DESIGN PERFORMANCE SPECIFICATION FOR SCHOOL BUILDINGS IN THE VICINITY OF GAS FLARING IN THE NIGER DELTA AREA OF NIGERIA

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Dedication

This study is dedicated to God Almighty,

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Declaration

This thesis is submitted under the University of Salford rules and regulations for the award of a PhD degree by research.

This researcher declares that she is responsible for the work carried out in this thesis. Furthermore, she wishes to state that no portion of the work referred to in this thesis has been submitted elsewhere for another degree qualification of this, or any other university

…………………………………………. (Signature)
Uche Joyce Ogbonda

………………………………………... (Date)

Abbreviations

AR	Action Research
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BC	Before Christ
BCM	Billion Cubic Meet
BE	Built Environment
BEP	Built Environment Professionals
BS	British Standard
CIB	Council for Research and Innovation in Building and Construction
CIS	Corrugated iron sheets
CO2	Carbon dioxide
CO	Carbon Monoxide
COS	carbonyl sulphide
CS_2	Carbon Disulphide
Defra	Department of Environment, Food and Rural Affairs
DIL	Drug Information Leaflet DQI
DQI	Design quality indicator
DS	Design Science
EFA	Education for All
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industry in Nigeria
EPA	Environmental Protection Agency
EU	European Union
FEPA	Federal Environmental Protection Agency
FGN	Federal Government of Nigeria
FT^3	Standard cubic feet
GF	Gas Flaring

GFDRR	Global Facility for Disaster Reduction and Recovery
GMR	Global Monitoring Report
GT	Grounded Theory
HVAC	Heating, ventilation and air conditioning
IAQ	Indoor Air Quality
ISO	International Standards Organisation
IT	Information Technology
PB	Lead
LEED	leadership in energy and environmental design
LGA	Local Government Area
LIS	Leaflet Information System
LSX	London Sustainable Exchange
MDGs	Millennium Development Goals
NBC	Nigerian Building Code
NBS	National Building Specification
ND	Niger Delta
NDA	Niger Delta Area
NG/M^3	Nano gram per millilitre
NNPC	Nigerian National Petroleum Cooperation
NO2	Nitrogen dioxide
NOx	Nitrogen oxide
O^3	Ozone
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
PPB	parts per billion
PPM	Parts per million
PPT	parts per trillion

PR	Performance Requirement
PS	Performance Specification
PSIP	Performance Specification Information pamphlet
PSB	Public School Buildings
SO2	Sulphur dioxide
SPSS	Statistics Package for Social Sciences
TiO_2	photo catalytic
UK	United Kingdom
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USA	United States of America
VGF	Vicinity of Gas Flaring
VOCs	Volatile Organic Compounds
WHO	World Health Organisation
$\mu g/m^3$	Micrograms per Cubic Meter of Air

Abstract

It is evident from research that there is a strong link between poor indoor environments, external façade of school buildings, schoolchildren's health and academic performance. In order to provide a better indoor environment for schoolchildren, meeting strict criteria in relation to indoor air quality (IAQ), thermal comfort, aesthetics and longevity is highly important. Stringent health criteria for school buildings' design and construction have led to innovations in selecting and manufacturing of materials that meet such criteria. However, the uses of prescriptive specification and outdated national building codes have proved to be challenging leading to the application of Performance Specification (PS). The prescriptive method, unlike the PS which permits innovation, is disruptive and cumbersome; using codes that hamper the adoption of newer and safer materials for today's environmental challenges.

This study developed a guidance document known as a PS to aid the design, selection of materials and construction of schools buildings in the Niger Delta area (NDA) where gas flaring (GF) is predominant. This excessive pollution poses the biggest challenge to indoor environments and building deterioration. School buildings in Nigeria currently follow the prescriptive specification and national building codes that were last updated in 2006. Such practices are clearly inadequate for tackling environmental challenges in the NDA. Therefore, PS, based on performance requirements and fit for purpose, is more likely to help in achieving clean indoor air and durable external façade of school buildings in the vicinity.

The study adopted the design science (DS) method as the philosophical approach due to its advantages in integrating other research strategies. Literature on GF impacts and the use of PS was reviewed followed by qualitative and quantitative data collection using both open-ended questionnaire and semi-structured interview. While 120 open-ended questionnaires were administered, 102 valid responses were retrieved and 10 expert professionals with more than ten years of experience in professional practice in the primary area of study were interviewed. Consequently, the data that emerged were analysed using Nvivo 11 and SPSS to identify specific environmental issues for potential mitigation.

The final PS was demonstrated in three iterative processes through subsequent data collection exercise using open-ended questionnaires administered to 102 respondents to provide the required environment specific requirements for design and construction purposes. This was carried out through experienced professionals and evaluated by potential dominant users in the study area. It concludes that the developed PS will potentially change current practices in terms of design and selection of materials for school construction. The use of PS as opposed to the sole reliance on the Nigerian building code which is prescriptive in nature is deemed feasible. The research outcomes also included the development of immediate environmental criteria for limits on hazardous substances and space cooling levels for performance requirements, among others. In addition, innovative triple and double filtration systems for use as air purifiers without energy costs were designed. These locally tailored criteria provide environment specific requirements without mirroring international codes to offer clean IAQ for the research environment.

It is expected that the DPS would be used by professionals in the Built environment and policy makers as a guiding tool during the design, selection and construction of buildings in the VGF and/or for (re) designing and renovation process to meet growing indoor air quality needs and achieves building durability in the NDA

CHAPTER 1. INTRODUCTION TO THE RESEARCH

1.1 Research Background and Motivation

High volatile gas regularly burned (or flared) by energy companies exploiting crude oil in the NDA of Nigeria causes air pollution. This occurs at oil wells, in refineries and in chemical plants (Akeredolu and Sonibare, 2004; Gervet, 2007; Sýkorová, et al. 2011). These flared gases release hazardous substances into the atmosphere resulting in adverse impacts on the Built Environment (BE) as depicted by Nkwocha and Pat-Mbano (2010); Ana (2011). Flared gases can cause the corrosion of metals, damage to painted surfaces, cracks in masonry, heat and poor air quality leading to building deterioration and numerous health hazards (O. 2013, Akobundu 2014). Many works like Abdulkareem and Kovo, (2006); Madu *et.al*. (2011); Dickson and Udoessien, (2012), noted that although Nigeria produces sweet sulphur gas, which means it has a low sulphur content, observed deterioration of roofing materials, and discolouration does affect buildings near to flare sites. A Unicef report authored by Rees (2016), confirmed that satellite imagery shows that around 2 billion children live in areas where outdoor air pollution is dominant. This, the organisation notes as being caused by factors such as vehicle emissions, heavy use of fossil fuels, dust and open air burning of gases and waste, exceeds minimum air quality guidelines set by the World Health Organization (Unicef, 2016). The adverse impacts have led to a growing realisation that there is the need for actions that will reduce air pollution.

The impact of air pollution on health is significantly high among children who are the most vulnerable (Health, 2004; Unicef, 2016) . Yet, public buildings such as schools have been observed to be constructed in close proximity to Gas Flare (GF) sites in the case of the Niger Delta (ND) (Ede and Edokpa, 2015). Notwithstanding that such public buildings are constructed from revenues derived from oil exploration and exploitation activities, residents and schoolchildren tend to suffer these damages in a more shameful way. Even though, the virtual appearance of such buildings shows that the condition lacks the merit to classify them as such. For instance, public school buildings by mere definition of public buildings and the very essence of their construction and design should meet public building standards and characteristics. Though stressing on the need to meet the second-millennium development goal (MDGs, 2000) on the right for every child to acquire education as stipulated is plausible and laudable, the vulnerability of children who spend most of their time in schools to adverse health conditions poses a challenge.

More than other building types, school spaces have a reflective impact on their occupants especially on teachers and pupils; on teaching, and both learning and performance respectively (Barrett, et al. 2015) . Children in various stages of development are stimulated by light, colour, the scale of their surroundings, even the directional aspects of their school with schoolchildren reacting adversely to poor environments(Vaughan, 2016) . An unsuitable environmental condition mostly depends on the immediate activities carried out in such surroundings. Therefore, building materials used for public school construction should have resistance to environmental degradations caused by activities in the immediate surroundings such as flaring (Obia, et al., 2011; Mollaoglu-Korkmaz, et al., 2013). In addition, the adaptability, lifespan, and functionality of different material types used to construct schools need to be investigated to ascertain their suitability under different climatic conditions. For instance, 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 for both materials and construction in such climatic region.

The rise in health risks such as cancer, asthma, and other diseases have been attributed to GF and subsequent release of hazardous gases inhaled by people that work or live around such areas (Nwanya, 2011; Rabinowitz, et al., 2014). According to Conceição and Lúcio (2006), children require clean air and a safe environment for both health and learning purposes. Studies have also shown that polluted air reduces the concentration level of children in school (Ofoegbu 2004; Clements-Croome, et al. 2008; Berhane, et al. 2014; Dong, et al., 2014). However, the state of most public schools in Nigeria is said to be deplorable (Daivid Theobald et. al as cited in Akuaka 2012, Brown 2013). Therefore, the constant flaring of gases is a major contributing factor to the deplorable condition of public schools in the ND.

Research on the inadequacy and deplorable nature of educational facilities and improvement guidelines including construction and materials has, over the years, covered recurrent issues with both the developed and developing worlds making progress. The educational sector in Nigeria has witnessed poor quality construction, and dilapidated buildings, and in some cases, structures not meant for human habitation (Mac-Ikemenjima, 2005; Odia and Omofonmwan, 2007). A nation-wide tour by the Federal Ministry of Education in 1997 to assess the basic infrastructure 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 institutions of learning increase the rate of out of school pupils. The Education for All (EFA) and Global Monitoring Report (GMR) of 2008 observed that despite the purported huge investment in the education sector, Nigeria is far from meeting the international minimum standards in the area of basic educational infrastructure (UNESCO, 2017). According to Volland (2014), humans spend almost all their life time in enclosed spaces with schoolchildren spending almost 30% of their life in schools and about 70% of their time inside a classroom during school days (Bakó-Biró et.al.2012) which presupposes that classrooms are most important indoor environments for children. Since children spend about 80% of their active time in schools, it is pertinent to construct school buildings with materials that can withstand these environmental hazards while providing clean internal air quality that is inhaled by pupils (Zande, 2011; UNESCO, 2013/14). Therefore, not only are buildings in which they are schooled important, the air inhaled and the quality is also extremely significant to their health and well-being.

Accordingly, the issue of Indoor Air Quality (IAQ) in school buildings cannot be properly addressed if the quality of the ambient air is ignored or overlooked. A wide range of pollutants generated outdoors is either known or suspected to adversely affect human health and the environment (DEfRA, 2013; DfE, 2016). Provision of standardised buildings has been seen as one of the essential factors in the creation of a learning environment conducive for the dissemination of knowledge and aiding the ability of students to comprehend (Sanoff, 2001; Ofoegbu, 2004). All building components and facilities are integral parts of the educational process which have aided the developed world in providing sustainable school environments. This is in contrast to the scenario in the developing world (Urwick 2002) Research has identified the major underlying problems resulting in the poor quality construction of school buildings to include the lack of specification criteria, design errors and the use of substandard and outdated laws for selection and procurement of building materials (Adejimi, 2005; Smith, 2008; Olusola and Akintayo, 2009). Furthermore, lack of prompt payment to contractors and fluctuations in materials, labour and plant costs have been identified (Mac-Ikemenjima, 2005; Aibinu and Odeyinka, 2006). Against this backdrop, the integration of criteria for educational purposes has enabled developed and some developing nations a guideline as a fundamental document during construction of school buildings. This is used for the selection of site/ location, materials, design, and construction for their respective countries and environment as a necessity for enhancing better quality as some countries like the United States of America, have different climatic conditions

Hazard prone areas require the integration of the construction process to achieve a conducive learning environment (GFDRR, 2009). To design a school building around an environmental hazard prone area one needs to start the design process by thinking carefully about the typical use scenarios of the building. Common points of stress due to normal use, as well as, the most likely situations in the environment that could test the integrity of the building and/or endanger its occupants (Meinhold, 2013). The local environment plays a critical part in determining factors that make a school building conducive. Therefore, the quest to design school buildings in the Vicinity of Gas Flaring (VGF) brings to the fore the exploration of requirements that should be met in order to build in such environments. Thus, in ND, exploration of requirements that will meet immediate environmental challenges due to GF should be obligatory or necessitated before construction of school buildings

1.2 Justification for Research and Research Problem

It is currently been accepted that clean school environment impacts on the academic performance of pupils, and deplorable school buildings increase the rate of absenteeism and psychological readiness for academic rigours (Sanoff, 2001; Ofoegbu, 2004). Thus, the level of concentration, performance, and enthusiasm depends on the school environment as affirmed by (Zande, 2011; UNESCO, 2013/14).. Schoolchildren spend 80% of their active time in schools, thus the air they inhale plays a significant role as it affects their health and performance as confirmed by number of research (Ofoegbu, 2004; Clements-Croome, et al. 2008; Berhane, et al. 2014, Dong, et al. 2014). They noted that polluted air reduce the level of concentration of school pupils. Although building passive design, appropriate orientation, and natural ventilation have been known to provide sufficient fresh air but the quality of such air most of the times proves to be poor in the Vicinity of Gas Flaring (VGF) areas. Currently IAQ guidelines are been researched and provided by leading organisations such as World Health Organisation (WHO), United Nations (UN), Environmental Protection Agency (EPA) and Federal Environmental Protection Agency (FEPA), yet this has fallen short in Nigeria and the ND where gas is constantly flared for oil exploration and exploitation purposes. Accordingly, Ogbonda and Yingchun (2017), noted that the hope that Nigeria will stop GF is a mirage, thus Nigeria continues flaring without consideration to regulations even though Nigeria is part of the Stop Gas Flaring Initiative.

The continued flaring of gases in the NDA due to oil exploration and exploitation activities leads to the release of hazardous gases that affect the environment. Although several attempts have been made to stop flaring as a means of refining crude through regulations and laws (Audu, 2013; Malumfashi, 2007), this has proved to be unsuccessful. It has also been noted that Nigerians prefer to collect levies and fines as the penalty rather than ask oil explorers to stop flaring even though these gases that are flared as waste gases amount to billions in monetary terms (Oluduro, 2012). This is in spite of the fact that these flare sites are found to be in communities and places where schools housing vulnerable people are situated. While studies in the ND have identified imminent structural and health impact through inhalation and residual effect from rainfall and precipitation (Odu, 1994; Obi, 2009; Ite and Ibok 2013). Yet the promulgators of laws and professionals in the BE tend to design, specify and construct school buildings with materials not environmentally adaptable to the immediate ND environment.

The difficulties in improving education facilities have also been affirmed by UNESCO (2007). Though claims of huge sums of money were poured into the educational sector to improve on its appearance yet physical structure disputes this as there is an increase in the number of out of school children (Ayeni and Adelabu, 2011; Owoeye and Yara, 2011). Thus, the deplorable state of facilities in Nigerian educational system is a constraint that makes it almost impossible to meet the millennium development goals. The deteriorated nature of most public school buildings in the NDA might be one of the reasons of a high level of absenteeism. Research has shown that poor school environment gives rise to high out of school pupil’s rate (Ladebo, 2005; UNESCO, 2007). The key reasons for the deplorable state of public schools building include material selection criteria and the lack of up-date standards and regulations used in developed countries to foster a good learning environment. The continued monopoly of architects as both designers and specifiers hamper adoption of newer standards and guidelines and innovative materials that can be substituted for durability. Contrarily, in the UK, specifiers are usually not architects and are under stringent rules to provide specification meeting highest standards. Thus, playing down on the use of the prescriptive method of specification due to increased research on innovative materials that are environmentally sustainable that meets standards. Performance criteria become the most used requirement as many environmental and green scoring teams have emerged to help push forward the realisation of a clean and safe environment.

Nigerian schools, even in the NDA comprising of 9 states, 187 Local Government Area (LGAs) as at 2014, constituted 9292 public primary schools with a male pupil population of 577,569 and female pupil population of 637542 (1,215,111 total pupil population) (NBS, 2016). Although, the proximity of some schools is more distant than others, the ND environment is enclosed in the same atmospheric composition which affects all of its populace and the residual effects are more adverse on these vulnerable children. More than 250 anthropogenic gases are emitted every day through flaring are in close proximity to schools, still rely on prescriptive specification method with architects having the sole responsibility (Emmitt, 2001). Users of schools and clients, therefore, rely on their professional judgment for design choice, material choice, and locational credibility. Furthermore, architects rely on the out-of-date Nigerian building code (NBC) to specify materials (Adenuga, 2013). The use of the NBC allows suppliers of material to pry on the lapses of the code to supply materials that are unfit for such environment. The use of such substandard materials leads to a deplorable state of schools even when huge sums have been reported to have been spent (UNESCO, 2007). Therefore, the dilapidated nature of these schools shows that materials used do not stand the taste of time leading to a deplorable state.

The main rationale behind the construction of any public building of which public schools play a major role is for children to acquire knowledge for a better tomorrow. Against the backdrop of dilapidation and deterioration, providing newer ways to enhance their academic performance to deliver the needed skills and knowledge to face the growing global demands is significant. Some researchers (Sanoff, 2001; Clements-Croome, et al., 2008; Parker, 2008; Stringer, et al., 2012) , have argued that school buildings should be developed and allowed to carry out the primary function according to different criteria including material, design, location and construction type. They further noted that material selection should form an integral part of the criteria for such approval and continuation of its use as schools.

In trying to address the consequences of air pollution, different laws, codes, regulations, and guidelines have been in progress over the years (Krzyzanowski and Cohen, 2008). However, the downside of using any of such guidelines is that most air pollution standards target moderate exposure countries, continents or regions, rather than targeting reduction and mitigation programs to those specific environments directly affected with the highest exposure (Jerrett, et al. 2001, Levy, et al. 2002). Nigeria still relies on the NBC which was last updated over a decade ago with little or no consideration for immediate environmental conditions of the ND.

Furthermore, NBC does not provide enough details to specification because of its prescriptive nature. Hence, the need for PS which is an effective system having the advantages of being combined with prescriptive specification method. It gives the designer, users, and clients the possibility of providing necessary performance requirements as specified before construction. It also has the advantage of exploring possible innovative materials that are presently being researched and scored using sustainable and environment-friendly criteria as provided by LEED, BEAM, Green building and even BIM, and recently, well standards. The pursuit for a better environment leads to evolving proactive actions which include the PS that entails the inclusion of specific performance criteria for an effective design, material selection and construction as required.

Therefore, within this research, a Performance Specification (PS) was designed for professionals in the BE in the Niger Delta Area (NDA) of Nigeria with a demonstration and elevation of its effectiveness carried out in the study area. The PS is a document detailing the requirement criteria for "indoor air and the external façade" of Public School Buildings (PSBs). The benefit of PS has been explored in different parts of the world based on the long term of commitment and links between suppliers of materials and BE professionals. For instance, in the UK, its advantages led to the recognition of the National Building Specification (NBS) which integrates building professionals and materials products covering building construction, engineering services, and landscape design. The explicit nature of information on performance requirement for different building types makes it clear for professionals to achieve such requirements. In the past, IAQ and thermal comfort were based on geographical and general climatic conditions of zones and determined by heating, ventilating, and air-conditioning specifications.

However, recently due to human intervention and explorations which have negatively impacted adversely the environment leading to pollution and subsequent heat and poor air inhaled with resultant health effects that could lead to carcinogenic diseases and death. Consequently, excluding such air from indoor, occupants, building-specific usage and local weather conditions are highly responsive systems for meeting immediate environmental challenges requiring the use of PS as the central norm for the design, selection of materials and construction. Due to the recent attributes of poor academic performance and health challenges of schoolchildren linked to poor IAQ and aesthetics of PSBs, prescriptive codes which require the calculation of the source strength and dilution to achieve target concentration is been blamed and cannot satisfy heterogeneity of occupants (Spengler and Chen, 2000). The reservations of scientific interpretations of the amount and effect of mixtures of atmospheric substances and mechanism leading to adverse effects are still in its infancy in Nigeria.

Therefore, the performance based specification for ventilation, IAQ, and durability of the SB that acknowledges the importance of clean indoor air is significant in the NDA. There is currently no stipulated guideline for school construction detailing requirement and performance criteria for IAQ and durability of the PSBs in Nigeria. The design of a PS detailing performance requirement and criteria will provide the needed information for BE professionals and policy makers during consideration, selection of location and building materials, design, and construction of schools in the ND. Although it was designed for public schools, using the same requirement will help developers and professionals in the BE to better understand the significance of designing and constructing healthy and durable buildings within the ambient air polluted environments.

1.3 Aim

The aim of this research is to develop performance specification guidelines for the design of PSBs in the vicinity of gas flares in the NDA. To satisfy the research aim, the following research objectives have been set:

1.4 Objectives

- To identify the typology of Public School Buildings (PSB) in use in the ND climatic region of Nigeria;
- To identify the reported effects of GF on building components in other developing regions in general and the ND region in particular;
- To examine the current building materials and their suitability for use in a GF environment;
- To examine the criteria used for ventilation system in schools in the vicinity of GF
- To develop performance specification guideline for GF areas where professionals in the BE can use it to achieve better design and construction of PSBs.
- To demonstrate the validity of the PS through systematic iterative process and evaluation using drawings.

1.5 Research Questions

According to Tashakkori and Creswell (2007), mixed method research requires the use multiple research questions that provide the possibility of integrated or hybrid questions.

Thus, questions could be more than the number of objectives however with the overreaching purpose of achieving research objectives.

For facilitating the development of this research, the following research questions are posed;

1. Does the climatic region of ND affect the typology of Public School Buildings (PSBs)?
2. Are there reported effects of GF on building components in the ND region?
3. Is there a correlation between GF activities in an environment and the discolouration of the external/internal finishing of a building fabric?
4. Are there building materials that could be resistant to the impact of GF?
5. Are there building materials that are appropriate for use in a GF environment?
6. What are the criteria used for the design of ventilation system in schools in the vicinity of GF?
7. How do immediate environmental conditions affect indoor air and PSB facades in the ND?
8. Are there robust techniques that can enhance the shelve life of building structure where metals are exposed to environmental conditions?
9. Are there possible design systems that can exclude contaminants, provide durable buildings and maintain the health of people?
10. Is there a performance specification guideline for professionals in the BE in GF areas that can be used to achieve better design and construction of PSBs?

1.5.1 Relationship between Research Objectives and Research Questions

Figure 1.1 shows the relationship between the primary objectives research and questions of the study

Research Objectives	Research Questions
To identify the typology of school buildings in use in the ND climatic region of Nigieria	• Does the climatic region affect the typology of school buildings?
To identify the reported effects of Gas Flaring on building components in other developing regions in general and the Niger Delta region in particular	• Are there reported effects of Gas Flaring on building components in the Niger Delta region? • Is there a correlation between GF activities in an environment and the discolouration of the external/internal finishing of a building fabric?
To examine the current building materials and their suitability for use in a GF environmente	• Are there building materials that could be resistant to the impact of gas flaring? • Are there building materials that are appropriate for use in a GF environment?
To examine the criteria used for ventilation system in schools in the vicinity of GF	• What are the criteria used for the design of ventilation system in schools in the vicinity of GF? • How does an immediate environmental condition affect indoor air and school building facades in the ND?
To develop performance specification guideline for Gas Flaring areas where professionals in the built environment can use it to achieve better design and construction of school buildings.	• Are there robust techniques that can enhance the shelve life of building structure where metals are exposed to environmental conditions? • Are there possible design systems that can excludes contaminants, provide durable buildings and maintain the health of people?
To demonstrate the validity of the PS for school buildings through systematic iterative process and evaluation using drawings.	• Is there a performance specification guideline for professionals in the built environment in GF areas that can be used to achieve better design and construction of school buildings?

Figure 1.1 Relationships between Research Objectives and Research Questions

1.6 Research Scope

The scope of this research is encapsulated in the main research aim, objectives and questions; thus combining both external building material and IAQ. The aim here is to provide a PS for public school construction around GF areas as a means to an end to the deterioration of buildings and poor IAQ. The nature of the PS is such that it will help professionals in the BE in the choice of materials and ventilation systems suitable for improving IAQ. This research should induce changes directly affecting the way design, selection of material and construction is carried out. Explores alternative methods of ventilation that will help provide clean indoor air in polluted environments and performance requirement for building durability and improve the external façade of PSBs in the NDA of Nigeria where the GF is the major environmental pollutant. Designing a performance specification (PS), the study relied on the documented literature and opinion of professionals in the study area using both qualitative and quantitative data. As a result, the scope of the study is confined to the internationally accepted building codes from the UK, EU and USA and guidelines and regulations from WHO, FEPA, EPA and ASTMA, suggestions and opinions of experienced professionals in the BE in the study area providing the necessary requirements and criteria to meet performance of PSBs in the ND. The scope of the study revolves around building codes, regulations, and standards with systematic amazements to meet environment specific criteria and evaluating the designed PS on the professional views dominant users of the designed PS.

1.7 Research Methodology

The motivation of this research was first derived from the observation, review of design and construction of PSBs and secondly the presumed health implication of ambient air inhaled since simple open ventilation systems is the design norm used in the vicinity of continuous GF lead to the refined aim and objectives. Achieving objectives of the research and finally the aim, a Design Science (DS) method was adopted. This allows the integration of other research strategies in the exploration of possible ways where immediate environmental requirement could be met without the reliance on the Nigerian Building Code (NBC) hardly updated to meet changing needs and international standards. The reliance on the prescriptive method of specification necessitates the use of outdated code while performance based specification relies on user requirement meeting environment base specifics. This was in particular reference to the NDAN where oil exploration and exploitation process through open air burning (GF) is used. Design, selection of material and construction relies on the

NBC first promulgated in 1990 and updated in 2006 without possible consideration to the environment whilst updating the code in 2006. This research exploring environment specific requirements, therefore, demonstrates and evaluates PS that meets the needed criteria for design, selection of material and construction of PSBs. It is important to select appropriate method/methods suitable for the problem at hand. Thus, in line with the DS method which deals with real life problems with the sole aim of producing the real solution to task or situation through development, design or construction of an artefact as affirmed by Johannesson and Perjons (2012) was adopted. As already mentioned in the research problem section, this research is within the realm of the BE and deals with public schools, schoolchildren, deterioration rate and IAQ.

DS is essentially a real life problem-solving method (Johannesson, 2012) and is considered a legitimate approach for iterative scenarios (Gregor, 2013), has its roots in engineering and the science of the artificial. Although applied in information science research, it is increasingly being applied to other sectors including the BE (Tezel, 2011; Rooke, 2012). DS allows the integration of other research methods to produce a solution to a real life problem (Johannesson, 2012). Thus DSM has been chosen as the philosophy with a combination of case study and mixed methods adopted for this research in order to achieve its objectives.

Therefore, this research leverages on the study approaches related to DSM, although different frameworks have been developed by different people mostly aligns with information technology, engineering, and science (March and Smith, 1995; Simon, 1996; Hevner, 2007; Peffers, et al. 2007). However, (Niehaves, 2007; Van Aken and Romme, 2009; Johannesson and Perjons, 2012) provided the basis for its adaptability to other schools and professions such as the BE. The adoptability provided justification and the adoption of the Johannesson and Perjons (2012) DS framework for this research.

The outline of the research and its process is presented in figure 1.2 which shows a graphical summary and representation of the main processes which were undertaken. The study although in nine chapters was divided into five stages developed as systematic refinements and adjustments. These stages are (1) explication of the problem; (2) outlining of the artefact and defining of the outline; (3) development of artefact; (4) demonstration of artefact; (5) evaluation and conclusion.

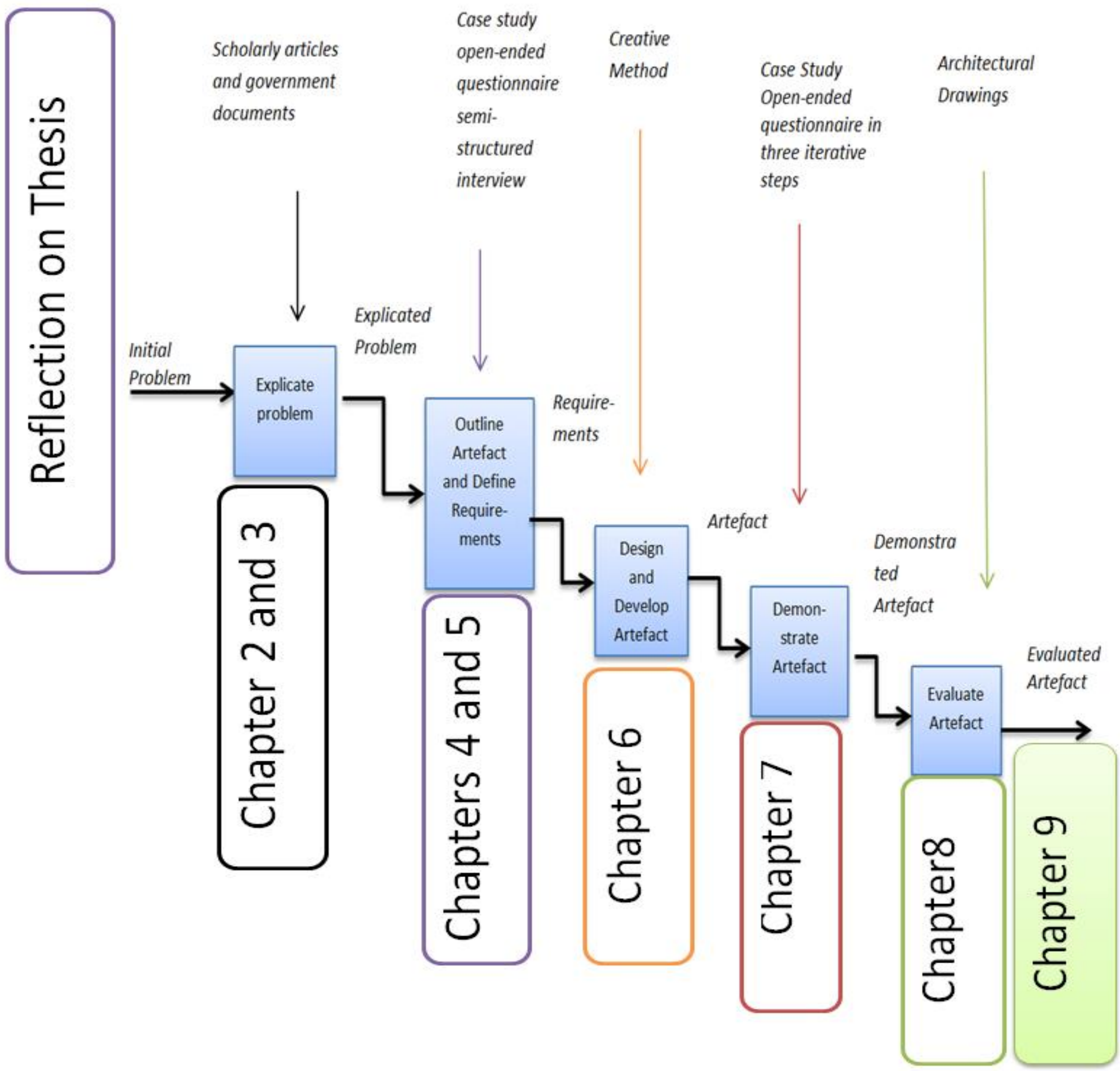


Figure 1.2 Adjusted Framework Adopted for this Study
Source: Johannesson and Perjons (2012)

Following the above graphically represented framework with the stages and chapters that inform them, the structure provided solution centred on selected strategies in exploring ways of achieving required objectives. From the initial problem identified, explication of the problem was carried out using scholarly articles from national and international reputed publications. In addition, government documents such as laws, regulations, codes and standards were used to clarify problem. The second stage was a further explication of problem identified providing extensive relevance to the research problem. This allows the use of strategies such as case study and research techniques to supplement explicated problem and thereby providing scenario for requirement necessary for the identification of the solution-base. Having explicated research problem using instruments such as opened-ended questionnaire and semi structured interview techniques, the third stage explored a solution-base using creative method which allowed the design and development of the artefact (solution). The fourth stage was the demonstration of the artefact using opened-ended questionnaire, this allowed the selection of professionals who are well-informed and experienced in the case-study area. And finally the fifth stage was the evaluation of the demonstrated artefact which is a form a validation but required respondents that participated during the demonstration phase to ascertain that the solution proposed solves problem identified and explicated. Following this description of the stages and processes in achieving the aim of the study, outline of the research is briefly discussed in the next section.

1.8 Chapter Outline

Chapter 1: This chapter provides the introduction and background of the research, which discussed the research problem, the research questions, the aim and objectives, and a brief discussion of the methodological approach adopted for this study.

Chapter 2: This reviews the literature on GF in relation to its impact on the BE specifically focusing on the PSB fabric and air quality. It looks at measures used by developed countries in providing a favourable academic environment for children and how this could be useful in the ND situation. It focused on the ND area and its GF reviewed the impact on the local BE and both outdoor and IAQ.

Chapter 3: This is another chapter on literature review focusing on PS. It reviewed PS of PSBs, the PS for air quality and different ventilation strategies explored and adopted by both developed and developing countries as mitigating measures. Its importance and how it can help in the choice of materials and ventilation systems that could provide clean indoor air and building longevity.

Chapter 4: This chapter presented a detailed discussion of the research design, methodology and the philosophical stance adopted for the study. DS Research approach is explained alongside with the justification of the research method, data collection and method of analysis adopted for the study are covered.

Chapter 5: Outlines the artefact and Design requirement, a detailed analysis of the data is presented which provides the study with a complete explicated problem which forms a prerequisite for the design of a PS detailing the type of artefact constructed and the requirement necessary for its development.

Chapter 6: This deals with the design and development of the artefact that will help in solving the problem building durability and poor IAQ following a clear understanding of the problem. Here a creative insight is needed as a method to help in providing details of the necessary requirement that will meet the design, selection of material and construction of schools in a GF environment. Details of hazardous substances and limits and performance requirements are explored and the most appropriate requirements, guidelines, and standards were selected based on their effectiveness in the ND.

Chapter 7: This chapter focused on the demonstration using an iterative process with feedbacks using an open-ended questionnaire. A discussion of difficulties encountered and the need to use a PS information pamphlet (PSIP) to define and discuss the various factors/criteria was used. Responses were analysed using Statistical Package for Social Sciences (SPSS).

Chapter 8: This is the evaluation chapter which forms the final stage of the DS Method used in the research. There were discussions on the selection criteria for experts selected for this stage of the process. A discussion of the brief steps taken to produce drawings based on designed PS from two architects with well over twenty years' experience in the study area. Discussions included feedback and comments. Research contribution, further research possibility and a comparative discussion of an existing building meeting DPS were carried out.

Chapter 9: The final chapter concludes the research by summarising the key findings. Since research is an ongoing process with the possibility of further research, potential future researchers were discussed. The limitations of this body of work, contribution to knowledge, key findings from the different chapters were summarized.

1.9 Summary

This chapter has presented the background of the study with literature review, highlighting the research problem and the need for the study. The research questions, aim, and objectives, scope, and contribution to knowledge were also presented in the chapter. An overview of the research methodology has been presented in this chapter. In addition, this chapter outlined the research process with an adjusted framework adapted to the structure adopted by this current study. The next chapter presents a review of the literature on areas of GF impact on PSBs and IAQ and PS as a tool in achieving a comfortable academic environment in the GF area of the NDA of Nigeria.

CHAPTER 2. ENVIRONMENT FOCUSED ON SCHOOL BUILDING FABRIC AND AIR QUALITY

2.1 Introduction

Having introduced the background of this study in the previous chapter, this chapter will provide in-depth discussions and description of the perspective which this study is positioned through literature reviews. According to Taylor (2007), the literature review is the summary and evaluation of the current state of knowledge or state of the art in particular. Its invaluable role is emphasised by many. For instance, Haywood and Wragg, 1982 as cited in Fellows and Liu (2015) noted that it must be critical which demonstrates that the author has studied existing work in the field with insights and a mere listing of articles, which, has been read, with summary of their main points is not sufficient (Fellows and Liu, 2015). Thus, Eisenhardt and Graebner (2007) views of the literature review as the basis for sound empirical research. Accordingly, Baker (2000) noted that it ensures that the researchers' knowledge in a selected subject area is up to date and that they are not reinventing the wheel Furthermore, (Randolph, 2009) observes that it helps in delimiting the research problem and with gaining methodological insights. Consequently, the reader of the research is provided with the summation of the main issues regarding GFs in the BE and the rationale for the research.

The literature review divided into two chapters with the primary aim of showing the extent to which relevant literature could address the aim and objectives of the study and whether this would then lead to an effective identification and development of solutions to the identified problems in schools in the NDAN. This is achieved through the establishment of facts that GF causes various problems in the environment with particular attention to external facades of PSBs and IAQ. Consequently, the deficient nature of literature in the study area in the Nigerian context led to the collection of primary data through a Likert Scale questionnaire and semi structured interviews to support the significance. This was to provide evidence of the need to carry out the research. In addition, reviews construction materials, building regulations, air quality guides, and ventilation system, and PS were carried out for PSBs.

The first chapter on literature section reviewed the literature on GF as a process in oil exploration and exploitation activities, countries that flare and the amount of flaring in such countries. Although many countries flare gases, however, this study limits itself with the world 20 most flaring countries. Highlighting the different economic, environmental and social impacts of their continued GF to the environment, which, is narrowed down to Nigeria with particular reference to the ND where these gas are flared. The impact of the residue on the ND environment, providing the specific review on the BE, its impact on façade of buildings and the health factor associated with the filtration of ambient into classrooms affecting IAQ were discussed.

2.2 Oil Exploration, Exploitation, and Gas Flaring

Flaring of natural or associated gas is done as a by-product of the drilling of crude oil from reservoirs in which oil and gas are mixed. GF is widely used to dispose of dissolved natural gas present in petroleum in production and processing facilities where there is no infrastructure to make use of the gas. However, innovations and environmental awareness have led to safer methods with open air burning seriously discouraged (Action, 2005; Andersen, et al. 2012). Although, (Broere, 2008) noted that some countries flare gases because of technical, regulatory, or economic constraints The design of the equipment used in oil production is constructed in a way where a flaring stack is provided as shown in Figure 2.1. The flaring stack is designed in a way that it is not a source of danger to itself or people working around it through pipe explosion due to the constant furnace. The gas emerges from crude oil when brought to the surface and is separated from the oil prior to transport.

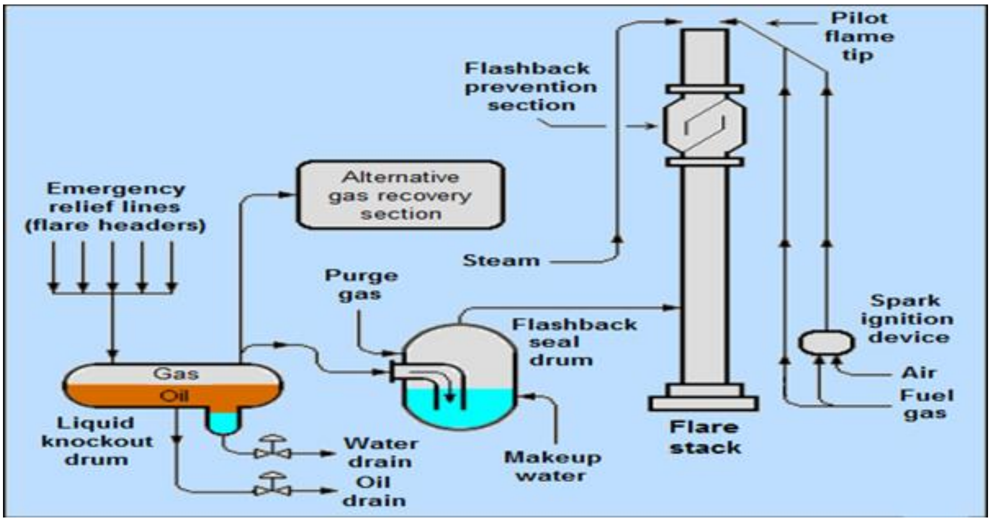


Figure 2.1 Diagrammatic Description of Gas Flaring Stack
Source: Frede (2008)

Flaring of unwanted flammable gases via burning in open atmosphere flames is a process used in reducing pressure on oil pipelines. The main reason for flaring stacks is to protect the plant from the explosion and bursting into flames. The flaring process can produce some undesirable by-products including noise, smoke, heat radiation, light, sulphur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), and an additional source of ignition were not desired. Although oil exploration and exploitation has continued to help many nations with needed manpower for economic growth and stabilisation, residues from flaring have become an environmental, physical, economic and social concern. Despite this fact most countries in the world that produce oil flare gases but for the purposes of this research the twenty most flaring countries in the world as shown in figure 2.2.

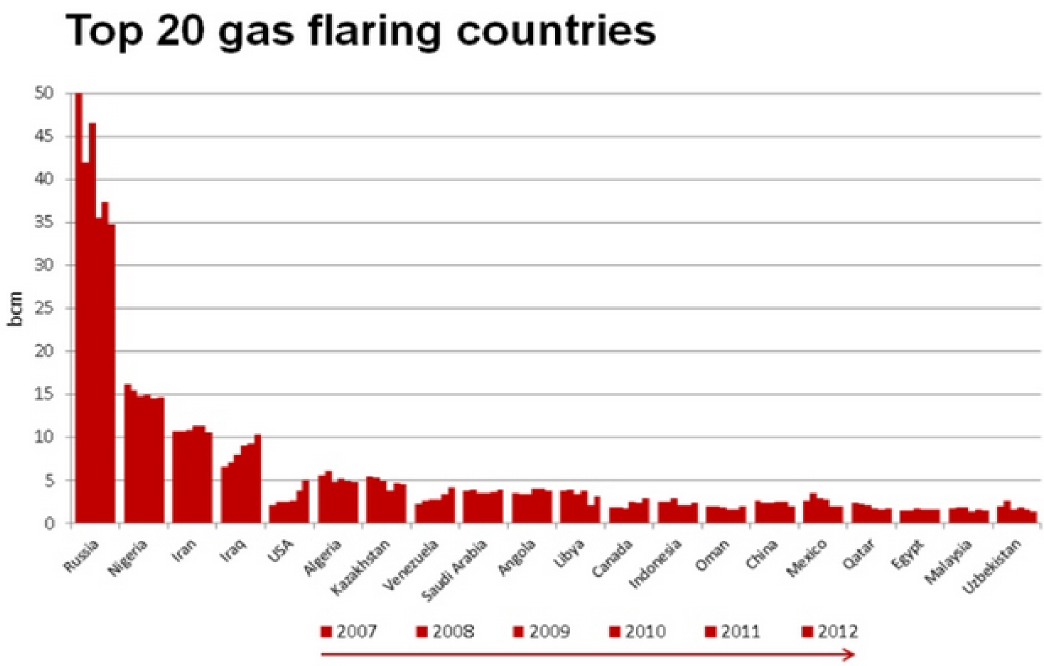


Figure 2.2 Top 20 Gas Flaring Countries
Source: World Bank report (2016)

As shown in figure 2.2 all flaring amount is in Billion Cubic Metres (BCM) with Russia is the highest in GF followed by Nigeria with Uzbekistan being the least flaring nation based on these statistics, with less the 5BCM. As a result, thousands of GFs at oil production sites around the globe burn approximately 140 billion cubic meters of natural gas annually, causing more than 300 million tons of CO^2 released into the atmosphere (World Bank report 2016). Although, reports from different studies indicate that flaring is either reducing or at a stable rate over recent years (Andersen, al., 2012; Anejionu, et al. 2015). Yet, this reduction does not reflect the magnitude of the challenges faced during operation, in which different countries rely on varying levels of infrastructure and opportunities for mitigation processes available to them as in the case of Nigeria. Consequent to the need in reducing GF as its adverse impact has continued to make waves; the rising concerns of its impact on a global scale, the World Bank in 2016 noted 4 common features of successful anti-flaring options:

1. Anti-flaring legislation accompanied by public reporting and monitoring
2. Flexible approach that adapts to specific field circumstances
3. Open and transparent access to pipelines and other infrastructure
4. Independent pipeline regulatory body with effective enforcement capability and capacity for quick response, based on international best practices. This body should be independent of influence from current and future participants. It could be a completely separate organization or be part of the government.

