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RESEARCH ARTICLE

EXAMINING THE STATE OF PUBLIC SCHOOLS IN THE GAS FLARING AREAS OF NIGERIA

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ABSTRACT

The Niger Delta region produces over 82.8% of the natural gas that is associated with oil production in Nigeria. Due to economic and political reasons, this gas is not retained for energy use. Instead, it is burned off in the air. The pollution caused by these flares creates many environmental, social and economic impacts on the building fabric of public schools and the health of the users of such buildings in the vicinity of oil fields. Current architecture and building materials used to construct school buildings have been described as being deplorable and dilapidated and are unsuited to withstand the effects of polluted air. To date there has been no comprehensive study of the environmental challenges associated with gas flaring and schools. There is thus the need to adopt a system of research that describes the current conditions of flares sites so that proposal on methods to protect fabric and the users of these buildings from harm. Design science has been adopted as the research approach that can provide solutions to this real life situation. This will discuss the issues arising from the impact of gas flares on schools and the approach that has been adopted to research the remedial or resilient steps that might be taken to mitigate its effects.

INTRODUCTION

Nigeria has a gas reserve of over 110 trillion standard cubic feet (ft^3), about ten times its crude oil reserves (1 barrel of oil equals 3.2 ft^3 gas on chemical conversion basis). In 1989, 617 billion ft^3 of associated gas was flared, releasing 30 million tons of CO, at the end of 1999, cumulative gas production in Nigeria amounted to ca. 27,795.22 Barrels per standard cubic feet (Bscf) of which ca. 23,005.35 Bscf was flared representing 82.8% of the net gas produced (Malumfashi, 2007; Nwanya, 2011). Nigeria flares about 2.5 billion cubic feet per day and has an estimated 5.1 MMtcm (106 Trillion m^3) of proven natural gas (Nwanya, 2011). Gas flaring is the burning of natural gas that is associated with crude oil when it is pumped up from the ground (Elvidge *et al.,* 2009). Atmospheric disposal of these gases is mostly for emergency as a safety measure, lack of infrastructures for alternative use, cheap and easy way of refining crude oil consequently saving pipes or vessels from over-pressure (Keller *et al.,* 1990; Nwaugo *et al.,* 2006 and Lohmann, 2009). Since the late 1940s, the statement that rainfall is acidic with acidity resulting largely from by-products of combustion has heightened the concern about this occurrence (Bowersox *et al.,* 1990; Weaver, 1991). Accordingly Larssen et al. (1999) argued that high concentrations of gaseous pollutants, particularly near the towns are likely to have harsh effects on wellbeing of population, materials and flora. According to Ite and Ibok, (2013) and Sýkorová, (2011) , more than 250 anthropogenic gases have been identified from flared associated gas like, carcino-gens, benzopyrene, benzene, carbon disulphide (CS_2), carbonyl sulphide (COS), and toluene; metals such as mercury, arsenic, and chromium; nitrogen oxides; and sour gas with H_2S and SO_2.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. The engineering design of pipelines are such that the gaseous substances produced by flaring are sometimes colourless, white brown or black; they could either be odourless or with offensive smell and emission seen as smoke of different colours with different locations as shown in figure 1 below. Acid rain have over the years been an issue that has defied solution because even coating the surface of a metal to protect it from corrosion is also destroyed by multi-pollutants resulting mainly from oil and coal combustion processes (Ozga *et al.,* 2011). The concentration of flaring points in the Niger Delta influences air pollution and affects buildings (Odu, 1994; Ojeh, 2012; Morrison and Vincent, 2013). Similarly, deposition of black carbon and fly-ash with atmospheric moisture content results to discolouration and blackening of roofing materials leading to potential degradation (Ismail and Umukoro, 2012; Jelle, 2012). This paper will discuss the adverse effects associated with gas

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flaring on school buildings, the vulnerability of children due to its health impact and a methodological process suitable for adaptable solution to a real life situation as experienced in the Niger Delta area of Nigeria.

