$^3$. The highest daily concentration levels of the three pollutants were recorded at sampling points located at Obrikom during the dry season, while the least were recorded at Omoku during the rainy season. The daily 8-h sampled data recorded in the sampling points showed that concentration levels of $SO_2$, $NO_2$ and $PM_{10}$ exceeded FEPA standards by 70%, 63% and 51% respectively. Consequently, there were 183 recorded exceedances for $SO_2$, 172 exceedances for $NO_2$ and 155 exceedances for $PM_{10}$ during the period of study. There were significant differences in the frequency of the effects observed among the buildings. Results showed that 60 buildings (56.6%) had below 15 year while 46 of them (43.4%) had more than 15 years. Out of the 106 buildings surveyed, 94 of them (88.7%) were used for residential purposes 6 for commercial (5.7%), one for industrial (0.9%) and 5 for other uses such as school, church, town halls (4.7%). Also 82 buildings (76.4%) were located within a distance ranging between 4 to 8km from the flare point while 24 buildings (23.6%) were located between 10 to 12km. Majority of these buildings (86.8%) used galvanized corrugated steel roofing sheets (NIS180:2004), 11 or (10.4%) used profile aluminium roofing sheets (NIS 448:2004) while only 3 or (2.8%) used asbestos (Table 1). There were spatial variations of changes observed on the sampled buildings. Seventy-six of these buildings (71.7%) recorded various changes which may be associated with gas flaring. Out of this number, 58 or (76.3%) were located at Obrikom (Zone A) while the remaining 18 (23.7%) at Omoku (Zone B). The roofing materials of the buildings in Zone A were 2.5 times more corroded than those in Zone B. Also, buildings in Zone A were 2.3 times more likely to suffer from leakage of roof tops, 1.9 times more likely to experience cracks on walls and 2.5 times more likely to suffer from weathering than those in Zone B. (Table 2). These results showed the role of proximity to source of gas flare and its likely impacts on the state of buildings in the area. Although the predicted concentration levels of pollutants did not match accurately with the measured values with high accuracy, both values were very close and consistent. Results from statistical analyses revealed a high positive correlation between pollutant levels and the level of impact recorded among the buildings; it was significant at 0.05 level and positive (0.78). This positive coefficient indicates that the two zones, especially Zone A, the more exposed area, experienced higher concentration levels of pollutants. The correlation between exposure to $SO_2$ and $NO_2$ was 0.83, and between $NO_2$ and $PM_{10}$ was 0.52. Among these gases, $SO_2$ correlated perfectly with corrosion of roofing materials (0.88), while $NO_2$ correlated with colour changes of building walls (0.56). Particulate matter correlated with weathering of building walls (0.61). Correlations during seasonal exposures (dry and wet seasons) were 0.77 and 0.81 for $SO_2$; 0.62 and 0.51 for $NO_2$ and 0.55 and 0.29 for $PM_{10}$. There was a strong correlation between $SO_2$ concentrations and pH level (0.89). Also, there was a strong association between the three pollutants and the observed changes on buildings in the overall sample. (OR =3.2, 95%, CI 1.3 – 6.7). However, this association varied according to age of buildings, materials used for roofing, and distance from the flaring point. It was strongest among buildings above 15 years of age (adjusted OR = 2.5, 95%, CI 1.7 – 8.5) than those below 5 years at