Furthermore, some countries which have had a successful reduction in GF adopted and used additional features as listed in table 2.1 below;

Table 2.1: Countries with Successful Reduction in Gas Flaring

No	Country	Anti-Gas Flaring Features
1	Norway	➢ Government directly regulates emissions through development and operational plans and environmental impact assessments ➢ Transparent process includes public consultation ➢ Open-access gas infrastructure jointly owned by multiple producers (replacing an earlier system in which Station oil control of the infrastructure blocked access for other producers) ➢ CO2 tax provides additional incentives ➢ Flaring restrictions are credited with creating incentives to develop gas infrastructure, enhanced recovery, and new technology such as “closed flare systems”
2	UK	➢ Policies designed to maximize economic recovery of oil and gas reserves and reduce greenhouse gas emissions ➢ Department of Trade and Industry (DTI) controls all flaring and venting through Licensing and Consents unit ➢ DTI reviews all Field Development Plans, which must consider feasibility of APG utilization all but the smallest fields also require Environmental Impact Assessments ➢ Annual reporting required from all fields ➢ Flare Transfer Pilot Trading Scheme designed to further reduce GF ➢ Third party access to upstream gas pipelines ➢ Unbundled midstream/downstream markets
3	Alberta, Canada	➢ Flaring regulated by province rather than the federal government ➢ Reduction of GF is a priority of the Alberta Energy and Utilities Board (EUB) ➢ EUB requires operators to assess alternatives to flaring and venting ➢ Latest EUB directive requires operators to eliminate flaring even when this requires some subsidy

		➢ Annual and public reporting requirements and periodic inspections ➢ Enforcement ladder system with escalating consequences for non-compliance ➢ Liberalized gas markets and open pipeline access with regulated tariffs ➢ Royalty waiver program designed to further reduce flaring
4	US	➢ Environmental Protection Agency regulates some APG components, but not methane itself ➢ Offshore operations regulated by federal Minerals Management Service (MMS), which permits only very limited GF ➢ MMS requires monthly production statements, including flared gas volumes ➢ Bureau of Land Management also has flaring regulations and reporting requirements ➢ Individual states have rules and regulations governing flaring and venting ➢ Highly developed hydrocarbons markets and transportation infrastructure with open access

Source: The World Bank Group (2016)

Based on the table 2.1, countries are making progress based on partnership with all stakeholders including government and individual investment even local based subsidy and incentive to promote investment in harnessing the waste gas for economic gains. The economic feasibility of other methods of oil exploration such as gas to liquid, reinjection method, etc. might also be a significant reason for flaring as affirmed by (World Bank 2004). For instance, Russia, since 2005 was flaring up to 15 Billion Cubic meters and increased to 20 BCM in 2007 even though there was a promise of the possible reduction in GF (Loe and Ladehaug, 2012) . Again, Knizhnikov and Poussenkova (2009) purports that only half of the flares have flow monitors in Russia. Therefore based on world Bank of 2004 at cited above, the economic feasibility could be the significant reason in the high level of flaring in Russia.

Intriguingly, a developing nation like Nigeria ranked second as shown in figure 2.1 will be faced with significant obstacles in trying to reduce flaring. The difficulties in Nigeria apart from the bureaucracy is the possibility of gathering gas from more than 1,000 wells scattered in the area larger than Portugal to gas collection facilities at the oilfields. Constructing extensive pipeline network to carry the gas industrial facility where it is turned into a liquid (Broere, 2008). Hence the probability that flaring might be a thing of the past for the nation is like a mirage.

2.3 Gas Flaring in Nigeria

Gases are burnt off as unusable waste gas or flammable gas released by pressure-relief valves during unplanned over-pressuring of plant equipment; It burns through a GF pipe on oil wells, in refineries, or in chemical plants (Akeredolu and Sonibare, 2004; Gervet, 2007). There are over 18 multinational oil companies which are involved in oil and gas exploration and production in the ND (Poindexter, 2008) . 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).

According to Andersen, et al. (2012) to avoid the inquiry, it may be the producer or government interest to limit access to data on GF levels. This tends to leave one to wonder if there is a deliberate attempt not to provide the accurate level of flares. This buttresses the negative effects associated with foreign investors undertake major economic activity in a developing economy like Nigeria (Pearson, 1970). Although, the atmospheric disposal of these gases is mostly for emergency as a safety measure, lack of infrastructures for alternative method(s) results to cheap and easy way of refining crude oil consequently saving pipes or vessels from over-pressure is used (Keller, et al., 1990; Nwaugo, et al. 2006).

Moreover, Nigerian industrialisation has resulted in other types of air pollution such as biomass burning, steel plant emission from the country's steel industry, vehicle emission, fuel combustion using generators as a primary source of electricity, dust pollution. Higher environmental pollution is observed to be generated from crude oil exploration through GF as affirmed by 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 the well-being of the population, materials, and flora. Furthermore, Solov'yanov, (2011); Ite, et al. (2013) affirmed that more than 250 anthropogenic gases have been identified from flared associated gas like, carcinogens, 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 and1.4 – 2.4% of heavier hydrocarbons. The engineering designs 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 the smoke of different colours with different locations as shown in figure 2.3 for coloured flare.

Figure 2.3 Red Cycle Showing Carbon Content
Source: limits (2013)

The flaring that occurs as shown in figure 2.3 is the black coloured flare although flaring is characterised by different colours ranging from colourless to black carbon (Elvidge, et al. 2009). However, the case of the ND all GF stacks flare in black carbons. It is pertinent at this point to discuss the ND region in Nigeria where there is continuous flaring of black carbon with hazardous anthropogenic substances emitting from it.

2.3.1 Gas Flaring and the Niger Delta Area (NDA)

It is worthy of note here to discuss in brief the NDA to further provide significant relevance of the need for this research having stated in section 2.3 the total amount of flaring emitted from Nigeria. The ND flares about 2.5 billion cubic feet per day and has an estimated 106 Trillion m^3 of proven natural gas (Nwanya, 2011) even though, the amount could be higher than what has been estimated as affirmed by the Nigerian National Petroleum Cooperation (NNPC) in their 2014 reports (NNPC, 2014). This is because the significant number of oil companies exploring oil and flaring gases do not provide figures for a number of flares, thus reducing the total amount in the ND (see appendix B). Therefore, records provided fall short due to this fact that some oil companies fail to provide the NNPC with the correct data of quantity of flares emitted, predominately in the NDA of Nigeria, as illustrated in figure 2.4 below:

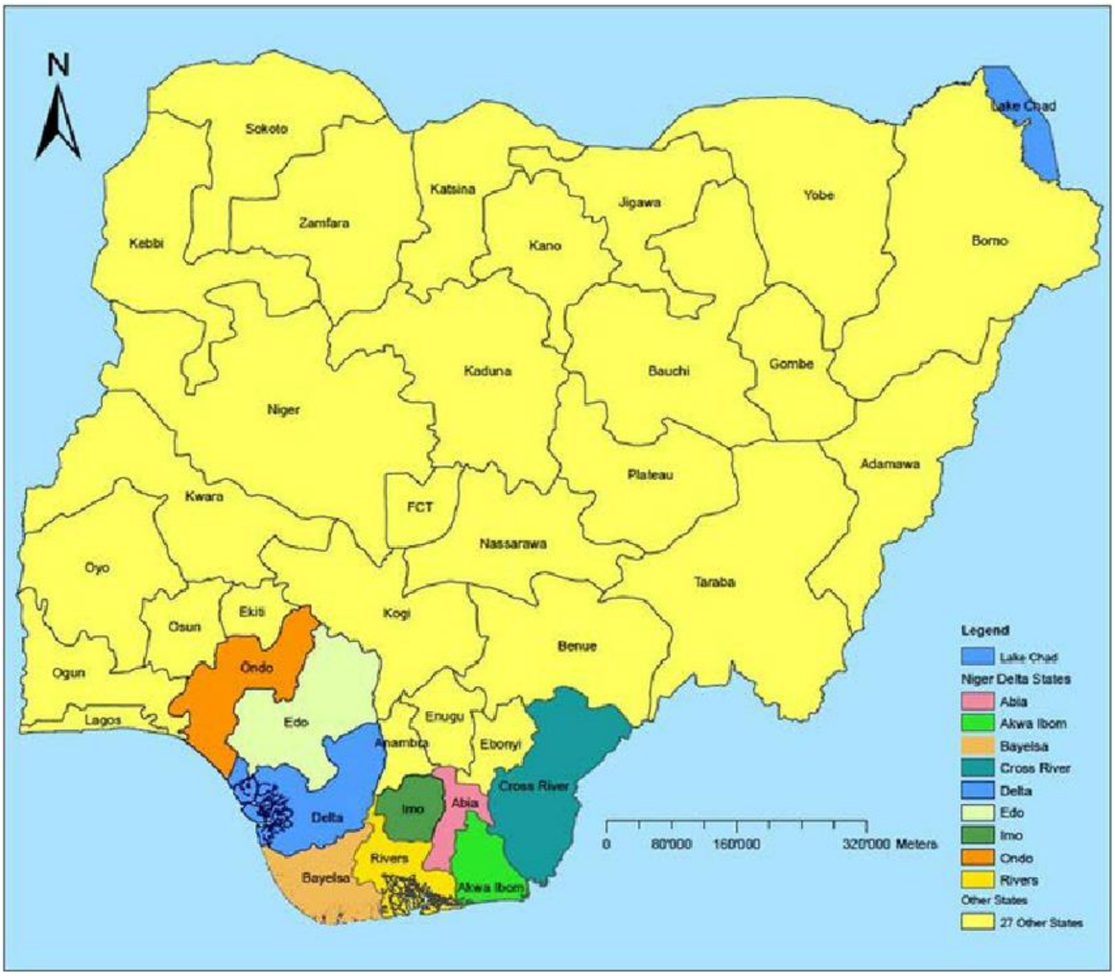


Figure 2.4 Map of Nigeria
Source: Ite, et al. (2013)

Nigeria has thirty-six states, with Abuja as the capital, of which nine constitute the ND situated at the zenith of the Gulf of Guinea on the west coast of Africa and on the Nigerian South – South geopolitical zone (NDDC, 2006) as designated on the map in different colours (figure 2.4). These 9 states namely; Abia, Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers as designated. The 9 states as designated in figure 2.5 spread across 185 local government areas. It is densely populated poor area representing 12% of Nigeria's total surface area with 112,110 square kilometres with an average population density of 265 inhabitants per square kilometre. It is mostly a flat, low-lying swampy basin crossed by a network of rivers and creeks. The area contains the world's third largest wetland with an extensive freshwater swamp forest. With these characteristics, it has been noted to have a challenging topography, which makes the region's population gather in small communities. With a total of 31 million people as affirmed by CRS (2008) and an extrapolated 2015 population of 39,157,000 (GTZ Population Projection as cited in NDDC 2006) clearly mapped in figure 2.5 of all ND states.

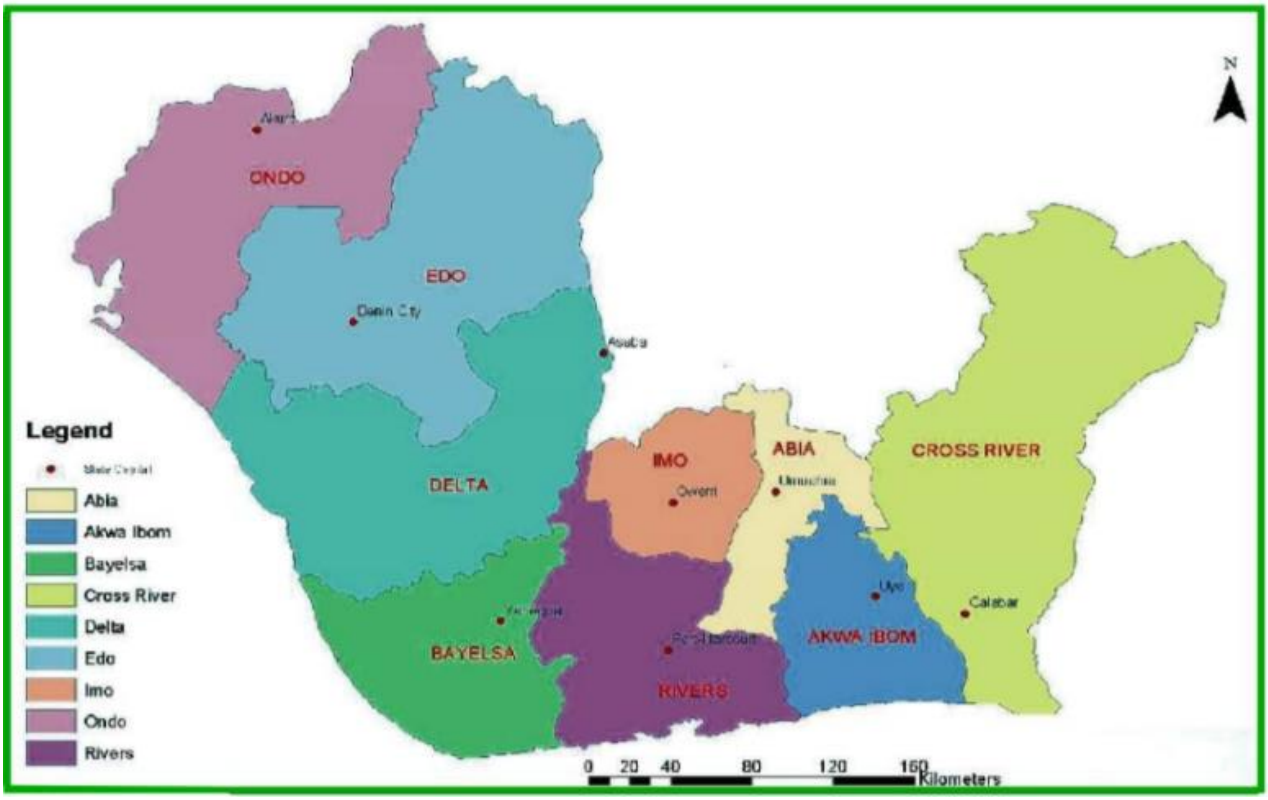


Figure 2.5 Niger Delta Map
Source: NDDC (2006)

The region illustrated in figure 2.5 above cuts across 800 oil-producing communities with a prevalent network of over 900 producing oil wells (Osuji and Avwiri, 2005; Oviasuyi and Uwadiae, 2010). There are over 18 multinational oil companies which are involved in oil and gas exploration and production in the ND (Poindexter, 2008). The ND basin has been one of the most studied basins because of the occurrence of vast deposits of petroleum resources and the current production of all Nigeria oil and gas is derived from the region (Obaje, 2009). According to Curtis (1986), hydrocarbon deposits of comparable quantity are found only in the U.S. Gulf of Mexico, Canadian Beaufort-Mackenzie Delta, and ND. Over 50 years since the discovery of oil in 1958 at Olobiri in the Rivers state now Bayelsa state, a total of about 1,182 exploration wells have been drilled to date in the delta basin, and about 400 oil and gas fields of varying sizes have been documented Obaje (2009). Similarly (Broere, 2008) affirmed that more than 1,000 wells and flaring sites are scattered over an area larger than Portugal. This presupposes that there is undocumented oil exploring sites hence the failure to fully document the amount of flaring that occurs in the area. Furthermore, GF activities are carried out both offshore and onshore, nevertheless, the number of onshore flaring sites in the ND area of Nigeria is twice that of the offshore as shown in table 2.2;

Table 2.2: Distribution of flare sites in the NDA of Nigeria

States in the ND	Onshore Flare Sites	Offshore Flare Sites	Total Flare Sites
Rivers	56	16	72
Delta	51	19	70
Bayelsa	41	12	53
Akwa Ibom	6	30	36
Edo	19	0	19
Ondo	5	4	9
Imo	11	0	11
Abia	1	0	1
Total	190	81	271

Source: Anejionu, et al. (2015)

The table 2.2 shows recorded flaring sites that were identified using a Moderate Resolution Imaging Spectroradiometer (MODIS), in the NDA (Anejionu, et al. (2015). The sheer number of identified flare sites gives an indication of hazardous chemical substances emitted from the flare stacks into communities where more than 31 million Nigerians inhabit. With a population, fewer than 5,000 in each settlement comprising of 13,329 settlements in NDA and 65% of this population are classified as children and youths (NDDC, 2006). Therefore, the impact of GF on 65% of more than 31 million people in the NDA becomes a crucial menace that needs to be averted.

Although different research as already discussed above showed that substances emitted due to GF are anthropogenic in nature thus, dangerous to humans and the environment, the proximity of children to flaring sites as illustrated in the figure in 2.6 below in NDA raises major health concerns. Furthermore, acid rain has defied solution, metal coating used as an anti-corrosive of surfaces, meant to protect it from corrosion is also destroyed by multi-pollutants resulting mainly from oil and coal combustion processes (Ozga, et al. 2011). However, the quality and specification criteria used for manufacturing such metal-coating remain questionable; it shows that the residual effect of GF is not only noticed by its colour but other factors that could harm the BE.

Figure 2.6: Children in Close Proximity to Gas Flare
Source: chemeng (2011)

The proximity of these children shows the obliviousness of the impact on the human health as they breathe the air around the environment where they sit and play. The local Environmental impacts show clear cases where flaring has been highly damaging to local populations and ecosystems with such problems most acute in places where intense oil and local community development overlaps (Andersen, et al. 2012). According to the calculation by (Peterson, et al. 2007), the chemical composition of a typical gas plant, as summarised in table 2.3, is an indication of the level of quantities of hazardous substances that are emitted in the NDA on daily bases causing different environmental impacts associated with flaring.

Table 2.3 Indicative quantity of Chemical Substances emitted from GF

Flare gas constituent	Gas composition, %		Flare gas, % average
	Min.	Max.	
Methane	7.17	82.0	43.6
Ethane	0.55	13.1	3.66
Propane	2.04	64.2	20.3
n-Butane	0.199	28.3	2.78
Isobutane	1.33	57.6	14.3
n-Pentane	0.008	3.39	0.266
Isopentane	0.096	4.71	0.530
neo-Pentane	0.000	0.342	0.017
n-Hexane	0.026	3.53	0.635
Ethylene	0.081	3.20	1.05
Propylene	0.000	42.5	2.73
1-Butene	0.000	14.7	0.696
Carbon monoxide	0.000	0.932	0.186
Carbon dioxide	0.023	2.85	0.713
Hydrogen sulfide	0.000	3.80	0.256
Hydrogen	0.000	37.6	5.54
Oxygen	0.019	5.43	0.357
Nitrogen	0.073	32.2	1.30
Water	0.000	14.7	1.14

Source: Peterson, et al. (2007)

Table 2.3 above provided an indicative composition and flare average from anyone flare constituent, showing that it is an absolute confirmation. Consequently, McDaniel and Tichenor (1983) illustrates that f1are emission measurement is hindered by the following:

- The effects of high temperatures and radiant heat on test equipment;
- The meandering and irregular nature of flare fumes due to external winds and intrinsic turbulence;
- The undefined dilution of flare emission plume with ambient air;
- And the lack of suitable sampling locations due to flare and/or flame heights.

Accordingly, Peterson, et al. (2007) affirmed that there is a growing disapproval on the estimation of volatile organic compounds (VOCs) as they argued that it might be higher. This is in agreement with the estimate given for carbon monoxide in the NDA. According to Ubani and Onyejekwe (2013), the quantity of carbon monoxide emitted by the flare in the NDA is about 2,525,000.0 tonnes of carbon per day. In addition to this chemical composition, the thermal radiation and noise pollution associated with flaring sites, as identified by Ghadyanlou and Vatani as cited in Emam 2016 in table 2.4, show the effect oil exploration activities in close proximity to schools have on academic performance due to heat and rumbling noise emanating from GF pipes and stacks .

Table 2.4: Thermal Radiation and Associated noise level from GF

Flare gas constituent	Gas composition, % Min.	Gas composition, % Max.	Flare gas, % average
Methane	7.17	82.0	43.6
Ethane	0.55	13.1	3.66
Propane	2.04	64.2	20.3
n-Butane	0.199	28.3	2.78
Isobutane	1.33	57.6	14.3
n-Pentane	0.008	3.39	0.266
Isopentane	0.096	4.71	0.530
neo-Pentane	0.000	0.342	0.017
n-Hexane	0.026	3.53	0.635
Ethylene	0.081	3.20	1.05
Propylene	0.000	42.5	2.73
1-Butene	0.000	14.7	0.696
Carbon monoxide	0.000	0.932	0.186
Carbon dioxide	0.023	2.85	0.713
Hydrogen sulfide	0.000	3.80	0.256
Hydrogen	0.000	37.6	5.54
Oxygen	0.019	5.43	0.357
Nitrogen	0.073	32.2	1.30
Water	0.000	14.7	1.14

Distance, m	Thermal radiation, kW/m^2	Noise level, dB
10	5.66	86.3
20	5.87	86.19
30	6.04	86.02
40	6.14	85.78
50	6.17	85.50
60	6.14	85.18
70	6.04	84.83
80	5.88	84.46
90	5.67	84.08
100	5.42	83.68

Source: Ghadyanlou and Vatani as cited in Emam (2016)

As shown in the table 2.4 above although the level of noise emitting from GF sites reduces as the distance increases, the noise level could be disruptive and affects hearing ability. Similarly, WHO in 2001 listed three main adverse effects of noise on children including the following:

- Direct ear damage

    - Noise induced hearing loss
    - Noise induced threshold shift
- Indirect adverse effects
    - Physiological effects
    - Psychological effects
- Impaired cognition:
    - reducing reading,
    - concentration,
    - memory and
    - attention

According to Mgbemena (2015), a region in the ND has7,000km of oil and gas pipelines. And some cases such pipelines are installed over the ground as shown in figure 2.7, the size and length of an example of an over the ground pipe.

Figure 2.7 over ground Oil Pipelines
Source: CAMPBELL (2012)

Figure 2.7 depicts an example of an over ground pipeline for exploration and exploitation showing their sheer sizes and lengths and their impact on mobility and other activities in the community. The rumbling noise from such oil pipelines is left to one's imagination; this, therefore, brings us to the need to examine these cases in relation to schools in the ND.

2.4 Impact of Gas Flare on the Built Environment

The (Odu, (1994); World Bank as cited in Aghalino, (2009); Ekpoh and Obia, 2010) affirmed that acid rain is primarily due to the emission of sulphur dioxide (SO_2) and oxides of nitrogen

(NOx) which combines with atmospheric moisture to form sulphuric acids and nitric acids in rain droplets, dew or precipitation. This was supported by the U.S Government's Energy Information Administration, which stated that

"*the continued process of GF has not only meant that a potential energy source- and source of revenue-has gone up in smoke, but it is also a major contributor to air pollution and acid rain"*(Environmental Rights Actions 2005).

Therefore, the chemical composition emitted from flaring has negative environmental consequences in the Environment.

The concentration of flaring points in the NDA influences air pollution and affects buildings (Odu, 1994; Ojeh, 2012; Ifeanyi and Nduka, 2013)). The rampant spread of GF sites in NDA will have an inexhaustible impact on the local environment. Table 2.2 identified 271 offshore and onshore flare sites using MORDIS (Anejionu, et al. 2015) in the NDA, a pictural evidence of flare sites in Figure 2.8 shows that most onshore flaring sites are in areas where human population resides.

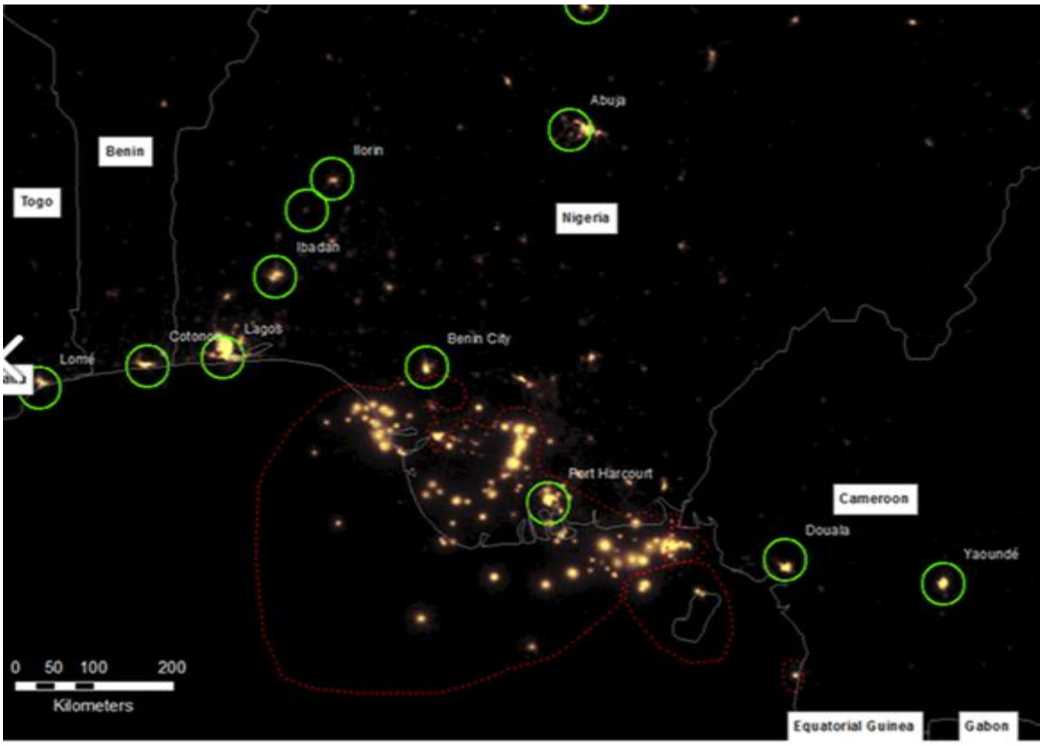


Figure 2.8 Satellite view of GF stacks in the ND
Source: National Oceanic Atmospheric Administration (NOAA) 2010

Figure 2.8 shows the satellite view of GF stacks and in the ND area. The yellow light with the red lines shows the NDA and GF activities as it lights up the environment even in the dark.

As a result, some research describes some areas in ND as the land of no darkness (Ihejiamaizu, 1999; Maass, 2009). Furthermore, Agbola and Olurin (2003) argues that about 45.8 billion kilo watts of heat are discharged into the atmosphere from 1.8 billion cubic feet of gas daily in the ND region, leading to temperatures that render large areas inhabitable. It does not suffice to say that heat gain is a problem that will affect the environment. Accordingly, Ite et.al, (2013) noted that the ineffective equipment used in the flare systems means that many of them burn without sufficient oxygen or with small amounts of oil mixed with the gas, creating soot deposited on vegetation, buildings and inhaled by children both indoor and outdoor while playing around a flare site as shown in figure 2.9;

Figure 2.9 Children playing near Gas Flaring Site
Source: Hondros (2011)

The proximity of the flare site to the school environment is illustrated in figure 2.9 above of school football field and a clear indication of the kind of air inhaled, the amount of heat radiating and the amount of noise due to the furnace from flare stack. This illustration buttresses discussions made above, along with calculations of heat radiation and noise effects in table 2.4, a depiction by Ghadyanlou and Vatani as cited in Emam (2016) as having the significant impact on the performance of schoolchildren as a result. Furthermore, GF negative effects have been linked to building deterioration as discussed below.

2.5 Impact of Gas Flares on Buildings

GFs produce gaseous substances, which combines with atmospheric moistures to deposit these gases through rain droplets, snow, and dew smog on the BE 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 GF areas of ND 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, 2011). Similarly, sulphuric acid decomposes cement matrix by decalcifying cement active ingredients such as calcium silicate hydrate Bassuoni and Nehdi, (2009) and Gao, et al. (2013). Other forms of the disintegration of building materials include 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). See an example of an impact as shown in figure 2.10:

Figure 2.10 Deterioration (Flaking) of facade painting
Source: Alaba (2014)

Figure 2.10 confirms to (Chew, 2005) findings noting that paint defects which he referred to as discolouration, peeling and blistering were observed as serious in PSBs, compared to other types of buildings. 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 pipes, sound from furnace of flare stacks, odour are some of the adverse effects of GF in the BE. See figure 2.11 on corrosion effect of zinc roof material in a public school in the NDA of Nigeria.

Figure 2.11 Corroded Roofing Materials
Source: Field Work (2015)

Figure 2.11 shows a typical public school in the ND with corrugated roofing sheet popularly known as zinc roofing sheet and the corrosion effect. Information during data collection exercise confirmed that the roofing material was changed in 2013. In an investigation into discoloration and corrosion in architectural applications, particularly metal roofs, Exponent (2010) found two cases of roofs made from lead-tin (terne)-coated stainless steel being severely discoloured instead of developing the dull gray appearance typically associated with lead roofs. They noted that metals such as copper and lead used for roofs developed a patina or surface film on exposure to the atmosphere as quoted below;

"*Our investigation showed that the discoloration of the terne-coated roofs was not caused by rusting of the stainless steel substrate. Rather, it resulted from the normal patination of the terne coating being disrupted due to adverse environmental conditions"* Exponent (2010).

Corrosion of roofing materials has been linked to acid rain due to GF effect (Akpan, 2003; Brimblecombe and Grossi, 2007; Obia et.al., 2011). Similarly, black carbon and fly-ash deposit with the mixture of atmospheric moisture content results to discolouration and blackening of roofing materials leading to potential degradation (Ismail and Umukoro, 2012; Jelle, 2012). See figure 2.12 and 2.13 for discolouration and blackening of aluminium roofs around the NDA.

Figure 2.12 Discoloration of Aluminium Roofing Material
Source: Field Work (2016)

Figure 2.13 Blackening of Aluminium Roofing Sheet
Source: Field Work (Pictured 2016)

The chemical composition of GFs mixed with rain water causes discolouration of roofing materials and deposition of black carbon gives blackening colour to roofing materials causing a negative appearance of buildings. The recent agitation of ***#STOPSOOT*** in Rivers State, due to the carbon deposits on building façades as shown in figure 2.13 and according to table 2.2 has the highest flaring sites showing the growing hazard.

Although some studies have shown significant correlation between building decay and air pollution (Jones et.al., 20010; Mills, 2007; Nkwocha and Pat-Mbano, 2010) , the quality of material used and adherence to specification requirement as provided by international and national building codes have lacked in-depth review (Awofadeju et. al., 2006; Emmitt, 2001;

Sobanke et.al., 2012). The level of awareness and competence of the specifier forms a greater parameter on the type of material specified (Folorunso and Ahmad, 2013). Thus the lack of immediate climatic specific criteria and the dominant use of architects as both designers and specifiers in the case of Nigeria and the lack of awareness of GF effect on air quality and ventilation parameters deter material selection.

2.6 Impact of Gas Flare on Air Quality

The Oxford Dictionary (2008) defined air quality as the degree to which the air in a particular place is pollution-free. Air quality deteriorates mostly due to industrialisation; population traffic and energy use as stated by (Zhao, et al. 2012), while EPA (2013) asserts that the decrease in air quality is because of air pollution. According to the Tenth Report of the Royal Commission on Environmental Pollution as cited in Colls (2002)

"Air pollution is the introduction by man into the environment of substances or energy liable to cause the hazard to human health, harm to living resources and ecological systems, damage to structure or amenity or interference with legitimate use of the environment" (Colls, 2002). World Health Organisation (WHO, 2014) defined 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. Outdoor and indoor air pollutions cause respiratory and other diseases, which can be fatal (WHO, 2014). A chemical, physical or biological agent that modifies atmosphere composition resulting in air pollution could either be natural or man-made (anthropogenic) (Jacobson, 2002). Although several definitions have been outlined above (Daly and Zannetti, 2007) opined that

"One could claim that air pollution started when humans began burning fuels. In other words, all man-made (anthropogenic) emissions into the air can be called air pollution, because they alter the chemical composition of the natural atmosphere" (Daly and Zannetti, 2007).

Based on the description above, possible deterioration effect of air quality would be said to be as a result of the impact of GF causing air pollution. The chemical composition from the exhaust of GF which impacts on air quality and subsequent health impact includes VOCs and hydrocarbons (containing methane, ethane, propane and buthane, ethylene, butylenes (Kindzierski, 1999). In addition, table 2.5 summaries health impacts associated with GF due to the emission of some chemical compositions and quantities.

Table: 2.5: Gas Flare and Health Effect Implications

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 damaging health effect in the summarised table 2.5 could further be supported by an empirical research as affirmed by Ovuakporaye, et al. (2012) in their research their findings showed that residents in GF community had reduced peak expiratory flow rate compared to children from the non-gas environment. Furthermore, in 2001, a scientific study was carried out in Canada on the adverse health effects of GF which found that cancers, respiratory disease, heart disease, rheumatic disorders and eye problems are all health challenges associated with GF (Argo 2001). Subsequently, BAUMÜLLER, 2011 in their research, noted that the EJP/ERA Report (2005) warns that gas flaring in Nigeria can cause leukaemia among populations living close to the flares between 1.3 to 5km radiuses of each site. Therefore, both indoor and outdoor air around GF environment will probably have health effects with serious deterring impact on children as the most vulnerable.

2.7 Ambient Air Quality

According to WHO, (2014) surrounding air poses a major environmental health concern affecting both developed and developing countries. Where the ambient air is polluted and is a source of indoor then such indoor air could be as polluted as the ambient air if not worse off in some circumstances (Guo, et al. 2008). Health effects, including mortality and morbidity from heart and lung disease, impaired lung function, and lung cancer have been linked to the inhalation of polluted ambient air (Brunekreef and Holgate, 2002) . Furthermore, it was affirmed that ambient air pollution has more serious health implications than is stated since low-level life expectancy is linked to it (Clancy, et al. 2002; McConnell, et al. 2002) . According to (Samet, et al. 2000), its effects appear to be without thresholds suggesting largely attributable risks in both the developing and developed world. The implication and adverse effects led to the specification of guidelines on accepted levels of pollutants by WHO used as target baseline for caution as shown in table 2.6 below:

Table 2:6 WHO Guideline for Ambient Air

Pollutant	Accepted Standard	Target
Particulate Matter	**$PM_{2.5}$** 10µg/m^3 annual mean 25µg/m^3 24-hour mean **PM_{10}** 20µg/m^3 annual mean 50µg/m^3 24-hour mean	If these interim targets were to be achieved, significant reductions in risks for acute and chronic health effects from air pollution can be expected. It is estimated that reducing annual average particulate matter (PM_{10}) concentrations from levels of 70µg/m^3, common in many developing cities, to the WHO guideline level of 20µg/m^3, could reduce air pollution-related deaths by around 15% (WHO 2014)
Ozone (O_3)	**O_3** 100µg/m^3 8-hour mean	Reduction in diseases such as breathing problems, asthma, better lung function and reduction in lung diseases.
Nitrogen dioxide (NO_2)	**NO_2** 40µg/m^3 annual mean 200µg/m^3 1-hour mean	Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2 at concentrations
Sulphur dioxide (SO_2)	**SO_2** 20µg/m^3 24-hour mean 500µg/m^3 10-minute mean	Reduction in hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels. Reduction in the formation of sulphuric acid which is the main component of acid rain which is a cause of deforestation and material deterioration.
Carbon monoxide (CO)	15 minutes – 100 mg/m3 1 hour – 35 mg/ m3 8 hours – 10mg/ m3 24 hours – 7mg/m3	Common symptoms include a headache, lethargy/fatigue, nausea, dizziness, and confusion. A victim may also suffer from shortness of breath, cardiac palpitations, convulsion, paralysis, loss of consciousness, coma and eventual death
Benzene	No safe level of exposure can be recommended. – The unit risk of leukaemia per 1µg/m3 air concentration is 6 × 10–6. – The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1000 000 are 17, 1.7 and 0.17µg/m3 respectively.	Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and a plastic anaemia. Acute exposure to benzene may cause narcosis: a headache, dizziness, drowsiness, confusion, tremors and loss of consciousness, moderate eye irritant and a skin irritant

Polycyclic Aromatic Hydrocarbons	1ng/m^3 (one Nano gram per millilitre)	Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers

Source: WHO, (2014)

The calculation of a given limit for any chemical substance that is emitted is based on different gradients as denoted in Table 2.6 causing no health implication. For instance, concentrations of pollutant gases in the atmosphere are usually measured in parts per million (ppm), parts per billion (ppb) or parts per trillion (ppt). An addition of volume to measurement changes the scale of measurement to ppmv or ppbv or pptv. Pollutant concentrations are also measured by the weight of pollutant within a standard volume of air, for example, micrograms per cubic meter (µgm-3) or milligrams per cubic meter (mgm-3). These pollutants and expected standard in the guidelines shows both unfavourable effect and target deliverables if the reduction in ambient pollutants is achieved (World Bank Report 2011) . Although standards and guidelines are frequently reviewed by developed nations and organisations such as Defra, (2013); EPA, (2013); WHO, (2014), they have noted that African regions do not yet have the capacity to enforce these guidelines, and still suffer from poor air quality standards. For example, the Nigerian guideline on ambient air limits is higher than WHO guidelines in some pollutants like PM and less comprehensive even though the country suffers from air pollution due its petroleum activities as shown in table 2.7;

Table 2:7 Nigerian Ambient Air Quality Standard

POLLUTANTS	TIME OF AVERAGE	LIMIT
Particulates	Daily average of daily values 1 hour	250ug/m^3 *600ug/m^3
Sulphur oxides (sulphur dioxide)	Daily average of hourly values 1 hour	ppm (26ug/m^3) 0.1 ppm (26ug/m^3)
Non-methane Hydrocarbon	Daily average of 3-hourly values	160ug/m^3
Carbon monoxide	Daily average of hourly values 8-hourly average	10 ppm (11.4ug/m^3) 20 ppm (22.8ug/m^3)
Nitrogen oxides (Nitrogen dioxide)	Daily average of hourly value (range)	0.04 ppm-0.06 ppm (75.0ug/m^3-113ug/m^3)
Photochemical oxidant	Hourly values	0.06 ppm

Source: FEPA (1999)

With reference to table 2.7, Nigerian professionals that deal with the design, selection of building materials and construction rely on the provision made in the Federal Environmental protection Agency (FEPA) Nigeria. Despite that, the above ambient standards are based on World Health Organisation (WHO) guidelines of 1983 (WHO as cited in FEPA, 1991, p. 73). This clearly indicates its level of insufficient information and the incomprehensive nature. Researchers like Ana, (2011); Tawari and Abowei, (2012) have claimed that most air quality analysis in Nigeria is done by private individuals adopting WHO, USEPA and UK guidelines as bases for analysis due to the absence of air quality data in Nigeria. These claims are clearly indicated by the absence of standard for CO/NOx (ppm) and the year in which standards from FEPA was released in Nigeria even though limits to pollutants have constantly evolved due to the world concern as shown in FEPA standards of 1999 in table 2.8;

Table 2:8 Pollution Emission and FEPA Standards

POLLUTANT	SIZE OF EMISSION (NIGER DELTA)	FEPA STANDARDS
TSP μ/m^3	92.2 – 583.3	250
NOX (ppm)	22.0 – 295.0	40 – 60
SO_2 (ppm)	7.0 – 97.0	100
CO (ppm)	5.0 – 61.0	10
CO/NO_x (ppm)	*20*	-

Source: Ana (2011), Tawari and Abowei (2012)

Furthermore, on the insufficiency of information on air quality, researchers follow WHO, USEPA and UK process as these have been able to provide more recent air emission data as compared to that provided by FEPA which is supposedly a standard adaptable for construction and other purposes.

2.8 Indoor Air Quality (IAQ)

The internal part of a building seen as a protector of humans from weather and climatic conditions may be more polluted than surrounding outdoor environment (Bruce, et al. 2014) . According to Volland (2014), humans spend almost all their life time in enclosed spaces both residential and non-residential making it a potential threat to health risk. In addition, (WHO, 2002) , affirmed 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 Chen (2000). Yet countries like Nigeria continually carry out activity that increases health risk of its populace. Even though constant awareness and research have proven that the most affected by the inhalation of poor air are children (Clements-Croome, et al. 2008, Madureira, et al. 2015). This has resulted in developed and some developing countries in providing air quality guideline for schools and monitoring systems, even with seasonal and yearly examination of such quality of air (Godoi, et al. 2009, Mumovic, et al. 2009, Pegas, et al. 2010). Yet this is a mirage in a country with its major economic manpower relies on oil.

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 IAQ 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); Kheirandish-Gozal, et al. 2014) . This shows that if there is clean indoor air then students and staffs can work well. Therefore, the possibility of achieving clean indoor in the vicinity of GF depends on the construction, air tightness, thermal performance, ventilation system used during design and construction of schools.

2.9 Indoor Air Quality (IAQ) and Health Effect

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 PSBs. 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).

In many regions like the ND area of Nigeria, the source poor IAQ is due to infiltration of outdoor air (Santamouris and Wouters, 2006). This will in no doubt create and raise some form of health issues which magnitude could lead to death. According to (Madureira, et al. 2015; and Neidell, (2004), respiratory and asthma diseases are the major causes of days lost from school and their socioeconomic costs cannot be exaggerated. The awareness that IAQ needs to be achieved for the comfort and well-being of users of PSBs is a process that shows an adjustment and readiness of stakeholders in providing clean air space for both present and future generations. Thus is it crucial at this point to describe different pollutants associated with GF as shown Table 2.9 highlighting descriptions and adverse health effect.

Table 2.9 Gas Flare Pollutants and Their Adverse Effects

Pollutant	Description	Adverse Effect
Particulate Matter ($PM_{2.5}$ & PM_{10}):	PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air.	The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.
Carbon monoxide (CO)	A colourless, odourless gas that interferes with the delivery of oxygen throughout the body.	Carbon monoxide causes headaches, dizziness, weakness, nausea, and even death
Nitrogen dioxide (NO_X)	Colourless, odourless gas	Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NOx. Reduced lung function growth is also linked to NOx and causes eye, nose and throat irritation, shortness of breath, and an increased risk of respiratory infection
Volatile organic compounds (VOCs)	VOCs evaporate into the air when these products are used or sometimes even when they are stored	Volatile organic compounds irritate the eyes, nose, and throat, and cause headaches, nausea, and damage to the liver, kidneys, and central nervous system. Some of them can cause cancer
Ozone (O_3)	Excessive ozone in the air can have a marked effect on human health.	It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases
Benzene	Benzene in indoor air can originate from outdoor air. Indoor concentrations are also affected by climatic conditions and the air exchange rate due to forced or natural ventilation	Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and a plastic anaemia. Acute exposure to benzene may cause narcosis: a headache, dizziness, drowsiness, confusion, tremors and loss of

		consciousness, moderate eye irritant and a skin irritant
Sulphur Dioxide (SO_2)	Gases formed by incomplete combustion of all carbon fuels.	SO_2 can affect the respiratory system and the functions of the lungs and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract.
Polycyclic Aromatic Hydrocarbons	PAHs are a class of organic compounds produced by incomplete combustion or high-pressure processes. PAHs form when complex organic substances are exposed to high temperatures or pressures.	Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers
1,3-butadiene	A product of incomplete combustion resulting from natural processes and human activity1, 3-butadiene is also a recognised genotoxic human carcinogen, as such, no absolutely safe level can be specified.	The health effect of most concern is the induction of cancer of the lymphoid system and blood–forming tissues, lymphoma, and leukaemia

Source: Alder (2000), EPA (2008)

Table 2.9 above clearly states GF substances emitted into the environment, their definition/description and health implications with the high risk of death where adequate care is not taken.

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 other staffs (Daisey et.al., 2003; LSX, 2013; Mustapha et.al., 2011). Although, Daiseyet.al. (2003) noted that there are no consistencies in the measurement of IAQ in schools as most researches lack quantitative and qualitative rigours. Nevertheless, a summary as tabulated in 2.9 above shows GF pollutants and their health effects, which could to lead potential loss of life. Therefore, if these adverse health effects are associated with GF then the use of open ventilation system as shown in figure 2.14 of a typical school constructed in the NDA will permit the infiltration of outdoor air inside of the classrooms. Thus providing clean indoor air in the vicinity of GF requires the provision or installation of a system (natural or mechanical) that will provide indoor air as compared to the simple ventilation system which entails the use of open windows and doors.

Figure 2.14 Open windows and Door as Ventilation System used in Public Schools
Source: Field Work (2015)

The figure 2.14 shows a typical school in the NDA of Nigeria with open windows and doors as ventilation system allowing the filtration of poor air from GF activities into the building where young children are acquiring education. Although, natural ventilation system provides comfort, improve IAQ and reduce building energy consumption (Busch, 1992; Zhao and Xia, 1998) (Busch 1992). However, a study by (Shi, et al. 2008) showed that natural ventilation affected both IAQ and room thermal conditions. This shows that a more appropriate method to provide clean air as already reviewed is required.