Source: Chemeng (2011); (limits, 2013)

Figure 1. Associated Gas from Flaring

Impact of gas flares on public school buildings

Gas flares produces gaseous substances, which combines with atmospheric moistures to deposit these gases through rain droplets, snow, dew smog on the built environment contributing to different hazards for instance, corrosion of roofing materials. Although it could be argued that in areas with constant rainfall this effect will not be significant yet corrosion effect has been observed in gas flaring areas of Niger Delta in Nigeria as stated by Odu (1994). In addition, change in colour of a building fabric has been linked to the presence of hydrogen sulphide in the air due to its reaction with a metallic pigment (Ababio, 2005 as cited in Julius, 2011a). Similarly, sulphuric acid decomposes cement matrix by decalcifying cement active ingredients such as calcium silicate hydrate (Bassuoni and Nehdi, 2009 and Jianminget.al., 2013). Other forms of disintegration of building materials includes the deterioration of the façade painting due to the impact of moisture deformation caused by the moisture drying circle strengthened by acidic precipitation and increment of surface acidic water absorption rate (Alaba, 2014).

Source: Akobundu (2014)

Figure 2. Corroded Roof in the Niger Delta Area of Nigeria

The level of corrosion of corrugated zinc roofing material due to acid rain, the discolouration of other types of roofing materials, heat, discomfort inside of a building, noise pollution due to the pressure from crude oil pipe, sound from furnace of flare stacks, air tightness/odour are some of the adverse effects of gas flare in the built environment. Public school buildings in Nigeria have been observed to be affected adversely by gas flaring though, the vulnerability of children who spend most of their time in schools and the right for every child to acquire education as stipulated in the second goal of the millennium development goals(MDGs, 2000) poses a challenge. The educational sector in Nigeria has witnessed poor quality construction, dilapidated and obscure buildings, and in some cases, structures not fit for human habitation(Mac-Ikemenjima, 2005; Odia and Omofonmwan, 2007). A nation-wide tour of the Federal Ministry of Education in 1997 to ascertain the basic infrastructure needs in schools such as classrooms, laboratories, workshops, sporting facilities, equipment, and libraries confirmed that many school buildings were in a state of total decay (Moja, 2000). In addition, he noted that derelict institutes of learning increases the rate of out-of school pupils. Building materials used for public school construction should have resistance to environmental degradations caused by flaring (Obia *et al.,* 2011b; Mollaoglu-Korkmaz *et al.,* 2013). In addition, the adaptability, lifespan and functionality of different material types used to construct schools needs to be investigated to ascertain their suitability in different climatic environments. Zolfani and Zavadskas (2013) noted that for construction to take place in Iraq, five different research studies were carried out to ascertain the best sustainable system formaterials, construction and achieving clean indoor air quality in such climatic region.

Impact of gas flares on air quality

According to Volland (2014), humans spend almost all their life time in enclosed spaces both in residential and non-residential buildings making it a potential threat to health risk and as affirmed by (WHO, 2002) every year IAQ is responsible for 1.6 million annual deaths and 2.7% global burden of disease. Therefore, its importance is vital due to adverse rising health issues as opined by Spengler and Chan, (2000). The need for clean air quality in schools is vital since children spend more than 30% of their life time in schools more than they spend anywhere else apart from their homes as affirmed by Bakó-Biró *et al.* (2012); and Rivas *et al.* (2014). The impact of indoor air quality and its effect on the performance of children and teachers during school period has been known to show adverse effects including lack of concentration and snoring of children in primary schools (Jones *et al*., 2007; and Kheirandish-Gozal *et al.,*2014). According to Ana (2011) the adverse health effect of air quality has been linked with an increase in the number of lung and skin cancer diagnosis. Many studies and standards have been provided in the developed world to help improve the level of IAQ in schools since children are the most vulnerable group of the population (Conceição and Lúcio, 2006; Rivas et.al. 2004). Countries like the UK and US provide guidelines on the limit of gaseous substances that can be tolerated during school hours in school buildings, for instance in the UK, carbon dioxide concentration in classes should not exceed 1,500 ppm. While the European standards limit it to 3,500 ppm (DfES, 2006; JONES *et al.,* 2007),and countries like Sweden have their limits set below 1000ppm (Smedje and Norbäck, 2000).According to EFA, (2001) and (Neidell, 2004) respiratory and asthma diseases are the major causes of days lost from school and their socio-economic costs cannot be exaggerated. Table 1 below shows list of gases flared and their resultant health effect.

