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A critique of the ventilation system used for public schools around gas flaring sites in the Nigeria Niger Delta Area.

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SUMMARY
The consideration of ventilation requirements in school buildings has significantly become a critically important factor in the academic performance of pupils in schools. Their health, concentration and performance output have been linked to the amount and quality of fresh air indoors. The ventilation systems employed in Nigerian schools are basic, simple and natural, often through windows and doors. This paper attempts to investigate the appropriateness of ventilation and specification systems used for ventilating classrooms in Nigeria based on documentary reviews of specification guidelines for school construction in other parts of the world. Using a purposive sampling and open-ended questionnaire, this paper finds that the ventilation system used in the Niger delta where gas flaring activities happens in close proximity to schools, falls short of WHO clean indoor air quality standards. Evidence shows that natural ventilation is inadequate to achieve clean indoor air quality. Improving indoor air quality in such areas require mechanical air purifier/humidifier systems, to provide satisfactory air quality.

KEYWORDS: *School buildings, Indoor Air Quality, Ventilation, Air Purifiers/Humidifiers and Gas Flares*

INTRODUCTION
Nigeria flares about 2.5 billion cubic feet of proven natural gas per day, representing 82.8% of the net gas produced (Nwanya 2011). 250 anthropogenic gases have been identified from flared gas (Ite and Ibok 2013). Its chemical composition ranges from 95% methane, with 1.5 – 2.0% carbon dioxide, 3.9 – 5.3% ethane, 1.2 – 3.4% propane, 1.4 – 2.4% heavier hydrocarbons and trace amount of sulphur (Sýkorová et al. 2011. Flaring activities are carried out both offshore and onshore in the Nigeria Niger Delta (ND), with the number of onshore flaring sites twice that of the offshore (Anejionu et al. 2015). The chemical composition from the exhaust systems of gas flares includes volatile organic compounds (VOCs) and hydrocarbons, nitrogen, sulphur, ozone, particulate matter and carbon monoxide with health effects ranging from eye irritation to death (DEfRA 2013). These adverse effects of pollution led to the specification of guidelines on acceptable levels of pollutants (WHO 2014). The WHO guidelines, when used as the baseline, show favorable effects, and target deliverables are realised. Yet it has been observed that African regions usually fail to enforce these guidelines (EPA 2013).

The internal part of building seen as a protector of humans from weather and climatic conditions maybe more polluted than the surrounding outdoor environment (Bruce et al. 2014). According to

Volland (2014), humans spend almost all their life time in enclosed spaces with school children spending almost 30% of their life in schools and about 70% of that time inside a classroom during school days (Bakó-Biró et.al.2012). This presupposes that classrooms are the most important indoor environment for children. The WHO opines that the indoor air quality (IAQ) is responsible for 1.6 million annual deaths and 2.7% global burden of disease (WHO 2002). Poor indoor air impacts negatively on the performance of children and teachers during school period (Mendell and Heath 2005), with known adverse effects including lack of concentration and snoring of children in primary schools (Kheirandish-Gozal et al. 2014). Other health related issues includes discomfort, irritation, and various short and long-term health problems (Mustapha et al. 2011). More than 250 anthropogenic gasses are emitted daily in the ND area within distances of 100 -250 meters in most instances from schools and communities (Uyigue and Agho 2007). Figure 1 and 2 below show a typical school and its proximity to a gas flare site.

Figure 1: Open Ventilation System used

figure 2: Proximity of school to flaring site

Source: Author

Figure 1 show a typical public school with its ventilation system, which relies on windows and doors openings. This ventilation system allows the filtration of ambient air. Figure 2 shows the proximity of a flare site and its possible impacts.

The natural ventilation system through open windows and doors has been the main source of indoor air in public school buildings in Nigeria. This study critiques this ventilation system where there is constant open air burning of gases from crude oil exploration as the mainstay of the economy. The ND area comprises 9 states consisting of 185 local government areas. It is a densely populated area representing about 12% of Nigeria's total surface area and covers about 112,110 km, with an average population density of 265 inhabitants per square kilometer with 39,157,000 people as extrapolated in 2015 by the Niger Delta Development Commission (NDDC) (GTZ Population Projection as cited in NDDC 2006). It is economically very poor.

The need for clean air in school buildings has led countries to constantly innovate and think of methods to clean-up the air. For instance, in Europe, the Air Pollution and Clean Air Act (EPA, 2013) indoor air for schools have a management framework that helps schools achieve good indoor air quality. Passive, hybrid, mechanical, photovoltaic and legal controls are different indoor quality strategies have in existence over few decades for reducing health risk to provide comfort in schools (Spengler et al. 2001). The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE, 2007) recommended an acceptable ventilation rate of 6.7 to 7.4l/s/p (liter/second/person). The Portuguese Standard recommended a rate of 8.3 l/s/p (Conceição and Lúcio, 2006 while Kim et al. (2005) reported that Swedish standards require 8 l/s/p, although in Nigeria, natural ventilation as a passive system have been widely researched, recommended and used (Olufowobi and Adenuga, 2012).