2. 10 Summary

This first review chapter examined oil exploration activities and its relationship to GF activities in and around the world with narrowed concentration to the world's twenty most flaring nations, how they have been able to reduce flaring activities. A more detailed discussion of oil exploration activities was reviewed for Nigeria as the second highest flaring country with more specific review narrowed to the ND area where all onshore flaring activities are carried out giving a breakdown of the total amount of anthropogenic gases flared based on flared amount published.

The effect of these flared gases on the BE and in particular reference its effect on building materials such as corrosion, blackening, discolouration of roofing materials, deterioration of mortar, paint and building façade of PSBs.

Descriptions of different GF pollutants were tabulated with its adverse effect on different parts of the BE. The health implications of GF were discussed in this section. This section clearly puts the needs to protect schools with young schoolchildren as the main concern. However, the above discussions will not be meaningful if there is no attempt to provide a solution to the problem already reviewed. It is the aim of this research to design a PS to be used while designing and constructing schools in such vicinity. Therefore the need to review PS in view of its dominance as a source that is used to achieve the aim of this research proposed solution base is discussed in the next chapter of the research.

CHAPTER 3. THE CONCEPT OF PERFORMANCE SPECIFICATION

3.1 Introduction

The literature review in the previous chapter pointed out and discussed GF effect both in the physical, social, economic and environment with particular reference to PSBs and schoolchildren. The drawbacks associated with the constant inhalation of ambient air filled with anthropogenic substances. The health of the children, their academic performance, and aesthetics of PSBs has remained a central topic in developed and developing nations. Many initiatives including guidelines require environment specific criteria that will help in designing, material selection, construction type and ventilation system for schools. However, the problems that exist in the various environment creates obstacles that hinder the suitability of anyone guideline, code, regulation because it is not a one size fit all.

New requirements and performance are required that may present appropriate enactment that will support and help BE professionals (BEP) including policy makers during design, selection, and construction in an air polluted environment. Immediate environment specific requirement and performance criteria, as well as the adaptability of newer environmentally friendly materials all, add up the possible improvement on PSBs. The design and construction of PSBs with the use of PS rather than relying on building codes regularly not updated allow professionals use tested innovative materials that can satisfy environmental conditions such that of the ND.

Most buildings rely on building codes as prescribed by their country codes and building regulations as bases for design and construction. While others depend either on international building codes from their colonial association or codes based on manufacturers manuals. This generic requirement may fail to address geographic specific needs. This, therefore, buttresses the need for a performance specific requirement that will allow the use of materials and construction types that will meet immediate environmental conditions rather than rely on standards and codes referred to as an obstacle to innovation (Foliente, 2000).

3.2 The Need for Specification

According to Mehta and Burrows (2001), the 21st century has inherited an environment that is prone to deterioration due to its acts over the years therefore, there is the need for a paradigm shift to help provide the solution. The heart of every building designed lies on the effectiveness of the materials used during construction. Materials used adds to the aesthetics, health of the users and durability of the completed building (Emmitt, 2001). Although most codes and standards try to meet sustainable principles however the downside of these codes and standards is that they are general in context with no geographic boundary or construction specifics. For instance, the American Standards is said to be unreasonable, narrowly defined and overly prescriptive (May, 2003). While the UK building regulations and codes are based on 'deemed to fit' bases because they are seen as traditional building codes which centre on technicalities which might fail to provide value for money or fit for purpose (Prior and Szigeti, 2003).

In addition, the difficulties in the harmonisation of building codes for Eurocode makes it an unease ground for a choice of code or standard against the other (Visscher and Meijer, 2006) . The rigidity of this codes and regulations makes it almost impossible for developers to use newer products, which therefore led to the need for specification, which provides both a product and the process. Again most fit for a developing nation like Nigeria a colony of Britain whom building codes and standards are prototypes of the British standards. The selection materials usually are reduced to selection reliant on tradition wherefore materials are selected based on familiarity (Emmitt, 2001). The reliability of any specification given depends on the observed durability of such material which means that every material specified meets their required performance (Murthy, et al. 2008). Therefore, where codes and regulations are out of date, certain materials manufactured under such codes might fall to meet performance criteria on current environmental conditions. Consequently, (Emmitt, Yeomans et al., 2008), affirmed the need for construction professionals to stay up to date with current building codes, regulations, and trending materials. The need to design and construct buildings that will stand the test of time and fit the environment in which it is designed for pushes further the need for the non-traditional or prescriptive method provided in a countries code. More so, rather than blame failure, deterioration and poor IAQ on the rigidity of a building code, specification document puts the developer and the manufacturer a duty to provide required criteria meeting specific environment as obtained in the specification document.

National Building Specification (NBS, 2008) defined specification as both a product and a process. The process is the total documentation detailed inside the contract and design document while the product is a written description of the quality of the built product and its component products. Furthermore, Emmitt and Yeomans, (2008); Meier and Wyatt, (2008) described specification as a performance or result based system and a design or function based system., that satisfies planning legislation, building codes, environmental constraints regardless of type, purpose or complexity of the building. Therefore every building should satisfy laws promulgated or enacted by the governing body (entity) of such environment while meeting function and requirements as illustrated in figure 3.1.

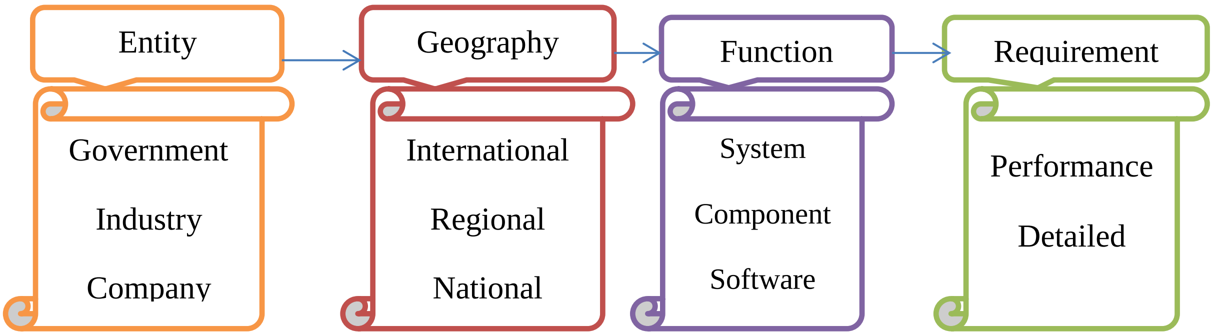


Figure 3.1 Different Categories of Specification
Source: Adapted from DoD (2009)

As shown in figure 3.1, the four different categorises of specification as adapted from (DoD, 2009). They noted in their report noted that categorisation of specification provides the needed criteria for verifying requirement. However, it is all a matter of terminology as there are basically two types of specification: performance-based (open), or prescriptive (closed) (NBS, 2008), although, they both have their benefits and drawbacks as illustrated in table 3.1.

Table 3.1 Benefits and Drawbacks of the 2 Types of Building Specification

Specification Type	Benefits	Drawbacks
Prescriptive	Provide detailed instructions. Require less engineering capacity	Limit design possibilities (restricted building materials and practices
Performance	Allows for innovative design (materials, technologies and methods approved by structural engineer) Commonly accompanied by more prescriptive compliance documents, suggesting appropriate methods and materials	Requires greater engineering capacity for design approval and quality assurance

Source: NBS (2008)

The table above shows the benefits and draw backs of the both main specification types, it is clear that the advantages of the performance based specification overweighs that of the prescriptive based specification due to the acceptance of innovations that meets performance requirement . More so, (Lee and Barrett, 2003), in the International Council for Research and Innovation in Building and Construction (CIB) First International State-of-the-Art report on Performance Based Building, affirmed that building requirements should be in terms of performance specifications, Similar to how computers are purchased (or cars, stereos or holidays). Noting that, there should be the possibility to stipulate memory, the size of the hard drive, the screen size and definition. Although they explained that consumers may not know the exact meaning of the ratings, but are aware of their relative performance, hence buildings design and construction should rely on performance. This they affirmed should be by changing the focus from the input materials specifications (traditional/ prescriptive approach) to the output user requirements (performance-based building) increasing both the quality and the long-term value for money of buildings. It is therefore necessary to discus in brief the two types of specifications.

3.3 Prescriptive Specification

The prescriptive approach of specifying enables users of the document to stipulate materials and workmanship in accordance with environmentally friendly practice (Lam, 2010). It is used to convey directions on the prescribed material and workmanship essential to achieve the design with the responsibility of achieving this by the design team. Yet users of specification documents have found it disrupting and cumbersome to digest since different classes of specifications are added to a single document making it bulky and difficult (Hasabnis, et al. 2015). This difficulty faced by users of specification document lead to the growing trend of PS, which provides opportunities for professionals in the BE on research for innovation meeting sustainable factors and the use of such new products (Lam et al., 2007; NBS 2013). Because buildings are composite in nature due to the integration of separate parts collected in various assemblages, the innovative system including modelling before construction to provide a prototype the finished has constantly evolved. The difficulties in provide maximum satisfaction to stakeholders due to the rigidity in code provisions further stimulated the need for corrective measures that can help the building industry.

The Prescriptive system of specification uses codes and hampers the use of newer and safer materials and provides regulators with an easy way to inspections (Foliente, 2000). The codes used which are mostly mirrored from the British standards or early 60s' and 70's do not reflect local conditions. This is buttressed more by Daoud (1997) who observed that impact of the quality of a finished building is based on the uniqueness of local weather and conditions. Furthermore, there is the difficulty in cost-optimisation with the prescriptive specification which in most cases increases the cost of construction due to over specification of materials. The unclear nature and ambiguity of words make delineation of task difficult (Lam et al., 2008). It reduces both international trade and the possibility of using locally manufactured materials as most of such materials have not been tested, codified or calibrated to meet international standards. Re-examining codes used, rather than the performance achieved, is a major derailing factor that holds back construction which requires modification of codes and regulations because clients and designers have continued to pay a heavy price due to the rigidity of prescriptive specification (O'Connor, et al. 1991). This is because most specification defaults are labelled on designers and suppliers of materials who do not always care to understand what might arise due to use, misuse and non-use material and code (Lam, et al. 2007). Although, faults due to specification has over the years lead to payment of monetary fines and corrective measures through heavy litigations in the developed world (Giunta and Ramirez 1991). The ineffectiveness of prescriptive method of the specification has led most construction and material manufacturing industries to rely on PS to design, select materials and construct a building to meet today's and growing needs (Gruner and Homburg, 2000; Lobo, et al., 2006). However, as Gross (1996) can attest, to implement the performance concept, prescriptive codes, regulation and procurement are needed. Due to its advantages, PS has been made compulsory since 2000 due to its advantages by the Federal Acquisition regulations as well as in Europe, both at the national and at the Union level to encourage the same end (Glaser and Tolman, 2008). Yet, developing nations like Nigeria has yet to tap into this growing importance of specification.

The reliance of manufacturing using prescriptive prescription as meeting criteria in countries with outdated codes and regulations relief them of any misgivings. For instance, with prescriptive specification, the clause *"at the discretion of the engineer"* is ambiguous and gives room for misjudgement and different interpretations. As admitted by (Sims and Broughton, 2009), the prescriptive method of specification prevents the use of newer and innovative materials and obstruct design freedom. As with other African countries such as Kenya and Ethiopia, the recommended specification process is the prescriptive method (Lam, et al. 2007). But if the purpose of building codes is to convey information translating to a physical property fulfilling its functional purpose then it should be explicitly stated rather than being left to implicit judgment. Thus both technical and Structural measures which includes the effective application of science and engineering principles for the development of the BE is necessary (Pathirage, et al. 2012). Therefore, PS allows innovation of measures that will produce an environment based specification for construction for public schools in the Vicinity of Gas Flaring (VGF).

3.4 Performance Specification (PS)

Describing PS for the purposes of this research is most suitable with the following quotes; *"The practice of thinking and working in terms of ends rather than means; It is concerned with what a building or building product is required to do, and not with prescribing how it is to be constructed"* (Foliente, et al. 1998). Thus PS is concerned with buildings meeting all requirements and criteria including immediate environmental specific conditions domiciled within a specific location.

The practice of PS has been carried out centuries before now and is clearly noted by King Hammurabi of Babylon who reigned from BC1955 to 1913 who is credited with the first recorded building regulation. It can still be viewed today inscribed on a monument housed in the Louvre museum, Paris. King Hammurabi is accredited with the statement:

"The builder has built a house for a man and his work is not strong and if the house he has built falls in and kills a householder, that builder shall be slain" (Prior and Szigeti, 2003).
It is a statement of required result that focuses on the desired quality or performance of the finished work. PS added to the design document provides means to motivate and allow the design team to find the inventive solution to save time, minimise disruption and enhance safety and quality (Scott III, 2014). Furthermore, he noted that PS focuses on outcomes and results rather than process, the required goods, and services rather than how the goods and services are produced (Scott III, 2014). In other words, PS is fashioned so that respondents are allowed maximum flexibility when satisfying building requirements as in the case of public schools in the vicinity of the GF. This is because PS is driven by user requirement, in other words, a shift of paradigm from building parts to user needs, and expectation and post occupancy evaluation (Foliente, et al. 1998). The users of the designed and constructed building needs and satisfied in terms of quality, habitability, and sustainability which also include the client as in the case public buildings.

Therefore, based on the criteria for performance and satisfaction it is clear that one professional might not be able to provide required services. Depending on the type of structure and the service environment, more than one criterion may need to be specified. It is the duty and responsibility of design team to specify appropriate materials for construction in terms of characteristic, behaviour and compliance with the immediate environment (Folorunso and Ahmad, 2013). This confirms with the assertion made by the American Society of quality control as cited in (Murthy, et al. 2008) that in the specification, performance as an attribute has the highest score of 9.5% from an overall score of 10% compared to other attributes of any product. Furthermore, PS initiators claim that the inspiration behind its drive is to overcome the integral barricades faced with prescriptive codes and standards, which does not take into consideration the willingness, scale and scope to create an adventure into technological and organisational innovation (Gross 1996, Sexton, et al. 2005). Therefore, it is important that materials used around GF vicinity should be designed as a defence line against climate specific conditions for durability and clean IAQ purposes. In addition, Dublin-Green, 2006 depicted that specifying materials without proper consideration of climatic factors remains an irreconcilable issue because climatic factors are major determinants of the performance. Similarly, Hyde (2013) advanced that matching building forms, materials and selection criteria during design and construction should carry out without a loss to performance. Thus the design team selects the materials and systems with the appropriate performance characteristics and anticipated life before construction.

The performance of the BE is important not only for its users and owners but also for the whole society because during its operation defects due to adaptability meeting environmental pressure leads to dissatisfaction reducing the quality of life and gives bad reputation (Huovila and Leinonen 2001). Consequently, information relating to climatic factor is a major determinant of the effective functionality, durability and longevity of buildings such as public schools. Special consideration has to be given to environment like the NDAN where the quest for oil exploration had led to constant emitting of anthropogenic substance that deteriorates buildings and affects the IAQ. As a result of these hazards released into the atmosphere, the provision of the comfortable learning environment as part of the responsibility of the Nigerian Government as stated in the Constitution (FGN, 1999) is needed. PS is a way of improving deficiencies caused by the method used in harnessing oil in the region of ND. This is because PS is classified in terms of the physical entities as well as the attributes of the BE and helps to solve human problems that cannot be resolved using codes and regulations considering that Standards and codes are bonds that bind the designer and client together (Sharif, 1983). Standards and code do not meet the pace at which innovations and research are continually evolving to more sustainable system with improved materials developed to cope with environmental challenges. The development of materials in the construction industry is evolving, and so environment specific conditions have to be considered during design, selection of materials and constructions (Lam, et al. 2010). In order to inspire innovations in the construction industry, many countries, in the developed world, have been adjusting their prescriptive building codes into performance base system (Hattis, 1999). Subsequently, advanced and used in different public construction projects such as schools illustrating the implication of using performance of materials rather than codified processes that are implicit in its nature.

3.5 Specification for Schools Building

In order to improve on PSBs to meet evolving needs and requirement for materials and environment to meet the fit-for purpose, criteria requiring the use of methods more than just codes and regulations remains an imperative (Dai Guoying, 2004) . The significance of criteria including user satisfaction is crucial and so, adherence to the quality of the building will provide satisfaction to all (Anosike, 2011; Taylor, 2002). Thus, building type, design and material is fundamental to meeting criteria and requirement. For instance, PSBs are open to tenders, meeting essential criteria requires the use of PS which provides a check on the material quality and not necessarily relying on the name/brand of the manufacturer (Meier & Wyatt, 2008). However, the use of the prescriptive method of the specification as provided by building codes are constantly been used and are deterring factor to the quality of buildings produced (Emmitt, 2001) . Accordingly, Branham, (2004); Durán-Narucki, (2008) affirmed that the quality of the school has been proven to affect the performance of schoolchildren. This could be linked to the use of the prescriptive form of specification.

Many factors have been linked to poor quality of PSBs which include, the way it is designed and constructed, as opined by Uline and Tschannen-Moran, 2008. Furthermore, defects, such as discolouration, blackening corrosion have been linked to gas exploration and exploitation (Odu, 1994; Ojeh, 2012; Ifeanyi and Nduka, 2013). The rapid acceleration of the defects has also been linked to other factors such as material quality, poor workmanship, material type, the lack of integration of all built environment professionals, and more so, the ineffectiveness of the Nigerian building code are some of the factors that lead to structural decay and defects of PSB in Nigeria. However, most emphases are laid on the effectiveness of the NBC, as opined by Ibem and Aduwo, 2013. A building code has been defined as a collection of legal requirements, whose purpose is to protect the safety, health, morals and general welfare of those in and about buildings. Thus, if this is the case, then what is the justification for adopting codes whose standards are set to meet the requirements of societies with different environmental factors and advanced management and information? (Omuta, 1986). Nigerian and the ND have a unique environment characterised by their method of oil exploration hence, the need to provide immediate performance requirements for school buildings. The design and construction reflect on the aesthetics and the receptiveness of students on their first day in school. Therefore, the environment with more specific reference to the location of the school and the structure is crucial and influences students behaviour because beyond homes children are influenced by the environment in which they have a long memory (Manzo, 2003). Thus, where quality is required, adequate measures should be taken to replicate buildings in terms of design and selection of materials and construction. Nevertheless even among builders due to lack of knowledge of the changing and modified Building Codes impedes the possibility of improving the quality of building (Baiche, et al. 2006; Loesch and Hammerman, 2013). While most building organisations have newsletters and updates on new issues majority of builders are not members of such organisations and therefore do not access specification information (JSCQB, 2002). More so, the guidance set out in "Building Control Performance Standards", noted that, in order to be effective, the building control process requires an inspection regime of appropriate intensity and frequency (DfCLG, 2014). This will thus provide an effective implementation of PS for the provider.

Building construction has gained recognitions due to the concerns of reducing pollutants and waste. Similarly, buildings for educational purposes have recently become a major concern in all parts of the world in meeting United Nations second Millennium goal (MDGs, 2000) which was further amended in the 2015 MDGs (UN, 2015). Their importance with regards to functionalities and impact proved the need to construct for sustainability purposes as noted in the House of Commons paper 'Sustainable Schools: Are we building schools for the future?'(Committee 2007). This was due to concerns following environment specific condition that has resulted in schoolchildren and staffs having complained over the functionalities of school facilities and the observed health impact (Haverinen, et al., 1999; Fukuchi and Ueno, 2004; Baker and Bernstein, 2012). The need for quality PSBs resulted in the developed world providing a guideline for school construction (EFA, 2001; DfES, 2006) . For instance, table 3.2 provides recommended construction materials for PSBs in the UK.

Table 3.2 Recommended Construction/Material Types for School Buildings in the UK

Building parts	Description	Material type	Lifespan
Floors	A continuous, supporting surface extending horizontally throughout a building, having a number of rooms, apartments, or the like, and constituting one level or stage in the structure	Ground bearing concrete floor slab • Suspended concrete floor slab • Pre-stressed concrete floor slab • Block and plank with screed • Cast in-situ concrete floor slab	Same as that of the lifespan of the building of sixty years
Walls	Various permanent upright constructions having a length much greater than the thickness and presenting a continuous surface except where pierced by doors, windows, etc.: used for shelter, protection, or privacy, or to subdivide interior space, to support floors, roofs, or the like, to retain earth, to fence in an area.	**External leaf** • Concrete block (plastered, dashed wet or dry) • Brick (clay or concrete) • Self-finish blocks • Timber cladding (Teak or Cedar only - 15% overall wall area max.) • Fiber cement sheeting • Concrete paneling **Internal Leaf** • Concrete block (plastered sand and cement – no hard wall) • Fair faced concrete block • Fair faced concrete • Timber Stud (with appropriate impact resistant plasterboard lining) • Steel Stud (with appropriate impact resistant plasterboard lining) • Concrete paneling	Same as above
Roofs	**Pitched Roofs** The roof covering should have a minimum design life span of 40 years. Safe access to the roof for repairs and maintenance should be provided **Flat Roofs** The area of the flat roof shall not exceed 10% of the overall roof area of the entire development when measured on the plan.	Slates, Tiles (concrete, clay) Metal profile sheeting • Composite roofing system • Build-up roofing system • Other approved roofing system equal to above • Asphalt • PVC • Modified Bitumen Membranes • EPDM • Rubber •Poly-isobutylene membrane	Minimum of 40 years Minimum of 15 years

Source: DfES, (2006)

The example is shown in the table 3.1 show recommendations for preferable material types, and description, building parts and expected the lifespan of schools constructed in the UK. Following specification provided, any material used should meet shelve life as specified which means the design team and material suppliers are held on legal content to provide required satisfaction even after construction has been commissioned and in use.

Furthermore in Ireland, though specification for PSB is provided in the country, professionals are required to adopt EU regulations if there are newer codes. This is made clear in the Dublin Technical Report on construction standards 2008 in page 7 of the Department of the Environment (DoE, H. a. L. G. 2008). This is to avoid the delays and choice of poor quality materials on the account of the less evolving nature of codes and regulation and as a form of statutory obligation where there is no legal backing, designers and contractors of public schools are held responsible for any default arising for poor specification. Therefore, it is important that every part of the building is given equal attention to details as any default or any part might be challenged. For instance, the importance of roof being the external covering that shelters all other parts of the building including external walls and cladding was provided with the explicit specification in the UK for the construction of PSBs. Its quality for schools informed the documentation of roof specification as shown in the table 3.3. Yet PSBs in developing countries like Nigeria and the Deltas with an environmental condition caused by crude oil exploration and exploitation which is the economic manpower of the nation do not pay attention to educational facilities in such environment.

Table 3.3 Roof Specification factors for School Buildings

Types of Roofs Coverings	
Continuously supported roof coverings	**Discontinuously supported roof coverings**
Types of Material	
Concrete, profiled metal (steel or aluminium) or timber sheeting	Timber trusses, battens or timber sheeting for slates/tiles, and metal purlins for metal clad roof systems
Description	
Roof coverings with no structural properties fully supported on a roof deck Roof decks	Roof coverings with structural properties supported on rafters or purlins
Roofing Types	
Reinforced bitumen membranes. Polymeric single ply membranes. Mastic asphalt. Liquid waterproofing systems. Malleable sheet metal roofing	Slating/tiling. Profiled sheeting. Insulated panels
Specification criteria	

The deck must have a minimum of 60years' life. The roof covering manufacturers' recommendations for the roof deck must be followed, including but not limited to: profiled metal deck suitable for applied load and any requirements for timber sheathing, surface finish, minimum timber sheet thickness and grade, fixing locations, requirements for isolation layers and vapour control layers. **Fasteners must be corrosion resistant and designed to withstand site wind loads to BS 399-2 and be to manufacturers' recommendations.** **Expansion requirements must be obtained from the roof deck manufacturer.** **The construction of the roof deck must be considered with regard to safety in construction.** **The roof deck must resist dead, live and wind loads.** **Metal decks must comply with BS 5950-6, BS EN 10147 (galvanised steel) and BS EN 485-2 (aluminium).**	The deck must have a minimum of 60 years' life. Expansion requirements must be obtained from the roof deck manufacturer. **Additional for slates and tiles**: Timber sarking may be required above timber roof trusses if the school is located in areas of severe wind or rain. Roof covering manufacturers' recommendations should be sought. Timber battens on tiled or slate roofs must not be less than those stated in BS 5534. Counter battens on tiled or slate roofs should be sufficient to provide a ventilation gap as recommended in BS 5250 and/or to provide drainage path beneath the battens. The roof covering manufacturer's recommendations for the roof deck must be followed, including but not limited to rafter/battens or purlin sizes and any requirements for timber sheathing, minimum timber sheet depths and grade, fixing locations, requirements for isolation layers and vapour control layers. Gable details must be developed in conjunction with requirements for external wall structural support and cladding requirements. Fasteners must be corrosion resistant and designed to withstand site wind loads. The construction of the roof deck must be considered with regard to safety in construction. Wood-based panels used as roof decking must as a minimum be either OSB/3 to BS EN300, type P5 particle board to BS EN 312, or plywood (Technical Class Humid) to BS EN636. All wood-based panels used as decking must comply with the performance characteristics and mark requirements for wood-based panels used as structural roof decking as specified in BS EN 13986. Timber and timber products for structural use must comply with BS 5268-2

Source: Parker (2008)

From table 3.2, the explicit detailing of the requirement that should be met in addition to the implicit specification pushes further the desired and required performance of the roof. Notice that different roof types, as well as material types, requires different performance requirement. Furthermore, to design for environment specific purpose countries like Iraq use design quality indicator (DQI) toolkit to check the functionality, building quality and environmental impact of school construction (Wadhah, 2012). Although PSB construction is usually open for tenders by all qualified contractors (Meier and Wyatt, 2008) . PS provides an added advantage for selection and award of the construction contract to tenderers.

The use of specification methods for PSBs has been documented since the early 60's as being used in California, USA as affirmed by (Cox, 1994 as cited in Meier and Wyatt 2008). The lack of specification factors for PSB construction might result in the failure of material due to environment specific requirements. Therefore, defining the standards and minimum performance requirement will enhance PSB construction (Robinson and Scott, 2009), thus, enhancing learnability and readiness for academic rigours.

Thus, the need for PS when constructing schools in the vicinity of GF to meet environment specific criteria which include the air quality as inhaled air affects the health and performance of both staffs and children with greater impact on schoolchildren are discussed in the session below.

3.6 Air Quality Specification for Schools

Aside from the quality of school with reference to its structure and materials used, the quality of air inhaled inside school indoor is vital. Many types of research in the recent years have considerable confirmation and affirmation on the impact of poor air on the performance and health of schoolchildren. This has led to most developed countries having regulations and guidelines for schools to follow in achieving clean air quality. For instance, in Europe, the EPA, (2013) indoor air for schools have management framework that helps schools achieve good IAQ 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 region of the United Kingdom (UK) being the most populated with traffic pollution through the London Sustainable Exchange (LSX, 2013) made specific provisions on the traffic time to reduce pollution emitted from cars into schools with distance allowable from schools to roads specified. Furthermore, added to the school curriculum is citizen science taught in schools classrooms and out of school lessons are held in other to educate students on the need for a clean environment. The integration of IAQ into school curriculum provides first-hand knowledge to the pupil. In some cases recommended 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 stated (Clements-Croome et.al., 2008; Gao et.al., 2014). In an environment where open ventilation system is enough to provide adequate clean indoor air mechanical system such air purifiers/humidifiers are recommended and used. Although, natural ventilation as a passive system has been widely researched, recommended and used as a means to ensure sustainable development since energy efficiency can be derived from it (Mavrogianni and Mumovic, 2010; Olufowobi and Adenuga, 2012; ASHRAE 2016). However, natural ventilation created by the 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.

Ventilation systems is a major criterion and have a significant influence on IAQ because it delivers fresh air into a conditioned indoor space and due to its significance, it is a major scoring point in leadership in energy and environmental design (LEED) (Srebric, 2011). The American Society of Heating, Refrigerating and Air-Conditioning Engineers ASHRAE (2016) recommended an acceptable ventilation rate of 6.7 to 7.4 l/s/p – person. Other national guidelines specify other ventilation rates for classrooms, for example, the Portuguese Standard prescribed a rate of 8.3 l/s/p (Conceição and Lúcio, 2006). While, Kim, Elfman et al. (2005) reported that Swedish standards require 8 l/s/p. 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). These differences are as a result of climatic factors, environmental factors and even construction type and materials used providing a rationale to ventilation rate. As well as ventilation rate, the impact of pollutants from indoor and outdoor affects the quality of air as well as the ventilation rate provided. The adverse effect of pollutants on the health of vulnerable people such as schoolchildren led the provision of the guideline by WHO on pollutants that are emitted from countries and their allowable limits. These limits are such that at the recommended rate, it should have minimal effect on no serious consequences (Bruce, et al. 2014). Although due to environment specific conditions, some countries have also developed different guidelines for different air pollutants. For instance, Figure 3.2 shows guidelines allowable by WHO and some countries for Formaldehyde;

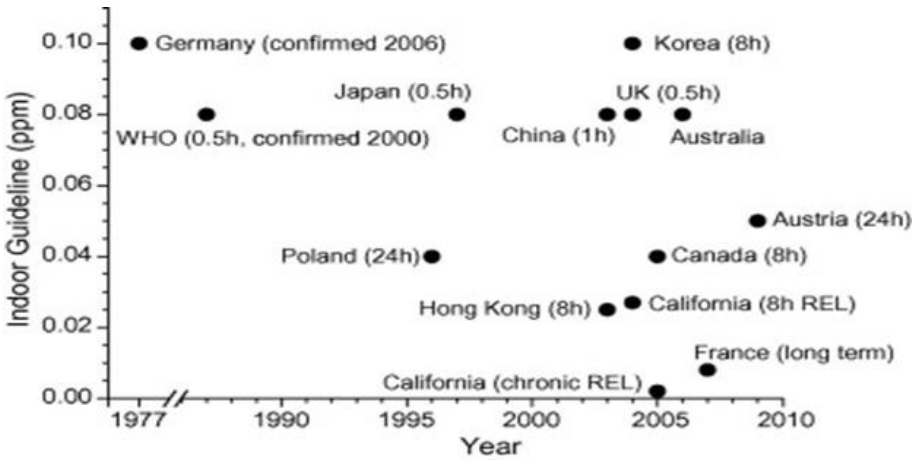


Figure 3.2 WHO Guideline for Formaldehyde and Countries Based Limits
Source: Salthammer (2011)

From figure 3.2, every country has a different guideline that references as the allowable limit which is based on when the research was carried out to prove its adverse effect on people and the environment. Therefore, if developed countries like France, Canada, UK only provided guideline from 2005, developing countries like Nigeria is far from providing a limit guideline. The Federal Environmental Protection Agency (FEPA) provides standards for air quality but due to the economic activities in the Niger Delta Area of Nigeria (NDAN), Ajao and Anurigwo, (2002); Orubu, (2002); Ana, (2011) affirmed that the quality of air in Nigeria is below FEPA standard. Therefore, the use of simple natural ventilation of open windows and doors as a means to achieving adequate IAQ will likely lead to increases in health risk and reduction in the shelve life of the building components. Emission of hazardous gases due to GF will significantly contribute to polluted air being inhaled by pupils in schools knowing that more than 20% of the world's population are children (World 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.

Despite the effort made by developed and developing nations, the Nigerian Building Codes (NBC) used for specification does not provide for any standard or guidelines on IAQ for public schools. The provision made in section 6:2:4:1 of the Code provides that a minimum open-able area shall be 4% of the floor area ventilated. This is complicated by section 6:2:5:1 which provides that it should conform to the specification as prescribed in the schedule by the manufacturers (FGN, 2006). This does not put into perspective the size, location and population of the pupil in a class. Similarly, environmental guidelines as promulgated by the Nigerian Government Departments such as Federal Ministry of

Environment, Federal Environmental Protection Agency and others did not include any IAQ standards (FEPA, 1991; NESREA, 2010). As opined by Ladan, (2013); Weli and Adekunle (2014), indoor air pollution is not yet a priority for the Nigerian Government. Furthermore, ESCAP, (2012), observed that developing nations are yet to embrace the updating of building codes as updated and integrated with criteria that meet environmental sustainability as PS details. Although, Huang et.al., (2012); Rösch et.al., (2014) all noted that 40% clean air quality is achievable through sustainable construction materials. Yet nations like Nigeria have failed to explore such sustainable materials. Therefore, if building codes are not updated using building materials that are sustainable might not be possible. The difficulties in addressing this concerns have been attributed to lack of inspection (Dahiru, et al. 2014). The lack of information on sustainable materials, uncertainty in liability of final work and maintenance concern were observed by (Akadiri, 2015). Furthermore, building code restriction, lack of comprehensive tools and data to compare material alternatives and a belief that will lead to additional cost incurred were attributes affirmed by (Worzala and Bond, 2011; Akadiri 2015).

In addition, environmental monitoring is hindered by the limited and unpredictable supply of electricity, the challenging environment of the ND with frequent political disturbances may also have contributed to a lack of both government and non-government-funded research for sustainable construction materials (Jike, 2004; Lawal and Oluwatoyin, 2011). Although, the provision made for simple natural ventilation system could be due to the inefficient electricity supply in the nation as opined by (Mustapha et al., 2011). Construction could explore ventilation systems that will provide clean indoor air while also preserving the buildings. The limitation of research due to the challenging nature of ND is far-fetched as this is not peculiar to the ND region. Most schools in Nigeria are in deplorable states not conducive for learning purposes (Barrett, 2009; UNESCO, 2007). Therefore, a functional system with the end user requirement should be introduced.

Many countries both in developed and developing nations have enacted laws to help in the mitigation of air pollution (Grimm, et al., 2008; O'Connor 2010), research showed that such mitigation effect might be observable from 2040-2050 depending on the pollutant and level of emission (Haines, et al., 2007). Measures undertaken in some countries are already been applauded, for instance, Mexico was commended by the Washington post of April 2010 (O'Connor, 2010) for the reduction of air pollution using Strategies similar to Brazil as shown in table 3.4.

Table 3.4 Mitigation Strategies Used to Combat Air Pollution in Mexico and Brazil

COUNTRIES	MITIGATING PROCESS	DESCRIPTION
Mexico	Reduce the use of private vehicles	To control the number of private cars in use at a given time, the government has implemented a one-day stop program called "HOY NO CIRCULAR" (today my car doesn't move). Stopping days are randomly distributed to encourage car owners to use public transport and/or adopt car-pooling.
	Control of vehicle conditions	As incomplete combustion in old or poorly maintained engines is a direct cause of carbon monoxide and unburned hydrocarbon emissions, the enforcement of engine maintenance standards has been another goal of ZMCM local government. The major compulsory program implemented in this direction is called the 'verification program'.
	Change of fuels	Reduction of lead and sulphur in fuels; Compulsory implementation of catalytic converters. Many reformulated fuels have already been tested in the metropolitan area but only small changes in gasoline quality have been accepted so far.
	Clean Air Mexico City Program	This will call for the purchase of 290 natural gas and hybrid engine buses and the construction of five natural gas stations. The natural gas stations will provide some hope for the future of natural gas technology in Mexico City
Brazil	The Brazilian ethanol programme	The Programme remains the largest commercial application of biomass for producing and using energy in the world. It succeeded in demonstrating the technical feasibility of large-scale ethanol production from sugarcane, and its use as a fuel for cars. The Ethanol Programme helped curb the increase of air pollution in Brazilian cities and reduce the greenhouse effect using ethanol has avoided the release of 5.86 mega tons of carbon per year between 1980 and 1990.
	The PROCEL (Electrical Energy Conservation The PROINFA: Incentives for renewable energy sources progra m)	To reduce the waste of electrical power on both the supply and the consumer side. The Brazilian Congress approved a law aiming to establish a compulsory market for renewable energy. The law also provides the necessary legal support for creating a scheme to feed power from renewable sources into the national electricity grid. It helps independent power producers using renewable sources of energy supply a higher share of electricity to the national grid.
	Stimulating large	To increase the attractiveness of, and opportunities for, private investments in hydropower generation. The new

	hydropower investments	regulations mean that hydropower projects cannot be presented to public tender until after the governmental energy planning agency grants an environmental license. The aim is to reduce environmental risks to investors and to stimulate hydropower investments.
	Brazilian Energy Initiative	Which set targets to increase renewable energy use throughout Latin America
	National Biodiesel Program	Aim to progressively increase the share of biodiesel content in diesel fuel used all over the country. The goal is to have at least three per cent of biodiesel added to fossil diesel

Sources: (Duke , Yip and Madl 2002, Lucas W. Davis 2008) Emilio Lèbre La Rovere and André Santos Pereira 14/02/07 http://www.scidev.net/

Table 3.3 provides an illustration of mitigating processes or strategies used by Brazil and Mexico because they have the same chemical composition of pollutants that cause air pollution leading to school absenteeism, health problems and potential infant mortality rate.

While the primary objective of air quality policies and other measures and strategies around the world is to protect human health (Neidell, 2004; Hoek, et al., 2008), the residual effect of hazardous gaseous substances emitted into the atmosphere will have environmental effect up to 2050 (Haines, et al., 2007; Ye and Economy, 2013). Accordingly DfE, (2016) noted that the impact of outdoor air plays a significant role in the quality of air indoor. The major source of air pollution like in the Nigerian situation is the incomplete combustion of fossil fuels (Bruce, et al., 2000). This combustion which is through open air flaring leads to economic, environment and social loss (Oni and Oyewo, 2011). Therefore, play a significant role in adverse health impact arising from their constant emission of these anthropogenic gases. The health risk associated with air pollution has led to so many innovations such as photo catalytic (TiO_{2}) construction and building materials noted to achieve both aesthetic and environmental advantages as an air pollution substance (Chen and Poon, 2009; Joseph and Tretsiakova-McNally, 2010; Santamouris, et al. 2011). Similarly, in 2011, a technology that could clean air around it was invented and used in a hospital building in Mexico as shown in figure 3.3 and has since been explored in building construction for health care facility in Mexico.

Figure 3.3 Pollution-Eating Facade used in Mexico
Source: Cartegena (2014)

Figure 3.3 shows the innovations and research constantly undertaken, materials used contained titanium dioxide, which effectively "scrubbed" the air of toxins by releasing spongy free radicals that could eliminate pollutants (Cartegena, 2014). Other strategies include green walls or cladding systems that have been studied (Imbabi and Peacock, 2003) . This is proven to be efficient in sucking up poor air like carbon dioxide and replace the environment with oxygen. Green facades also knew as ‘Living Walls' or ‘Vertical Greening Systems is a building façade but internal and external wall intentionally covered with vegetation providing aesthetic and functional purposes. It could be a modular, or a trellis-type system and can be attached to an existing building façade, or be a free standing structure as shown in figure 3.4.

Figure 3.4 Green wall on Edgware Road London
Source: Nicola Cheetham, Annabelle Woods et al. (2012)

Figure 3.4 is used in the UK in a traffic congested environment, the purpose of this wall is to allow the green vegetation suck up the air and release oxygen to the environment providing clean air. In addition, benefits of green cladding include atmospheric improvement, air purification to regulating ecosystem services as submitted by (Cheetham, et al. 2012) and illustrated in figure 3.5.

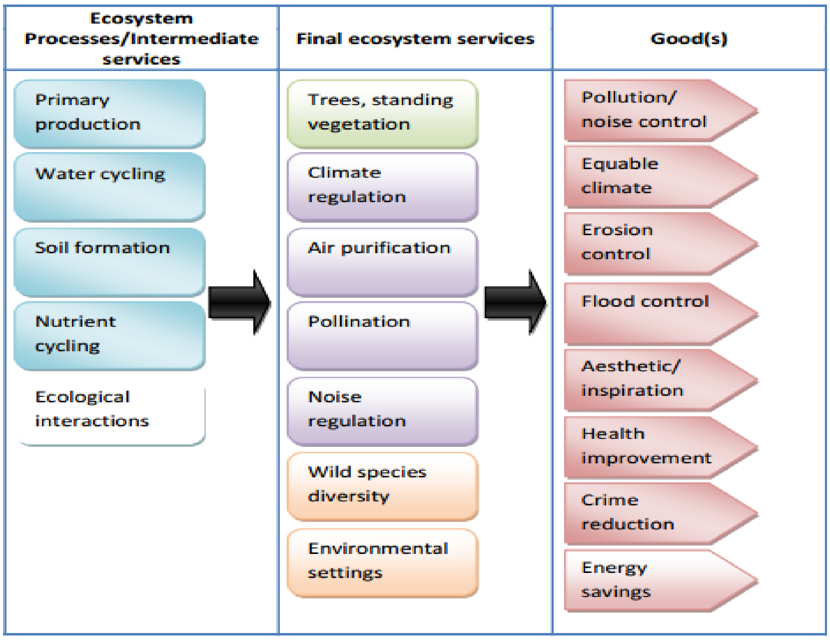


Figure 3.5 Ecosystem processes, Services and Goods Provided by Greening
Source: Cheetham, et al. (2012)

From figure 3.5, shows the gains from greening the environment ranging from pollution control to energy savings. Thus adopting this form of pollution control system in the NDAN will not only benefit sucking of air pollution but another form of advantages including, air purification, climate regulation, health improvement and energy savings. Although the natural ventilation system offers the possibility to control air flows indoor, the system depends on the outdoor weather conditions (Karimipanah, et al. 2007). However, mechanical systems do not necessarily depend on outdoor weather conditions.

Mechanical systems have continued to make an innovative entry in the construction industry as a means of achieving clean air quality. This is used in buildings where the treatment of air filtration is mandatory due to high levels of noise and air pollution (CIBSE, 1997). Its use and reliability were confirmed in the market report of a consumer water and ambient air; Air Purification System (Industry, 2002), noting that air cleaners accounted for large sales in 2001 with projected increase over coming years. Accordingly, the promoters of well-building standards encourage the use of advanced air purification systems such as spacing and the use of Ultraviolet Germicidal Irradiation and Photocatalytic Oxidation (IWBI, 2016). Some of these air purification systems used in the developed world are illustrated in table 3.5 and show a compilation of such systems and their description and functionalities.