Obrikom (OR = 1.9, 95%, CI 1.3 – 4.6) and those at Omoku (OR = 2.2, 95%, CI 1.5 – 4.2). Exposure estimates for the three pollutants co-varied. Despite the continuous emission of pollutant gases on daily basis from the Emission Stack of Agip Company, the absence of a strong wind, especially during the dry season, contributed to heavy concentration of pollutants within the built-up areas. Results show that $SO_2$, $NO_2$ and $PM_{10}$ were the major pollutants that may have acted as causative agents of the observed impacts due to their toxic properties (Mauderly 1997, Swanson et al 2007). The corrosive effects of these acidic gases ($SO_2$, $NO_2$) on roofing materials and metallic objects appeared greater during the months of lighter rains (February – April) than other periods of the year. During this period, the scanty rain droplets and high concentrations of $SO_2$ and $NO_2$ with an average pH value of 4.9, all combined to form acidic solutions which acted as corrosive agents, exerting high oxidative stress on the metallic surface of buildings especially on roof tops (Bhatia 2009, Lowton 1997, Jones 1996). This suggests that the mechanism of resistance of buildings to these pollutants may have been altered by age, materials used, length of exposure, seasonal variations in humidity (acid rain), wind speed, coupled with the increased effects of other environmental stressors (Potera 2009, Rothman and Greenland 1998; Drisko and Jenkins 1998). The nature and orientation of buildings contributed significantly in either the dispersion or concentration of emitted gases. High concentration of buildings in the two communities blocked free circulation of gases at ground level in the form of eddies thereby limiting their dispersion and dilution. Also, the poor turbulent mixing of the pollutants in the built-up areas especially during the dry season characterized by gentle breeze may have led to high concentration of pollutants at ground level. However, during rainy season, wind direction and slight increase in its speed were much more favorable to the mixing of the gases and their dispersion and dilution. This partly explains the low concentration levels of pollutants during this period. Also, the common use of cheap and substandard roofing materials (galvanized steel sheets as low as 0.15mm thickness instead of the 0.18km standard and profile aluminum sheets as low as 0.35mm instead of 0.50mm standard) made them more susceptible to leakages and discoloration due to increased corrosion and weathering. The same observation was made on the use of substandard paints on building walls which became less resistance to humidity and weathering thereby causing frequent discoloration of these walls. As Agip Company continues to flare gases in the area, there are concerns about the long-term effects due to residential exposure and the health and property of the local population. Already, there is growing anger among these people about the damages already caused to their ecosystems and health by gas flaring and increasing incidence of crude oil spillage (Ahove 2006). It has therefore become imperative to conduct epidemiological studies on the surrounding communities to determine the health effects from exposure to continuous gaseous emissions from this flare point. From the above results, Obrikom and Omoku communities fall within *non-attainment ar*eas (Turk and Turk, 1998) in terms of the three criteria pollutants for the simple fact that they do not meet the ambient air primary standards necessary to protect public health and as their standards for 1-h and 8-h records were exceeded on daily basis.

## Conclusion

This study has tried to examine the impact of gas flaring on the buildings at Obrikom and Omoku communities. Results revealed a strong association between emissions from the flare point and some impacts observed on the buildings in the area. The results showed that the most probable air pollutants that caused these observed impacts were $SO_2$, $NO_2$ and $PM_{10}$ as they matched the criteria for causative agents in this case. However, further studies need to be carried out in the area for confirmation. It is possible that these three gaseous pollutants correlated with other gases as the flared gas is a cocktail of many known and unknown gases (Fox *et al* 2004, Caldwell et al 1998). The study was also conducted only on a sub-set of the total buildings in the area which may not have been adequately represented the entire population. Although the Gaussian Plume Model used for gaseous emissions prediction is still, at best, a crude model, it is still useful since it has wide acceptance (Masters 2006). Despite these shortcomings, the results obtained in this study should serve as a useful adjunct, not only to informed decision on how to mitigate air pollution levels among the local population, but also to justify the need for further research on the growing problem of gas flaring in the Niger Delta Region of Nigeria.