Table 1. Associated Gases and its Health Effect

Pollutant	Health effects at very high levels
Nitrogen Dioxide, Sulphur Dioxide, Ozone	These gases irritate the airways of the lungs, increasing the symptoms of those suffering from lung diseases.
Particles	Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of heart and lung diseases
Carbon Monoxide	This gas prevents the uptake of oxygen by the blood. This can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease

Source: DEfRA (2013)

The awareness that IAQ needs to be achieved for the comfort and wellbeing of users of school buildings is a process that shows an adjustment and readiness of stakeholders in providing clean air space for both present and future generations. Various studies have shown that poor IAQ in schools interferes with learning activities and can cause discomfort, irritation, and various short and long-term health problems in students, teachers and staff (Daiseyet.al., 2003; LSX, 2013; Mustapha *et al.,* 2011). Most developed countries have regulations and guidelines for schools to follow in achieving clean air quality in schools for instance in Europe the EPA (2013) indoor air for schools have management framework that helps schools achieve good indoor air quality for the comfort of the students and staffs. The European Union (EU) have also implemented different indoor quality strategies to help in reducing health risk and provide comfort for the school environment (EFA, 2001). The London Sustainable Exchange (LSX, 2013) made specific provisions in school curriculum where citizen science is taught in schools and out of school lessons are held in other to educate students, teachers, support staff and maintenance team on the need for a clean environment. Ventilation systems including both naturally by open window ventilation systems and mechanically by any device that will allow clean air inside of a building with minimal energy have been recommended Clements-Croome *et al.,* 2008; Gao *et al.,* 2014). ASHRAE (2007) recommended an acceptable ventilation rate of 6.7 to 7.4 l/s – person. Other national guidelines specify other ventilation rates for classrooms, for example, the Portuguese Standard prescribes a rate of 8.3 l/s (Conceição and Lúcio, 2006whileKim et al. (2005)reported that Swedish standards require 8 l/s per person. The rate of ventilation given is based on Pettenkofer's work in which carbon dioxide concentration was used as a measured variable for the ventilation rate (Sundell 2004 as cited in Salthammer, 2011).

Natural ventilation as a passive system have been widely researched, recommended and used as a means to ensure sustainable development since energy efficiency can be derived from it (ASHRAE, 2007; Daisey *et al.,* 2003; Khan et.al. 2008; Mavrogianni and Mumovic2010; Olufowobi and Adenuga, 2012). However, natural ventilation created by pressure difference between the outside and the inside of a building provides clean air in the internal space of the building if the outdoor air is clean. According to Ajao and Anurigwo (2002); Ana (2011); Orubu (2002) quality of air in Nigeria due to her economic activities is below Federal Environmental Protection Agency (FEPA) standards aimed at ensuring a healthy environment. Therefore, the use of natural ventilation systems as a means to achieving adequate IAQ will likely lead to increase in health risk and reduction in the shelve life of the building components, as it will admit polluted ambient air. Emission of hazardous gases due to gas flaring will significantly contribute to polluted air being inhaled by pupils in schools knowing that more than 20% of the world population are children (Bank, 2013) who spend one third of their life in school and are vulnerable due to their immune system and developing lungs creating pandemic situations. Although, most developed world have guidelines as a measure to guide against adverse effect of gas flare, Daisey*et.al*. (2003) noted that there are some inconsistencies in the depth of analysis of schools criteria as most researches lack quantitative and qualitative rigours. It is therefore imperative to produce a guideline that will help in achieving clean indoor air quality and improve the deplorable state of public school buildings through a methodological process that allows in-depth rigours and a systematic process to be adopted.