Table 3.5 Air Purification Systems Used in Developed Countries

No	Name	Description	Functionality
1	Filtration: panel filters HEPA HVAC filters Powered electronic filters (EACs) Composite component systems (a combination of either of the above)	HEPA (High-efficiency particulate air filter); HVAC, Heating, ventilation, air-conditioning system are both air filters used to remove suspended particles containing airborne microbes. A mechanical device used to prevent outdoor air pollutants entering internal space. However, due to adhesion of particles over time on the filter surface, it becomes a source pollution itself	They are densely-packed glass fibres arranged in a special way so that air molecules can pass through, but larger pollutant molecules are trapped within the fibreglass mat. Particles can be trapped in a number of ways. These filters can trap up to 99.97% of airborne particles.
2	Photocatalytic oxidation	An emerging technology in the HVAC industry In addition to the prospect of Indoor Air Quality (IAQ) benefits, it has the added potential for limiting the introduction of unconditioned air to the building space, thereby presenting an opportunity to achieve energy savings	This process exposes ultraviolet light to a catalyst such as titanium dioxide to produce primarily hydroxyl radicals (OH). It transforms the harmful pollutants and destroys them, unlike the panel fitters that trap airborne particles until the filter is cleaned.(Fujishima, Rao et al. 2000)
3	Desiccant rotor	This method is used to purge airborne hazards from indoor air although an investigation is still carried out on its efficiency	Desiccant mounted on a rotating wheel. As the wheel turns, the desiccant passes alternately through the incoming process air where the moisture is adsorbed and through a "regenerating" zone where the desiccant is dried and the moisture expelled. The wheel continues to rotate and the adsorbent process repeated. Desiccant rotor employs both dry and wet systems.
4	Plasmacluster ions (PCI)	PCI is an encouraging method from removing outdoor air pollutants from indoor surfaces although more studies need to be carried out with	The ion generator uses an alternating plasma discharge (between two electrically charged plates: anode and cathode) to split the airborne

		regards to health factors	molecules of water into positively charged hydrogen (H+) and negatively charged oxygen (O2−). A chemical reaction occurs, and the collision of hydrogen with oxygen ions creates groups of highly reactive OH radicals that react with proteins/polysaccharides in the cell wall or surface structure of the pathogen, thus damaging it and rendering it incapable of causing infection
5	Essential oil	They are used in pharmaceutical, cosmetics and food and beverage industries have a strong germicidal effect which could serve the same possible as UVGI (No. 2 on this table)	Distil or use them in a disinfecting room spray because they surf cold and flu viruses. They are also known to kill certain kinds of bacteria
6	Nanotechnology	Use to decompose unwanted air pollutants from indoor or outdoor pollutants from contaminating indoor air.	It functions through the use of Nano catalysts with increased surface area for gaseous reactions. Catalysts work by speeding up chemical reactions that transform harmful vapours from cars and industrial plants into harmless gases. Catalysts currently in use include a nanofiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks
7	Thermodynamics sterilization system	Is an indoor a purifier better than normal HVAC as it deactivates natural pollutants such as gases from flaring.	TSS is not a filtering technology that uses heated air to destroy airborne pollutant particles, it is a kind of like an incinerator of sorts
8	Polarized-media electronic air cleaners	An ionizing element is used to charge dust and other air polluted particles through an attraction with the fibrous pad.	This is an enhanced media incorporating aspects of both electronic air cleaners and passive mechanical filters and are non-ionizing. It induces a charge into the filter and turns it into a dust magnet.
9	Electrostatic Air Filtration	Electrostatic filters are very effective, and can collect	Its technique is based on a two-stage filtration principle,

		particles as small as 0.01 microns in diameter, which even beats HEPA filters! They have an open cell design which is there to maintain a low-pressure drop which in turn, means less power is required	and they consist of two sections: the charging section and the collection section. The first stage begins when the electrostatic filter employs ionized wires in order to infuse the contaminant particles, such as dust, pollen, smoke and fumes with small positive charges. The charged particles are attracted to the negatively charged electrical field in the collection section, which contains a row of metal plates. The particles are then collected on the plates, and thus trapped whilst clean air is released into the room. (Air 2015)

Sources: Air, (2015) ; Fujishima, et al., (2000); Zhao, (2009); Ole Fanger, (2006); Grinshpun, et al. (2007)

Most mechanical ventilation systems require the use of energy that helps with the powering of the equipment however, some require less energy than others do, and depending on the use and the size of the room, the effective system is selected. As affirmed by Bradshaw (2010), the mechanical system is the treatment of air to properly maintain temperature and humidity while providing clean IAQ for occupants to satisfy them, given a specific process and space. Although mechanical air purification systems provide clean IAQ, changes in building codes that include minimum ventilation openings, immediate climate specific conditions and building materials should be taken into consideration. Furthermore, building regulations should be functional whereby changes, as obtained and adopted worldwide should be looked at as they relate to and satisfy local and environmental conditions of the ND.

Details of location and weather specific criteria are pertinent while adopting and using new codes or any form of the mechanical system. This is because warm and humid climates such as that of the ND requires avoiding infiltration to reduce forming of condensation realised through pressure from mechanical ventilation system (Mohammed, et al. 2013). Thus innovation in local construction materials will enhance productivity and provide cost-benefits efficiency to all shareholders has been depicted (Ole Fanger, 2006; Zolfani and Zavadskas, 2013). Although the mechanical system provides clean indoor air, the use of local materials could form better environmental adaptable materials as it would have been manufactured from raw material from the environment.

3.7 Evolving Nature of School Building Construction

Although environmental changes are moulding the pace at which design and construction are being carried out with recent emphasis on schools and schoolchildren being impacted by school building type and quality, many countries now apply performance specification criteria and requirements. However, this has fallen short in the ND area where the peculiarity of the immediate environmental conditions requires a revisiting of the design and construction method. With the help of modern technological innovations like BIM and more research into building healthy classrooms over the past twenty years, the era has seen a growing addition into school building requirements made as an essential part for developmental criteria. This is clearly defined in table 3.6 showing additions made necessary to improve buildings for educational purposes

Table 3.6 Evolving Nature of Primary School Design from 1976-2016

S/N	1976	2016
1	High-level opening windows deliver single-sided, wind-driven ventilation	Stack (wind catcher) Ventilation
2	Large areas of single glazing without shading and a high window-to-wall ratio	Low-level ventilation through louvered unit below the window; sometimes these can be integrated with the classroom heating system
3	Lighting has no daylight controls/dimmers	High-level and middle-level windows for temperature control. High-level open first
4	U-value and airtightness of façades are poor compared with today's Building Regulations	Middle-level windows are used when maximum window-opening area is required at peak times
5	No attention paid to orientation – all the façades are treated identically	Window areas are smaller, double-glazed and with solar-control glass
6	No attention paid to orientation – all the façades are treated identically	External shading canopy provides solar protection and minimises glare potential
7	Classrooms are generally larger and identical ; very few specialist teaching spaces	Glass area is optimised with shading unit to allow good daylight levels, to benefit the internal environment for occupant comfort and enable electric-light dimming to reduce energy
8		Highly insulated, airtight façades to prevent heat losses and minimise air infiltration
		Classrooms arranged in wings to maximise daylight and ventilation

ICIBSE, (2016)

Table 3.6 illustrates 20 years of primary school additions to design and construction requirements providing for climatic changes and adjustments to environmental needs. Column 2 in table 3.6 shows additions made to the existing design process and procedure used for construction of school buildings in the UK. However, this is contrary to what is currently in existence in Nigeria and in the ND.

According to the UBE Act of 2004, the UBE Commission is to "prescribe the minimum standards for basic education throughout Nigeria in line with the National Policy on Education and the directive of the National Council on Education and ensure the effective monitoring of the standards" (UBEC, 2010).

Table 3.7 Minimum Standards Specifications for School Buildings in Nigeria

S/N	Elements	UBEC MINIMUM STANDRADS	REMARKS
1	Roof Type	Shape shall be symmetrical, hip roof	
2	Roof Covering	0.55 mm gauge Long span Aluminum Roofing sheet (oven baked)/0.35 mm gauge AluZinc roofing sheet or 28mm gauge Galvanized Iron	
3	Roof Members	Well-seasoned, well-treated timber members while steel members are to be used for buildings with long span roofing sheets.	
4	CEILING	Hard board ceiling (Brazil) and Asbestos ceiling for termite-infested areas.	
5	I. Columns ii. Beams iii. Lintels	Reinforced concrete (14 days running) Concrete mix of 1 :2:4 Reinforcement of high yield 12mm for main reinforcement, high yield 8mm for links Size = 225 x 225 for columns	
6	Load Bearing Walls	Block size = 230 x 230 x 450 mm	
7	Floors	25 mm terrazzo floor finishing 150 mm reinforced (BRC mesh) concrete slab Hardcore of 300 mm depth Compacted earth-filled to make up level foundation	
8	Doors and Windows	Steel doors and windows framed with black hollow pipe and 18 gauge panel sheet (a)Tropical steel door size 1200 x 2100 mm high including lockset complete (b)Tropical steel window size 1200 x 1200 mm high complete	
9	Foundation	Pad footing, strip foundation and reinforced strip foundation or raft foundation.	
10	Rendering/ Plastering	Thickness shall be 12 mm in a mix ratio of 1:6.	

11	Painting	Two under-coat and one final coat application of good quality emulsion paint and skirting of 1.50 m. High gloss paint application for both internal and external wall surfaces.	
12	Toilets	Well-constructed VIP Toilets for areas without adequate water supply or functional water system (Squatting type Toilets).	
13	External Works	1.2 Shoulders (in concrete or block work) round the building. 2.2 Storm water drainage. Interlocking paving stone. Kerbs. Edger's. Erosion control measures and horticultural works.	
14	Water Supply	Deep wells. Hand pump wells. Existing public water system and motorized bore hole.	

UBEC, (2010)

Following table 3.7, there are no immediate climatic conditions even though Nigeria as a nation has different climatic zones and environmental requirements as in the case of ND hence, the need for a more environment specific requirements. This is clearly an extension made from the NBC with no specific requirements for the different geographical zones in Nigeria and up to date no specification or criterion has been stipulated. This is made apparent in the type and method of school construction to date as already discussed in chapters 2 and illustrated in figure 2.14 of a prototype school building construction and design in Nigeria.

3.8 Summary

This section has evaluated the literature on different codes and standards and how these influence design and construction by clearly showing the disadvantages inherent in the rigidity and blaming it all on lapses in the building codes and standards. It also shows that relying on manufacturers' notes enclosed in a product does not necessarily mean that the product is durable or serves such purpose or such materials adaptable in environments such as the ND. Thus detailed criteria and requirement is necessary if specification is to achieve required performance

The discussion was also carried out on specification at a considerable length to justify the need for PS as a means of achieving comfortable learning environments rather than reliance on the prescribed specification method. Both natural and mechanical ventilation systems examined, different mitigating systems used by both developed, and developing countries to combat air pollution illustrated as well. However, this general discussion and review of the literature are not enough to provide a solution to the research problem. This is because of the shortage of information and research carried out on the impact of GF on PSBs and IAQ. Therefore, there is the need to adopt a methodological process that will allow an in-depth data collection and analysis from professionals in the primary research area as discussed in the next chapter.

CHAPTER 4. RESEARCH METHODOLOGY

4.1 Introduction

It is an essential requirement for every research study to provide an appropriate process and justification for achieving its aim and objectives in helping to offer valid answers to questions posed in the study. This is achieved through the presentation of a detailed discussion of the methodological approach embarked upon for the study. Beyond empiricism, there is the need to position and relate any methodological assumption with the foundation of the field study and philosophical stance which according to (Holden and Lynch, 2004) a philosophical solution to "Why research" is needed. The research falls into the realm of a real life issue that requires a solution-based approach.

However, it is pertinent to outline most research approaches by considering research philosophies in the light of 3 of the best-known stance describing beliefs associated with academic research. Research strategies and logic, approach, the justification for the mixed method approach adopted, discussions of the questionnaire and semi-structured interview techniques as the two main data collection techniques were discussed in this chapter. Clear and elaborate discussions of the DS method as a problem-solving research approach which is mainly concerned with designing artefacts of significance that are effective and solution-driven (March and Smith,1995; Alan, et al., 2004). This means that it is fundamentally a problem-solving paradigm. By paradigm, Blaikie, (2009) referred to a theoretical and methodological tradition which provides the researcher with an intellectual context for conducting research.

The DSM has roots in engineering and the science of the artificial as affirmed by Simon, (1996). Although its outputs are referred to as artefacts, which include models, constructs, methods, and instantiations, it is suggested by Lukka, (2003) that all human artefacts such as models, diagrams, plans, and information system designs are constructions. Whereas DS is increasingly being applied in the realm of information science research and health and engineering sciences, it is also applied to other sectors such as the BE (Tezel, 2011; Rooke, 2012). Therefore, based on its core features chosen as the best fit for outlining its characteristics, it was adopted as the process to be followed systematically to achieve the research goal.

Furthermore, following the possibilities of using different strategies to provide a solution to the problem, a full description of the methodological process used is presented in the relevant chapters. This chapter also provides details on the selected research method, a comparison between DS and other research strategies such as case study, grounded theory, action research, and ethnography. Although the DSM provides different frameworks as a guide in providing the solution, the adopted framework showing the systematic steps as proposed by Johannesson and Perjons, (2012) was used in this study. Its focus was on how the DSM can be usefully applied to solving the problems caused to PSBs and the health of pupils due to their nearness to GF. This is done through effective problem explication to the design of the solution, demonstration, and evaluation of the designed solution while adopting relevant strategies necessary to achieve the solution designed. Furthermore, this Chapter concludes with a summary of the main points followed in the research process with the initial discussion on the philosophical interpretation of the research.

4.2 Research Philosophy

The practice of questioning fundamental beliefs and answering important questions about anything in the environment transformed into philosophy is a term attributed to Pythagoras as depicted by Reich (2013). It is an ideological way in which an inquiry into a paradigm is resolved (Bryman, 2012). According to Burke (2007), research philosophy is the questioning of basic important thoughts and the need to embrace a meaningful acceptance of a particular field. Furthermore, she pointed out that the pursuit of such a philosophical perspective provides a useful starting point as it allows the research approach to be clearly communicated in a context that is well understood by others.

On their part, Saunders et al. (2009) noted that it is a way of examining social phenomena from which a particular understanding can be gained and explanations attempted. They suggested that the philosophical propositions made by a researcher through the mixture of research strategies have a significant influence on what the researcher does. In addition, it helps with how the researcher understands what it is that is being investigated. However, the continual discontentment between academics in different fields of study makes one wonder if there is any need to relate one's research to a particular philosophy at all as opined by (Eastman and Bailey, 1996). Nevertheless, the philosophical level of a research method narrates to its conventions based on the general features encompassing such aspects as the mind, matter, reality, reason, truth, nature of knowledge, and proofs for knowledge (Hughes, 1994). Therefore, one's perception of a philosophical stance is based on the study of perception and beliefs.

There are three renowned philosophical stances explored in any theoretical belief namely, Axiology, Ontology and Epistemology (Bryman, 2012; Fowler, 2014 and Saunders et.al., 2012). Although, Webb (1989) observed that the distinction between the different philosophies are overstated, philosophically informed research plays a significant role, as shared beliefs, and also forms the basis for the selection of the research paradigm, the data collection strategy and method of analysis (Morgan, 2007). The contrasting ontological and epistemological assumptions implicit in some communities of sciences have been explicated (Vaishnavi, et al., 2009; Johannesson and Perjons, 2012). The researcher's experience, understanding of philosophy and personal beliefs may also have some bearing on the method adopted (Denzin and Lincoln, 1994). For instance, Saunders (2011) provided a methodology referred to as the research onion (figure 4.1). The model represents the research problem in the centre and from its interpretation all the layers forming the onion have to be peeled off methodically to enable the researcher to resolve the problem through data collection and analysis.

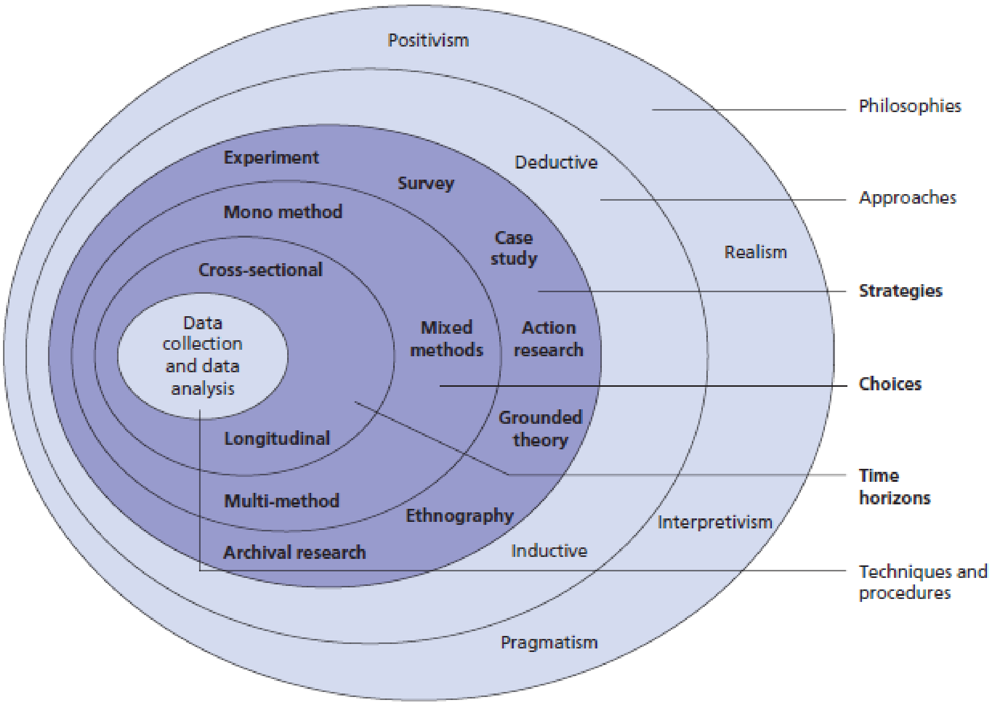


Figure 4.1 Research Onions
Source: Saunders et al (2009)

From figure 4.1, research philosophies, approaches, strategies, choices even the time horizon all need to be identified before data collection and analysis can be carried out to form the main purpose of the research.

Similarly, in a bid to provide a methodological approach as a follow-up sequence in attempting to solve a research question, Kagioglou, et al., (2000) developed the nested approach as a process adaptable in achieving the aim of a research as illustrated in figure 4.2.

Figure 4.2: The Nested Approach Research Methodology
Source: Kagioglou, et al. (2000)

Here in figure 4.2, this methodology provides an integrated research approach and techniques beneficial from an epistemological point as illustrated. Diagrammatically, the nested approach is fundamentally theory-driven with testing methods and data collection methods clearly stated. This defies the possibility of explicitly stating any solution for practical purposes based on its theoretical conclusions.

According to Koskela (1992), most research paradigms are implicit and do not really fit into a real life situation. Such approaches, if adopted, are not particularly testable; their domain of feasibility is not known to be applied to real life situation and often rely on the ever-evolving rule of thumb. Both the onion and nested approach are theory generated and testing methods without practical application in a real life scenario. For this reason, Shih (1998) listed four areas for consideration when deciding on a research method:

- The philosophical paradigm and goal of the research,
- The nature of the phenomenon of interest,
- The level and nature of the research questions,
- The practical considerations related to the research environment and the efficient use of resources.

This identified a linkage between philosophical assumptions and the creation of knowledge in relation to a research approach. Reich, (2013) affirmed that Philosophical practice involves dialect, dialogues, and determining the result of dialogue by consensus. It is about designing to create stories, arguments, and other logical or rhetorical structures for delivering messages whose logical status are determined by people. Therefore, a good researcher follows the steps of Galileo who was thought not only to be an astronomer, mathematician, physicist, and a philosopher but an engineer who got interested in all the fields listed above through his work in solving practical problems (Valleriani, 2010). Since the expectation was to solve a real life problem, the combination of methods whether observation, experimental, induction or deduction is not significant, rather the proof of functionality and effectiveness is the ultimate goal. As noted by Reich (2013), engineers know that there is really no single method to knowledge discovery; it can be premeditated to fit its goals. Furthermore, Reich (2010) observed that there is no single way better than others to design such knowledge or any product; it is all a matter of what works.

The justification for a particular philosophical stance has been argued over and over due to its nature and has been opined and concurred by several researchers stating that

"Since the nature of philosophy and its relationship to other forms of knowledge is itself a major matter of philosophical dispute. There is, of course, no real basis for us to advocate any one view on these matters as the unequivocally correct conception of the relationship between philosophy and social research" (Connell and Nord, 1996; Hughes and Sharrock, 1997).

Following this line of argument and the contest between a defined methodological or philosophical stance, this study adopts this position based on the model illustrated in figure 4.3 distinguishable from the research onion and nested approach known as the DS. This is because of its reliance on methodological process which is more solution-driven than theory-driven. The main aim of the research is the realisation of solutions through rigorous research rather than just a theory-generation or testing model.

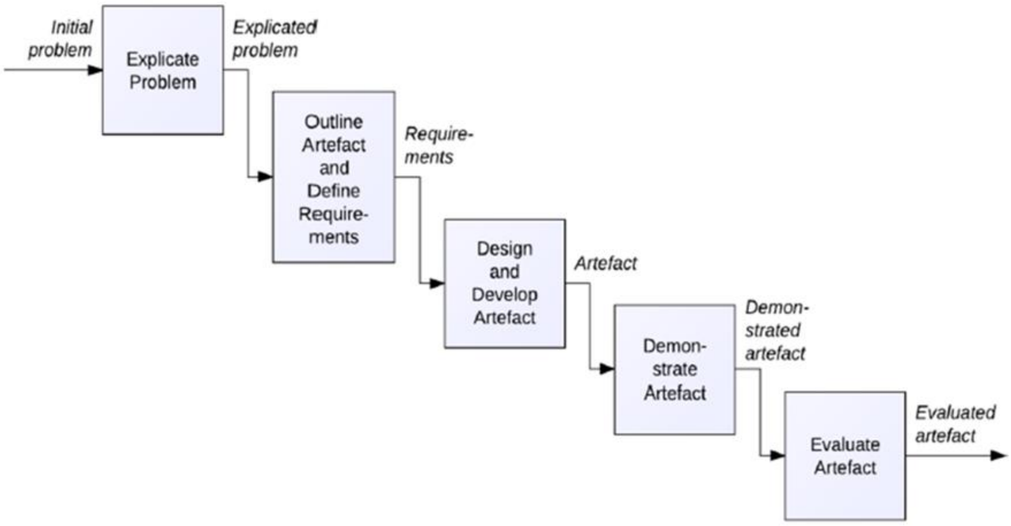


Figure 4.3 Design Science framework
Source: Johannesson and Perjons (2012)

The DS framework has constantly been improved due to its acceptance as a practical-base system where solutions to real life problems are provided. Different scholars and researchers have, over the years, produced a framework that has been explored and used to provide solutions. Although different processes and ways of reaching a defined solution are constantly being explored and used, all frameworks follow an iterative process. For instance, Takeda et al. (1990) introduced a general design cycle with an in-depth understanding of the problem providing clear enumeration, suggestion of solutions and evaluation. Furthermore, Nunameker et al, 1992; March and Smith, 1995; Vaishnavi and Kuechler, (2004); Peffer, et al., (2008) also designed a framework that had two, three and four processes which fit more into the information system. However, Johannesson and perjons (2012) designed an extended framework with five processes involving the need to explicate the problem, define the requirements and outline the artefact, develop the artefact, demonstrate and finally evaluate the artefact as illustrated in Figure 1.2, which has been well adjusted to suit this study. From the framework as adjusted, the first process and stage started with an initial problem, which might not be realistic or might have been generated due to unseen issues not explicated and in most cases requiring the use of both primary and secondary data to provide valid problem identification. The explicated problem leads to the solution and then evaluation of the solution that requires that the solution is functional and effective and not theory based.

The DS framework allows the use of a philosophical stance that proffers a solution to a problem rather than a fit for purpose or a discipline based handed down assumption of the general way of doing things. The dispute and the contention of using one philosophical stance to the other prompted the advancement of alternatives such as DS (Holden and Lynch, 2004) . The ability to use personal skill and knowledge acquired during the lifetime experiences and other research methods to provide a solution through the science of the artificial makes DS a worthy method. The interaction between different paradigms and the ability of the researcher to infuse them into a single research through diversification makes the research more rigorous.

Although there are three renowned philosophical stances, axiology, ontology and epistemology, the repeated usefulness of DS provided another contrasting view. This is added as the DS philosophical interpretation due to the meta-level of assumption known as the "Socio-technologist/Developmental approach" (Gregg, et al 2001). Therefore, due to the iterative nature of DS, its philosophical stance is denoted by the perception and the focus of achieving results that solve practical problems rather than adopting a single belief system as discussed below.

4.2.1 Axiology

According to Creswell, (2002) the role value plays in research qualifies findings, indicating that it may be value free or value laden, determined by objective criteria or human belief and experience depending on the reason presented to identify what truth pattern to follow. As opined by Pathirage, et.al. (2008), different people have different viewpoints and thus have their different opinions due to their experiences and beliefs on what the truth should be. This value belief is divided into Value-free or Value-laden and it is required that a piece of research is based on either one of them.

While the objectivist is of the view that a researcher distances herself from the research, the subjectivists cannot distance themselves from what is being observed; the subject of the research and the method of study. In other words, the subjectivists' biases put them in a value-laden stance of the axiological philosophy. According to (Holden and Lynch, 2004), subjectivists believe that a problem can be better understood through investigation of the problem in its totality rather than justifying the study by relying on an instance. However, the formulation of DS as a method makes this dispute a less valid notion because according to (Kuechler and Vaishnavi, 2008), DS research is shared value because the choice of one belief to another might reduce the impact on the means-end evaluation significance. Therefore, knowing that the gains of the research are based on the hope to find a creative manipulation and control of the environment, it is left to the researcher to have a clear and definite control measure in the solution-oriented process

4.2.2 Ontology

This philosophical stance explains the different views of the nature of reality (Creswell, 2007). It is a form of metaphysics, which raises questions about how researchers view the world, assumptions on how the world operates and commitment to a particular observation (Saunders et.at, 2009). In addition, Blaikie (2009) states that ontological assumptions are ways of answering the question: '*What is the nature of social reality?*', and that these assumptions are concerned with what exists, what it looks like, what units make it up and how these units interact with each other.

There are two broad divisions of ontological stance namely the Objectivists and the Subjectivists. Objectivists believe that social phenomenon exists independently from social actions (Knight and Ruddock, 2009), which implies an action existing without biases of social factors. It has been criticised as an inappropriate stance of study for social sciences, as opined by Holden and lynch (2004). Its explanatory successes in the natural sciences have not been manifested in the social sciences. It is a position that holds that the goal of knowledge is simply to describe the phenomena that are experienced. However, Subjectivist ontology assumes that what is taken as reality is an output of the human mental process (Fellows, 2009) since the human mental process is continually changing due to social actions as a constant phenomenon. Subjectivism is more suitable for the complex nature of social science research, which deals with human behaviour. It is a position proclaiming that objects are created from insights and consequent actions of social factors responsible for their creation (Saunders, et.al., 2012). Furthermore, Proctor (1998) suggests various influences of social factors with culture, gender, and cultural beliefs as the most significant due to the complex relationship between individual behaviour, attitudes, external structures, and sociocultural issues. Following the above explanations of ontological beliefs and the reconcilable nature as opined by Orlikowski, (1991), there is a clear contrast with DS because ontology is comfortable with the alternation of the world-state as the typical position of the positivist stance as a single entity or concept of analysis. With DS, the research question mostly changes as the research continues through its systematic process leading to newer discoveries of the solution.

Although Goldkuhl, (2012) opposes DS research as essentially pragmatic in nature due to its emphasis on relevance he is convinced of its clear contribution to the application environment. However, Niehaves, (2007) argues that epistemological assumptions are essential to DS research and heavily impact on how the research is conducted, demonstrated and evaluated.

4.2.3 Epistemology

It is a branch of philosophy that borders on the theory of knowledge with the focus on ways of acquiring such knowledge, how such knowledge is used to distinguish between reality and fiction. There are different epistemological assumptions made by different researchers that include Positivism and Realism, Interpretivism, constructivism and a pragmatic position exploring avenues in finding answers to research questions and hypotheses (Creswell and Clark, 2007). Epistemological positivism, on one hand, assumes that there exists in principle the possibility that objective knowledge about the real world can be achieved. Critics of the positivist approach (Crossan, 2003; Caldwell, 2010) argue that it yields useful but limited data that only provide a superficial view of the phenomenon investigated.

In summary, the positivist philosophy embraces a conception of truth in which verifiable reports correspond to the certain facts of reality. However, interpretive epistemology stresses that knowledge is always determined by the subject hence no such thing as objective knowledge exists. It is the broadest and most used philosophical stance in the research process in the social sciences, the sciences and the behavioural sciences (Fellows, 2009).

In addition, based on the research adopting the DS research method, the essential trait is justified within the epistemological foundations of pragmatism as opined by (Goldkuhl, 2012) and are summarized below:

- The focus on utility and usefulness, and contribution to practice;
- Knowledge development through building and intervention;
- Problematic situations as a starting and driving point for inquiry and design;
- The search for what is possible and desirable;
- Going beyond description; aiming for perspective, normative and prescriptive knowledge.

Similarly, Clark (1998) noted that the combination of two philosophical stances in one research limits the disadvantage in one stance as represented to provide an in-depth understanding, and the use of each strength or weakness to explore and engage in a study is vital. This, therefore, supports positions and the implication of relying on one stance as summarised in table 4.1;

Table 4.1: Summary of the Positivist and Subjectivist Philosophical Perspectives

Positivist Perspective		**Subjectivist perspective**	
Elements	**Discussion**	**Elements**	**Discussions**
Independence	The researcher is independent of what is being researched	Interaction	The researcher interacts with the subject being observed
Value-freedom	The choice of what to study and how to study it should be determined by objective criteria rather than by human beliefs and interest	Value-laden	Inherent biases in the choice of what to study and how to study it as researchers are driven by their own interest beliefs skills and values
Causality	The aim of the research should be to identify causal explanations and fundamental laws that explain human behaviour	No Cause and Effect	The aim of the research is to understand what is happening
Hypothetical-deductive	Science proceeds through a process of hypothesising fundamental laws and then deducing what kinds of observations will demonstrate the truth or falsity of these hypotheses	No Hypothetical-deductive reasoning	Develops ideas through induction from evidence, mutual simultaneous shaping factors
Operationalisation/methodological	Concepts need to be operationalised in a way which enables facts to be measured quantitatively static design –categories isolated before study	Operationalisation/ methodological	Qualitative methods in small samples investigated in depth or over time; emerging design categories identified during research process
Reductionism	Problems as a whole are better understood if they are reduced to the simplest possible elements	No reductionism	Problems as a whole are better understood if the totality of the situation is looked at
Generalisation	In order to be able to generalise about regularities in human and social behaviour, it is necessary to select	Generalisation	Everything is contextual; patterns identified, theories developed for understanding

	samples of sufficient size, aim of generalisation is to lead prediction explanation and understanding		
Research language	Formally based on set definitions; impersonal voice; use of accepted quantitative words	Research language	Informal, evolving decisions; personal voice; use of accepted qualitative words.

Table 4.1 shows the differentiated elements of both positivist and subjectivist philosophical perspectives. Having differentiated the elements that clearly describes the objectivist and subjectivist characteristics of each philosophical stance as it relates to epistemology of the knowledge inquiry method; their intermediate measure provides an avenue to explore both characteristics in the pragmatic perspective

4.2.4 Pragmatic Position

According to Creswell and Clark (2007), it is a new paradigm gaining importance in the last few years with a philosophical underpinning in mixed methods studies enabling knowledge to be derived from a problem. The pragmatic approach is based on knowledge claims arising out of actions, situations, and consequences rather than antecedent conditions (Creswell, 2012). This provides the need for a dual action of both an objective and subjective assumption explored to proffer solution to a research problem.

A strict adherence to a particular philosophical assumption with the research not entirely scientific creates an avenue of bias interpretation for researchers and readers, thus the need for a dual assumption of a philosophical stance (Holden and Lynch, 2004). The adoption of a dual philosophical stance has over the years provided reliable and easy assumptions whether it is a case study, qualitative or quantitative research. For instance, (Remenyi and Williams, 1998) in Table 4.2 illustrated a practical guide of research method through philosophical assumptions. They noted that most researchers assume that case study uses a single assumptive qualitative method but with increasing coding system explored, it allows the use of statistical techniques, which add a quantitative aspect to its method to make it a dual assumptive method.

Table 4.2: Practical Guide to Research Approaches Using Philosophical Assumptions

Research approaches	**Objectivism**	**Subjectivism**
Action research		Strictly interpretivism
Case studies	Have scope to be either	Have scope to be either
Ethnographic		Strictly interpretivism
Field experiments	Have scope to be either	Have scope to be either
Focus groups		Mostly interpretivism
Forecasting research	Strictly positivistic with some room for interpretation	
Future research (Design Science)	Have scope to be either	
Game or role playing		Strictly interpretivism
In-depth surveys		Mostly interpretivism
Laboratory experiments	Strictly positivistic with some room for interpretation	
Large-scale surveys	Strictly positivistic with some room for interpretation	
Participants-observer		Strictly interpretivism
Scenario research		Mostly interpretivism
Simulation and stochastic modelling	Strictly positivistic with some room for interpretation	

Source: Remenyi and Williams (1998)

From table 4.2, most research approaches adopt a dual assumptive philosophical stance in other to provide a clear, concise and defined interpretation of the study. A clear in-depth understanding provides the study and the research a clear interpretation and basis of conclusions.

A pragmatic position holds context and pursues stability among varied standpoints, eliminating the separation between analysis and action to provide a useful rationale (Hoch, 2002). As affirmed by Feilzer (2010), pragmatism is correctly a paradigm for utility and the search for practical consequences. This philosophical stance aligns well with the DS method as it allows actualisation of a solution to solve a problem. It is pragmatic in nature due to its emphasis on relevance as illustrated in table 4.3 outlining DS's place in the three philosophical assumptions already discussed.

Table 4.3 Philosophical Assumptions and the place of Design Science

Research believe	Positivist	Interpretative	Design Science
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	Truth: universal and beautiful; prediction	Understanding: situated and description	Control; creation; progress (i.e., improvement); understanding

Source: Vaishnavi and Kuechler (2007)

Table 4.3 shows the DS philosophical interpretations of the three research beliefs which, in summary, are a combination of both positivist and interpretive beliefs.

Based on the nature of the study and description of all philosophical stances, this study will adopt a pragmatic stance of epistemology. This is because, in the DS academic research, objectives are of a more pragmatic nature. The pragmatist attitude is to intervene into the future with the purpose of constructing a better world (Göran Goldkuhl, 2012).

Research in these disciplines can be seen as a quest for understanding and improving human performance. It is solution-oriented, using the results of description-oriented research from supporting (explanatory) disciplines as well as from its own research contributions (Van Aken, 2005). Again, aside from the acknowledgment given by Van Aken, other researchers such as (March and Smith, 1995; Alan, et al. 2004) associated DS with a pragmatic philosophy. In their explanation, the world to be is not just a possibility but a desirability which means that it can be achieved where both exploratory and explanatory paradigms are inter-used to produce a solution.

Pragmatism is a school of thought that considers practical consequences or real effects to be vital components of both meaning and truth. Accordingly, Lee and Nickerson (2010) noted that the practical consequences of interest to pragmatism include truthfulness, moral rightness of beliefs, ideas, concepts, plans, decisions, policy, designs to elevate and restore usefulness and moral rightness to the same level of importance as truthfulness. Pragmatism is a research paradigm that is concerned with knowledge for action and change. This research is providing the solution, the understanding of the causative effect of GF on roofing materials and internal air quality of PSBs in the NDAN is vital. The information gathered will provide the needed base for solution design. Therefore, it is suitable to adopt the pragmatic philosophy due to the iterative nature of the DS method and the possibility of solving a practical problem without relying on an existing phenomenon that brings to effect, a solution-driven philosophical stance rather than a theory-driven process.

The graphical representation of the current study is in figure 4.4:

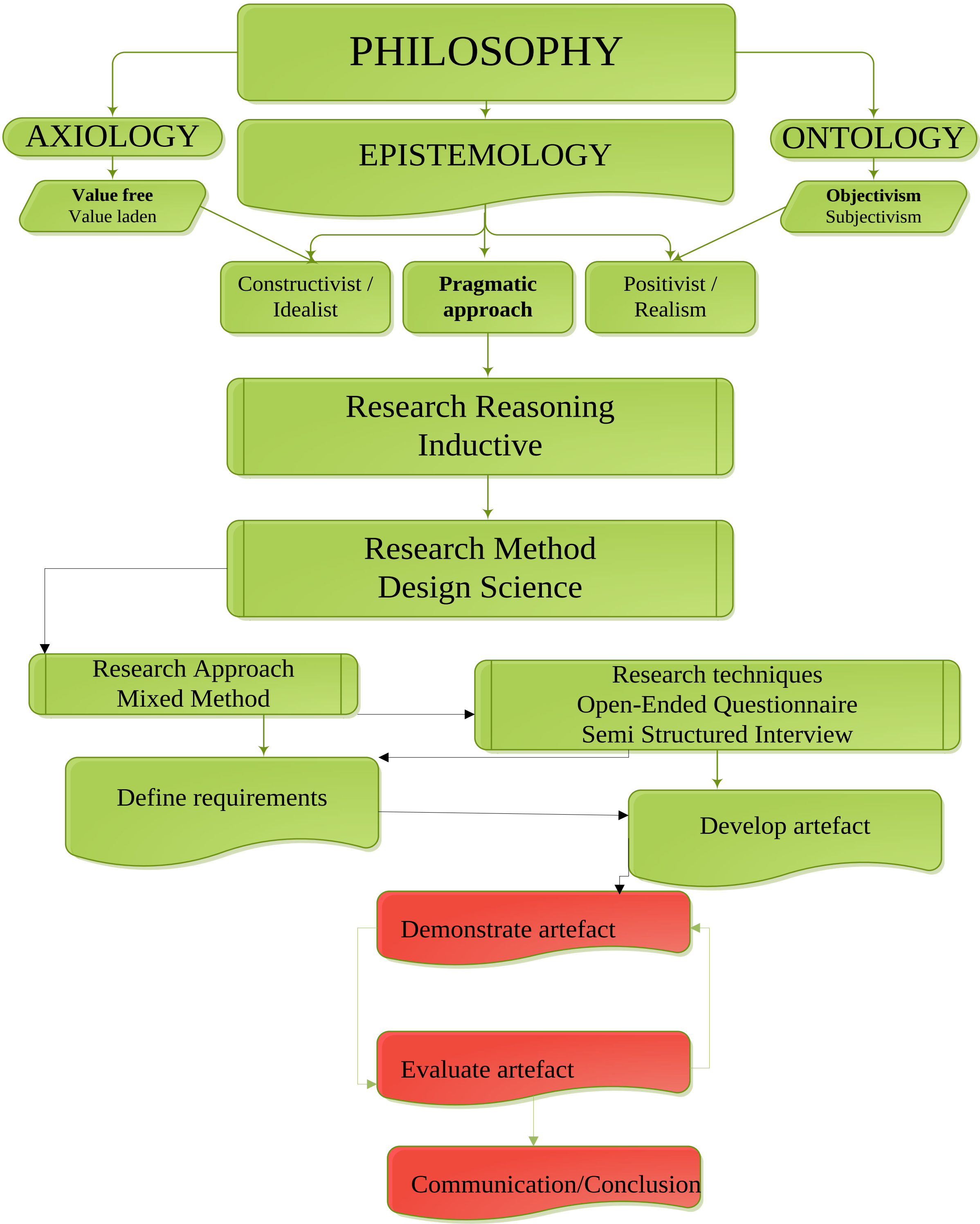


Figure 4:4: Graphical Representation of the Research Structure
Source: Author

4.3 Research Strategy

Research strategy provides the overall direction of the research including the process by which the research is conducted (Remenyi, et al. 2004) . While (Saunders et al 2009) defined research strategy as "*the general plan of how the researcher will go about answering research questions",* Bryman (2012) also acknowledged research strategy as "*a general orientation to the conduct of research*". Therefore, the definitions above show that no single strategy can solve a particular research problem, hence a combination of these have been recommended in mixed methods application (Caracelli and Greene,1993; Onwuegbuzie and Teddlie, 2003) . Following this, Yin (2003), recommended three conditions for the selection of a particular strategy; the type of research questions, the extent of control an investigator has over actual behavioural events and the degree of focus on contemporary or historical events.

The various research strategies largely overlap and so it is important to consider the one most suitable for a particular study, an idea both Yin (2003) and Saunders et al. (2007) acknowledge. Nonetheless, (Johannesson and Perjons, 2012) noted that investigating a practical problem requires an adoption of an overall strategy that helps provide the solution. Therefore, the strategy adopted should fit into a method providing needed criteria and justification of the research outcome through proving research rigor and understanding of a research process. And so, in view of the above and as no one strategy fits all, the DSM is adopted due to its ability to combine different strategies through its iterative process; mixed methods, a multi-disciplinary approach to research, was used to meet the objectives of the research.

4.4 Mixed Method Research Approach

A combination of both qualitative and quantitative research approaches in order to arrive at a sound interpretation of findings, which will be biased-free (Onwuegbuzie et. al., 2011). Over the years, its usefulness has made remarkable prominence due to the viable nature of using both qualitative and quantitative rather than a single method (Hanson *et al.,* 2005). However, a mixed method researcher needs to be skilled in both qualitative and quantitative research approaches, as it requires combining both elements of qualitative and quantitative research approaches (Folorunso and Ahmad, 2013). Accordingly, Holden and Lynch (2004) opined that due to the causal flaws associated with extreme assumptions, research which is not core scientific in nature tends to be moderate in their aligning of assumptions and such research not strictly quantitative or qualitative in nature.

Although, mixed method research approach has been criticised by different researchers as a new approach with limited importance as noted in Onwuegbuzie, et.al. (2011). Nevertheless, its benefits provide a counter to the biased nature of quantitative or qualitative approach as outlined in table 4.4.

Table 4.4: Advantages and Disadvantages of Quantitative and Qualitative Research Approach

Qualitative Research Approach	
Advantages	Disadvantages
Provides detailed perspectives of a few people	Has limited generalization
Captures the voices of participants	Provides only soft data (not hard data such as numbers)
Allows participants' to experiences to be understood in context	Studies few people
Is based on the views of participants, not of the researcher	Is highly subjective
Appeals to peoples' enjoyment of stories	Minimizes use of researchers' expertise due to reliance on participants
Quantitative Research Approach	
Advantages	Disadvantages
Draws conclusions for large numbers of people	Is impersonal, dry
Analyses data efficiently	Does not record the words of participants
Investigates relationships within data	Provides limited understanding of the context of participants
Examines probable causes and effects control bias	Is largely researcher driven
Appeals to peoples' preference for numbers	

Source: Onwuegbuzie, et.al. (2011)

Table 4.4 shows the advantages and disadvantages of each research approach, however, each single traditional method has both advantages and disadvantages crossed out with the use of a mixed methods strategy.

The use of mixed methods research is recent compared to qualitative or quantitative approach but its legitimacy has been argued and supported by several researchers like (Amaratunga, et al. 200; Creswell and Tashakkori, 2007; Hibbard and Onwuegbuzie, 2012) among many. For example, (Bichard and Kazmierczak, 2012) used mixed methods to achieve results on sustainable energy efficiency. Furthermore, (Feilzer, 2010; Creswell, 2013) noted that mixed methods tend to base its knowledge claim on pragmatic grounds. Evidence revealed that using the single method for a problem that has real life implications as found in the BE is far from being actualised because investigating such multifaceted interrelations and interactions requires accessing substantial information (Creswell and Garrett, 2008). In addition, the combination of relative strength from multiple-perceptions has the possibility to offer a more all-inclusive and desirable outcome (Minger, 2001). Thus, designing PS, which primarily involves a multidisciplinary team with enormous research challenges and combining different strategies such as qualitative and quantitative will enhance the reliability and real-world impact of the findings.

This method provides the clear understanding of the research problem, its root causes and possible solutions based on the explicated problem by allowing the researcher the ability to expand the analytical techniques at their disposal for better solution driven and real life impacts. Further justification and legitimation of the choice of mixed methods are illustrated in table 4.5.

Table 4.5 Justification for a Mixed Method Research Approach

LEGITIMATION TYPE	DESCRIPTION
Sample integration	The extent to which the relationship between the quantitative and qualitative sampling designs yields quality mate-inferences
Inside-outside	The extent to which the researcher accurately presents and appropriately utilizes the insider's view and the observer's view for the purposes such as description and explanations
Weakness Minimisation	The extent to which the weakness of one approach is compensated by the strengths of the other approach.
Sequential	The extent to which one has minimised the potential problem wherein the meta-inferences could be affected by reversing the sequence of the quantitative and qualitative phases
Conversion	The extent to which the quantising and qualitising yields quality meta-inferences
Paradigmatic mixing	The extent to which the researcher's epistemological, ontological, axiological, methodological and rhetorical beliefs that underlie the quantitative and qualitative approaches are successfully (a) combined or (b) blended into a usable package
Commensurability	The extent to which the meta-inferences made reflect a mixed worldview based on the cognitive process of Gestalt switching and integration

Multiple validities	The extent to which addressing legitimation of the quantitative, qualitative and mixed validity types, yielding high-quality meta-inferences
Political	The extent to which the consumers of mixed methods research value the meta-inferences stemming, from both the quantitative and qualitative components of a study.

Source: Onwuegbuzie et.al. (2011)

Following justification as summarised in table 4.5, the arguments and justification of mixed method have been itemised into nine legitimation types with descriptions provided. However, the method of data collection determines the act being legitimate. And for the purposes of this research, the quantitative and qualitative techniques are discussed as follows;

4.5 Quantitative Using Questionnaire

Questionnaire forms a vital part of mixed methods research used for the collection of information. This gives significant depth of understanding with reduced bias of the perception of stakeholders already chosen for the research. Following the nature of the research, the limited nature of documented information in a local context and the need to further explicate research problem, an open-ended questionnaire was adopted. This provides selected respondents the opportunity to provide information that might be relevant to the research.

The questionnaire was divided into three sections: Section one (A) deals with the identification of building materials, specification criteria used and the impact of GF on PSBs. Section two (B) focused on the impact of GF on IAQ, health impact and ventilation systems used for clean air in public PSBs. Finally, section three (C) was on general information of participants and their knowledge of the research area. (See Appendix G for a sample of open-ended questionnaire). The idea behind the general information section being the last part of the questionnaire was to further eliminate any form of biases and any probability of respondents not giving adequate responses to the questions based on fatigue or apathy. This could be referred to as using a top-down rather than a bottom-up system.