However, natural ventilation providing clean air for the internal space of the building only happens when the outdoor air is clean (Guo et al. 2008). In the ND, concentration of carbon monoxide has been observed to range from 400-450ppm (parts per million) (Ede and Edokpa 2015). This exceeds the recommended daily average hourly limits of 10ppm and 8-hourly and average limits of 20ppm of standards set by the Federal Environmental Protection Agency (FEPA 1999). Resultant health conditions have been confirmed to include cancer, distorted growth, asthma and other carcinogenic effects (Ana 2011). Air pollution and poor ventilation systems through open windows and doors are significant factors where this limit might not be achieved (Ideriah et al. 2001). Attempts to provide ventilation in Nigeria, only specifies openable ventilation floor areas for public schools in section 6:2:1 of the Nigerian Building Codes (NBC) to be 4% of the total floor space for each room (FGN 2006). This is without consideration of location, immediate environment, size of room, and the ventilation system used. This shows that appropriate design specifications for public schools, focusing on indoor air quality, does not exist and necessitates an urgent need for such specifications for the design and construction of schools.

MATERIALS/METHODS

Purposive sampling was used to recruit respondents made up of Architects, Estate Surveyors and Valuers, Land Surveyors, Air Pollution Experts and Quantity Surveyors for this study. They included academic and practicing professionals with over ten years' experience based on the membership of their respective professional bodies. The level of qualification, expertise and proximity to research study area requires the use of data collection methods that will provide relevant expert opinions on the questions posed. The descriptive interpretation involved will require responses that can be judged based on respondents understanding of the primary aim of the research. The use of a purposive sampling technique provided the necessary advantages and fit for the purpose approach, due to the availability of experts within the study area (Tongco, 2007).

Open-ended Questionnaires were hand delivered to all respondents giving them an extended time for collection. A total of one hundred and twenty (120) questionnaires were administered from the first week in May to the first week in July 2015 out of which 103 were retrieved. A total of 86% response rate was achieved, which forms a reliable and useful basis for analysis for the study (Baruch and Holtom 2008). The Statistical Package for Social Sciences (SPSS), was used for analysis.

Information gathered from the questionnaires includes the impact of gas flaring (GF) on IAQ, GF effect on the academic performance of pupils, health impact of GF on pupils and staffs, type and effectiveness of ventilation system, and the possible effective air quality standard that can be used in the ND.

RESULTS

Table 1: Impact of Gas Flare on IAQ

Analysis showed the views of respondents on the impact of GF on IAQ (table 1) presently used.

Impact of Gas Flare	No Impact	Less Impact	Moderate Impact	High Impact	Very High Impact
Indoor Air Quality	2.00%	5.00%	20.00%	49.00%	24.00%
Health Impact	5.00%	6.00%	21.00%	35.00%	20.00%

Performance of Schoolchildren	0.00%	6.00%	28.00%	41.00%	25.00%

From Table 1, the impact of GF on IAQ, health and Performance of school children analysed showed that 25.00% of respondents agreed that there is a *very high impact* of GF on IAQ while 35.00% indicated *high impact* and 21% of respondent moderate impact with 6.00% showing less impact and no impact. The impact on health of schoolchildren and staffs ranges from 20.00% *very high*, 35% *high* and 21% *moderately high* with 6.00% *less impact* and 5.00% *no impact*. The impact of GF on performance of school children as analysed showed 25% GF effect performance as *very high*, 41% *high*, 28% *moderately high*, 6% *less effect* and 0% *no effect*.

Table 2: Types of ventilation system used for Indoor Air

Analysis revealed opinions on types of ventilation systems used in the ND in table 2

Ventilation System	Not Used	Fairly Used	Moderately Used	Frequently Used	Very Frequently Used
Open windows	0.00%	0.00%	0.00%	21.40%	78.60%
Closed windows	78.0%	20.00%	2.00%	0.00%	0.00%
Ceiling fans	0%	14.60%	10.70%	34.00%	40.80%
Air conditioners	75.70%	24.30%	0.00%	0.00%	0.00%
Air humidifiers	96.00%	4.00%	0.00%	0.00%	0.00%

Results on ventilation system for IAQ purposes analysed showed that open windows had 78.60% of *very frequently used*, 21.40% of *frequently used*, 0% *moderately*, *fairly* and *not used*. While results from analysis of closed windows and air humidifiers showed that it is hardly used as closed windows showed 78.0% *not used*, 20.0% *fairly used* and 0% *moderately*, *frequently* and *very frequently used*. Results from analysis for air humidifiers showed 96.00% *not used*, 4.00% *fairly used* and 0% *moderately*, *frequently* and *very frequently used*. However, ceiling fans had 40.80% *very frequently used*, 34% *frequently used*, 10.70% *moderately used*, 14.60% *fairly used* with 0% *not used* and air conditioners had 0% for *very frequently used*, *frequently* and *moderately used* while 4.00% showed *fairly used* and 96.00% *not used*.