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### Equation 1: The Gaussian Plume Dispersion Model

The Gaussian Plume Dispersion Model is used for predicting the concentration of pollutants from a single point source at ground level (ecosystem receptors such as buildings) and applies only for z = 0:

C(x,y)

$$\frac{Q}{\pi U_H S_y S_z} \exp\left(\frac{-H^2}{2S^2_z}\right) \exp\left(\frac{-y^2}{S^2_y}\right)$$

Where:

$C(x, y)$ = concentration of pollutants at ground level at the point x and y, $\mu g/m^3$

x = distance directly downwind, m

y = horizontal distance from the plume centerline, m

Q = emission rate of pollutants from stack, µg/s

H = effective stack height, m ($H - h + \Delta h$, where h = actual stack height and $\Delta h$ = plume rise)

$U_H$ = average wind speed at the effective stack height, m/s

$S_y$ = horizontal dispersion coefficient (standard deviation), m

$S_z$ = vertical dispersion coefficient (standard deviation), m

- Surface wind speed was measured at 10m above the ground
- Atmospheric condition was considered neutral, class D
- Estimation of the dispersion coefficients ($S_y$, $S_z$) was done using Pasquill and Gifford graphs.

**Emission data (efflux velocity, stack height, stack diameter, wind speed, etc) were obtained from Agip company at Obrikom.**

**Table 1:** Descriptive Characteristics of Buildings an Exposure

| **Age of Buildings (years)** | **No (%)** |
|---|---|
| < 5 | 28 (26.4) |
| 6 – 15 | 32 (30.2) |
| >16 | 46 (43.4) |
| **Use of Buildings** | |
| Residential | 94 (88.7) |
| Commercial | 6 (5.7) |
| Industrial | 1 (0.9) |
| Others | 5 (4.7) |
| **Materials Used for Roofing** | |
| Zinc | 92 (86.8) |
| Aluminum | 11 (10.4) |
| Asbestos | 03 (2.8) |
| **Distance of Buildings from Flare Point (Km)** | |
| < 5 | 17 (16.0) |
| 6 – 8 | 65 (60.4) |
| > 9 | 25 (23.6) |

**Table 2: Summary Statistics of Air Pollutants and Meteorological Data**

| | ± SD | | | | Percentile | | |
|---|---|---|---|---|---|---|---|
| **Variable** | **Mean Annal** | **Minimum** | | **25th** | **50th** | **75th** | **Maximum** |
| **Air Pollutants (µg/m$^3$)** | | | | | | | |
| $NO_2$ | 78 ± 12 | 53.5 | 52.1 | 66.0 | 79.6 | 81.2 | |
| $SO_2$ | 70 ± 6 | 20.1 | 23.3 | 32.1 | 46.7 | 88.5 | |
| $PM_{10}$ | 48.2 ± 13.1 | 18.5 | 25.8 | 34.5 | 60.3 | 65.6 | |
| Temperature ($^0$C) | 27.3 ± 3.8 | | 25.2 | 21.2 | 27.5 | 29.8 | 33.7 |
| Humidity (%) | 78 ± 8.2 | | 43.3 | 72.2 | 80.8 | 83.3 | 94.1 |
| Wind Speed (m/s) | 2.8 ± 0.5 | | 2.3 | 2.5 | 2.7 | 2.9 | 3.5 |
| *p*H of Rain Water | 4.9 ± 0.8 | | 4.7 | 4.9 | 5.1 | 5.3 | 5.5 |

Source: Field Data 2008

**Table 3:** Odds-Ratio Values For Frequency of Observed Effects Buildings

| Observed Effects | Effect in Model | Odds-Ratio | P-Value For | P-value for Model |
|---|---|---|---|---|
| | | **(CI: 95%)** | **The Effect** | |
| Corrosion of Roof tops | Location of Buildings | 2.553 | 0.0723 | 0.000 |
| Distance from Flare point | Age of Buildings | 2.121 | 0.0001 | |
| Leakage of Roof tops | Location of Buildings | 2.356 | 0.0053 | 0.002 |
| Distance from Flare point | Acidity of Rainwater | 1.568 | 0.0001 | |
| Cracks of walls | Location of Building s | 1.987 | 0.0032 | 0.004 |
| Colour changes of walls | Location of Buildings | 1.724 | 0.232 | 0.1271 |
| Weathering due to age | Location of Buildings | 2.597 | 0.274 | 0.098 |