A Likert scale point system was used in the open-ended questions and it is a scale in which all the responses from categories were worded. The choice of a Likert scale is based on its stress-free use merely requiring subjects to indicate the extent of their agreement or disagreement with each of the several questions or statements posed them. A 5-point Likert scale system was used in the first instance of further explication of the problem (see appendix G) whiles a 6-point Likert Scale was used for the demonstration phase (see appendix I).

According to Remenyi (2012), most Likert scale questions are based on odd number sequence. However, the open-ended questionnaire provided the opportunity for respondents to provide more information which can better help with problem identification. This, therefore, further gives the researcher a better insight into how well to explicate the problem and provide the means to developing the required solution. 120 open-ended questionnaires were administered to selected respondents and 102 valid responses were retrieved over three weeks of extensive communication and constant reminders to emails, text and phone calls. Adopting this type of questionnaire system provided the researcher with additional 25 variables which formed a total of 122 variables in total compared to 97 originally identified during coding of themes.

Although there are three types of the questionnaire survey, Self- administered questionnaire system was adopted which included covering letter showing clearly the choice of respondents opting out from providing answers and also stating clearly the importance of confidentiality as shown in appendix D and E.

4.5.1 Sampling Criteria

The estimation of the valid number of respondents required to form an accurate sample size has over the years been daunting yet, a fundamental requirement for the validity, reliability and replicability of a study (Morse 1991), in most cases, has proven difficult as researchers are often met with challenges when conducting research. The population of an accessible group who meets a well-defined set of eligibility criteria, the estimation of the number of respondents required to provide them with the information, as well as, the processes through which sufficient information can be generated to achieve their research objectives (Sarantakos, 1998) have always proved difficult. The selection of a population is of significant importance as the population should be clearly defined so that the sample can be accurately identified.

However, sample sizes could be less than five or more than 20 depending on the data collection method used as opined by Mason (2010). This is because with qualitative studies, which use techniques such as interviews, a larger sample size does not necessarily lead to more information (Guest et al., 2006). Nevertheless, for quantitative studies, Krejcie and Morgan, (1970) in their work provided a table used in selecting the sample size from a given population at the .05 degree of accuracy. For instance if a population of 200 is chosen, then the sample size will be 136 at the .05 level of confidence. Although in recent years software such as Raosoft has been developed to help with the calculation of the population and sample size that form validity of responses. Similarly, it is pertinent to note here that the purposive sampling technique has been adopted which allows participants to be selected according to predetermined criteria relevant to research objectives. Therefore, for the purposes of this research, table 4.6 shows the list of selected participants, sampling type and rational behind each sample population.

Table 4.6 List of Selected Participants

Sampling Type	Participants	Rationale
Purposive/ Judgemental	Architects	Architects work in the construction industry and are involved with the design, extensions or alteration, working with their clients and users to make sure that projected designs match their needs and are functional and economical
	Estate Surveyors	Involved in the maintenance of public infrastructure/assets, acts as land economists for infrastructural development schemes, custodians of land and landed properties
	Urban and Regional Planners	Design, promote and administer government plans and policies affecting land use, zoning, public offices, community facilities, housing and transportation. Determine the effects of regulatory limitations on projects. Assess the feasibility of proposal and identify necessary changes
	Quantity Surveyors	Seek to minimise the cost of project and enhance value for money, while still achieving the required standards and quality as specified by statutory building regulations.
	Land Surveyors	Land surveyors assess land due for redevelopment and survey a range of different areas, including airports, landfill sites, mines and quarries, and pipeline and distribution systems
	Environmentalist	Knowledgeable on impacts of industrial/globalisation, environmental impact assessment, strategic environmental assessment. Sustainability Assessment/Appraisal, appropriate assessment, health impact assessment and forecasting and modelling the environment.
Voluntary	Universities	Trainers of prospective professionals in the Built Environment

Source: Author

Table 4.6 lists and provides the rationale for the participants selected and the sampling method adopted for this phase of the study. The selection criteria are significant as they helped to further explicate problem and define the requirement necessary to push the study further.

Information derived from the questionnaire was analysed using statistical package for social sciences (SPSS) and with statistical analysis, there are basically two tests, the parametric and non-parametric tests which depend on the type and nature of the data. Parametric tests are based on an assumption about the population from which the data is taken (Fellow and Liu, 2008). While non-parametric test relies on fewer suppositions about the data and used in situations where the data collected is skewed or not normally distributed. The difference between the two statistical tests is that the parametric tests depend on interval-scaled data based on a normal distribution and not skewed. Parametric tests analysis processes tend to be considerably more tough and complex than non-parametric tests. More so, the nonparametric test is suitable to use with relatively small amount of data measured on nominal and ordinal scales and more flexible to apply (Pallant, 2010). Therefore, a good analysis can be carried out when the researcher is aware of the analytic procedures and assumptions underlying their choices.

For the present study, the data collected were analysed using a non-parametric test. This is because according to Pallant (2010), where statistical analysis is not normally distributed such an ‘abnormality' in the distribution of the data collected provides justification for the use of a non-parametric test as the best approach for the analysis of the study.

4.5. 2 Reliability Test

The reliability of responses across questions is vital information that shows the consistency of the measurement and tests carried out. Although a number of methods can be used for reliability tests to measure inter-item reliability and internal consistency, for questionnaire survey, the Cronbach’s Alpha is best fit for this purpose (Pallant, 2010). The level of acceptance on a measure of the internal reliability of the items on the questionnaire survey when using Cronbach's Alpha ranges from 0 to 1.0 (Fellow and Liu, 2008), where "0" means a completely unreliable result and "1.0" means a complete reliability result. The significant level to determine internal reliability is using Cronbach's Alpha coefficient considered to be acceptable at 0.7 (Pallant, 2010). Therefore achieving values above 0.865 provides more acceptable results and a better internal reliability. According to Fellow and Liu (2008), inter-item reliability is a good measure of questions of more than one variable and also provides an indication of the degree of internal consistency among variables on the scale.

The reason for this measurement was to determine if the questionnaire used was reliable in measuring what it was intended to measure and to check the internal reliability (Sarantakos, 2013) of the data, Cronbach's Alpha was conducted. The reliability test conducted on the questionnaire in table 4.7 shows the Cronbach's Alpha value of 0.817, which suggests that the questionnaire has good internal consistency reliability. As stated by Pallant (2010) achieving Cronbach's Alpha coefficient above 0.7 is generally considered to be acceptable, and values above 0.817 are considered to be a very good level of internal consistency.

Table 4.7: Snap shot of Reliability test of data collected and inputted into SPSS

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.817	.838	108

4.5.3 Descriptive Analysis Method

Using SPSS for data analysis provides the use of the descriptive method of analysis. This method, as its name implies, presents the simplest way to represent the analysed data in a manner that gives a general overview and picture of the findings (Naoum, 2013). Basically, it is carried out to provide statistical information such as the mean, median, and standard deviation as well as percentages of the variables (Pallant, 2010). While the mean, medium and mode measure the central tendency, the standard deviation value provides an indication of dispersion of the data (Seale, 2005). The descriptive method allows the researcher to "perform validity checks on the samples" (May 2011, p.122). For example, a descriptive analysis performed on selected professionals and their years in practice around the study area provides assurance that respondents are able to discuss and provide information necessary during the development of the solution. For this reason, and mainly, as analysed and discussed in the relevant sections, the quantitative data collected for this study were subjected to descriptive analysis to determine the mean values, standard deviation, and percentage values, to aid the analysis in providing a detailed account of the data for the study. In addition, it enabled the researcher to describe and compare the results both graphically and numerically. Furthermore, the researcher was able to apply further statistical analysis methods to establish relationships and interpretation of the results.

4.5.4 Inferential Statistics

As the name implies, it is used to make inferences from a smaller sample of a larger population in order to make generalisations. Based on the population selected for the study, the aim is to find out information that will help with solution development while meeting research objectives. The main reason for this type of statistical analysis is to draw conclusions from the sample population. Inferential statistics are performed to determine the significance of research findings in relation to the larger population from which the sample was drawn (Sarantakos, 2013). Classified into two key categories - the test of significance and measure of association (May, 2011), the former allows the researcher to analyse the extent to which the results can be generalised from the sample to the entire population while the latter, on the other hand, provides an indication of the level of relationship between the variables.

Although usually used to test hypotheses, they can also be applied when examining research questions and theoretical models of the research (Saunders et al., 2009). The most commonly used tests to determine the level of significance and a measure of the association include Chi-Square, Mann Whitney U test, Kruskal-Wallis tests, Spearman's rank correlation tests and Pearson's moment-product correlation coefficient tests (Sarantakos, 2013; Fellows and Liu, 2008). Although they all fall under different forms of measurement and comparison, for this research, the test employed is the correlation test which allows the researcher to measure the strength and direction of the association between variables. However, for the purposes of this study, the Spearman's rho was used to further make inferences and provide further statistical justification to data analysed descriptively.

4.5.5 Correlation Analysis

Spearman's correlation and Pearson's moment-product correlation coefficient tests provide the basis for which a more precise assessment of strength and direction of the association between pairs of variables can be obtained (Nardi, 2006). Correlation analysis provides the basis from which an accurate assessment of the level of association between variables can be obtained. However, Spearman's rank correlation coefficient is a non-parametric test used to measure the difference in scores ranked on a number of issues by separate different respondents determined through the ranks of observation of the variables (Naoum, 2013; Fellows and Liu, 2008). Adopting this type of statistical test supposes that the data collected for the analysis is skewed and not normally distributed (Naoum, 2013). While Pearson's moment-product correlation coefficient is a parametric test employed if the research is the measurement of the precise strength of the relationship between two sets of scores. Unlike the non-parametric test, the data is normally distributed and measured on an interval or ratio scaled data (Naoum, 2013). The similarities lie in the resulting coefficient interpreted despite the different method in their computations (Saunders et al., 2011). The determination of Spearman's rank coefficient or Pearson's moment-product correlation coefficient ranges from -1 through 0 to +1. A positive relationship is indicated by +1, while a negative relationship is denoted by -1 with the '0' value indicating the absence of any relationship between the variables (Seale, 2005). The closer the coefficient is to 1.0, the stronger the level of association and statistical significance of the association (Nardi, 2006).

Consequently, in order to determine the level of significance and strength of association between the variables, to draw statistical inferences about the wider population for this study, further statistical analysis was carried out using the Spearman's correlation test. The aim of this section of the study was to determine whether there was any statistically significant association or differences in the opinions of the professionals involved in the study. The significance of this test enabled the researcher to measure the level and strength of the relationship between the variables leading to a clearer interpretation (Naoum, 2013; Saunders et al., 2009). Thus, shows the relationship that exists between variables.

Therefore having discussed analytical tools that are used in this research while adopting an open-ended questionnaire, it is important also to discuss the tools adopted for the semi-structured interviews. This is because a combination of both methods will help in understanding the meanings that people ascribe to the occurrences (Gray, 2014). Therefore, a summary of the characteristics of both questionnaire and interview methods of data collection is illustrated in table 4.8;

Table 4.8: Characteristics of Interviews and Questionnaire

Characteristics	Interviews	Questionnaires
Provide Information about	As for questionnaires, but potential for exploring in more depth	Attitudes, motivation, opinions, events
Best at	Exploring stories and perceptive of informants	Testing the validity of a hypothesis
Richness of Response	The dialogue between interviewer and respondent allows for nuances to be captured and for questions to	Questions cannot be modified once printed and nuances of respondent's voice cannot be heard. Long

	be clarified and adapted or improvised. Long interview common	questionnaires rarely acceptable.
Ethics	Interviewers know whom they have interviewed although transcripts can be anonymised	Anonymous questionnaire responses can be assured
Sample Size	With the exception of telephone interviews, less suitable for wide coverage	If generalising to a population, samples often have to be large
Time Cost, Planning, and Design	Devising interview guide, piloting etc., may be less an issue	Devising questionnaires (checking validity and reliability), piloting, etc., may be very time-consuming
Operation	Arranging interviews, traveling, establishing rapport-all time-consuming.	Distributing questionnaire
Data Transcription	Typically 7-10 hours for 1-hour interview	Usually swift, especially where optical readers are used.
Data Analysis	Time needed usually underestimated	Usually swift (unless there are many opened –ended questions)
Money Costs	High if includes interviewers, travel costs, memory sticks and cards, batteries, transcription of digital recordings	Mainly costs of printing, distributing and receiving questionnaires. Looks cheap per questionnaires, but looks more expensive if return rate low

Source: Gray (2014)

Table 4.8 clearly provides features of questionnaire and interview data collection techniques, this, therefore, shows that the disadvantage of one creates an opportunity for remedial thus justifies the need to discuss the semi-structured interview type of data collection.

4.6 Semi-Structured Interview System of Data Collection

An integral part of the second stage of the DSM is to gather as much possible information from professionals knowledgeable with the wealth of experience around the study area. Although open-ended questionnaire was adopted allowing the selected respondents the possibility of providing more details to their answers, a further investigation reduces the biases of a single data collection method. A face-to-face interview method provides the research the needed opportunity to see the impression and make judgement of respondents' answers. Therefore, a semi-structured interview was the preferred method of initial investigation in the study as it provides a guide whilst allowing the opportunity to ask spontaneous questions for gaining further information.

Using this data collection method provides an invaluable reliability for the interviewer to explore and clarify inconsistencies within respondents' account and also highlight the interesting and significant issues raised (Bryman, 2003) . The choice of the semi-structured interview was for the purposes of exploring further the perception and opinions of respondents regarding sensitive issues such as health implication and material durability of the PSB in GF area of the ND. This is to provide further clarification of the required strategy in proffering a solution; however, it requires the researcher listing out themes and areas to be covered, raising questions on the identified themes, and recording their responses. The feasibility of interviews for this research is based on the researcher's direct access to prospective interviewees being professionals based in the study area as identified by their umbrella bodies in Nigeria. The search for respective experts was narrowed down to the years of experience working and living in the study area. The selection of experts through their professional bodies provided a quicker choice, minimising the cost and time spent in the field for collecting data and served as an advantage for the data collection method selected.

Conducting interviews was to compliment the Likert scale questionnaire data collection method adopted as clearly distinguished above in table 4.7 with summaries characteristics of each method. The semi-structured interview system adopted as the best option for this exercise allows the interviewee the opportunity to discuss freely by providing a more in-depth understanding of the research problem within a particular context(Mitchell, 2015). In addition, Bryman (2012) noted that it provides flexibility leading to further questions in response to what was earlier perceived as the substantial reply.

Based on the above, ten (10) semi-structured interview respondents were selected with questions mirroring that of the open-ended questionnaire (see appendix H) conducted for qualitative analysis using content analysis and Nvivo 11 software. Professionals represented in table 4.9 were selected based on their high level of experience and professional engagements both as academics, researchers and practicing professionals in the study area following their acceptance to the request for interview presented to them.

Table 4.9 Selected Professionals for Semi-Structured Interview

Number of Interviews	Types of Profession	Years In the Profession	Affiliation
2	Architect 1 Head of Practice 2 Academia	 20 25	Nigerian Institute of Architects
3	Environmentalist Director of Pollution Control Academia	 15 25	Institute of Pollution Control
2	Quantity surveyor Head of Practice Academia	 20 20	Nigerian Institute of Quantity Surveyors
2	Estate Surveyors Head of practice Academia	 30 25	Nigerian Institute of Estate Surveyors and Valuers
1	Urban and Regional Planners Academia	 11	Town Planners Association of Nigeria

From table 4.9, all selected interviewees had a minimum of 11 years the wealth of experience and professional expertise, which indicates that they had lived or worked in the study area for over a decade and were well aware of GF in the NDA.

The choice of ten interviewees was based on their availability, the length of time it takes to interview one respondent and the need to complete the research. It was also important to get different participation from two major sources; firstly, from professionals in the industry, and secondly, from professionals in academia to enable the research to explicate further to the root courses while understanding ways for possible solution.

Furthermore, the semi-structured survey was considered to be the best data collection option in situations where the objective of the research is concerned with the exploration of feelings and attitudes of participants, in an attempt to gain a deeper appreciation and greater understanding of a particular occurrence (Denzin and Lincoln, 2008; Gary, 2006). Hence Saunders et al.'s (2009) affirmation that interviews based on face-face approach involving one-to-one interactions are significantly beneficial in several ways by providing the real opportunity for record taking and interpretation of a non-verbal communication that allows the interviewee to expatiate on follow up questions.

Notwithstanding its positive insight, semi structured interviews have some notable drawbacks such as the lack of statistical generalisations about the entire population and standardised approach often adopted to elicit information, which in some instances leads to a further lack of rigor and reliability of the findings (Saunders et al., 2009). It is also argued that data collected through such an interview approach may take some time for the researcher to transcribe and in some cases, difficult to code and analyse, especially when they involve a large number of interviewees (Gary, 2006). Again, inadequate probing and long conversation on issues during the interview process can lead to insufficient and superficial responses from interviewees (Castro et al., 2012). These drawbacks necessitated the need to select few respondents with long professional practice and experience in the research and study area. Semi structured interview combines features of both structured and unstructured interview techniques (Cachia and Millward, 2011). Its distinctive advantages and uniqueness make it most suitable for this research. However, the most significant part is the ability to analyse data gathered, as already noted the transcription and interpretation of data depend heavily on the method of analysis used.

4.6.1 Software Adopted for Semi-Structured Interview Data Analysis

According to Saunders (2011), data analysis is a critical stage in data processing because it requires the use of analytical methods and techniques as a tool to attain the goals of the research objectives. Data collected are transformed into files for computer analysis; no matter what form or methods used, they will be transformed into a form appropriate for analysis by computer software built for such purposes (Fowler, 2014) . This software includes computer-assisted qualitative data analysis software (CAQDAS) program such as ATLAS.ti, MAXqda, and Nvivo. Nvivo is the latest of the tools for analysing qualitative research with its roots from a Non-numerical Unstructured Data Indexing Searching and Theorizing (NUD*IST) specifically designed for qualitative data management in the 1980's (Zamawe, 2015).

Every respondent selected was willing to take part in the study and at each interview section, a minimum of 45 minutes and a maximum of 1hour 40 minutes was spent giving the researcher a large set of data to transcribe code and allocate nodes before further analysing the data**.** The large information gathered led to the use of Nvivo for ease through the creation of nodes and themes rather than content analysis with time assuming factor. Thus, limitation of time and completion requirements justifies the use of Nvivo. Therefore, both SPSS and

Nvivo were used to analyse data for the second stage of the DSM, providing extended issues of the impact of GF in the ND not already documented.

Although qualitative and quantitative methods were used for this stage of the research, data collected was analysed differently with different statistical software as already stated. However, the rules remain the same because it is crucial that data collected should be cleaned of possible errors, and omissions corrected, presentation of findings done in both graphical and tabulated format with ease of interpretation, explanation, and drawing conclusions from findings clearly discussed (Waller, 2013). Furthermore, Saunders (2009) noted that paying attention to such steps has the potential to reduce possible errors and reduce the possibilities of misinterpretations leading to the drawing of wrong conclusions from data analysed.

Therefore, for the purposes of this research, both questionnaires and interviews questions were both dispatched and collected by the researcher, inputted into SPSS, codified to reflect each question in the questionnaire and where other themes were generated due to its open-ended nature, new codes, themes and nodes in the case of Nvivo and SPSS were produced to meet such information. Although, Nvivo provides a virtualised structure of information explored in data analysis as an easy way of sharing and communicating data and virtualised through word cloud, word tree, charts, cluster analysis and models.

Figure 4.5 snap shot of the map from transcribed data

Figure 4.5 represents the word cloud analysis showing the virtualised data and information as made prevalent during discussions with interviewees. All information discussed more by each participant is made evident by the conspicuousness of the word or phrase, that is, the larger the word or phrase, the more it was used.

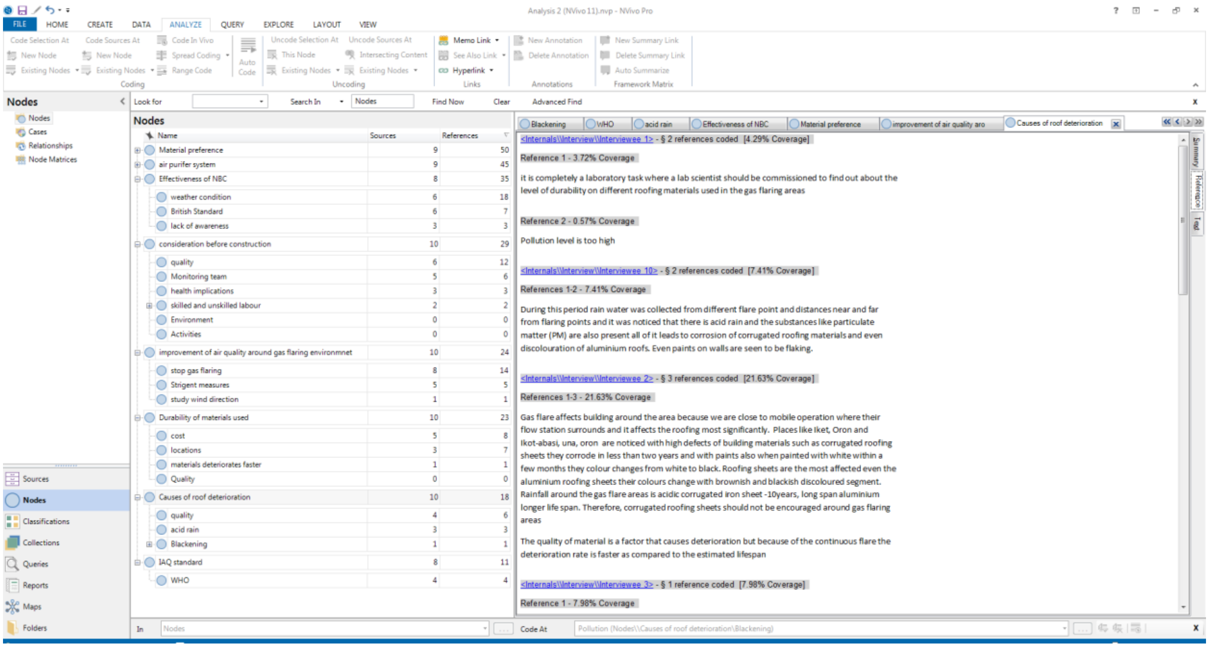


Figure 4.6 shows a snap shot of Nvivo Nodes.

Figure 4.6 shows a snap shot of some nodes created on the left-hand side and analysis based on the query on the right-hand side of the table. The advantages of Nvivo has been categorised into five important responsibilities namely; management of data, management of ideas, possibility of data querying, modelling virtually and reporting data in a more professional way (Bazeley, 2007). Accordingly, Taylor-Powell and Renner (2003) affirmed that the themes have to be categorised into developing and existing. Thus, a mixture of the two types of themes removes any form of bias usually present in qualitative data. Therefore, the research adopted a mixture of both present and developing themes.

4.7 Research Reasoning/Logic

The need to understand the logical underpinning of any research, as well as other research methods and strategies, is important. DS process aims at searching through alternatives following an iterative system until that which satisfies the goal and solution to the problem is achieved. There are different forms of reasoning in DS such as deductive logic, which is the process of inferring particular instances from a general law; inductive logic which involves the inference of a general law from a particular instance. And more recently, abductive reasoning describing the operation of making a leap to a hypothesis by connecting known patterns to a specific hypothesis has been added (Pietarinen, 2006; Walliman, 2011). With deductive reasoning, theory comes first while with inductive reasoning data comes first. Deductive reasoning is effective where objective reasons are the decisive factor. Dealing with research where its primary research study area has obvious problems but lacks empirical evidence than a contextual base of information is required to enhance research. This study deems it logical to use an inductive reasoning where the amount of data collected will prove or disprove research questions. The output of DS constitutes a general solution to a class of problems focusing on 'how' rather than 'what'.

This means that the research will try to understand the perception of stakeholders that carry out construction around such vicinity and criteria used in providing clean indoor air as well as material types used for construction. The inductive approach provides a valid method for gathering information that will help to identify and define required process outlining, defining and developing the solution that could resolve the research problem.

In the ND, there are few types of research documented that could provide concrete information that can be termed as theory and used for research purposes. The use of this reasoning provides an exploratory view of the problem from the beginning. Thus, the choice of selected professionals in the environment will provide information that will be used to refine required solutions.

4.8 Justification of Selected Research Method

Many research works in the BE have relied on methods such as case study, which investigates in detail one specific case of the general phenomenon under investigation. Thus, painting a rich picture of a single object or situation as a basis for obtaining a deep and comprehensive understanding of some general phenomenon (Johannesson and Perjons, 2012). However, the ethnographical study requires the researcher to be part of the story she is trying to tell or researching on (Pink and Leder Mackley, 2014). Whereas, grounded theory is an inductive approach involving a systematic set of procedures to arrive at a theory about a social process (Charmaz, 2011). Its usefulness is based on the transferability of theories from one study to another (Toles and Barroso, 2014). However, action research requires the researcher to introduce a method or technique in solving a practical problem in an environment 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 an alternative future.

In research areas dealing with practical problems or issues that are close to the industry, using other research methods exclusively (i.e. surveys, observation, interviews) leads to unsatisfactory and low results (Lukka, 2003). However, alternative research methods could provide the key to solutions that impends solution based research that deals with real problems (AlSehaimi, et al. 2012). Furthermore, (Lukka, 2003) also mentions that to confirm the research, and identify whether a certain solution or hypothesis really works, is to test the idea in the field with practitioners. It is extremely difficult to validate such research by the mere distribution of questionnaires or collecting data through surveys. The DS approach believes that there is the need to find out what can actually solve a problem through its iterative process illustrated in a real world by the interference of the researcher.

Again, the phenomenon base of other research methods excludes the DS method as this is left to the researcher to create its own artificial phenomenon (Holmström, et al. 2009) . Although, the artefact produced is mostly the goal of both theory builders and the natural scientist as illustrated in table 4.10, the artificial phenomenon base of DS shows the ability of the researcher to design/produce something that will solve real life problem.

Table 4.10 Exploratory and Explanatory Research

Distinctions	Exploratory (Design Science)	Explanatory (Theoretical/Naturalist Science
The phenomenon	"artificial phenomena" have to be created by the researcher	"out there"
Data	created, collected, and analysed	collected and analysed
End product	solving a problem	explanatory theory, prediction
Knowledge interest	Pragmatic	cognitive/theoretical
Disciplinary basis	engineering, fundamentally Multidisciplinary	natural and social science, primarily uni-disciplinary

Source: Holmström, et al. (2009)

Following exploratory process of DSM at shown in table 4.10, it is evident that the objectives of the research requires a methodological position which is problem solving rather than relying on a philosophical position.

4.9 Design Science and other Approaches

The relationship that exists between DS and other strategies provides added justification of the choice of DS. As stated by Simon (1996) it deals with how things ought to be in order to attain goals and to function. Furthermore, Johannesson and Perjons (2012) affirmed that DS allows the integration of other strategies. This is because it is not an approach of its own but a method that provides the solution with the help of other strategies, approach, and methods used in schools of BE, which includes case study, action research, ethnography and grounded theory.

4.9.1 Case Study

Yin (2009: 18), defines case study as "*an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*". Accordingly, Yin (2013) affirmed that the unclear phenomena have existence and can be used to explain the functioning of the clear phenomenon. In other words, an existing phenomenon is explored either in a single and multiple case studies. This definition provides an opportunity for researchers to explore a particular problem statement within a local context. However, Flyvbjerg (2006) noted that it is hardly a methodology in its own right but subordinate to surveys of larger samples. The good thing about the case study approach is that it can be combined with other research methods.

Case studies are useful where there are needs to understand some particular problem in great-depth with the identification of study areas rich in information (Noor, 2008). Further investigation into this strategy reveals that Case study research can be single or multiple; case studies, can include quantitative evidence, rely on multiple sources of evidence and benefit from the prior development of theoretical propositions (Bryman, 2012). This method follows the philosophical stance and reasoning supporting the use of qualitative, quantitative or mixed methods. It is an in depth exploration of a study, bounded by time and activity where detailed information is collected using a variety of data collection procedures over a sustained period of time (Stake, 1995 as cited in Creswell 2013). This, therefore, leads to the availability of so many variables, which might become difficult and time-consuming and in the case where such research is dependent on time, the probability of analysing all the variables becomes an issue that needs a cognitive reasoning of the researcher. However, (Gray, 2014) opined that case studies explore subjects and issues where relationships may be ambiguous or uncertain. He added that the method is very useful where the researcher is trying to discover the connection between an occurrence and the environment in which it is occurring.

It provides leading evidence by directing an environment specific study rather than relying majorly on theories. Furthermore, Lukka (1999) referred to the case study as an isolated method because it is seen as one distinctive mode of research neglecting the option that different sub-methods can be distinguished under the case study umbrella. Therefore, because of the possibility of providing an understanding of the root causes of the main problem in the research, it gives this strategy a probable synergy for this research, thus complimenting the DS method adopted.

4.9.2 Action Research

Action research (AR) is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives (Stringer, 2007). It provides a logical solution to a particular problem in a particular context and pursues its aim. Thus, Greenwood and Levin (2006) noted that AR is a social research carried out by a team that includes a professional action researcher and the members of an organization, community, or network ("stakeholders") who are seeking to improve the members' situation. It is a logical inquiry into a problem faced by an organisation seeking to provide a specific solution. Furthermore, AR aims to contribute both to the practical concerns of people in an immediate problematic situation and to advance the goal simultaneously (O'Brien, 2001) . He further noted that with AR, there are twin obligations to study a system and simultaneously to work together with members of the organization in changing it to a vital path. The importance of this type of approach is that the researcher becomes the enabler rather than the external professional (Devins and Gold, 2002). The purpose of undertaking AR is to bring about change in specific contexts.

Unlike the DS method, AR focuses on problem-solving processes or group dynamics in a specific problem situation without an explicit development of artefact (Beer, 2003). Although there are similarities between both approaches, AR must explicitly focus on the design and implementation of a means to an end to be considered DS (Allen, et.al., 2000). It is a research done with people not on people (a research through practice), dealing with a specific focus. Nevertheless, like DS, evaluation of its solution is intrinsic as compared to other strategies where evaluation is optional. However, the difference is with the AR, the solution should be a means to an end where the researcher has to be part of the organisation that requires the solution.

4.9.3 Ethnography

According to Whitehead (2005), ethnography is a holistic approach to the study of cultural systems. It is the total understanding of a culture or society and their way of life. It can be defined as both a qualitative research process or method and the product whose aim is cultural understanding (Randall, et al. 2007). This research approach allows the researcher to go beyond reporting the events and providing details of experience (Hoey 2000-2015). It seeks to develop systematic, generic understandings and propositions about social processes (Snow, et al. 2003). Also, it is a systematic understanding of a social process and includes the historical knowledge and underpinning of the actual existence and occurrences of the way of life in such society (Whitehead, 2005). Notably, (Reeves, et al. 2008) affirmed that the fundamental aim of ethnography is to provide rich, holistic insights into people's views and actions, as well as the nature (that is, sights, sounds) of the place they populate. This is the collection of detailed observations and interviews.

The personal encounter and interaction between the researcher and the society in which the study is undertaken as an insider are with the aim of understanding reasons why events occur; thus giving the first-hand knowledge rather than depending majorly on secondary data. Although the researcher might immerse herself deeply into the society under study, in most instances it affects her judgment which becomes a defect to this approach (Iloh and Tierney, 2014) . In addition, this type of research strategy has been said to be problematic due to the long periods of time a researcher will spend talking to participants and observing actions. In addition, it can be difficult to secure repeated access as depicted by (Reeves, et al. 2008). This becomes a setback if the research is time specific with limited resources.

4.9.4 Grounded Theory

The foundations of grounded theory (GT) are embedded in symbolic interactionism, which assumes that one's communications and actions express meaning (Byrne, 2001). It is a research strategy that is grounded by data collected. With this method, the theory is not chosen before the commencement of research, rather it is an outcome from data collected (Corbin and Strauss, 2014). This has led some researchers to associate GT to an inductive system of reasoning (Borgatti, 2005; Thomas and James, 2006). However, (Charmaz, 2011) submitted that GT adopts inductive kind of reasoning at first for data collection and analysis to build middle-edge theories and then uses abductive reasoning because where there are surprising findings in inductive reasoning, GT researchers try to use other means available to back their theoretical findings.

Although, grounded theory is an iterative method just like the DS method, its comparative nature of going back and forth between data collection and analysis until a saturation point is reached makes it different from the DS science method. This is because the DS method requires a creative mind, which allows the researcher to be imaginative in proffering solution to a real life problem. Again, while DS can adopt other approaches as a means to derive a solution to its problem, GT relies mainly on qualitative techniques for theory testing or development. The process of providing systematic submission by either disproving or approving findings requires an imaginative system to push forward the creative mind of a researcher.

The need for a more holistic and advantageous research approach is required if the BE researcher intends to reduce dependence on a positivist stance (Knight and Ruddock, 2009) . In another submission by (Aken, 2004), the use of prescription-driven methods used by both Information Technology and Engineering rather than description-driven research approaches provides more valid and reliable solutions to problems. Finding a research strategy that can provide the solution to a problem in a real context puts the BE researcher alongside other researchers from other disciplines in solving real life problems.

4.10 Design Science (DS)

According to Hevner (2007), DS is the process of organising, defining and solving problems, of formulating a goal, and is a systematic part of reaching that goal. It is the scientific study and creation of artefacts developed and used by people with the goal of solving practical problems (Johannesson and Perjons, 2012). This is to say that the final research output when using the DS approach is an artefact. The artefact has been defined as "something created by humans usually for a practical purpose" (Artefact, 2010). Due to its uniqueness and recent exploitation by different disciplines, different terminologies have been linked and used to connote it. For instance, Lukka (2003), and Järvinen (2007) refer to the artefact as the construct, construction, future research, design, mode, methods, and social system. Its aim is to design, build, and change, improve, develop, enhance, maintain, extend, correct, adjust, and introduce solutions to real life problems. This method proffers a solution for a recognised problem and represents its solution in a practical environment. The divergence between what is being practiced and what is researched creates difficulties that make it almost impossible for research outputs to be used to solve observed problems.

The DS likes to envisage the world where, although the environment might be polluted, adequate facilities are put in place so that the adverse effects do not have any social, economic, financial and environmental impact on people. It is a hybrid of practicalities, which is the ability to understand the problem to be able to develop technical knowledge which is the ability to develop a solution base that predicts and controls adverse actions in reality (Barab and Squire, 2004) . DS provides answers to design questions with the aim of designing to sustainability standards through a multidisciplinary integration of disciplines and methods used for actualisation (Cross, 2006; Reich, 2013; Hubka and Ernst Eder, 1987). According to Lukka (2003), the interaction between practitioners and academics, and their trade-off of information and designs is a natural part of the study progression.

Due to its multidisciplinary system of problem-solving, it adopts both forecasting and back casting methods for solutions (Robinson, Burch et al. 2011). However, Riedy (2009); Slaughter (2009); 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 has been criticized by researchers for its limitations in terms of implementation - the 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 DS to explore and propose changes on larger scales for developing prototypes on the basis of lifestyles rather than basing the speculation on technologies only. In this regard, all stakeholders, including the researchers, are significant factors inherent in the achievement of research goal(s). Accordingly, Simon (1996) noted that DS is about how things have to be in order to fit certain design standards for efficiency. It adds an alternative which applies a strong, problem-solving type of intervention and an intensive attempt to draw theoretical conclusions based on the empirical work (Lukka, 1999). Even with all its advantages and prospects, Johannesson and Perjons (2012) affirmed that it is not another research strategy but a method which uses a holistic approach to problem-solving in other to achieve a specific goal by means of the creation of an artefact.

The fragmentation of other strategies brings to the fore visible potentials inherent in DS as a synergy infusing together a solution-based in collaboration with other approaches. Moreover, its uniqueness is its ability to create and implement a solution that is able to influence or modify a particular occurrence. Furthermore, (Van Aken, 2005) submitted that the core mission of DS is to develop knowledge that can be used by professionals in the field in the quest to design solutions to problems. Similarly, Meyer (2003) argues that diversity is a positive attribute and ensures the continued viability of different fields in a rapidly changing environment. The need to adjust and provide solutions requires a constant diversification and exploration of other methods used as a solution provider. It is a strategy that complements other strategies whether it is quantitative and qualitative in nature.

The increasing use of DS as a solution for real life problems in the sciences, engineering and even in the arts shows the uniqueness. It is a method that could provide a solution to the air quality and building durability in a polluted environment like the ND. Its uniqueness allows a combination of other research strategies and approaches to solving a practical problem hence the adoption of both case study and mixed methods as a synergy in providing needed solution in this research.

4.10.1 Design Science Characteristics

According to Van Aken and Romme (2009), the prominence of DS lies in research questions driven by field problems, solution-oriented knowledge linking mediations to outcomes and proving that the actions based on the knowledge really produce anticipated outcomes. Effective problem identification, construction/building of artefacts and evaluating their effectiveness in real life are its core activities (Venable, 2006). Consequently, Järvinen (2007) summarised the essential characteristics of DS as follows:

- Its products are assessed against criteria of value or utility;
- It produces design knowledge (concepts, constructs, models, and methods);
- Building and evaluation are the two main activities of DS;
- DS research is initiated by the researcher(s) interested in developing rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people;
- It solves construction problems (producing new innovations) and improvement problems (improving the performance of existing entities);
- Knowledge is generated, used and evaluated through the building/construction
- DS is the design and investigation of artefacts in context.
- DS iterates over solving design problems and answering knowledge questions.
- The social context of a DS project consists of stakeholders who may affect or be affected by the project.

- The knowledge context consists of knowledge from natural science, DS, design specifications, useful facts, practical knowledge, and common sense.
- Generalizations produced by DS research are the middle range. They may be abstract from some conditions of practice but do not make unrealizable idealizations. They generalize beyond the case level but are not universal

4.10.2 Design Science Process

Literally, all DS literature is filled with recommendations on how the process should progress starting from problem identification all the way through demonstration to evaluation of proposed solutions. These recommendations are compared in table 4.10 as it seems that these recommendations are the problem based solving cycle. Though submitted by (Aken, 2004) have been updated to meet present study with inclusion of selected framework adopted. This comparison provides us with the choice of a process adopted for the purposes of this research.

Table 4.11 Design Science Process at a Glance

(Takeda, Veerkamp et al. 1990)	Nunamaker et al. (1991)	March and Smith (1995)	Vaishnavi and Keuchler (2008)	Peffers et al (2008)	Johannesson and Perjons, (2012)
Enumeration of problems	Construct a conceptual framework		Awareness of problem	Problem Identification and motivation. Define the objectives of a solution	Explication of problem
Suggestion Development	Develop a system Analyse the designed System Build the System	Build	Suggestion Development	Design and development	Outline artefact and define requirement
Evaluation to confirm the solution Decision on solution to be adopted	Observe and evaluate the system	Evaluate	Conclusion Evaluation	Demonstration Evaluation	Design and Develop artefact
				Communication	Demonstrate
					Evaluate Artefact

From table 4.11, different processes have been outlined by different authors according to their submissions and interpretation of the DS process.

It is clear that the most important things with DS processes are the identification of a problem and the development and evaluation of the artefact. Although March and Smith (1995) are of the opinion that DS consists of only two activities highlighting the demerit of inadequate understanding of the environment for which the artefact is intended, they maintained that it can result in unsuitable designed artefacts with unwanted side-effects. Incidentally, this disagreement in their opinion is the main reason for initial problem explication providing the root causes of the problem and giving the solution a leap way. Three and four processes were identified as means to a solution using the DS process as submitted by(Takeda, et al. 1990) and as listed in the table. However, this research adopts (Johannesson and Perjons 2012) framework with the five-step process. This is because it is found more suited for the research and also provides current research advancement in the DS methodological process.

This five-step process starts from problem explication, through outline artefact and define requirement, design and develop artefact, demonstrate artefact and finally to the evaluation of the designed artefact as illustrated in figure 1.2 of chapter one. The adjusted framework adopted as proposed by(Johannesson and Perjons, 2012) has its process divided into five separate blocks as compared to two, three and four blocks submitted and represented in table 4.11. Each block provides a defined goal achieved as a prerequisite to the next block and to the final evaluation block.

The explication of the problem is the first block and the first real step taken after the initial problem has been observed and identified. The difference between the initial problem phase which is the precedent to the explicated problem is because most initial problems might not be researchable and root causes need to be identified. Although the diagrammatical representation of the adopted DS process looks straight forward, the iterative process implored to achieve the desired goal makes it a more suitable process to adopt. Therefore, juxtaposing the above framework into the research problem in focus, the steps have been individualised as a separate block linked together at the end to provide a stage-by-stage clarity of a problem and solution process.

4.10.2.1 Explicate problem

The first step of the DS process is to clarify the problem; notice that before the explicated problem box there is an initial problem conception, which might not be clear enough. The purpose of this section is to reduce or eliminate any ambiguity, motivate its importance and to investigate the root causes. It addresses the question: "what is the problem experienced by some stakeholders of a practice and why is it important?" (Johannesson and Perjons, 2012). That is, a general view of the initial problem as reported. Although answers could be descriptive or explanatory knowledge, initial problem identification includes literature reviewed, other written sources and information from relevant stakeholders.

The adoption of a research strategy that will help define precisely the problem with reduced misrepresentation and interpretation is required. In trying to precisely define the problem, a research sub-phase was identified and literature review was carried out. The relevance of an initial literature review as observed by Neuman (2007) identified four goals to the literature review, namely:

- To demonstrate familiarity with a body of knowledge and establish credibility.
- To show the path of prior research and how a current project is linked to it.
- To integrate and summarise what is known in an area.
- To learn from others and stimulate new ideas.

The problems identified in the NDAN show that PSBs are designed and constructed based on the NBC, which has no environmental or geographical performance requirement and specification for designing schools in GF and air polluted environments as that of the ND. Furthermore, it was also observed that open ventilation systems through windows and doors are the main sources of indoor air in such vicinities.

Therefore, in the context of this research, literature review was initiated to meet some of the objectives of the research, which tries to answer some of the research questions posed.

However, most developed and developing nations with environmental pollution problems design and build schools with the help of PS clearly stipulating all performance requirements to be achieved by each material type or construction type as discussed in chapter 3. Yet there is no defined PS used for the design and construction of schools in air polluted environments of the ND.

Information necessary to completely explicate the problem includes discussions on general material types used for construction and ventilation systems, as well as, guidelines that determine IAQ. Assessment of the NBC code used as a yardstick for PS for designing and constructing PSBs in the GF areas of Nigeria was reviewed. However, information from literature was limited and found lacking in many criteria necessary to meet the research objectives. It is, therefore, necessary to explore mixed methods using both open-ended questionnaires and semi-structured interviews of professionals domiciled in the research area for information gathering. This assessment provided evidence that the problem posed in this research has not been solved by both academicians and professionals in the study area, and thus offers the opportunity for further research in this area.

4.10.2.2 Outline Artefact and Define Requirement

Having explicated the problem, the second step following the DS approach is to outline and define requirements. It could be referred to as further explication of the problem (Johannesson and Perjons, 2012) but in this instance, the question to be answered specifies requirements that will suit the artefact that meets stakeholders' needs. The performance of the artefact in the environment for which it is designed justifies the expectation of the desired outcome. Firstly, outlining the artefact means describing the types of artefacts, which include construct, model, method, and instantiation. Constructs are defined as "concepts" and "conceptualizations" (Vaishnavi and Kuechler, 2007) while Kolfschoten and De Vreede (2009) denote it as "vocabulary and symbols". Construct could be seen as the notion which provides the language, in which problems and solutions are defined and communicated (Hevner and March, 2003). They explain that it refers to the terms is used when describing and thinking tasks. Its importance bears on the significant impact in which tasks and problems are conceived because the working design of an artefact consists of a large number of things and their associations (Kuechler and Vaishnavi, 2008). Thus, the initial idea around a piece of research is usually refined all through the design phase leading to the creation of a solution.