MATERIALS AND METHODS

According to Purao (2002) research methodology is important because it legitimises how knowledge may be created and what constitutes valid knowledge. Therefore, for any research to be valid a research paradigm becomes inevitable. So many research works in the built environment have relied on methods such as case study, ethnography, grounded theory, content analysis and action research as a choice of methodology following implied sanctions of the research community. Such methods explain or interpret the past to discover the truth rather than intervene and improve to realise alternative future as opted by design science (DS) methodology. According to Hevner (2007), design science is the process of organising, defining and solving problems, of formulating a goal, and in a systematic part of reaching that goal. It is the scientific study and creation of artefacts as they are developed and used by people with the goal of solving practical problems (Johannesson and Perjons, 2012). This method proffers solution for a recognised problem and represents its solution in a practical environment. It is like envisioning a world where although the environment might be polluted but adequate facilities are put in place so that the adverse effect do not have any economic, financial and environmental effects on people. DS provides answers to design questions with the aim of designing to sustainability standards through a multi-disciplinary integration of disciplines and methods used for actualisation (Cross, 2006; Reich, 2013; Hubka and Ernst Eder, 1987). For instance, while some research adopts philosophical stances that are theoretically based, field-driven problem solving methods are becoming the best fit for researchers enabling alternative courses of action to solving real issues. This method allows the generalisation of findings from one environment to the other with the same characteristics due to its multi-disciplinary system of problem solving which adopts both forecasting and back casting methods for solutions. Although Riedy, (2009); Slaughter, (2009) and Valkokari, (2014)noted that science and technological concepts have relied on foresight as a means of forecasting into the future and providing solutions to environmental issues yet this method of solving problems have been criticized by researchers for its limitations in terms of

Table 2. Philosophical Assumptions and DSR perspective

Basic Belief	*Positivist*	*Interpretivist*	*DSR*
Ontology	A single reality Knowable, Probabilistic	Multiple realities, socially constructed	Multiple, contextually situated alternative world-states Socio-technologically enabled
Epistemology	Objective; dispassionate, Detached observer of truth	Subjective (i.e., values and knowledge emerge from the researcher participant interaction)	Knowing through making: objectively constrained construction within a context Iterative circumscription reveals meaning
Axiology: what is value	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (improvement); understanding

Source: Hanid (2014); (Vaishnavi and Kuechler, 2007)