Table 3: Effective Air Quality Guideline

Table 3 shows analysis of different air quality guidelines and perception of respondents on effectiveness

Air Quality Guidelines	Not Effective	Less Effective	Fairly Effective	Highly Effective	Very Highly Effective
FEPA	10.70%	29.10%	30.10%	25.20%	4.90%
WHO	18.50%	34.00%	12.60%	22.30%	12.60%
EPA	1.00%	43.70%	9.70%	22.30%	23.30%
USEPA	47.60%	6.80%	15.50%	29.10%	1.00%
UK Guideline	14.60%	14.60%	32.00%	30.10%	8.70%

Table 3 revealed 10.70% not effective, 29.10% less effective, 30.10% fairly effective, 25.20% highly effective and 4.90% very highly effective of FEPA standards. WHO as an effective standard showed that 18.50% indicated it is not effective, 34.0% less effective, 12.60 fairly effective, 22.30 highly effective and 12.60 very highly effective, the EPA analysis revealed a 1.00% as not effective, 43.70% less effective, 9.70% fairly effective, 22.30% highly effective and 23.30% very highly effective. Contrarily, USEPA standards showed a 47.60% not effective, 6.80% less effective, 15.50% fairly effective, and 29.10% highly effective and 1.0% as very highly effective, here the high percentage of almost a 50% indicated the reluctance of professionals accepting the

USEPA as a standard to adopt. Finally, the UK guideline had a response of 14.60% not effective, 14.60 less effective, 32.0% fairly effective, 30.10% highly effective and 8.70% very highly effective.

DISCUSSIONS

The impact of GF on IAQ is significantly high as shown in table 1, observed impact could be due to more than 250 anthropogenic substances that are emitted from GF activities (Ite, *et al.* 2013). Other causes of poor IAQ include: the proximity of this GF stacks to communities and public schools also increases the immediate inhalation of these polluted air by school children (Uyigue and Agho 2007); in addition, lack of a monitoring system for IAQ (Fagbeja, *et al.* 2008), location selection criteria and specification selection criteria for school buildings (Mohd Ibrahim *et al.* 2014) contribute to high effect of GF on IAQ.

The health impact of GF on school children and staffs as analysed in table 1 showed that all participants noted that there was some form of health impact as a result of constant flaring. Many health implications are as a result of air pollution to which GF is a major contributor (Ite and Ibok 2013). Many health issues arising from GF inhalation has been discussed by Ana (2011) who stated that exposure leads to dizziness, cough, cancer, blood related infection and cardio-versacular effect with death as the worst case. The performance of school children was also linked to GF filtration and its inhalation by pupils as analysed in table 1 above indicating that GF impact on school children performance. This therefore could be linked to inhalation of poor air as observed by Bakó-Biró *et al.* (2012). Most countries have measures that help with ventilation systems and clean indoor air. Yet analysis from table 2 shows that open windows and doors are the most used ventilation system and the use of air humidifiers and air conditioners are almost none existent. The use of open ventilation systems in an environment where ambient air is noted to be polluted increases the rate of polluted air inhaled (Guo *et al.* 2008). Contrary to using open windows, Anderson and Albert (1998), affirmed that using closed windows have provided considerable positive effect on infiltration of outdoor air into buildings.

Although analysis shows that the UK air quality guideline has a higher acceptability as shown in table 3, this may be due to Nigerian laws mirroring those of the UK because of its colonial relationship. Nevertheless, the responses of various levels of high effect to moderate effect between the EPA and WHO guidelines, indicates that some professionals are aware that other air quality guidelines exist aside from the UK guideline. One might infer that such guidelines rather than the UK guideline might be more effective and more adaptable in the ND of Nigeria. This could be due to environmental characteristics which are different in all criteria between the UK and the ND.

The ongoing discussion over the inadequacy and the need for local air quality management framework shows the importance of each environment and their ability to help monitor and reduce pollution, although there is constant update and implementation of newer strategies due to health implications of poor air quality (Krzyzanowski and Cohen 2008). The relationship between these laws and strategies makes it necessary for most countries to adopt a process such as improving on regulations, strategies, guidelines and specifications to achieve clean air (Zigler *et al.* 2016). The downside of using any of the guidelines is that most air pollution standards' target is to moderate exposure of countries, continents or regions, rather than targeting exposure reduction and mitigation programs to those specific environments receiving direct and the highest exposure (Levy *et al.* 2002). Nigeria still relies on the NBC which was last updated more than a decade ago with little or no consideration for immediate environmental characteristics of the ND. It is therefore necessary to develop a specification for the design of schools in the ND due to its unique environment.

CONCLUSIONS

This study concludes that ventilation systems used for public school buildings around GF environments might not provide clean air for pupils to inhale. Although, most GF nations have made progress in air quality laws, Nigeria is yet to change her dependence on open ventilation systems. It is pertinent that Nigeria should emulate this progress, being a member of Action for Gas Flare Initiative. In addition, since it involves lives, policies and guidelines for the construction of schools should be provided and public enlightenment on the lasting effect of poor IAQ should be encouraged. Therefore, investing in newer technologies to enhance clean air indoors will improve the academic performance in schools in ND.

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