Models can also be used to describe potential solutions to practical problems; it could be an informative tool used to represent the current situation and explain challenges that occur (Johannesson and Perjons, 2012). It is a problem and solution statement, providing relationships between constructs. The DS model may need to capture the structure of reality in order to be a useful representation of a structured performance. While this is so for a model, the method as a type of artefact in DS approach is a set of steps used to perform a task. Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space. They are often used to translate one representation into another in the course of solving the problem. Methods are guidelines and procedures that help people to work in systematic ways when solving problems. They are goal directed plans manipulating the construct for the solution model to be achieved. And finally, instantiation, also known as, implementation shows how well the artefact performs in the environment it is made for; in order words, the realisation of the artefact in its environment.

Instantiations operationalize constructs, models, and methods. However, an instantiation may actually precede the complete articulation of its underlying constructs, models, and methods. Instantiations demonstrate the feasibility and effectiveness of the models and methods they contain. Although these four types of the artefact have been defined by most DS model/framework developers, Johannesson and Perjons (2012) further add that artefacts could also be new properties of technical, social, and/or information resource. Therefore, the artefact produced should not necessarily fall under the definition of a construct, model, method or instantiation. The artefact created enables the representation, analysis, understanding, and development of a successful structure within an environment hence, a further justification of the framework adopted and discussed in section 4.8 and 4.10.

The type of artefact chosen determines the effectiveness of the solution posited. Following the description of the different types of artefact, this research is formed under the instantiation of adaptive PS that is an integration of existing standards and requirements used in developed countries for clean IAQ and durability of the external façade of a building envelope. Although they do not particularly deal with GF, the composition of chemicals emitted in such environments is the same as that of the ND although not necessarily in the same volume of emissions. Yet, they have been used to reduce corrosion and poor IAQ around air-polluted environments as discussed in chapter two of this research. Hence, it provides reliability and viability of the research outcome through evaluation of instantiations considering the efficiency and effectiveness allowing for Professionals' input into the realisation of the effectiveness of the artefact in solving an existing issue.

Having outlined the artefact, defining the requirement depends on the characteristics of the problem. Therefore, any study that has been done in relation to the research problem, its individuality, and documented solutions available and proper representation of all stakeholders including end users, is required. According to Courage and Baxter (2005), the single most important activity in developing a quality artefact is a thoughtful consideration of who the users are and what they need and documenting it. Again, knowing that PS-based design and construction require the building constructed to meet certain expectable performance requirements, an in-depth understanding of the requirement is significant. The need to sample the views of professionals in the study area is crucial, bearing in mind that the designed output must either solve a problem that has not yet been solved or provide a more effective solution (Johannesson and Perjons, 2012). Therefore, both the construction and evaluation must be done rigorously. This is to maximise the effectiveness of the output from inception, while engaging users of the PS to assist in designing the final product thus, creating a balance of stakeholder's involvement in the whole process. This creates a more collaborative process; an avenue of an awareness of a possible solution to a problem.

Defining requirements for the development of an artefact requires a choice of research strategy and method. As noted in section 4.8 on the justification of the research method, a case study, and mixed methods research was adopted as suitable strategies. The case study defines the area of study, and the mixed method adopted was through qualitative and quantitative studies involving an open-ended questionnaire and interview techniques Respondents selection was based on their relevance to design, construction and health issues in the NDAN.

A Design Science and Case Study

Although case study and DS have been discussed in chapter four of the research, an integration and clear explanation of both methods for the stage of the research is necessary. According to Johannesson and Perjons (2012), case studies offer opportunities for investigating stakeholder needs and requirements as well as their practice in greater depth over an extended period. In addition, they noted that a researcher could categorise requirements even if a stakeholder does not explicitly state them. Again, their real-life holistic nature makes them particularly suitable for exploring a wide range of complex societal issues, processes and their interrelationships (Carcary, 2009). Since the boundary between phenomenon and context are not evident, as noted by (Yin, 2009), the case study approach is best suited for the DS method adopted.

In this regard, over 9000 public primary schools built in the ND area of Nigeria (NBS, 2016) were selected, providing a guide for participant stakeholders in the dissimilation of information that will help in furthering the explication of the problem. This in return forms the breakdown for the development of an artefact, which then becomes the solution. It also grants the researcher the opportunity to define the requirement without heavily relying on literature that might not fit into a local context like that of GF and the ND.

B Method of data analysis for Outline Artefact and Define Requirement

Following the DSM selected for this research, the adoption of the most fitting research strategy to produce the required answers or further understanding of the research problem is crucial. As already discussed, the complete understanding of a real life problem is set towards the actualisation of a solution.

Based on this and the background of the researcher, the choice of mixed methods was made using an open-ended questionnaire with a 5-point Likert scale system in this phase ("1" representing the "best" and "5" the "worst"). However, an opportunity was created in the questionnaire where respondents could provide information not covered (Appendix G).

4.10.2.3 Design and Development of the Artefact

According to Johannesson and Perjons (2012), it is the third step in their DS process used to create a design that addresses the explicated problem and fulfils the defined requirements. This stage is described as the search process through a solution space (Simon 1996). Having explicated the problem, outlined and defined requirement, it is pertinent that the solution should be created. Here, both knowledge from literature and opinions made by professionals during the requirement stage should be explored and used to create a solution.

Again, according to Johannesson and Perjons (2012), this stage requires a creative mind and innovative measure to enable the development of a solution. It is the integration or a combination of using, reusing and adapting actualised solutions used in the past in a more innovative way. There are different approaches in generating or providing a solution although the ability to design a solution depends on the researcher, as observed by Louis Pasture (1854) as "*chance only favours the prepared mind"*. Therefore, following the exploration of PS as a solution to the research problem, as already discussed in chapter 3, the possibility of combining, using, reusing and adapting components from a different environment to provide an effective solution, makes it an innovative system. Furthermore, other reasons behind the choice of the design of a PS include the following;

1. The research has clear aim, objectives, and solution
2. The research requirements are unchanging during the design and development of PS
3. The target users are BEPs working and resident in GF areas of the ND and are fully knowledgeable about environmental hazards due to GF.

4. Considering the research focus, timeline, resources and the background of the researcher, the design of a PS is integrated into the entire research methodology process.
5. The different guidelines, criteria, and specifications provided by developed countries, their environmentally specific consideration for materials and indoor air provide a strict requirement already in existence.
6. It is an encapsulation of a refined and updated process of achieving the solution.
7. The researcher's experience and observation of deterioration in the ND over the past decades.

4.10.2.4 Demonstrations

Having designed and developed the PS, it is imperative that the designed solution solves the intended problem. The demonstration stage also referred to as the proof of concept stage, is the fourth stage. Here the main goal is to determine how the developed artefact can be used to solve the explicated problem. According to Pries-Heje (2008), the principal aim is to determine how well the artefact works, not to theorize about or prove anything about why the artefact works. Similarly, Johannesson and Perjons (2012) referred to this stage as a weak form of evaluation. The ability of the designed PS to solve a problem in a real life scenario provides a proof of concept required of the DS method. Although this method centres on conditional prediction (Peffers, Tuunanen et al. 2006), its purpose is to show that the solution is functional and provides a communication avenue to the intended audience in a comprehensive and convincing system.

The functionality of the designed PS is through the use of the case study approach although other approaches such as action research have been reported to also be effective forms of demonstration (Johannesson and Perjons 2012). Based on the case study approach adopted, selected professionals as listed in table 4.6 were required to indicate their opinions or suggestions effectively by showing that the designed PS can solve the problem. The demonstration stage allows the researcher to gather information from willing end-users or experts in the study area. The choice of experts is because of the consideration of cost, time constraints and appropriateness of the method when choosing a demonstration method to any task (Fathi, 2009). Although both qualitative and quantitative research strategies could be used and in this case, a quantitative technique though open-ended questionnaire was adopted, this gives the opportunity to adjust the designed PS to suit the environment based on professional opinions through three iterative processes.

A Method of Data Analysis for Demonstration Purposes

Unlike the outline and define requirement stage, the demonstration phase adopted a more robust option of a 6-point Likert scale point system. This was to give respondents the opportunity to clearly state what their take is on the options provided. Furthermore, it allows the researcher an opportunity to cross examine information provided if it clear, concise and easily understood and interpreted to provide needed answers.

Although, A 5- point Likert Scale point system is mostly used, Remenyi (2012) affirmed that most Likert scale questions are based on odd number sequence, however MacDougall et. al 2003 affirmed that both even and odd number system can be used for Likert scale questions as any scale can have any number of points with or without a midpoint.

The 6-point Likert scale questions were designed (See appendix I) to make provision for an option giving respondents the opportunity to provide further insight into their choice to an option. This, therefore, further gives the researcher a better insight on how well the designed PS will be acceptability and effective to solve problems explicated.

4:10:2:5 Evaluation

Evaluation is the fifth and final stage of the DSM adopted in this study. It is important that every requirement built into the PS should be evaluated with selected professionals expected to test the functionality of the PS. It is the fundamental aspect of DS, were experts in the field appraise the output, in this case, a PS.

The quality of the PS depends on the depth of the evaluation process, hence the choice of the evaluation method is crucial to the testing of the solution. Although different evaluation methods exist, table 4.12 provides a summary of some of these methods.

Table 4.12: Types of Evaluation Methods for DS

Evaluation Method	Advantages	Disadvantages
Questionnaires	Potentially big data sets. Multiple-choice questions are better for providing statistics, but you do need enough people to complete them for the statistics to mean anything.	Questionnaires do not tend to access the underlying reasons for responses. Only interested people will respond. Answers will be limited to pre-chosen questions (unlike interviews).
Interviews	Great to understand different people's experiences of being involved. Allows you to	Interviews can be staff intensive. There is a limit to how many interviews

	explore in-depth reflections, and can uncover surprising findings.	you can conduct, so you might end up with small numbers. You can end up with a skewed sample.
Observation	Useful for studying and gathering information on an activity (what happens, what someone does or how they behave). Uncovers what people really do, rather than what they say they do.	Only useful for some participatory and interactive projects. Observations can be very subjective: a template should be generated outlining the activities to be recorded.
Walk and talks	A 'go along method' which involves both walking and talking, can be particularly useful for evaluating location based projects or activities e.g. festivals or exhibitions.	These can take the time to organise, conduct and analyse. There is a limit to how many walking interviews you can conduct, so you might end up with small numbers participating.
Focus groups	Useful for organised discussion with a group of individuals to understand their views and experiences of a project. More qualitative information than a questionnaire will provide you and will take less time than administering several individual interviews.	Focus groups require good mediation. As it is an open-ended process, you may not get the precise answers that you would expect from a questionnaire or interview. The size and composition of the group are important considerations.
Personal logs (diaries, log books, reports)	This can take many shapes or forms. Personal logs that are kept throughout a course of a project can provide evidence of personal development, behaviour, thoughts, and feelings.	The value of the information collected depends on how truthful it is. They are unpredictable, some will provide lots of information; Others will be brief and uninformative.
Workshops	It is an excellent, interactive way to understand different peoples' opinions and experiences of a project. It is also a useful tool to provide participants with the chance to challenge the agenda set by the project leader; raising new issues and/or asking questions back.	As with focus groups, workshops require good mediation. Openness and honesty: if undertaken as a group exercise looks out for shy individuals who may feel intimidated by the situation and require encouragement.
Creative	It is an excellent visual way to	The information you

Methods Drawing is a natural mode of expression. It is a nonverbal Language and form of communication that can be analysed for structure, quality, and content.	understand different peoples' opinions and experiences of a project. Creative methods can be very attractive, providing a focus for discussion.	obtain will be unpredictable. You will not get precise answers, compared to what you expect from a questionnaire or semi structured interview.

Source: Hevner, (2007); Johannesson and Perjons, (2012); Peffers, et al., (2012)

Table 4.12 shows types of evaluation methods that can be used for DSM. It clearly shows that all methods have both advantages and disadvantages, which means that no one method is the best fit. However, it is left to the discretion of the researcher, based on her ability, to select a method that can provide the required information necessary to justify the solution designed.

The approach selected should be the best suitable for the research because the final step is, very crucial for the DS method (Hevner, 2007) . Therefore, for the purposes of this research designing a building based on PS shows its achievability. Although different fields of studies interpret pilot design/studies to mean different things, some see it as an offset of the main study, providing a justification for a further study. Providing drawing shows, to a large extent, the validity of the specification designed. Although the PS focuses on how the building should be built, the drawing or building plan focuses on what to build and therefore there is a vital communication inherent in both the PS and building plan. Different disciplines, such as the engineering profession, see drawing as a proof that the system works in a large scale development (Pahl and Beitz, 2013). This is adopted as an effective evaluation base for the designed PS.

The most important point in any design is the possibility of representing it in diagrammatical or pictorial format, making a real life interpretation possible. With the current use and development of architectural software, design based on PS is as good as that physical representation (Gao, et al. 2005, Isikdag, et al. 2012). Here the point is the realisation of the PS in the form of shape and appearance referred to as drawing or building plan. The usefulness of this type of evaluation method is to provide an architectural drawing showing the efficacy of the study. The benefits of this type of evaluation process include, but not limited to, time and money constraints. In addition, it allows the experts, on whom the use of the designed solution rests, to provide an innovative solution base represented in the drawings. Furthermore, it allows the possibility of refining the designed PS, which also gives more justification to the iterative process in the DSM.

4.11 Summary

This chapter examined different philosophical stances, associated with research strategy and approach. The section also elaborated on different research methods and strategies narrowing down on the adopted method, the DS process, as submitted by Johannesson and Perjons (2012). A brief discussion of the five block represented in figure 4.4 will be discussed further in the next chapter with its integration into the research study approach clearly established. Starting with an overview of the explication of the problem discussed in chapter two and three. However, the shortage of literature from the study area necessitated the need for collection of data informing the development of a solution to the research problem. A combination of different strategies and approaches in the DSM chosen is aimed at providing the needed information to enable the design of PS for the design and construction of PSBs in GF areas of the ND and forms the focus of the next chapter.

CHAPTER 5. OUTLINE AND ANALYSIS OF DESIGN REQUIREMENTS

5.1 Introduction

The chapter reports on the both the quantitative and qualitative data carried out in the study area. The chapter is presented in three main parts following the sequence of the process from the adopted framework as represented by Johannesson and perjonss 2012 and used for this study. First the general recap of explicated problem which formed the first blocks in the framework. The second block which is in two segments requiring an outline of the artefact which is the solution to the problem under study and the analysis of the design requirements. This, in other words, represents what is referred to as further explication of the research problem. The essence of this chapter is to try to remove every dispute from the assumption that GF has no impact on both the building façade and the health of the school children while providing information that is lacking in literature in the study area.

5.2 Explicated Problem

Although most people think that design has to do with the functional and aesthetics alone, Garrett (2010) argues that it might lead to failure. There is, therefore, the need to clearly define state and communicate the expectation of the design. "Design" means more than a just order of some sort, it goes beyond styling and the surfaces of products, it is both a process and an outcome from the process (Lawson, 2006). Nevertheless, the functional and aesthetics of the finished design will confirm the efficacy of the process. For the purposes of this research, the design aspect is the process that targets users whose requirements need to be identified very carefully at the beginning of the design process (ISO 9241-210, 2010 and Maguire and Bevan, 2002). Designing a PS for an environment prone to continuous pollution due to GF requires an interaction between professionals in the environments in addition to laws, regulations and building codes around the world that improve on the external facades and provide clean IAQ.

Liaising with the users of a PS gives a clear outline of the solution and provides a clear definition of terms needed for a clear understanding of the requirements. That is, providing the essential feature attributes that the designed PS should have to fulfil its purpose. To achieve this, there is the need to gather information such as the identification of professionals and specification requirements to generate requirements based on the information gathered, PS is designed to suit requirement.

.For the benefit of the DS process adopted is it pertinent that the initial problem identified through already reviewed literature should be recapped. Thus, a diagrammatical representation is shown in figure 5.1

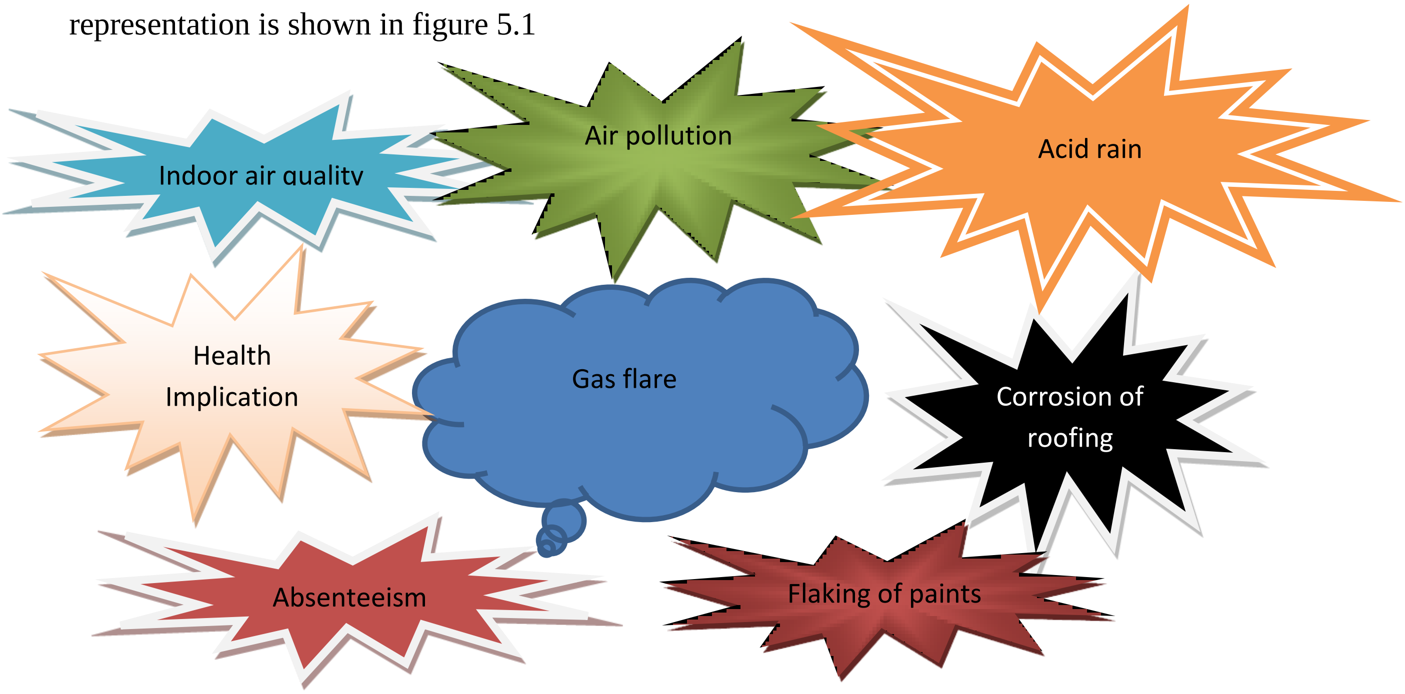


Figure 5.1 Initial Problem of Gas Flaring in the Environment
Source: Author

Figure 5.1 shows, from the physiological interpretation of the researcher that GF in the study area leads to air pollution which causes acid rain and affects IAQ degenerating into building deterioration and negative health implications. Further insight into causes of the initial problem showed from the literature that residues from anthropogenic gases flared into the atmosphere are the main factors that result in the initial problems. These residues are represented in figure 5.2 as combined substances causing both deteriorations of buildings and health effects of the occupants of public schools. Yet, major oil exploration companies have constantly refuted the issue of GF causing acid rain in Nigeria. Furthermore, the limitation of the effect of GF on IAQ affecting health and academic performance of schoolchildren, although investigated and treated as an urgent consideration in the developed world, is yet to be given any consideration in the ND as no literature provides this evidence. Thus, providing more justification and reasons for the adoption of DS as affirmed by Ogbonda and Bichard (2017) noting that it provides rigors and systematic process of valid information in a study where documented evidence is scarcely evident.

The sole purpose of further explication is to justify the need to design a PS to suit these geographical regions of Nigerian.

Carbon monoxide (CO_2)

- Carbon monoxide (CO) is a colourless, non-irritant, odourless and tasteless toxic gas. Common symptoms include headache, lethargy/fatigue, nausea, dizziness and confusion. A victim may also suffer from shortness of breath, cardiac palpitations, convulsion, paralysis, loss of consciousness, coma and eventually death

Particulate Matter ($PM_{2.5}$ & PM_{10}):

- PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, (≤ PM10), which can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.

Ozone (O_3)

- Excessive ozone in the air can have a marked effect on human health. It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases

Nitrogen oxide (NO_x)

- Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NOx. Reduced lung function growth is also linked to NOx

Sulphur dioxide (SO_2)

- SO2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital
- . When SO_2 combines with water, it forms sulphuric acid; this is the main component of acid rain which is a cause of deforestation and deterioration in building materials.

Benzene

- Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and aplastic anaemia. Acute exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion, tremors and loss of consciousness, moderate eye irritant and a skin irritant

Polycyclic Aromatic Hydrocarbons (PAHs)

- Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers

Figure 5.2 Root Causes of Negative Impact from Gas Flaring
Source: Author

Following the review of the literature, figure 5.2 shows the chemical substances that are emitted from GF, which are the main causes of the research problem, as already reviewed in chapters 2 and 3. The adverse effect of these gases described above cannot be over emphasized as they have led to many international, national and regional regulations and monitoring agendas to help reduce its emission rate into any given environment by any country or industry (Dolman, et al., 2010; Le Quéré, et al., 2014, Pachauri; Allen et al., 2014). Nigeria as the second highest emitter of these gases from GF processes in the world has tried to enact laws and regulations to help check and reduce GF yet, these gases are continually being flared in the ND area of Nigeria (See Appendix C for a tabulated list of the laws related to gases and air pollution).

To understand the adverse effects of GF, provide solutions that will help reduce its effect on both the buildings and health of schoolchildren in such vicinity, it is pertinent to collect and analyse field data to show the perception of professionals working in the study area. This will provide the needed information concerning the effects of these flared gases not currently available. The interaction with selected professionals in the primary area of study using open-ended questionnaires and interviews provides a further explication of the problem as opined by Johnasseson and Perjons (2012). In addition, the analysis provides clearly defined and quickly gathered opinions and perceptions of professionals about the research problem under consideration.

The level of concern shown through information gathered and attributes made through GF will provide the need for a solution and further justify the relevance of the research. As denoted by the DS framework developers, such as (Takeda, et al. 1990; March and Smith, 1995; Johannesson and Perjons, 2012), this is an extended explication of the problem in the particular study area, wherein, outlining the artefact and defining the requirement are a leap to finding possible answers and a solution to the study.

5.3 Outline of the Artefact (Solution) Type and Define Requirement

The artefact produced provides answers to the explicated problem. Artefacts are solutions described as man-made objects developed in other to solve real life problem ranging from software, physical objects like buildings and drawings, a blueprint or a guideline used to solve real life issues (Johannesson and Perjons, 2012). The type of solution determines the method of reaching possible answers that will suit that, which meets stakeholders' needs.

Care, therefore, must be taken because the performance of the artefact in the problem environment justifies the expectation of the desired outcome.

The interaction of the artefact within the environment may lead to assuming about the internal workings of the artefact in the environment. The context in which the DS artefact is anticipated to function depends on research outputs such as; construct, model, method, and instantiation or new properties of technical, social, and/or information resource (Johannesson and Perjons,2012). Although, four of these deliverables have been discussed in section 4.10.2 of chapter four with the justification given based on the choice of insanitation table 5.1 gives a brief discussion and description of the artefacts. The artefact created enables the representation, analysis, understanding, and development of successful solution within an environment.

Table 5.1: Types of Artefact and Description

Artefact Types	**Description**
Construct	Constructs are defined as "concepts" and "conceptualizations" (Vaishnavi and Kuechler 2007) and "vocabulary and symbols" (Kolfschoten and De Vreede 2009). Construct could be seen as a notion which provides the language in which problems and solutions are defined and communicated (Hevner and March 2003), they explain the terms used when describing and thinking tasks. Its importance as an artefact type is that they have a significant impact on the way in which tasks and problems are conceived because the working design of an artefact consists of a large number of things and their associations (Kuechler and Vaishnavi 2008). The initial idea around a research is usually refined all through the design phase leading to the creation of a solution.
Model	Accordingly, to models can also be used to describe potential solutions to practical problems, it could be an informative tool used to represent current situation and explaining challenges occurring (Johannesson and Perjons 2012). It is a problem and solution statement, providing relationships between constructs. DS model position utility representing what a model may need to capture the structure of reality in order to be a useful representation of a structure performance
Method	This a set of steps used to perform a task. Methods are based on a set of underlying constructs (language) and a representation (model) of the solution space. Methods are often used to translate from one representation to another in the course of solving the problem, they are guidelines and procedures that help people to work in systematic ways when solving problems. They are goal directed plans manipulating construct for the solution model to be achieved.
Instantiation	Also known as implementation shows how well the artefact performs in the

	environment it is made for, in order words, the realisation of the artefact in its environment. Instantiations operationalize constructs, models, and methods. However, an instantiation may actually precede the complete articulation of its underlying constructs, models, and methods. Instantiations demonstrate the feasibility and effectiveness of the models and methods they contain.

Source: (Vaishnavi and Kuechler 2007; Kolfschoten and De Vreede, 2009; Hevner and March, 2003; Kuechler and Vaishnavi, 2008; Johannesson and Perjons, 2012)

Following the description from table 5.1 of the different types of artefact, this research is formed under the instantiation of the adaptive specification. However, this is based on the effective problem representation which is crucial to finding an effective design solution(Weber, 2003). This is through the integration of existing standards and requirements used in developed countries in achieving durability of the external façade of a building envelope and clean IAQ. Nevertheless, these standards and buildings codes including regulations are not particularly dealing with GF but have been used to reduce corrosion and poor indoor quality around the air-polluted environment as discussed in chapter two of this research. In addition instantiation as a solution, type provides reliability and viability of the research outcome to solve real life issue through evaluation which shows an example to support the explanation. It provides an opportunity for users of the developed solution to make an input into the efficiency and its impacts on the environment and the possibility of the artefact in solving the existing problem. Therefore, the type of artefact chosen determines the effectiveness of the solution posited requiring the users of the solution to provide and define the requirements significant to solution development.

5.4 Define Requirement

Defining the requirement necessary for the solution of the research problem requires information from users of the intended solution. The designed solution should either solve a problem that has not yet been solved or provide a more effective solution better than what is currently available. Both the construction and evaluation of the artefact must be done rigorously. In other words, it is a goal for the to-be-designed treatment (Wieringa, 2014) . It is a transformation of the problem into systematic objectives (Miske, et al. 2014). This is because a problem well explicated provides, in many ways, the needed solution, which further justifies the need for that age.

Defining the requirements, therefore, involves the selection of a research strategy and method that will provide the needed technique necessary to gather further information. Following the adopted framework as illustrated in chapters 1 figure 1.2 as adjusted to suit current research, Figure 5.3 shows the framework with the choice of strategies recommended as is the best fit for the DSM. However, the choice of any strategy should meet the required need and provide the needed results that will enable the research move on to the next stage. Therefore, both the selected professionals and the questions should be clear to help in developing the needed solution.

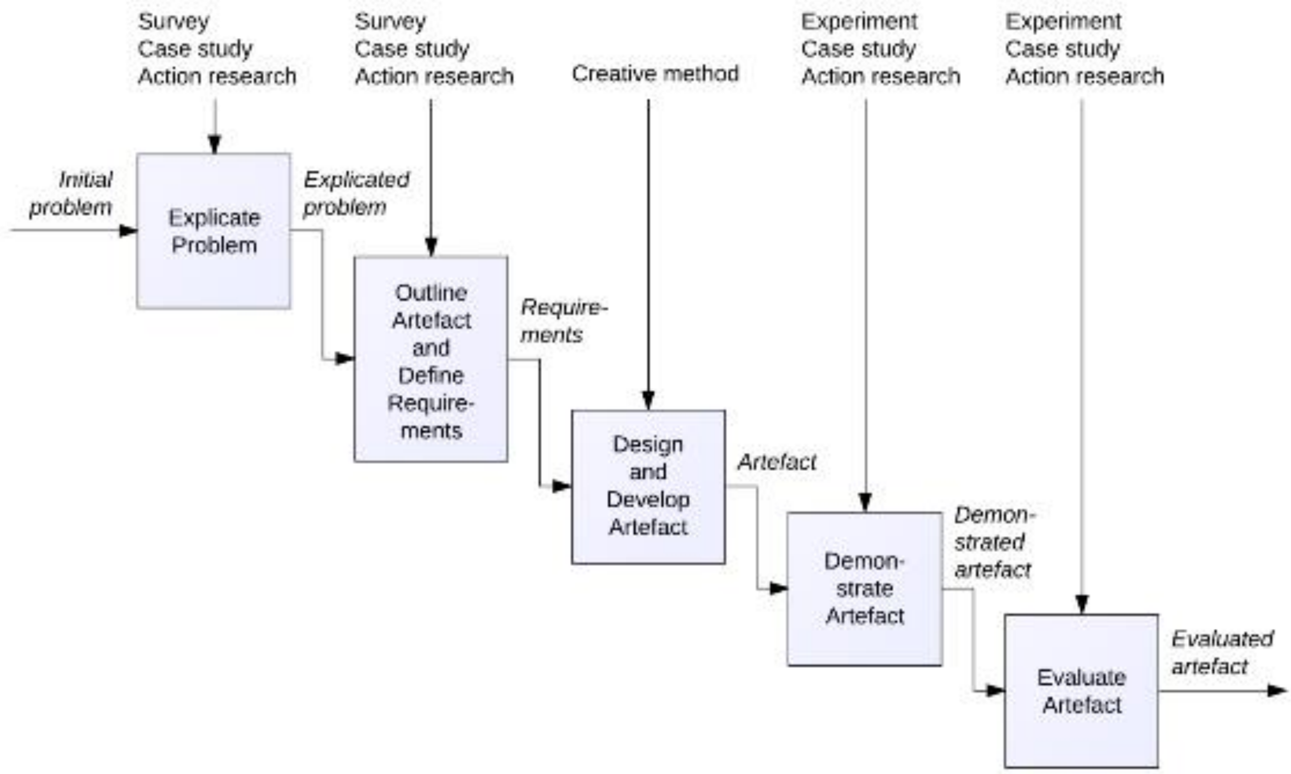


Figure 5.3 Adoptable Strategies for Design Science Framework
Source: Johansson and perjons (2012)

From figure 5.3, survey, action research and case study are the choices as affirmed by Johannesson and Perjons (2012) from the second block of DS process. A survey offers a relatively low cost with the possibility of a large number of responses and makes it possible to examine the needs of different stakeholders. However, it is biased and the possibility of stakeholders not wanting to spend a significant amount of time on answering the questions posed them leads to low response rate and dishonest answers. On the other hand, action research provides an accurate and more reliable information from respondents as the researcher is part of the organisation that requires the solution (Järvinen, 2007). Yet, its drawbacks include the duration of time for data collection and costs associated with gathering information (Järvinen, 2007). However, the case study research method, like the survey method, is also a low-cost approach but allows the researcher and the respondent an extended period of time to give more thoughts to the answers provided (Yin, 200). Thus, as noted in chapter 4 sections 4.6 and 4.7.1 on the justification of the research method, a case study with mixed methods which provides a better understanding and evidence-based research was adopted as suitable strategy and methods.

Adopting a mixed methods strategy, quantitative and qualitative data collection techniques were chosen to avoid the issue of bias, which is the weakness of the survey method. Qualitative research typically involves purposeful sampling to enhance understanding of the information-rich case through exploring in depth and understanding the reasons for success or failure of a system while using responses to identify strategies to solve problems raised (Suri, 2011) . Purposeful sampling entails the identification of respondents that are knowledgeable and experienced with the phenomenon of interest (Creswell and Plano Clarks, 2011) and, also such experts must be willing to communicate their experience and opinions in an articulate, expressive and reflective manner (Bernard, 2002). Unlike qualitative, less explicit and less evident in nature, the quantitative technique involves probability sampling to permit statistical inferences to be made based on probability theory.

Probability sampling method is used to ensure the generalisation of findings by reducing the possibility of bias in selection and to control the probable influence. Although purposeful sampling is oriented towards the development of specific knowledge from simplifications and individual cases, probability sampling is concerned with the development of general knowledge from samples. However, the choice of sampling method depends on the possibility of gathering required data that answers research questions while meeting research objectives.

Nevertheless, the research deals with the design and construction of a building which is part art and part transformation; its process involves a wide spread of professionals who should work together to address and meet requirements (Lee and Barrett, 2003). Therefore, the choice of professionals should be able to provide the information required.

The interaction of different professionals in construction helps to achieve the required performance of buildings especially the ones that have to protect the health of the occupants and their durability.

Therefore, based on the research problem, there was the need to have a wide view of the different professionals in the study area and their perception of the continuous GF in the

NDA as tabulated in table 4.6. The selection criteria are significant as they helped to define the requirement necessary to push the study further.

Following the selection of participants, an open-ended questionnaire was used for the quantitative section allowing respondents to make selections from the Likert scale options provided. For the qualitative part, a face-to-face interview was adopted; this allowed a clear and in-depth understanding of the problem. However, it is important to note that this study is bound to the "Ethical Approval Studies of the University of Salford". This means that requests for respondents to participate in the research were sent out as attached in appendix D and E and consent was also provided for the semi-structured interview. Moreover, the open-ended questionnaire had a section added for respondents to confirm their consent in agreeing to participate in the data collection exercise. Nevertheless, conducting field work is guided by the University of Salford code of conduct, which stipulates that all students must seek Ethical approval before administering questionnaires or conducting interviews. This was obtained under the Code of Ethics of the Engineering and Physical Sciences Research Council (EPSRC) in the United Kingdom (See attached approval as Appendix F).

The first phase of data collected lasted for two 10-week periods this was because the researcher had to travel to different states in the ND to meet professionals in order to gain varied and wider opinions hence the need for combining the case study with the DSM. This is due to the significance of the second step in the DS process wherein information collated helps in the structuring of defined problem assertion and in developing the necessary solution. It was important that a case study is adopted providing an in-depth understanding of professionals predominantly from the study area.

5.5 Data Analysis

A total of one hundred and twenty (120) questionnaires were administered to all the professions selected for this study across the NDA from the first week in May to the first week in July 2015. Open-ended Questionnaires were hand delivered to all respondents selected based on the information provided through their various bodies and years of experience as already discussed in section 4.5.1 and 4.6. On administration of the open-ended questions, a two-to-three week's period was allowed for respondents to complete the questionnaires to give them an extended time for completion. Gentle reminders by emails, calls and text messages helped to achieve a high response rate (Saunders, 2009). Thus, due to distance and associated cost of travel to study area, follow up emails, calls, and texts were sent to respondents. Within a period of 8 weeks, one hundred and three (103) questionnaires were retrieved for quantitative data analysis. Knowing that academic research is at the mercy of respondents, (Baruch, 1999; Porter, 2004; Baruch and Holtom, 2008) observed that 45% and above forms a reliable and valid response rate. Therefore, using SPSS descriptively, it was found out that a total of 86% response rate was achieved which forms a reliable and useful analysis for the study.

The questionnaire survey for this study was targeted at professionals associated with construction, environment, and health implication in the vicinity of GF in the NDA. The results and breakdown of all professionals who responded to the questionnaire are shown in figure 5.4;

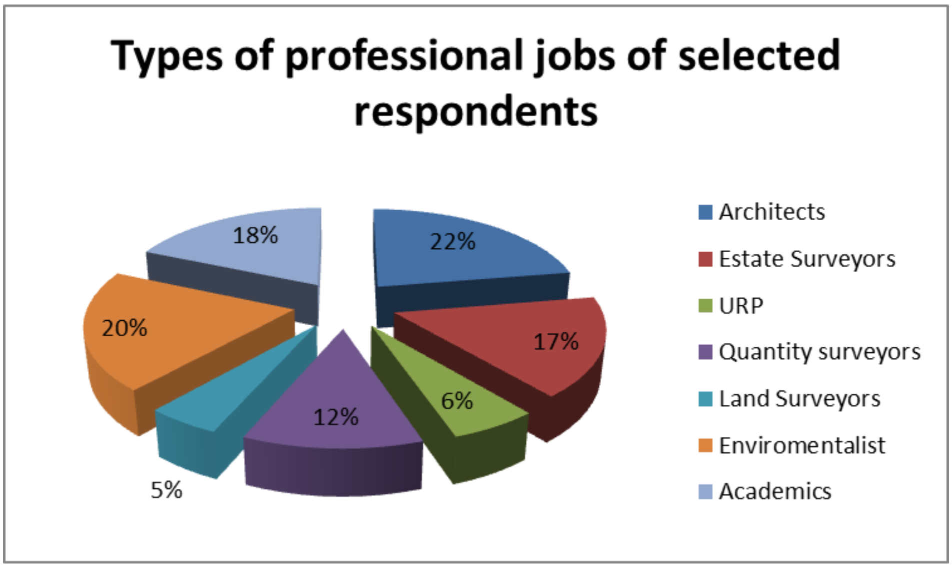


Figure 5.4 Types of Professional Jobs of Selected Respondents

Figure 5.4 shows the list of various professionals that were selected. From the descriptive analysis, Architects have the highest percentage of responses at 22.3% and Environmentalists represented at 20%. The rest were as follows: Academia 18.4%, Estate Surveyors 16.5%, Quantity Surveyors 11.7%, Urban and Regional Planners 5.8% and Land Surveyors 4.9%, all of whom participated in the questionnaire survey.

Information about their job types will not necessarily produce good conclusion if their years of practice are not indicated. Therefore, as part of the general question to establish the basis for judgment of their understanding of the research, the question was asked to ascertain the how long the respondents have been practicing their various professions. From the analysis, as illustrated in figure 5.5, it is demonstrated that 68% of the professionals had been practicing in their various professions for over 20 years.

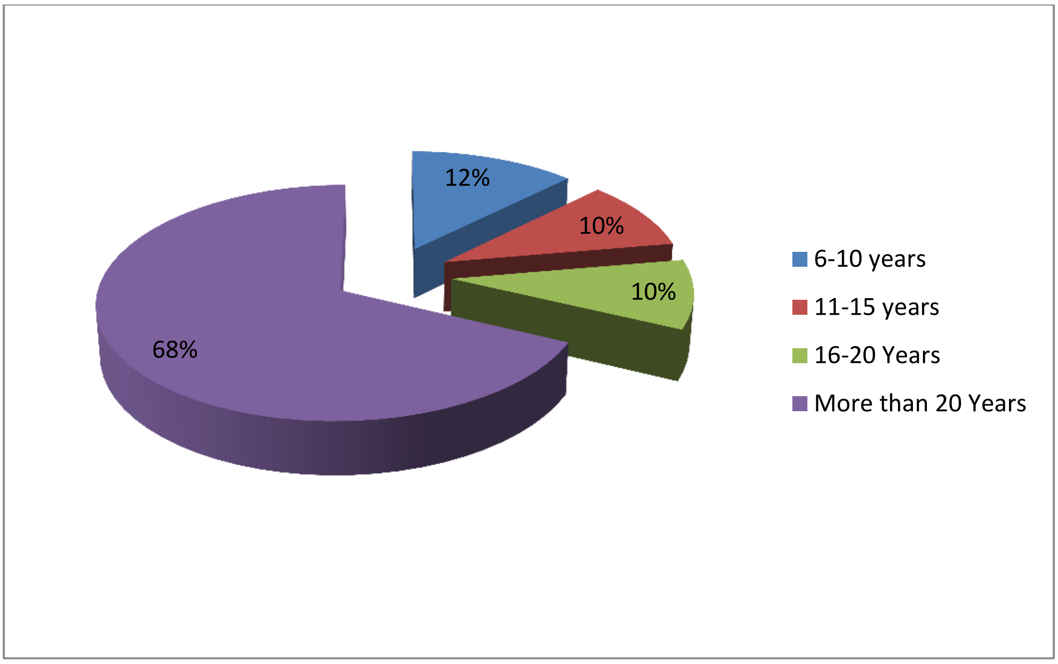


Figure 5.5: Numbers of Years in the Profession

From figure 5.5, all the respondents have been practicing for more than half a decade with 12% practicing between 6-10 years 20% have been in their professions for over a decade with the majority at 68% having spent more than 20years. Therefore, following the criteria for inauguration into fellowship in professional bodies such RICS, NIESV, CIB etc. most professionals would have become fellows of their various professional bodies. This, therefore, confirms that their knowledge and opinions should be well informed. Although their years of professionalism would be long, the immediate understanding of the terrain is also vital in information gathering. This is because well-informed respondents on the subject matter will provide valid information to help the research process. This then led to the next question, which was for the main purpose of showing how long respondents have been working around the study area. The results from figure 5.6 show that 52.40% have been working around GF environment for more than 20years, 27.20% between 16-20years, 9.70% between 11-15years, 7.80% between 1-5 years and 1% less than one year. This, therefore, shows that the responses gathered were valid based on their experience in the research area.

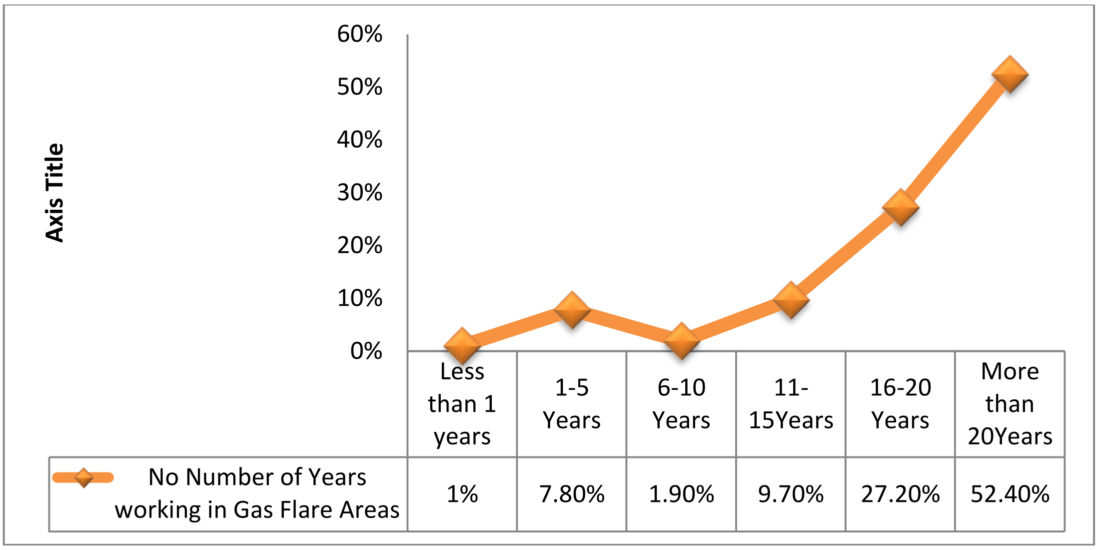


Figure 5.6 Professionals and Years of working in the VGF

Following analysis of the general information section, it can be concluded that all professionals had a significant understanding of the research, with reasonable experience based on their years in the profession, practicing and working in the study area and elsewhere. The next section deals with the impact of GF on building materials.

5.6. The Impact of GF on Building Materials

This section is mainly to achieve research objectives 2 and 3 as stated in chapter one. This is because, from reviewed literature, there are no empirical studies documented on the impact of GF on PSBs. There is also no documented evidence emphasising on building materials and the effectiveness of the Nigerian Building Code (NBC) used for regulation during design and construction of public schools around the vicinity of GF. The main aim here is to understand how material choices are made, factors influencing the quality of materials used and if GF actually affects building materials used with particular reference to the external façades of buildings. It is the focus of this section to understand how professionals see laws, regulation, and codes, which are deciding factors in construction design and specification. Thus questions generated include participant's knowledge of construction materials, the quality of construction materials and factors that influence the choice of these materials and in their opinion if GF affects the fabric of buildings. These questions were all asked in relation to PSBs. Although some of the questions sound basic in nature, answers generated helped to provide the needed criteria and factors necessary during the design of the PS.