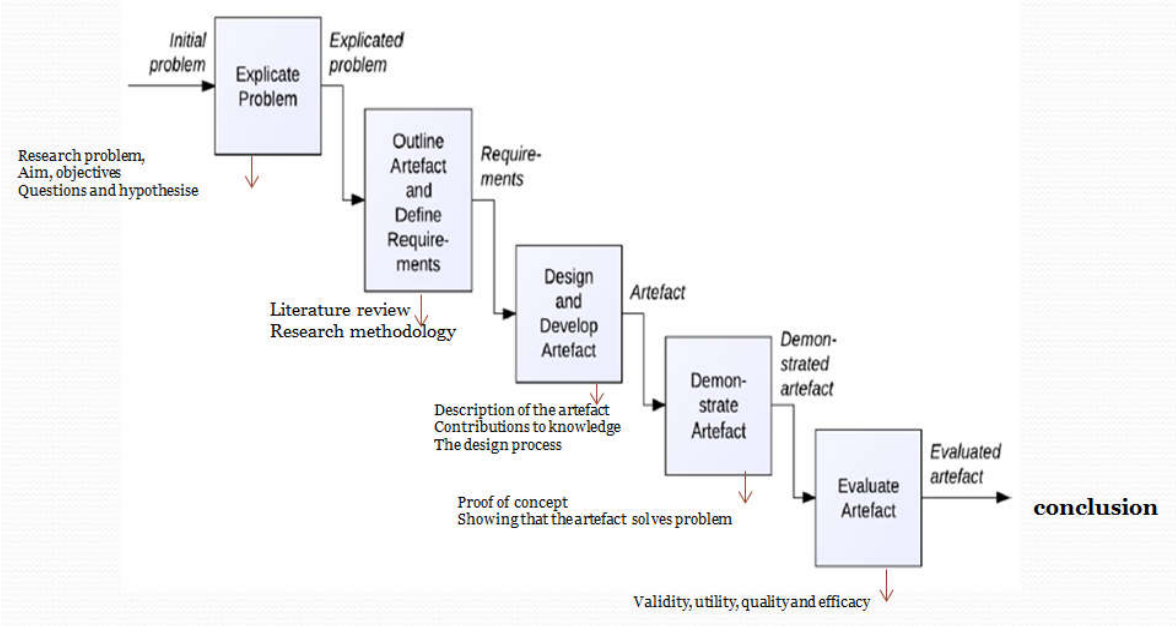

Figure 3. Design Science Framework

implementation, decision between time and action (Georghiou, 2003; Georghiou *et al.,* 2010). However, as opined by Ilstedt and Wangel (2013) there is good potential for using design science to explore and propose changes at larger scales, for developing prototypes on the basis of lifestyles rather than basing the speculation on technologies only. However, it is not another research strategy but it a method which uses a holistic method of problem solving in other to achieve specific goal by means of a creation of an artefact (Johannesson and Perjons, 2012). Thus in other to carry out this research, the DS will be used as it allows the combination of other research philosophies, strategies and approaches to solve a practical problem as shown in the table below. With reference to the above table DS with a prescriptive intent, is embedded in a system of theoretical, descriptive and empirical knowledge (Niehaves, 2007). DS begins with an important opportunity, challenging problem, or insightful vision/conjecture for something innovative in the application environment (Hevner 2007; Hevner *et al.,* 2004; Iivari, 2007). It provides an environment specific solution to issues as can be adaptable in similar situation. According to Barab and Squire (2004); Hanid (2014) DS focuses on understanding the chaos of real world practise, with the context of being a fundamental part of the research allows a flexible design revision, multi dependent variables and captures social interaction with participants as part of the design and analysis method in contrast to other research methods. Therefore, DS provides the most reliable method that can be adopted to proffer solution to real life situation as that experienced in the Niger Delta area of Nigeria.

An adaption of DS framework as represented by Johannesson and Perjons (2012), showed infigure 3 below illustrates the bases for a systematic exploration while focusing on achieving aim of research. This gives the researcher the ability to clearly, identify what is in existence and how to produce or improve on the existing body of knowledge thus the DS artefact will be developed through a step-by-step process of continuous iterative research process necessary to provide rigours in order to provide an adaptable system through the artefact design.

Conclusion

This paper has examined the adverse effect of waste gas due to oil exploration activities in the Niger Delta area of Nigeria with particular reference to public schools and the vulnerability of children who spend more than 80% of their active time in school. It is envisaged that there should be a remedial factor that can be used to reduce the adverse effect of the associated gases on the built environment. Although most countries both in the developed and developing world have led down guidelines and mitigating factors as a guiding principle, Nigeria is yet to achieve one. However, considering the different environmental and climatic conditions, it important that rigours systematic process has to be carefully undertaking to produce an environmental specific design guide that will reduce if not eliminate deteriorating effects as observed with public school buildings.Design science research method possess required systematic guide with an existing framework, which allows this type of research fitted appropriately on each stage with successful achievement of research goal.

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