5.6.1 Participants Knowledge of Construction Materials

It is significant that all participants are knowledgeable and understand construction materials used in the vicinity of the study. This forms the opening and accesses their ability to provide answers to questions posed them. Moreover, in the Nigerian construction industry, the architects are the only ones that deal with specification and design of buildings. Other professionals such as estate surveyors, quantity surveys, urban and regional planners, land surveyors, environmentalists and health practitioners though involved in construction and the environment, deal with other aspects of the BE as already identified and illustrated in table 5.1 of section 5.4 of this chapter. From the literature, it was noted that the concentration of flaring points in the NDA influences air pollution and affects buildings with no clearly defined form of effect on the building or the building types (Odu, 1994; Ojeh, 2012; Ifeanyi and Nduka, 2013). Therefore, it is only necessary that selected professionals should be knowledgeable in building materials, choice, quality and effectiveness of building codes used. In an attempt to establish this, respondents' level of knowledge on construction materials as represented in the questionnaire survey is captured in table 5.2

Table 5.2: Respondents Knowledge on Construction Materials

Knowledge of Construction Materials Used	1 Not knowledgeable	2 Low knowledge	3 Moderate knowledge	4 Highly knowledgeable	5 Very highly knowledgeable
	0%	1.9%	17.5%	51.5%	29.1%

From the analysis, as indicated in table 5.2, all participants are knowledgeable in construction materials. From the analysis, no participant ticked the first option of not knowledgeable. Although, 1.9% showed that they had low knowledge of materials used and 17.5% indicated that they had a moderate knowledge, a whopping 51.5% of all participants indicated that they are highly knowledgeable with 29.1% showing as very highly knowledgeable of material types used for construction. Therefore, the above table shows that data collected and participants involved are conversant with the materials types, which impact on their knowledge of the research issues.

5.6.2 Quality of Materials Used in the GFAND

From literature authors such as, Akpan, (2003); Brimblecombe and Grossi, (2007); and Obia et.al. (2011) illustrated that the quality of materials affects the acceleration of corrosion on them because the level of acidity inherent in rainwater or dew droplets increases the level of alkalinity. This, therefore, indicates that low-quality materials when used cannot withstand the level of alkalinity, which leads to corrosion. Thus, questions concerning the quality of materials were asked in the relevant sections of both the questionnaire and face-to-face interview and the results are shown in table 5.3.

Table 5.3: Quality of Materials used in the GFAND

Rate the Quality of Materials Used	1 Very Poor Quality	2 Poor Quality	3 Average Quality	4 Good Quality	5 Very Good Quality
	18.4%	48.5%	22.3%	7.8%	2.9%

From table 5.3, 18.4% of all the respondents indicated that materials used for public school construction are of very low quality, while 48.5% indicated that they are of poor quality, 22.3% indicated that materials used are of average quality while the fourth and fifth options of good and very good quality both got 7.8% and 2.9% responses respectively. This also affirms comments given by interviewee 1 and 2 when the question was posed to them during a face-to-face interview:

"The use of the right quality of material to combat the environmental effect will be the best thing rather than quantity; quality should be the first consideration while constructing buildings that will house the public"

Interviewee 1 went further to give the reason why good quality materials should be used, *"I mean let's be realistic this person suffer all the negative vices that come from oil exploration"*

Although a summed up answer was generated using SPSS as shown in table 5.4, the same question posed during the semi-structured interview section provided a clear indication that the right quality of material will help combat GF effects. Central to the need for good quality materials are factors influencing the quality of materials used.

5.6.3 Factors Influencing Quality of Material Used in GF Vicinity

Although from literature and subsequent responses from professionals in the research area indicated from the analysis that the quality of materials accelerates deterioration (see the analysis of table 5.4), the need to further understand why these materials are used was asked in both the questionnaire and interview questions. This is because, from literature, most economies with similar environmental challenges adopt different ways of material selection, vis-à-vis, and not limited to buildings meeting newer building codes and international standards, involvement of all experts, consideration of material type and mostly the need to overcome any in different attitudes (Wadhah, 2012; DfES, 2006; JSCQB, 2002). Similarly, Alibaba and Özdeniz, (2004) stated that the choice of any building material, amidst vast numbers of substitutes, is an integral part of the design as wrong materials have the significantly negative impact on an economy, construction functionality, and aesthetics. Also, the consideration for project and stakeholders specific requirements impacts on the choice of materials. The entire discussion necessitated questions that focused on factors affecting the quality of materials used for construction. Results from the analysis as represented in table 5.4 show these responses.

Table 5.4: Factors Influencing Quality of Material Used in GF Vicinity

Factors Influencing Quality of Materials	Least Influential	Low Influence	Moderately Influential	Highly Influential	Very Highly influential
Finance	2.90%	5.80%	10.70%	52.40%	28.20%
NBC Specification	2.90%	6.80%	6.80%	53.40%	30.10%
Politics	0.00%	6.80%	22.30%	37.90%	33.00%
lack of Expertise Knowledge	15.50%	22.30%	33.00%	18.40%	10.70%
Material Availability	13.60%	4.90%	33.00%	45.60%	2.90%
Unconcerned Attitude	4.90%	13.60%	22.30%	48.50%	10.70%

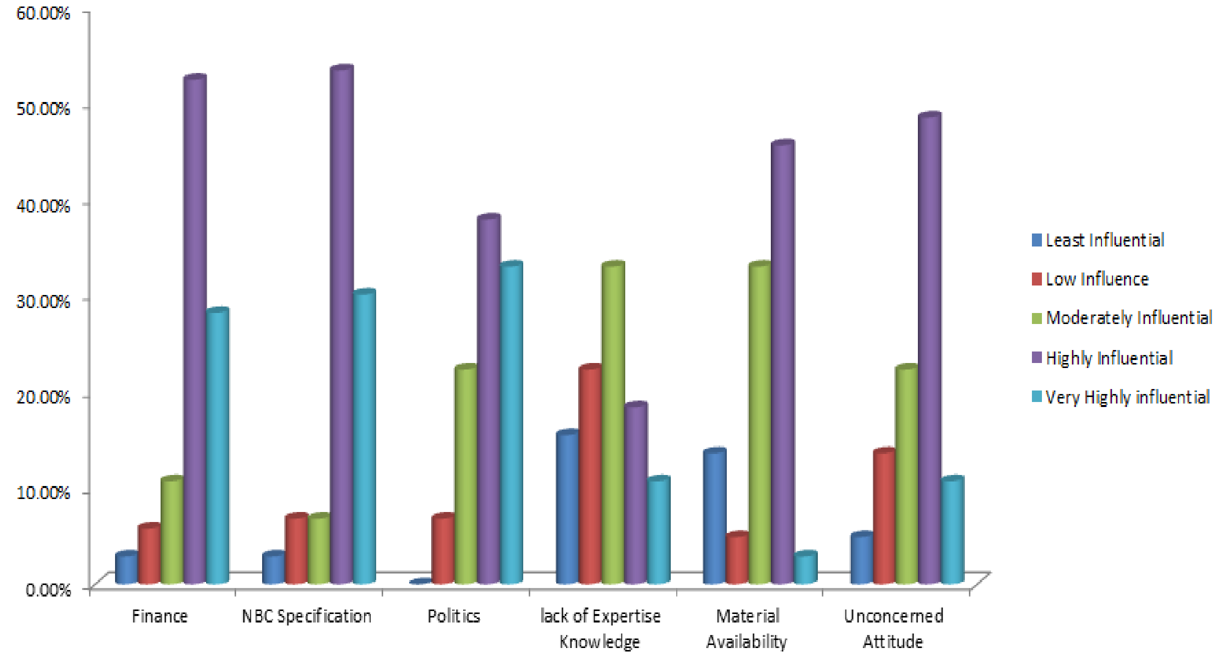


Figure 5.7 Graphical Representations of Factors Influencing Quality of Materials

From table 5.4 and figure 5.7, factors influencing the quality of materials include finance, NBC specification, politics, lack of expertise, material costs, availability of materials and unconcerned attitude all in a five point Likert scale range from least influential to very highly influential. The results showed that finance has 28.2% very highly influential, 52.4% highly influential, and 9.7% moderately and low influential with 0% of least influential. The NBC specification as a factor that influences material quality showed 9.7% least influential, 18.4% of low influential, 49.5% of moderately influential, 16.5% highly influential and 5.8% very highly influential. Politics as a factor had 33.0% and 37.9% of very highly influential and highly influential, 22.3% indicated moderately influential and 6.8% low influential with 0% least influential. These results show that politics influences the choice of material. The identification of lack of expertise as a possible factor that influences quality of materials showed from the analysis that 10.7% chose very influential, 18.4% highly influential, 33.0% moderately influential, 22.3% low influence and 15.5% least influential while material cost showed 16.5% very influential, 58.3% highly influential, 17.5% moderately influential, 3.9% low influential and 2.9% least influential. Furthermore, availability of materials as factor showed 16.5% very influential, 58.3% highly influential, 17.5% moderately influential, 3.9% low influence and 6.8% least influential indicating that availability of material is also a major factor that influences material quality. Finally unconcerned attitude revealed 10.7% very influential, 26.2% highly influential, 35.9% moderately influential, 24.3% low influential and 2.9% least influential.

Overall, the analysis as represented in table 5.4 and figure 5.7 shows that specification, as provided by the NBC, finance, and politics, influence the quality of material most as compared to cost, material availability, unconcerned attitude and lack of expert knowledge. This is clearly shown in Table 5.5 with the mean average highlighted in red.

Table 5.5 The Mean Average on all Factors Influencing Quality of Construction Material Statistics

Mean Representation of Factors Influencing Quality of Construction		Finance	Specification NBC	Politics	Lack of Expertise	Costs	Material Availability	Unconcerned Attitude
N	Valid	103	103	103	103	103	103	103
	Missing	0	0	0	0	0	0	0
Mean		3.9709	4.0097	3.9709	2.8641	3.7670	3.1942	3.4660
Median		5.0000	4.0000	4.0000	3.0000	4.0000	3.0000	4.0000
Mode		5.00	4.00	4.00	3.00	4.00	4.00	4.00
Std. Deviation		1.04460	.95481	.91240	1.20496	.97220	1.06696	1.01764
Skewness		-1.389	-1.329	-.495	.095	-1.407	-.942	-.703
Std. Error of Skewness		.238	.238	.238	.238	.238	.238	.238

Using the mean average, table 5.5 shows the factors that have the most and least influence on the quality of material used for construction. Information gathered from statistics shows that specification provided in the NBC play a more insignificant role on the quality of material used as compared to finance and politics having the same mean average of 3.9709. This might be due to the provision in the code not reflecting the present material quality manufactured having that Nigeria imports most of its construction materials. In addition, finance, politics, unconcerned attitude, material availability all influence material quality with lack of expertise knowledge having the least influence on the quality of the material.

From all analysis, every factor had some reasonable level of influence on the quality of material used. In addition, question 2 was posed in the semi structured interview and interviewee 3 response agrees with some of the factors already analysed as shown below;.

"The National Building code is not functional because people build according to what they desire and the resources available to them. Even with public facilities like schools, you will find out that those in the political positions do not involve the services of experts in the BE to provide expert knowledge before and after construction. In fact, construction is based on your level of involvement and how connected you are with people in politics".

This comment from interviewee 3 showed that politics, NBC and lack of expert knowledge all affect the quality of materials used in the construction of schools. Therefore, could be deduced that there is a relationship between quality of material and the factors that influence its quality as clearly illustrated using the Spearman rho correlation.

A further statistical analysis revealed that there is a correlation between the quality of material used and NBC as illustrated in table 5.6. Here the choice NBC is based on it being the highest influential factor to the quality of the material.

Table 5.6 Spearman's rho correlations between quality of material and NBC

Correlations

Correlations			Rate the Quality of materials Used for Construction	Specification NBC Influences Quality of Materials
Spearman's rho	Rate the Quality of materials Used for Construction	Correlation Coefficient	1.000	.206*
		Sig. (2-tailed)	.	.037
		N	103	103
	Specification NBC Influences Quality of Materials	Correlation Coefficient	.206*	1.000
		Sig. (2-tailed)	.037	.
		N	103	103

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5.6 shows the relationship between quality of material and the influence of NBC on material quality. Using the Spearman's rho correlation, it shows the value of between the two variables as it increases or decreases. There is an association of 0.05 (2 Tailed) significance, this is represented by a positive correlation of .206 between the quality of material used for construction and specification provided by the NBC. Therefore, one can infer that the quality of material used for construction in the vicinity of GF is influenced by the specification provided in the NBC. This further proves that the reliance on the prescriptive specification as provided in the NBC limits the possibility of innovative measures to attain quality even though health is wealth and children's academic performance is affected by inhaled air which also impacts on the aesthetics of the school environments.

Furthermore, it is also pertinent to show from the analysis the common defects on PSBs although discussion on these defects and pictorial evidence has been illustrated in chapter 2.

5.6.4 Factors Causing Defects on School Buildings in the Niger Delta.

According to a UNESCO report (2007) already discussed in chapter 1, 2 and 3, schools in Nigeria are in a derelict condition and in most instances not fit for human habitation. In addition, pictorial evidence, during data collection, shows the forms and types of defects on public schools. Therefore, questions relevant to these observed defects in relation to the general factors were acclaimed. Five defects were noted which include: corrosion, discolouration, blackening, deposition of debris and leakages and factors which influence the defects are inferred to include: weather condition, low-quality material, poor workmanship, material type, lack of maintenance and 'I don't care' attitude. Although provision for additional factors was made, respondents did not provide any others. Following the question format, their responses were discussed in separate clusters to provide clear understanding and interpretations. Hence, it is based on factors provided in question 5 as attached in the questionnaire appendix G

A Factors that Causes Corrosion on School Buildings

This section looks at causes of corrosion based on respondent's views as analysed. This is initiated to provide a guide to critical information necessary for a design solution to the research problem.

Table 5.7 Causes of Corrosion on School Buildings

Causes of Corrosion on School Buildings	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**
Weather Condition	0.00%	1.90%	7.80%	54.40%	35.90%
Low-Quality Material	0.00%	0.00%	17.50%	41.70%	40.80%
Poor Workmanship	4.90%	21.40%	23.30%	40.80%	9.70%
Material Type	6.80%	13.60%	15.50%	41.70%	22.30%
Maintenance Culture	15.50%	31.10%	33.00%	18.40%	1.90%
"I don't Care Attitude"	23.30%	14.60%	15.50%	35.90%	10.70%

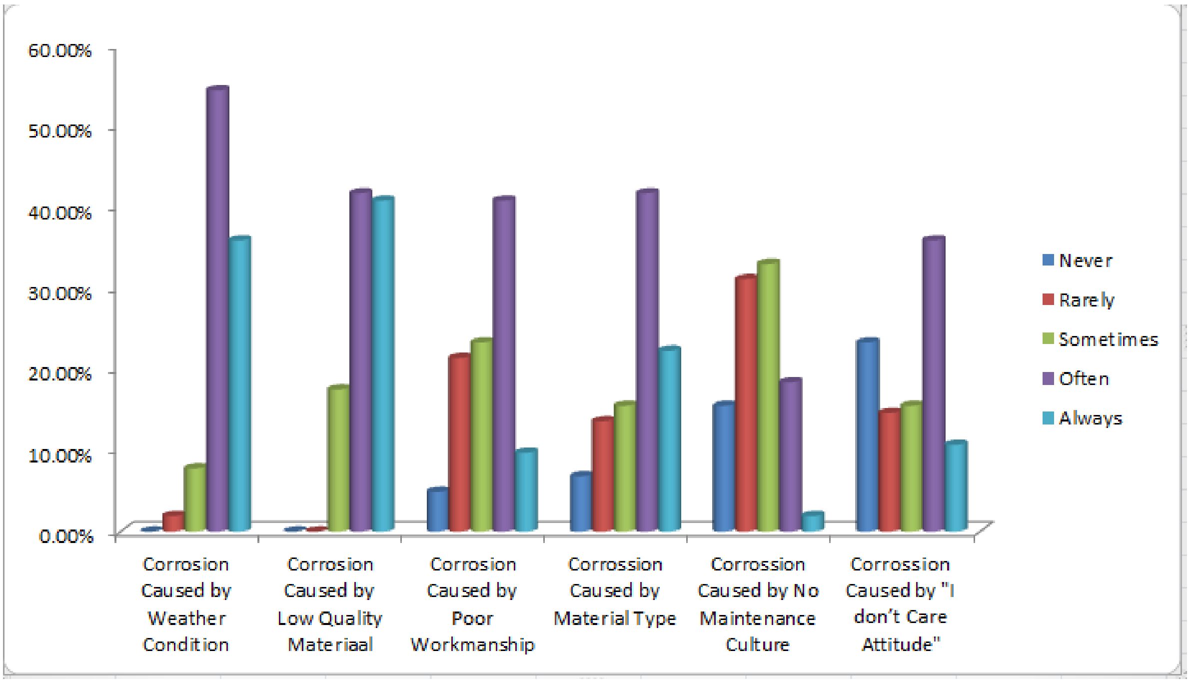


Figure 5.8 Graph Showing Causes of Corrosion on School Buildings

Both table 5.7 and figure 5.8 are used to interpret the same data. From the analysis, as illustrated, corrosion in PSBs as shown in figure 2.4 of chapter 2 are as a result of different factors. Weather, as a factor to corrosion, showed 0.00% never, 1.90% rarely, 7.80% sometimes, 54.40% often and 35.90% always. Corrosion Caused by Low-Quality Materials showed 0.00% never, 0.00% rarely, 17.50% sometimes, 41.70% often and 40.80% always. Corrosion Caused by Poor Workmanship indicated a 4.90% never, 21.40% rarely, 23.30% sometimes, 40.80% often and 9.70% always. Corrosion Caused by Material Type had 6.80% never, 13.60% rarely, 15.50% sometimes, 41.70% often and 22.30% always with Corrosion Caused by No Maintenance Culture revealing a 15.50% never, 31.10% rarely, 33.00% sometimes, 18.40% often and 1.90% always. And finally, Corrosion Caused by "I don't Care Attitude" showed 23.30% never, 14.60% rarely, 15.50% sometimes, 35.90% often and 10.70% always.

According to the analysis, respondents agreed that corrosion is triggered by all the factors listed as more than 50% of the responses confirmed this based on the summation of both *often* and *always*, while added together, less than 40% declared *never* and *rarely agree*. Although all the factors identified have been reported as causes of corrosion as the analysis has shown, weather, quality of material and material types are the major factors that lead to corrosion on PSBs. This is rated in order of ranking based on responses analysed and the mean average of all the factors that cause corrosion as illustrated in table 5.8

Table 5.8 The Mean Average of Causes of corrosion on School Buildings

Statistics

Mean Representation of Causes of corrosion		Corrosion caused by Weather condition	Corrosion Caused by Low-Quality Material	Corrosion Caused by Poor Workmanship	Corrosion Caused by Material Type	Corrosion Caused by No Maintenance Culture	Corrosion Caused by 'I don't Care Attitude
N	Valid	103	103	103	103	103	103
	Missing	0	0	0	0	0	0
Mean		4.2427	4.2330	3.2913	3.5922	2.6019	2.9612
Mode		4.00	4.00	4.00	4.00	3.00	4.00
Std. Deviation		.67832	.73035	1.06302	1.17521	1.02268	1.37143
Skewness		-.725	-.394	-.360	-.706	.083	-.231
Std. Error of Skewness		.238	.238	.238	.238	.238	.238
Sum		437.00	436.00	339.00	370.00	268.00	305.00

Using the average of all responses as analysed, gives the mean average as indicated in the red figures in table 5.8, which provides a general level of importance or association placed on each factor responsible for corrosion. From the table, weather condition, low-quality material, and material type have the highest mean average followed by *poor workmanship*, *I don't care attitude* and *no maintenance culture* having the less impact on corrosion causes. This, therefore, shows a clear linkage as pictures provided in chapters 2 and 3 show materials with visible corrosion effect as with the corrugated zinc roofing materials. Furthermore, it provides the necessary information to consider while designing a solution for the research problem.

Furthermore, there is a significant correlation between corrosion caused by *low quality*, *material type* and *I don't care attitude* at 0.01 and 0.05 levels of association as represented in table 5.9.

Table 5.9: Spearman's rho correlations between low quality of material, Material type and I don't care attitude

Correlations

			Corrossion Caused by Low Quality Material	Corrossion Caused by Material Type	Corrossion Caused by 'I don't Care Attitude
Kendall's tau_b	Corrossion Caused by Low Quality Material	Correlation Coefficient	1.000	.274**	.182*
		Sig. (2-tailed)	.	.001	.033
		N	103	103	103
	Corrossion Caused by Material Type	Correlation Coefficient	.274**	1.000	.268**
		Sig. (2-tailed)	.001	.	.001
		N	103	103	103
	Corrossion Caused by 'I don't Care Attitude	Correlation Coefficient	.182*	.268**	1.000
		Sig. (2-tailed)	.033	.001	.
		N	103	103	103
Spearman's rho	Corrossion Caused by Low Quality Material	Correlation Coefficient	1.000	.307**	.214*
		Sig. (2-tailed)	.	.002	.030
		N	103	103	103
	Corrossion Caused by Material Type	Correlation Coefficient	.307**	1.000	.320**
		Sig. (2-tailed)	.002	.	.001
		N	103	103	103
	Corrossion Caused by 'I don't Care Attitude	Correlation Coefficient	.214*	.320**	1.000
		Sig. (2-tailed)	.030	.001	.
		N	103	103	103

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

From table 5.9, the correlation of 0.01 and 0.05 shows a positive relationship between the factors indicating that there is both strong and weak relationship between the selected variables. Although correlation does not prove causative effect in some cases, there is a clear indication that material type and low quality show a higher significance level of 0.01 as compared to low-quality material and I don't care attitude with a 0.05 level of significance. Therefore, we could infer that the lower the quality of material, depending on the type, the higher the corrosion rate.

B Factors that Causes Blackening of School Buildings

Observed defects on PSBs include blackening however, there is no local information that has identified this as a problem. Hence, the views of the professionals practicing in the study area provide the needed information that will help in the design of a solution. Analysis of the open-ended questionnaires administered to respondents provided a guide to the proposed PS.

Table 5.10: Causes of Blackening on School Buildings

Causes of Blackening	Never	Rarely	Sometimes	Often	Always
Weather Condition	5.80%	7.80%	23.30%	39.80%	23.30%
Low-Quality Material	2.90%	21.40%	21.40%	32.00%	22.30%
Poor Workmanship	13.60%	39.80%	26.20%	14.60%	5.80%
Material Type	10.70%	8.70%	21.40%	40.80%	18.40%
No Maintenance Culture	13.60%	16.50%	17.50%	35.00%	17.50%
"I don't Care Attitude"	20.40%	20.40%	8.70%	35.80%	15.50%

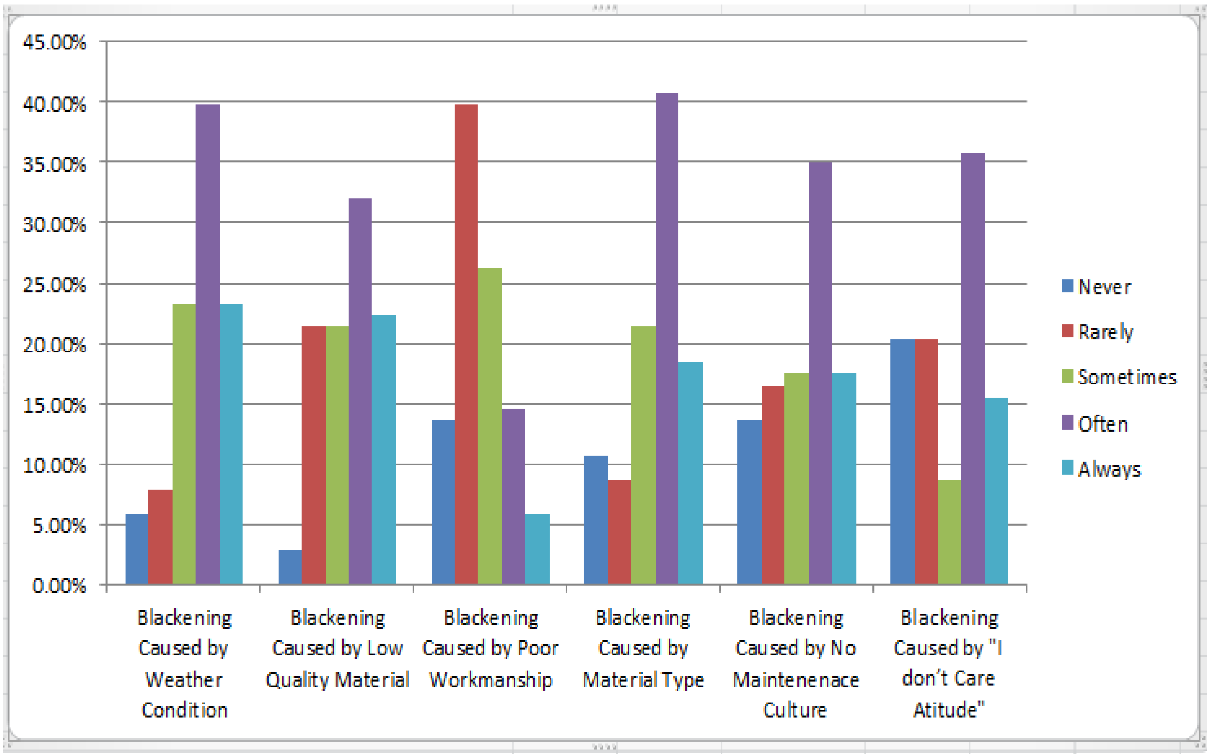


Figure 5.9: Graph showing causes of Blackening on School Buildings

Illustrated in table 5.10 and figure 5.9 are the factors that were identified as the likely causes of blackening. The same factors were used in all the identified deteriorative effects common on PSBs and in the ND. Following analysis, therefore, all the factors except poor workmanship were shown to have blackening effect on roofing materials at more than 50%. This is indicated by 5.80% specifying *never*, 7.80% *rarely*, 23.30% *sometimes*, 39.80% often and 23.30% always, of the respondents noting that Blackening is caused by Weather Conditions. Low-quality material noted for causing blackening showed 2.90% never, 21.40% rarely, 21.40% sometimes 32.00% often and 22.30% always. However, poor workmanship showed 13.60% never, 39.80% rarely, 26.20% sometimes, 14.60% often and 5.80% always. Compared to Material Type with 10.70% never, 8.70% rarely, 21.40% sometimes, 40.80% often and 18.40% always and No Maintenance Culture with 13.60% never, 16.50% rarely, 17.50% sometimes, 35.00% often and17.50% always and blackening caused by *'I don't Care' Attitude* showing 20.40% never, 20.40% rarely, 8.70% sometimes, 35.80%often and 15.50% always. Therefore, the analysis revealed that poor workmanship is not a significant factor when considering the required solution for PSBs in the vicinity GF as further analysed using mean.

Table 5.11: Mean of Causes of Blackening on School Buildings

Statistics

Mean Representation of Causes of Blackening		Blackening Caused by Weather Condition	Blackening Caused by Low-Quality Material	Blackening Caused by Poor Workmanship	Blackening Caused by Material Type	Blackening Caused by No Maintenance Culture	Blackening Caused by 'I don't Care Attitude
N	Valid	103	103	103	103	103	103
	Missing	0	0	0	0	0	0
Mean		3.4466	3.4369	2.5728	3.4757	3.2621	3.0485
Mode		4.00	4.00	2.00	4.00	4.00	4.00
Std. Deviation		1.21048	1.26545	1.10792	1.20330	1.30580	1.41684
Skewness		-.346	-.640	.386	-.717	-.393	-.193
Std. Error of Skewness		.238	.238	.238	.238	.238	.238
Sum		355.00	354.00	265.00	358.00	336.00	314.00

Table 5.11 is used to show the level of importance placed on each factor of the causative agents resulting in the blackening of roofing materials on PSBs in the ND area of Nigeria. Using the mean to indicate the level of importance attached to each factor shows that material type is more receptive to blackening effect followed by weather condition, low-quality material, no maintenance culture, 'I don't care' attitude and lastly poor workmanship having a mean average of 2.5728 compared to 3.4757, 3.4466, 3.4369, 3.2621 and 3.0485 respectively. This, therefore, signifies that when designing solutions, workmanship does not form an important factor in the solution development stage when considering material durability requirements.

C Factors that Causes Discolouration on School Buildings

Although factors causing blackening of PSBs have been analysed and discussed, discolouration as an important deteriorating factor was noted to have less importance in the GF area. Thus looking at its effects, respondents revealed three major causes of discolouration which were considered during the design of the solution. Although six factors were listed in the Likert scale question, three out of the options provided had higher considerations as illustrated in table 5.12 and figure 5.10.

Table 5.12: Factors that Cause Discolouration on School Buildings

Causes of Discolouration	Never	Rarely	Sometimes	Often	Always
Weather Condition	3.90%	7.80%	11.70%	53.40%	23.30%
Low-Quality Material	2.90%	10.70%	26.20%	37.90%	21.40%
Poor Workmanship	15.50%	22.30%	35.00%	22.30%	4.90%
Material Type	10.70%	12.60%	15.50%	46.60%	14.60%
No Maintenance Culture	17.50%	45.6%	16.50%	18.40%	1.90%
"I don’t Care Attitude"	17.50%	23.30%	15.50%	38.80%	4.90%

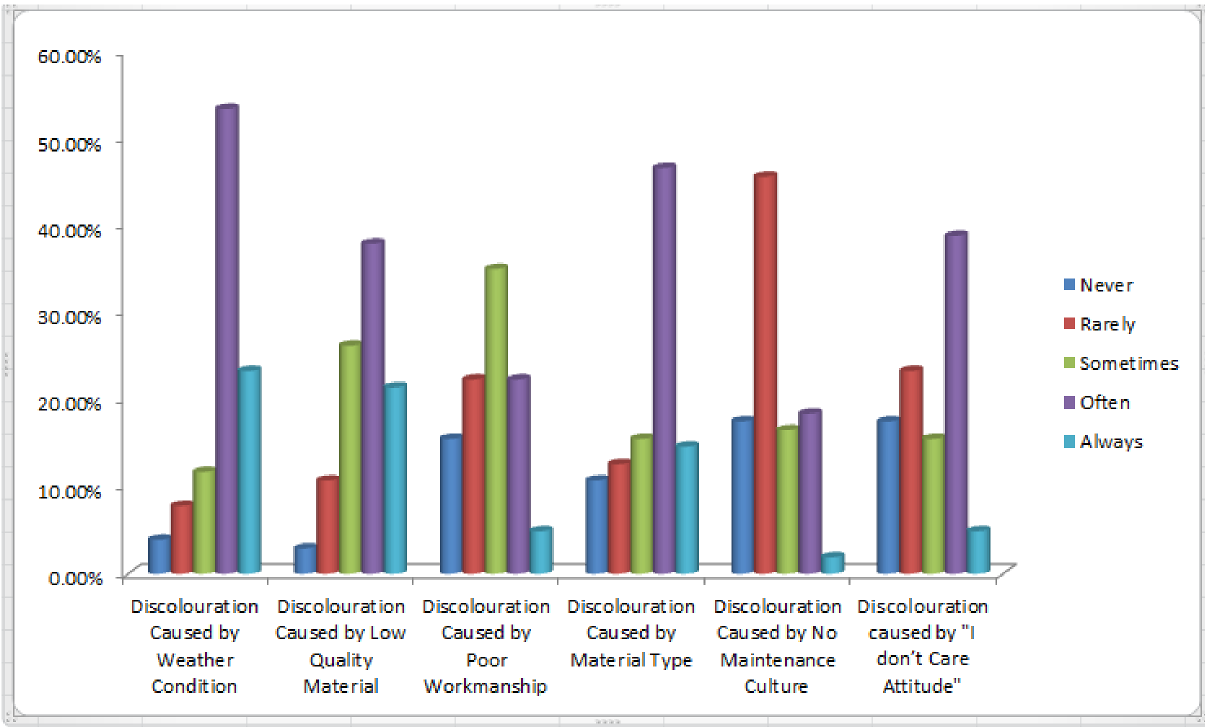


Figure 5.10: Graphical Representations of Discolouration Factors

Table 5.12 and figure 5.10 revealed the opinions of professionals in the BE in the study area on the causes of discolouration in PSBs. From the analysis, as illustrated, weather, quality of material and material type had more than 55% of factors causing discolouration while less than 45% of respondents indicated that poor workmanship, no maintenance and 'I don’t care' attitude cause material discolouration in buildings in the VGF. Therefore, from the analysis, factors significant during the design of PS should be related to weather, material quality and type when considering discolouration effects.

D Factors that Causes Deposition of Debris on School Buildings

This section discusses the results based on the analysis of responses on the causes of deposition of debris on PSBs.

Table 5.13: Factors Causing Deposition of Debris on School Buildings

Causes of Deposition of Debris	Never	Rarely	Sometimes	Often	Always
Weather Condition	7.80%	24.30%	26.20%	18.40%	23.30%
Low-Quality Material	7.80%	29.10%	22.30%	29.10%	11.70%
Poor Workmanship	7.80%	16.50%	21.40%	45.60%	8.70%
Material Type	12.60%	40.80%	16.50%	20.40%	9.70%
No Maintenance Culture	1.9%	17.50%	21.40%	45.6%	13.60%
"I don't Care Attitude"	3.90%	21.40%	22.30%	46.60%	5.80%

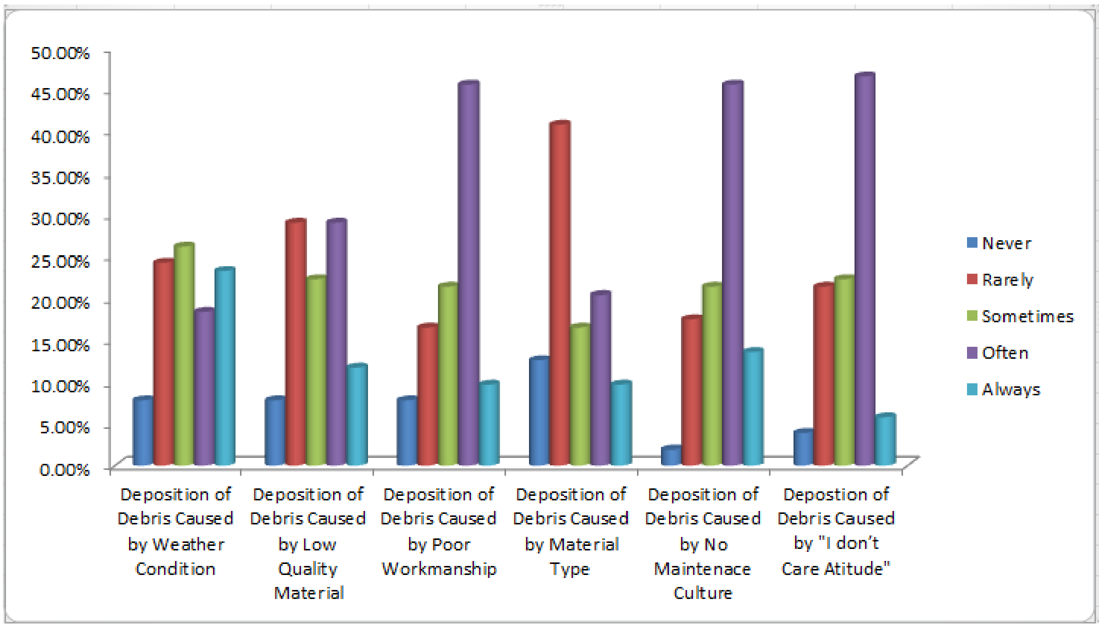


Figure 5.11: Graphical Representation of Deposition of Debris Factors

From table 5.13 and figure 5.11, the analysis showed that deposition of debris caused by the weather factor had 7.80% *never*, 24.30% *rarely*, 26.20% *sometimes*, 18.40% *often* and 23.30% *always*. While low quality of materials as the second factor showed 7.80% never, 29.10% rarely, 22.30% sometimes, 29.10% often and 11.70% always, poor workmanship indicated 7.80% as never, 16.50% rarely, 21.40% sometimes, 45.60% often and

8.70% always. Material Type revealed 12.60% *never*, 40.80% rarely, 16.50% *sometimes*, 20.40% often and 9.70% always. However, No Maintenance Culture showed 1.9% never, 17.50% *rarely*, 21.40% *sometimes*, 45.6% *often* and 13.60% *always* and the *"I don't Care Attitude"* indicated a 3.90% *never*, 21.40% *rarely*, 22.30% sometimes, 46.60% *often* and 5.80% *always*.

Thus, the results of the analysis indicate that No maintenance culture, poor workmanship and 'I don't care' attitude lead to deposition of debris on building materials. In addition, weather condition had a high response indicating that it is a significant factor to the deposition of debris. This could be as a result of the prevailing wind direction where high winds carry light enough particles along to be deposited on roofing materials and are unable to flow down due to the roof type or the inability of the workman to align roofing sheets properly to form the right slope required. This means that the low gradient of the roof stops the flow or wash off chemical deposits through precipitation. This is further made clear using the mean average from all responses as indicated in table 5.14.

Table 5.14: Mean average for analysed factors on table 5.13 and figure 5.11

Statistics

Mean Representation of Causes of Deposition of Debris		Weather Condition	Low-Quality Material	Poor Workmanship	Material Type	Maintenance Culture	'I don't Care Attitude
N	Valid	103	103	103	103	103	103
	Missing	0	0	0	0	0	0
Mean		3.2524	3.0777	3.3107	2.7379	3.5146	3.2913
Median		3.0000	3.0000	4.0000	2.0000	4.0000	4.0000
Mode		3.00	2.00[a]	4.00	2.00	4.00	4.00
Std. Deviation		1.27355	1.16896	1.09391	1.20425	.99867	.99638
Variance		1.622	1.366	1.197	1.450	.997	.993
Skewness		-.024	-.003	-.602	.419	-.462	-.496
Std. Error of Skewness		.238	.238	.238	.238	.238	.238

Table 5.14 shows the mean statistical representation of the responses as analysed. Using the mean, material type and low-quality material are less significant to the causes of deposition

of debris on the roofing material. This, therefore, means that in designing performance requirement for the avoidance of deposition of debris, emphasis should be more on roof type and the direction of the wind, and the realisation of this factor will depend on the workmen used during actual construction.

E Factor that Causes Leakages on School Buildings

This section discusses the results based on the analysis from respondents on the causes of leakages on PSBs. The importance of this factor will provide BEPs with information that will guide them in the choice of material type and construction, and workmen to consider when constructing buildings in the vicinity of GF.

Table: 5.15 Factors that Cause Leakages on School Buildings

Causes of Leakages	Never	Rarely	Sometimes	Often	Always
Weather Condition	12.60%	10.70%	33.00%	16.50%	27.20%
Low-Quality Material	2.90%	11.70%	17.50%	48.50%	19.40%
Poor Workmanship	2.90%	10.70%	29.10%	39.80%	17.50%
Material Type	13.60%	45.60%	9.70%	21.40%	9.70%
No Maintenance Culture	12.60%	27.20%	13.60%	28.20%	18.40%
"I don't Care Attitude"	15.50%	19.40%	24.30%	31.10%	9.70%

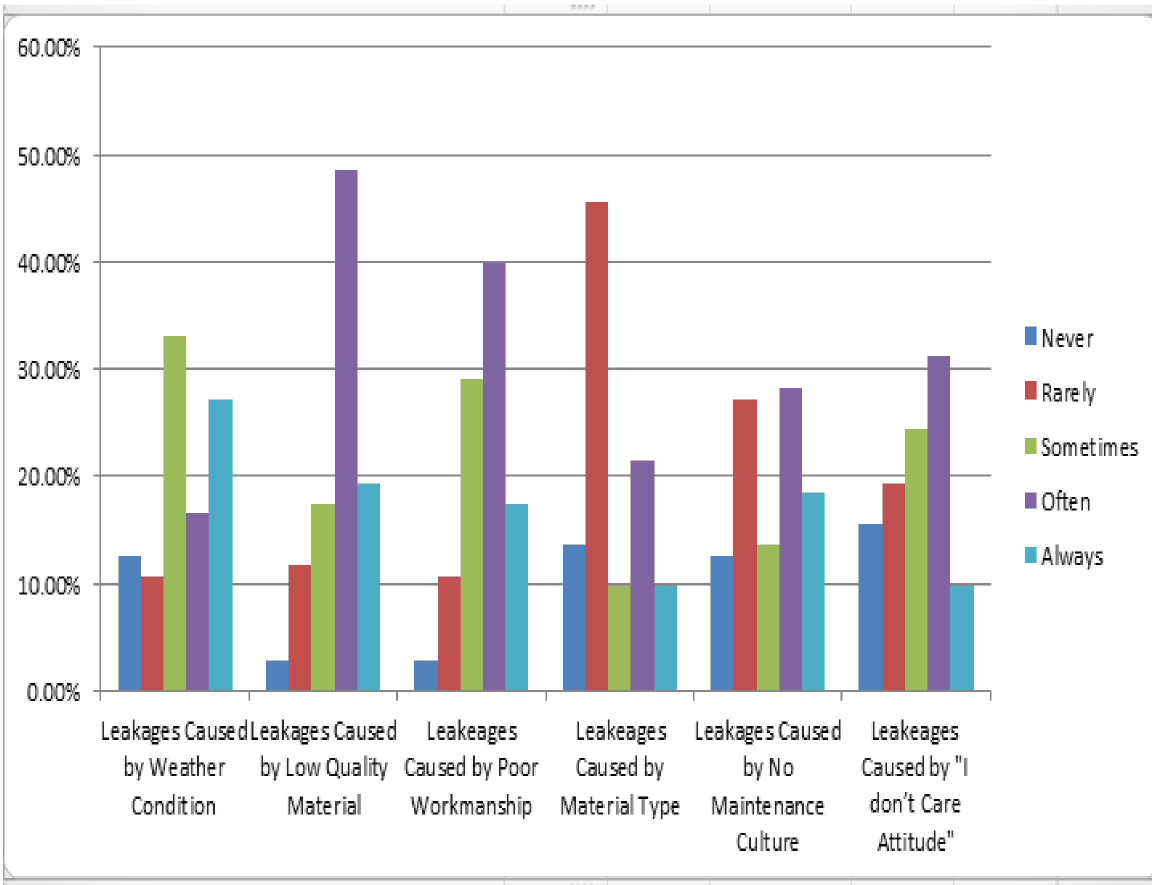


Figure 5.12: Graphical representations of causes of leakages in School Buildings

From table 5.15 and figure 5.12 leakages in PSBs are represented by six contributing factors. And, from the analysis, Leakages Caused by Weather Condition indicated 12.60% for never, 10.70% rarely, 33.00% sometimes, 16.50% often and 27.20% always. While Leakages Caused by Low-Quality Material showed 2.90% for never, 11.70% sometimes 17.50% rarely, 48.50% often and 19.40% always, Leakages Caused by Poor Workmanship had 2.90% never, 10.70% rarely, 29.10% sometimes, 39.80% often and17.50% always. Likewise, Leakages Caused by Material Type revealed 13.60% for never, 45.60% rarely, 9.70% sometimes, 21.40% often and 9.70% always. Though, Leakages Caused by No Maintenance Culture had 12.60% never, 27.20% rarely, 13.60% sometimes, 28.20% often and 18.40% always, Leakages Caused by ‘I don’t Care Attitude’ had comparatively slightly higher percentages at 15.50% never, 19.40%rarely, 24.30% sometimes, 31.10% often and 9.70% always.

Following these analyses, the low-quality material shows as the highest causative factor as it had more than 60% of the main causes of leakages. Therefore, consideration should be given to material quality to prevent leakages. However, further analysis indicates that apart from the quality of material, the experience and expertise/knowledge of workmen used should be considered as leakages have also been linked to their inefficiencies. In addition, weather condition, ‘I don’t care’ attitude and No maintenance culture are also contributory factors and hence should be put into consideration during the design of a solution.

This is further represented in table 5.16, which shows that statistical representation of the frequency distribution where the mean average is used to further buttress the points made above.

Table 5.16 Statistical Representation of causes of leakages in school building

Statistics

Mean Representation of causes of leakages in school building		Weather Condition	Low-Quality Material	Poor Workmanship	Material Type	No Maintenance Culture	'I don't Care Attitude
N	Valid	103	103	103	103	103	103
	Missing	0	0	0	0	0	0
Mean		3.3495	3.6602	3.5825	2.7767	3.1262	3.2233
Median		3.0000	4.0000	4.0000	2.0000	3.0000	3.0000
Mode		3.00	4.00	4.00	2.00	4.00	4.00
Std. Deviation		1.32627	1.10749	.99533	1.53350	1.34076	1.13701
Variance		1.759	1.227	.991	2.352	1.798	1.293
Skewness		-.285	-1.144	-.476	2.315	-.086	-.534
Std. Error of Skewness		.238	.238	.238	.238	.238	.238

Following information represented in table 5.16, mean average used to show the level of significance and the factors that should be given adequate consideration during the development of a solution. From the table the mean average of the factors shows that low-quality material had the highest causative effect followed by poor workmanship and then weather condition, I don't care attitude, no maintenance culture and the lowest consideration was on material type. This shows that material type does not cause leakages but the quality used leads to the possible leakages. Therefore considerations should be placed on the quality which is usually controlled and monitored through the code, regulations, and standards.

Furthermore, there is an association between weather condition, corrosion, discolouration, and blackening of building materials used for construction in the VGF as represented in table 5.17.

Table 5.17: Correlation between defects due to weather condition

Correlations

			Corosion caused by Weather condition	Blackening Caused by Weather Condition	Discolouration Caused by Weather Condition
Kendall's tau_b	Corosion caused by Weather condition	Correlation Coefficient	1.000	.201*	.198*
		Sig. (2-tailed)	.	.020	.026
		N	103	103	103
	Blackening Caused by Weather Condition	Correlation Coefficient	.201*	1.000	.675**
		Sig. (2-tailed)	.020	.	.000
		N	103	103	103
	Discolouration Caused by Weather Condition	Correlation Coefficient	.198*	.675**	1.000
		Sig. (2-tailed)	.026	.000	.
		N	103	103	103
Spearman's rho	Corosion caused by Weather condition	Correlation Coefficient	1.000	.233*	.222*
		Sig. (2-tailed)	.	.018	.024
		N	103	103	103
	Blackening Caused by Weather Condition	Correlation Coefficient	.233*	1.000	.751**
		Sig. (2-tailed)	.018	.	.000
		N	103	103	103
	Discolouration Caused by Weather Condition	Correlation Coefficient	.222*	.751**	1.000
		Sig. (2-tailed)	.024	.000	.
		N	103	103	103

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The relationship associated with defects caused by the weather factor is shown in the correlation table 5.17. Here, it shows a correlation between corrosion caused by weather condition, blackening, and discolouration. The table clearly indicates that there is a positive between the factors, although, the level of association is different showing a weak positive relationship between weather condition and blackening of 0.05 and strong positive correlation between blackening and discolouration of 0.01 significance. Therefore, one could infer that there is some level of significance between the factors, there is, however, a more significant relationship between *weather causing blackening* and *weather causing discolouration*.

5.6.5 Factors Influencing the Quality of Materials Used for Construction of School Buildings

During the course of this study, factors influencing the quality of materials for construction were identified through the initial question posed. Six factors were found and include Finance, Specification in the NBC, Politics, Lack of Expertise, Costs and Material Availability. However, the merits of the open-ended questionnaire type that was used provided the study with other factors such as unconcerned attitude, corruption, Government attitude, accessibility to projects and Poverty which were known to influence the quality of materials used as established from analyses of the entire factors illustrated in table 5.18

Table 5.18: Factors influencing the quality of materials used for the construction of school buildings

Factors Influencing Quality of Materials	Not Influential	Slightly Influential	Moderately Influential	Highly Influential	Very Highly Influential
NBC	2.90%	6.80%	6.80%	53.40%	30.10%
Politics	0.00%	6.80%	22.30%	37.90%	33.00%
Lack of Expertise	15.50%	22.30%	33.00%	18.40%	10.70%
Cost	16.50%	58.30%	17.50%	1.00%	16.50%
Material Availability	13.60%	4.90%	33.00%	45.60%	2.90%
Unconcerned Attitude	4.90%	13.60%	22.30%	48.50%	10.70%
Corruption	2.90%	9.70%	14.60%	51.50%	21.40%
Govt. Attitude	5.80%	5.80%	19.40%	57.30%	11.70%
Accessibility to Projects	20.40%	30.10%	22.30%	20.40%	6.80%
Poverty	21.40%	35.90%	19.40%	14.60%	8.70%

From table 5.18, the quality of materials used as indicated in the analysis is influenced by most of the factors excluding cost, accessibility, and poverty. Respondents revealed that specification provided in the NBC were at 2.90% Not influential, 6.80% slightly influential, 6.80% moderately influential, 53.40% highly influential and 30.10% very highly influential. Also, Politics had 0.00% not influential, 6.80% slightly influential, 22.30% moderately influential, 37.90% highly influential and 33.00% very highly influential. But, Lack of Expertise indicated a 15.50% not influential, 22.30% slightly influential, 33.00% moderately influential, 18.40% highly influential and 10.70% very highly influential. However, Material Availability showed 13.60% not influential, 4.90% slightly influential, 33.00% moderately influential, 45.60% highly influential and 2.90% very highly influential. With Unconcerned Attitude, Corruption and Government Attitude having 4.90% not influential, 13.60% slightly influential, 22.30% moderately influential, 48.50% highly influential and 10.70% very highly influential; 2.90% not influential, 9.70% slightly influential, 14.60% moderately influential, 51.50% highly influential and 21.40% very highly influential; 5.80% not influential, 5.80% slightly influential, 19.40% moderately influential, 57.30% highly influential and 11.70% very highly influential respectively. While accessibility showed 20.40% not influentials, 30.10% slightly influential, 22.30% moderately influential, 20.40% highly influentials and 6.80% very highly influential, poverty level had 21.40% not influential, 35.90% slightly influential, 19.40% moderately influential, 14.60% highly influential and 8.70% very highly influential. This shows that cost, poverty level, and accessibility to projects do not influence material quality as analysis showed less than 40% indicative influential rate on quality of material, while all the other factors were shown to influence the quality of material with all responses having more than 50% of influence. Therefore, using the mean with no indication of all the factors as illustrated in table 5.18, the factors that do not influence the quality of material with less than 30% influential rate were ignored. The main factors which influence the quality of material used in construction are illustrated in table 5.19.

Table 5.19: Statistical Representation of the Mean Average of Factors that Influences Quality of Materials

Statistics

Mean of Factors that Influences Quality of Materials		Specification NBC	Politics	Lack of Expertise	Material Availability	Corruption	Govt. Attitude	Unconcerned Attitude
N	Valid	103	103	103	103	103	103	103
	Missing	0	0	0	0	0	0	0
Mean		4.0097	3.9709	2.8641	3.1942	3.7864	3.6311	3.4660
Median		4.0000	4.0000	3.0000	3.0000	4.0000	4.0000	4.0000
Mode		4.00	4.00	3.00	4.00	4.00	4.00	4.00
Std. Deviation		1.18842	.91240	1.20496	1.06696	.98668	.97004	1.01764
Skewness		-.556	-.495	.095	-.942	-.930	-1.168	-.703
Std. Error of Skewness		.238	.238	.238	.238	.238	.238	.238

Table 5.19 shows the mean of all the factors selected for the interpretation as already discussed. Following the analysis, the mean average shows the level of importance placed on each factor by respondents. Here, a factor with the highest importance as shown in the table is the NBC. It is evident that the NBC plays a significant role in the actualisation of sustainable PSBs that can be adaptable in the ND. In addition, this reveals that within the Nigerian context, government, political factors and unconcerned attitude, all influence material quality and must be of interest to the providers of education.

The Nigerian Building Code provides the criteria for the quality of material used during any form of construction. This is because it provides the guiding principle on manufacturing and importation and use of building materials. Thus the adequacy of this code could necessitate the improvement on the quality of materials used in construction. Therefore the factors the influences its effectiveness was sought after.

5.6.6 Factors Influencing the Effectiveness of NBC

From literature, it was manifested that most developed nations use specification as an essential document in the building; it is made a requirement attached to the building plan and contractor's tender documents (The Joint Contracts Tribunal, 2001; NBS, 2008). This is because where the specification is prescribed and adhered to, the quality of the building will provide fit-for-purpose satisfaction to all (Anosike, 2011; Taylor, 2002). Although PSBs are open to tenders, PS provides a check on the material quality and not necessarily depends on the reputation of the manufacturer (Meier & Wyatt, 2008). However, Nigeria relies solely on the NBC; it was, therefore, important for the research to understand its effectiveness in meeting the environmental conditions during design and construction. Question 5 in the questionnaire was regarding the NBC and factors influencing its effectiveness with the results from the responses illustrated in table 5.20.

Table 5.20 Factors Influencing the Effectiveness of NBC

Factors Influencing the Effectiveness of NBC	Not Influential	Low Influential	Moderately Influential	Very Influential	very Highly Influential
Lack of Awareness of NBC	4.90%	13.60%	16.50%	40.80%	24.30%
Inadequate Provisions	12.60%	16.50%	31.10%	35.90%	3.9%
Lack of Current Regulations	5.8%	9.70%	31.10%	46.6%	6.80%
No unified Calibration with Imported Materials	2.90%	14.60%	9.7%	63.10%	9.70%
No Enforcement Team	2.90%	4.90%	6.80%	45.60%	39.80%

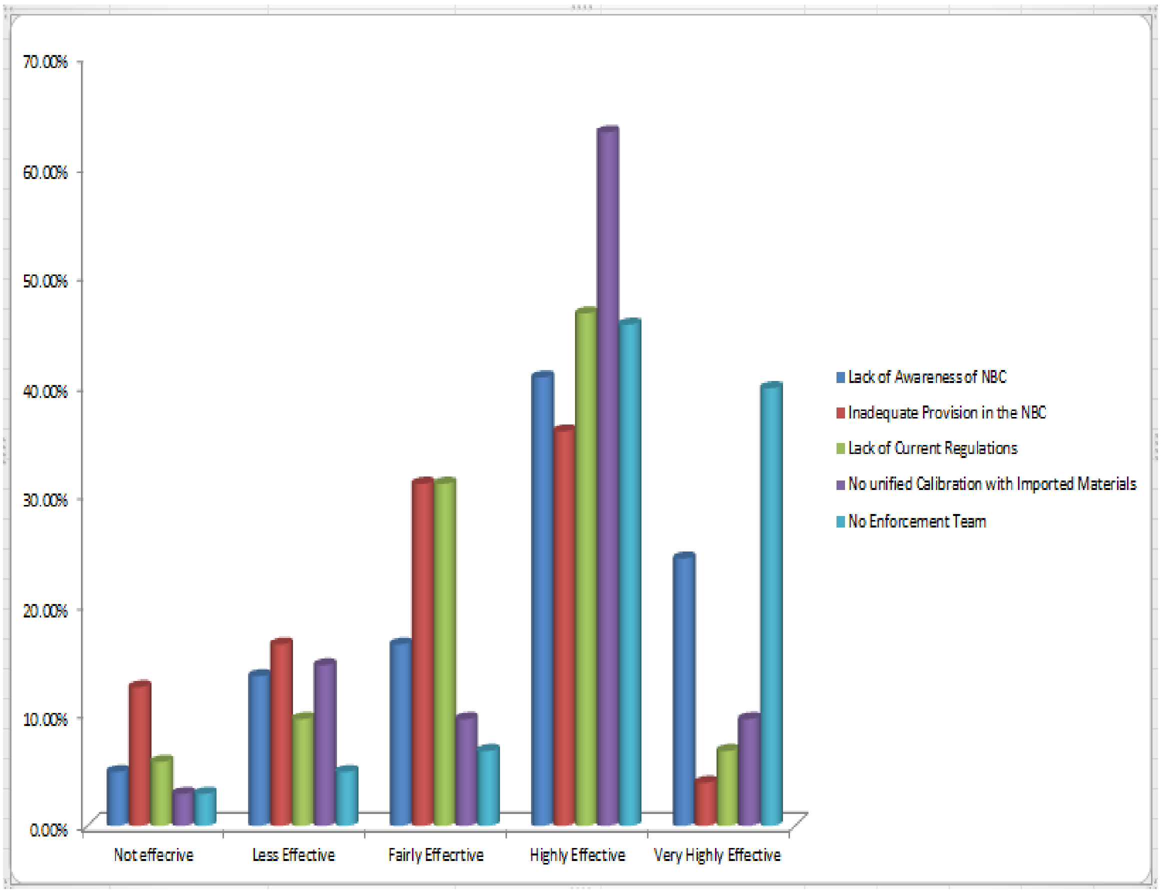


Figure 5.13 Graphical Representation of Factor Influencing the Effectiveness of NBC

From the results of the analysis in table 5.20 and figure 5.13, respondents were asked to indicate from the list provided, factors influencing the effectiveness of NBC. Starting with the lack of awareness of NBC, 4.90% indicated that it is not influential, 13.60% noted low influence, 16.50% went for moderately influential, 40.80% for highly influential and 24.30% for very highly influential. Inadequate provisions made showed 12.60% of not influential, 16.50% low influential, 31.10% moderately influential, 35.90% very influential and 3.90% of very highly influential. This proves that the contents of the NBC are inadequate hence, they do not meet the challenges of current environmental factors required to reduce the effect of GF around the NDAN. Factor 3 from table 4 above showed that the lack of current regulations had 5.8% not influential, 9.70% low influential, 31.10% moderately influential, 46.60% highly influential and 6.80% very highly influential proving that the NBC regulations are not updated to meet international standards.

This was further backed by results of the analysis of No unified calibration with imported materials as 2.90% showed no influence, 14.60% of low/moderate influence, 63.10% of highly influential and 9.7% of very highly influential. This, therefore, shows that there is no unified calibration of imported materials as professionals rely heavy on the calibration of manufacturers. The No assessment panel influencing NBC showed 39.80% of respondents indicated very highly influential, 45.60% highly influential, 6.80% moderately influential, 4.90% low influential and 2.90% not influential. This clearly shows that there is no monitoring team responsible for the assessment of materials used or imported into the country. Therefore, both importers and suppliers are a liability for the sale and purchase of any kind or quality of materials, as they are not cross-checked for conformity with the NBC. This is with no consideration to the country from which such materials originate, and most especially disregarding the suitability for the respective weather condition as noted in the interview section. Comments from participants suggested that the NBC lacks updated information on materials as happens in the developed world during the face-to-face interview:

Interviewee 10

"Most building materials used in construction in the ND area are not manufactured locally neither do the sellers of such materials aware of what NBC is and where they can access it from making developers rely heavily on words of dealers of such building materials and country name tag on them. If the NBC is updated, it should generally merge its code with that of the developed world and besides building materials dealers are in the business to make money hence imports materials that increase their profit margin since there is no unified calibration anyway"

Interviewee 3

"The current influx of made in China goods found cheaper in the markets also blinds the eyes of both dealers and suppliers of building materials. In many cases experienced marketers/dealers of building materials fill their shops with cheap materials as clients themselves determine what cost should be spent on any material".

He also noted that

"Most public building material suppliers are in for the profits and are not really interested on quality but on price difference which affects their overall turnover".

Interviewee 5

"In addition, there should a monitoring team to check material quality because makes it difficult to check materials imported into the country, their quality, and sustainable factor of

such materials. After all, there are zoning restrictions for aviation and railways why not do the same for materials used for construction around GF areas".

5.6.7 The Efficiency of Building Materials Used in the Construction of School Buildings

Most materials used for construction in the Nigerian Construction industry are imported from different parts of the world. This is one of the impending factors that hinder the effectiveness of the NBC as analysis had shown in table 5.17 with no unification and calibration system influencing the NBC. It is, therefore, necessary to enquire which country's construction material types provide adequate efficiency that could be relied on for construction. Although, construction materials are imported from all over the world, and are currently in the market the most recognised and used materials, aside from the locally manufactured materials, are from China, USA, and the UK; hence information and the questions were based on these countries.

Table 5.21 Efficiency of Imported Building Materials for Building Construction

Efficiency of Imported Building Materials	Not Efficient	Low Efficiency	Moderately Efficient	Very Efficient	Very Highly Efficient
Efficiency of UK Imported Building Materials	5.80%	22.30%	23.30%	27.20%	21.40%
Efficiency of US Imported Building Materials	5.80%	23.30%	21.40%	39.80%	9.70%
Efficiency of China Imported Building Materials	26.20%	21.40%	26.20%	14.60%	11.70%
Efficiency of Locally Manufactured Building Materials	2.90%	11.70%	23.30%	47.60%	14.60%

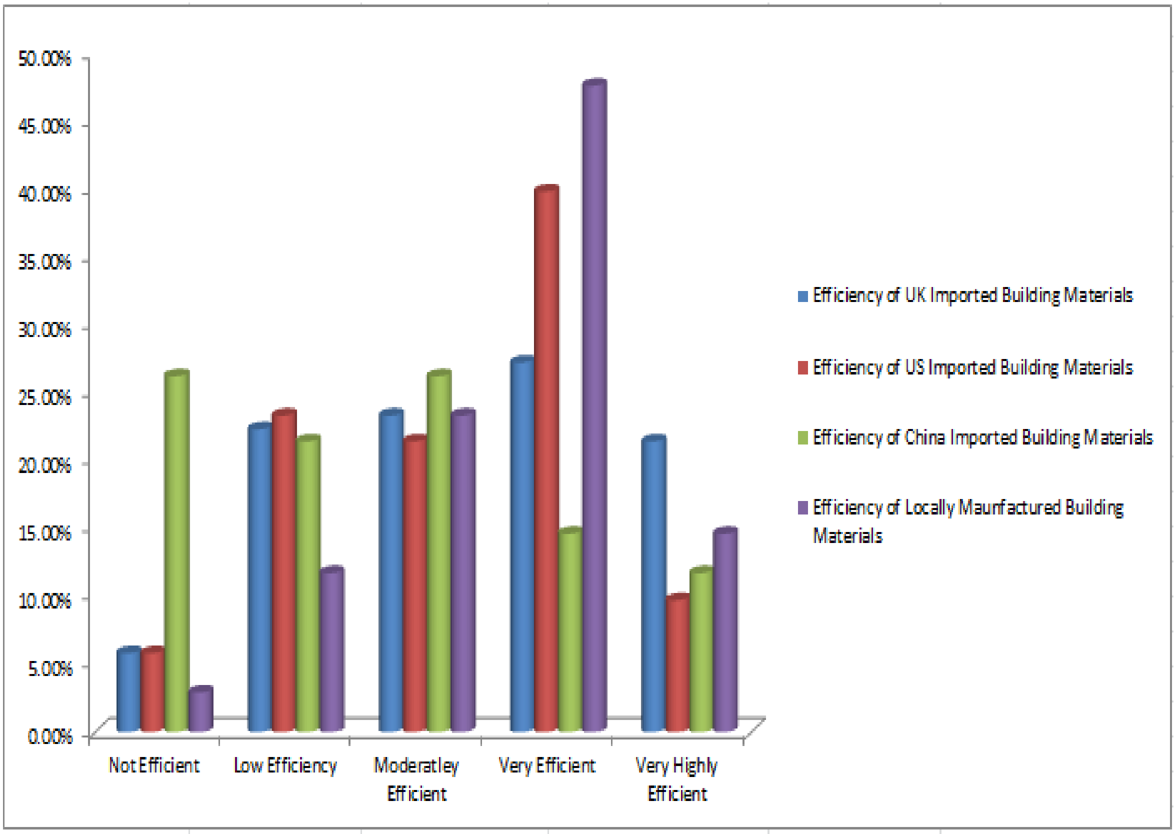


Figure 5:14 Graphical Representation of the Efficiency of Materials used for Building Construction

The table and graph denoted with number 5.21 and 5.14 show the analysis of the efficiency of building materials used for the construction of PSBs in the ND of Nigeria.

Analysis showed that responses on the efficiency of UK Imported Building Materials should 5.80% not efficiency, 22.30% low efficiency, 23.30% moderately efficient, 27.20% very efficient and very highly efficient 21.40%. While efficiency of US Imported Building Materials indicated 5.80% not efficient, 23.30% low efficient, 21.40% moderately efficient, 39.80% very efficient and very high efficiency 9.70%. Also, the efficiency of China Imported Building Materials showed 26.20% not efficiency, 21.40% low efficiency, 26.20% moderately efficient, 14.60% very efficient and very high efficiency 11.70%. However, the efficiency of Locally Manufactured Building Materials 2.90% not efficient, 11.70% low efficient, 23.30% moderately efficient, 47.60% very efficient and 14.60% very highly efficient. This, therefore, shows that materials locally manufactured showed more efficiency as compared to imported materials with imported materials from UK and US. Following their response, made in China imported materials shows a low efficiency for the construction of PSBs in the VGF. In addition, the interview conducted with professionals reflected these responses which provided reasons why the locally manufactured materials showed high efficiency and the reason why imported China made materials are popular and used more often.

Interviewee 3

It is shocking that we (building Industry) still rely on imported building materials because most of these imported materials are below standard as compared to the made in Nigeria materials.

Interviewee 4

The make belief that imported materials developed in countries with different specification, the calibration system and most times sub-standard though cheaper than locally manufactured materials amazes me.

Further comments from interviewee 3, confirmed that

The made in Nigerian electric wires (cables) are more durable and better quality than all the other wires from every part of the world

Most interviewees noted that

Builders and suppliers of building materials buy imported materials because they are cheap and the right quantity can be found in the market

5. 6. 8 Factors Influencing Material Selection

Material selection depends on many factors; however, with the observed deterioration rate and the activity of constant GF in the ND, there was the need to understand if materials used are selected based on basic factors such as durability, cost, availability, workability (skilled and unskilled labour) etc. The aesthetics of PSBs has over 30 decades been identified as a major factor that either impact positively or negatively on the performance of schoolchildren (Moore and Lackney, 1993; Barrett, et al., 2015). This has led nations to construct schools meeting today's needs to allow interaction and easy to use space adjusted to serve different purposes (Robinson and Robinson, 2009). However, in the ND and Nigeria as a whole, construction of schools remain the same; hence, this section set out to find the factors that influence material selection.

Table 5.22 and figure 5.15 illustrate the responses on the factors influencing the selection of construction materials for PSBs.

Table 5.22: Factors Influencing the Selection of Construction Materials for School Buildings.

Factors Influencing Selection of Construction Materials	Least Influential	Slightly Influential	Moderately Influential	Very Influential	Extremely Influential
Funds	6.80%	2.90%	23.30%	26.20%	40.80%
Policy	4.90%	13.60%	36.90%	27.20%	17.50%
Building Code	3.90%	23.30%	28.20%	33.00%	11.70%
Material Availability	3.90%	10.70%	35.00%	44.70%	5.80%
Lack of Skilled Labour	8.70%	9.70%	26.20%	41.70%	13.60%
Lack of Unskilled	43.70%	9.70%	39.80%	1.90%	4.90%

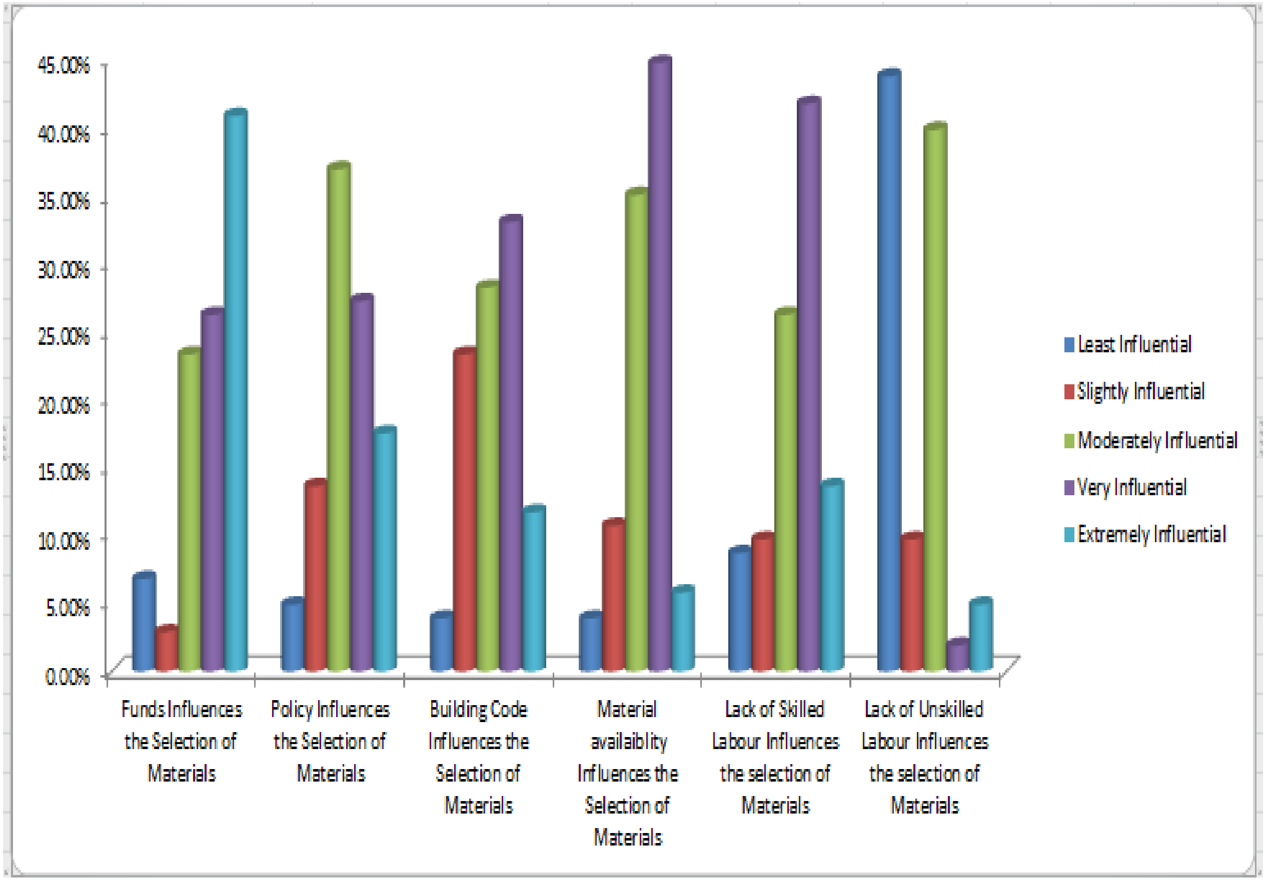


Figure 5.15 Graphical representation of analysis from table 5.22

From table 5.22 and figure 5.15, results of the analysis on the factors influencing the selection of materials for construction of schools in the ND area of Nigeria are clearly shown.

Six factors were identified and from the analysis, the results showed that Funds influencing the selection of materials had 6.80% least influential, 2.90% slightly influential, 23.30% moderately influential, 26.20% very influential and 40.80% extremely influential. Policy indicated 4.90% least influential, 13.60% slightly influential, 36.90% moderately influential, 27.20% very influential and 17.50% extremely influential. In addition, Building Code showed 3.90% least influential, 23.30% slightly influential, 28.20% moderately influential, 33.00% very influential and 11.70% extremely influential. Material availability revealed 3.90% least influential, 10.70% slightly influential, 35.00% moderately influential, 44.70% very influential and 5.80% extremely influential. Again, lack of skilled labour influencing material selections indicated 8.70% least influential, 9.70% slightly influential, 26.20% moderately influential, 41.70% very influential and 13.60% extremely influential. And finally, lack of unskilled labour showed 43.70% least influential, 9.70% slightly influential, 39.80% moderately influential, 1.90% very influential and 4.90% extremely influential. Therefore, from the analysis, respondents indicated that Funds, material availability and lack of skilled labour are the main reasons why such materials are selected and used for school construction. In addition, building codes and policies have significant levels of influence on material selection and choices for materials as compared to the lack of unskilled labour. This is further illustrated using the mean average as represented in table 5.23.

Table 5.23: Further Statistical Representation of the mean average and level of skewness

Statistics

Mean of Factors Influencing Selection of construction Materials		Funds	Policy	Building Codes	Material Availability	Skilled Labour	Unskilled Labour
N	Valid	103	103	103	103	103	103
	Missing	0	0	0	0	0	0
Mean		3.9126	3.3883	3.2524	3.3786	3.4175	2.1456
Median		4.0000	3.0000	3.0000	4.0000	4.0000	2.0000
Mode		5.00	3.00	4.00	4.00	4.00	1.00
Std. Deviation		1.17245	1.07770	1.06383	.89789	1.11605	1.15816
Skewness		-.981	-.208	-.125	-.663	-.673	.559
Std. Error of Skewness		.238	.238	.238	.238	.238	.238

From table 5.23, the mean average is used to determine the level of importance of all the factors influencing material selection listed. The mean average of fund showing 3.9126 is the highest factor followed by lack of skilled labour with 3.4175 mean average, the policy having 3.3883, material availability 3.3786, building code 3.2524 and unskilled labour 2.1456 being the least factor that influences material selection. The reason for the selection of nonparametric test is based on the skewness in the data indicating that it is not normally distributed as will be shown by plotting the curve hence the choice.

In addition, during the semi-structured interview, a respondent commented as follows:

Interviewee 2

"Building materials used are highly influenced by funds and I d o not mean that there are no funds available for construction of school but those making this policy and allocating funds for educational purposes also expect to be appreciated with some of the money when approved. It is therefore difficult to source for materials above the available funds at one's disposal not forgetting that most of the school building construction as contracted out to companies without any knowledge in building or construction process".

5.6.9 Impact of GF on Building Fabrics

This research presupposes that GF is a major problem that accelerates the level of deterioration and poor IAQ. Some literature already supports this assertion (Nwanya, 2011; Rabinowitz, et al., 2014; Mollaoglu-Korkmaz et.al., 2013) although not in the specific context of the primary problem of research consideration. It is therefore significant that a question relating to its perceived impact based on researchers' general observations is necessary to further justify and provide information in the research area. Eight factors were identified through observations by the researcher and were considered through questions and analysis from table 5.24 below showed the response from respondents of the effect of GF on the building fabrics.

Table 5.24: Impact of GF on Building Fabrics

Impact of Gas Flare on Roofing Material	Very Low Impact	Low Impact	Moderate Impact	High Impact	Very High Impact
Corrosion	1.90%	9.70%	8.70%	26.20%	53.40%
Blackening	5.80%	7.80%	8.70%	44.70%	33.00%
Discolouration	2.90%	12.60%	4.90%	43.70%	35.90%
Dry and Wet Rot	3.90%	8.70%	32.00%	25.20%	23.30%
Leakages	3.90%	8.70%	18.40%	27.20%	41.70%
Anti-Corrosive substances	7.80%	15.50%	20.40%	40.80%	15.50%
Life Span Reduction	7.80%	17.50%	23.30%	39.80%	11.70%

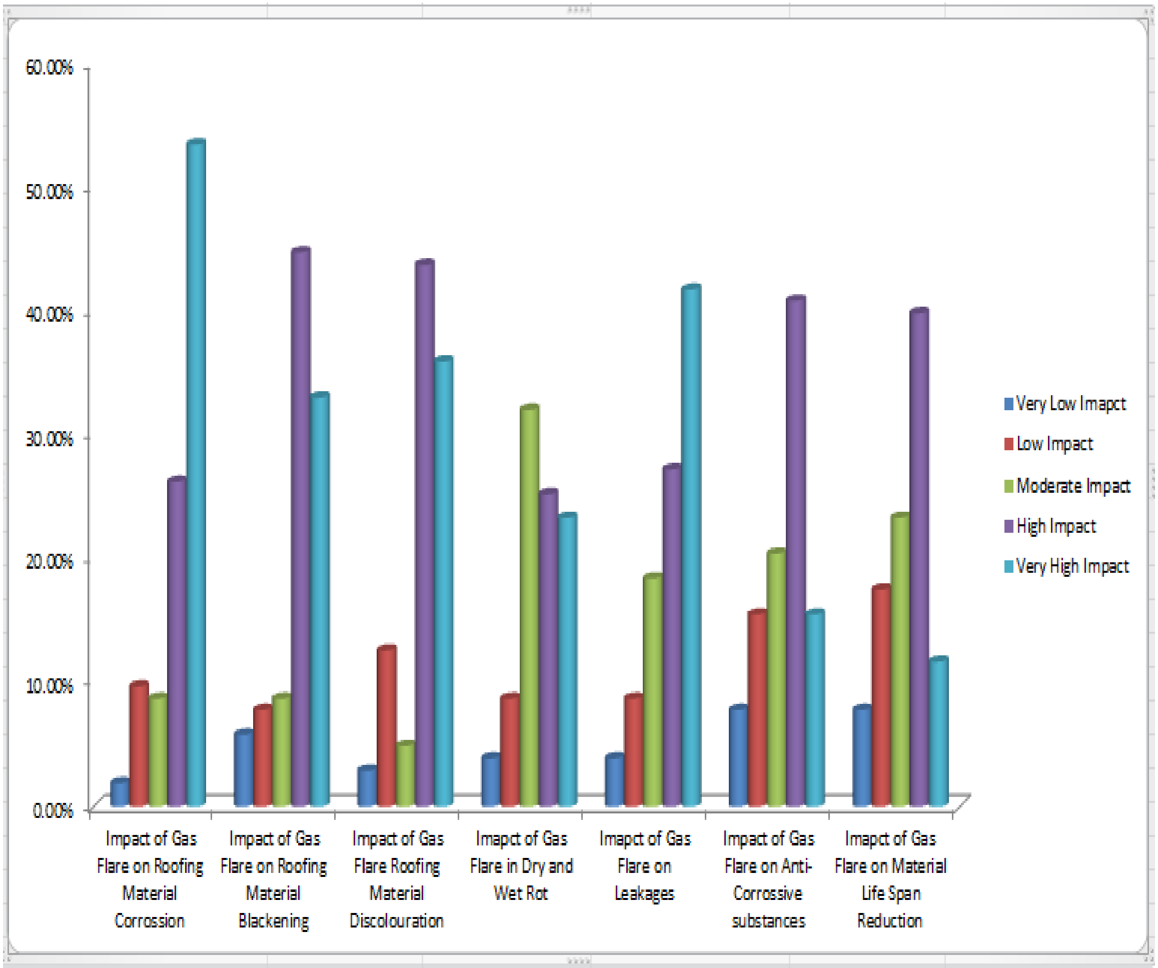


Figure 5.16 Graphical Representation Impact of GF on Building Fabrics

Although literature indicated that GF causes corrosion in buildings, the World Bank report of 1995, as cited in Aghalino 2009, had argued that gases from oil exploration activities are sour or sweet sulphur and therefore cannot cause corrosion on building materials. Contrary to this claim, results from the field data show that corrosion as a factor caused by GF revealed 53.40% of respondents favouring *very high impact*, as against just 1.90% for *very low impact with the relevant details in-between covered in the table and figure above*. Similarly, blackening effect due to GF shows a 33.0% very high impact, 44.70% high impact, 8.70% moderate impact, 7.80% low impact and 5.80% very low impact option from the Likert scale which supports pictorial evidence during field survey as illustrated in chapters 2 figure 2.9, 2.10 and 2.11 and the comment from the face-to-face interview thus;

Interviewee 8

"I do not believe that GF does not cause acid rain which leads to corrosion of roofing materials because even particulate matter which is part of gases that are flared is a major

corrosion defector, therefore such summation that GF in Nigeria does not cause acid rain which in turn corrodes roofing materials are far-fetched".

Furthermore, it was noted during the interview section that climate specific conditions have to be met before material selection is made because according to one of the respondents immediate conditions accelerate deterioration rate as commented below;

Interviewee 9

"The immediate weather condition in the ND area has to be taken into consideration first before material choice"

Also, respondents indicated 35.3% very high impact of dry/wet rot caused by GF with 25.20% high impact, 32.00% of moderate impact, 8.70% of low impact and 3.90% of no impact. However, responses on the impact of GF on leakages revealed 41.70% very high impact, 27.20% high impact, 18.40% moderate impact, 8.70% low impact and 3.90% very low impact. This could be linked to the high level of corrosion resulting in wearing and tearing. In addition, the impact of GF on anti-corrosive substances revealed 15.50% of very high impact, 40.80% high impact, 20.40% moderate impact, 15.50% low impact and 7.80% of no impact indicating that anti-corrosive substances used in coating building materials are not resistant to GF impact in the GF of ND. Thus adequate consideration should be given to the level of resistance of any material used for construction in the study area. In addition to the question posed the impact of GF on material life span revealed 11.70% very high impact, 39.80% high impact, 23.30% moderate impact, 17.50% low impact and 7.80% very low impact. Therefore, it could be inferred that the impact of GF on all the other factors listed and analysed will lead to building materials not reaching their specified life span hence adequate considerations should be placed on materials and the possibility of reaching their specified life span.

Furthermore, using the mean average, table 5.25 shows the very various impact of GF on the factors as analysed and discussed in the table 5.16.

Table 5.25 Statistical Representation of the Impact of GF on Deterioration of Roofs

Statistics

Impact of Gas Flare Roofing Material		Corrosion	Blackening	Discolouration	Dry and Wet Rot	Roof Leakages	Anti-Corrosive Substances	Life Span Reduction
N	Valid	103	103	103	103	103	103	103
	Missing	0	0	0	0	0	0	0
Mean		4.1942	3.9126	3.9709	3.4854	3.9417	3.4078	3.3010
Median		5.0000	4.0000	4.0000	3.0000	4.0000	4.0000	4.0000
Mode		5.00	4.00	4.00	3.00	5.00	4.00	4.00
Std. Deviation		1.07611	1.12116	1.08877	1.12776	1.14468	1.15840	1.12751
Skewness		-1.264	-1.187	-1.103	-.214	-.884	-.543	-.453
Std. Error of Skewness		.238	.238	.238	.238	.238	.238	.238

From table 5.25 shows deteriorative impact Gf on roofing materials. Following the table, respondents should high acceptance of GF causing corrosion on roofing material with a 4.1942 mean average, followed by discolouration, which had 3.9709, leakages 3.9417, blackening 3.9126, dry and wet rot 3.4854, anti-corrosive substance 3.4078 and life span reduction 3.3010 average mean. Therefore, more consideration should be given to requirements that will reduce corrosion impact even though such materials are used in an environment with the clear presence of substances that intensifies corrosion and another effect.

Furthermore, the level of association of GF impact causing deteriorative as discussed in chapters 2 and 3 are made more clear using the correlation table illustrated in table 5.26;

Table 5:26 Correlations of Impact of GF on Roofing Material

Correlations

Impact of Gas Flare on roofing material			Corrosion	Blackening	Discolouration
Spearman's rho	Impact of Gas Flare on roofing material Corrosion	Correlation Coefficient	1.000	.554**	.586**
		Sig. (2-tailed)	.	.000	.000
		N	103	103	103
	Impact of Gas Flare Roofing Material Blackening	Correlation Coefficient	.554**	1.000	.680**
		Sig. (2-tailed)	.000	.	.000
		N	103	103	103
	Impact of Gas Flare Roofing Material Discolouration	Correlation Coefficient	.586**	.680**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	103	103	103

****. Correlation is significant at the 0.01 level (2-tailed).**

Following table 5.26, correlation significance shows the level of association between the factors selected in relation to GF. Further analysis using spearman's rho correlation coefficient shows that there is an association of 0.01 level (2 tailed) significance between the impact of GF on corrosion, blackening, and discolouration of roofing materials. This further agrees to the comments provided by the interviewees on the impact of gas on building deterioration.

A Effect of GF on Build Walls

Table 5.27 represents the response from analysis on the effect of GF on paint flaking, damp wall, cracks, sand-crate, and bricks

Table 5:27 Effect of GF on Build Walls

Effects of GF on Building Walls	Very Low Effect	low Effect	Moderate Effect	High Effect	Very High Effect
Effect of Gas Flare on Flaking/peeling of Paints	0.00%	11.70%	27.20%	37.90%	23.30%
Effect of Gas Flare on Damp Walls	21.40%	20.40%	35.90%	19.40%	2.90%
Effect of Gas Flare on Cracks	9.70%	27.40%	14.60%	36.90%	11.70%
Effect of gas Flare on sand-crate Blocks	10.70%	8.70%	38.80%	35.00%	6.80%
Effect of Gas Flare on Bricks	14.40%	33.00%	32.00%	12.60%	7.80%

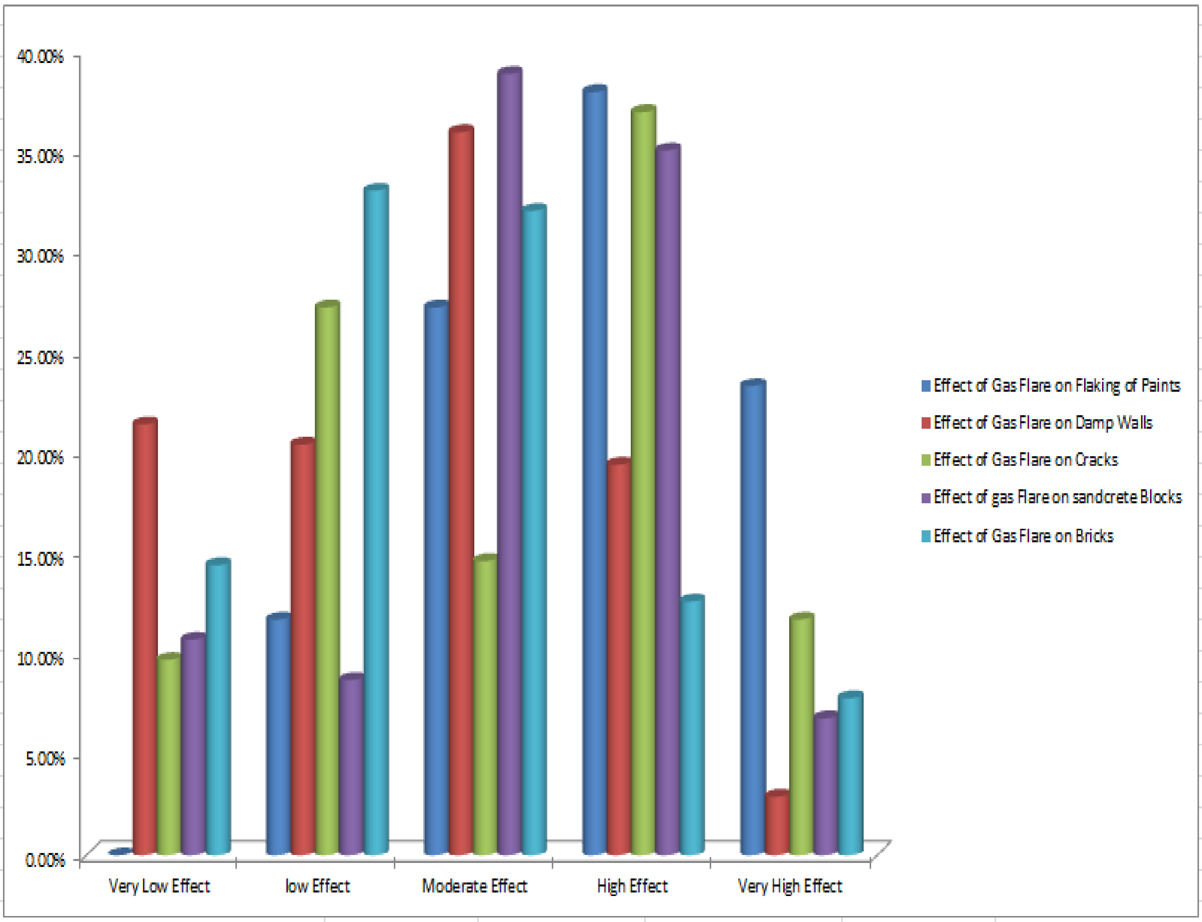


Figure 5.17: Graphical Representation of Effect of GF on Walls

Table 5.27 and figure 5.17 represent the table and graph showing responses as analysed for effect of GF on building fabric. From literature and initial problem identification as represented in figure 5.1, some of these effects are observed in the study area. However, there is no documentary evidence relating this effects and GF. The response provided by professionals formed a further justification and necessities the inclusion of performance requirements that help mitigate such defects.

Analysis showed that GF effect causes the flaking of paints as 0.00% revealed No effect, 11.70% very low effect, 27.20% moderate effect, 37.90% high effect and 23.30% very high effect. While GF effect on Damp Walls showed 21.40% no effect, 20.40% very low effect, 35.90% moderate effect, 19.40% high effect and 2.90% very low effect. Also, the effect of GF on Cracks indicated 9.70% no effect, 27.20% very low effect, 14.60% moderate effect, 36.90% high effect and 11.70% very high effect. This could be as result of rumbling sounds and weaken of the cement due to constant deposition of alkaline and other acidic substances. Furthermore, the effect of GF on sand-crate blocks showed a 10.70% no effect, 8.70% very low effect, 38.80% moderate effect, 35.00% high effect and 6.80% very high effect which justifies the response on cracks. However, the effect of GF and bricks indicated 14.40% no effect, 33.00% very low effect, 32.00% moderate effect, 12.60% high effect and 7.80% very high effect. This shows that brick has a high resistant factor on the chemical substances deposited on building fabric in the ND. However, significant considerations should be given to other factors as illustrated with the mean average in table 5.28

Table 5.28: Mean average of identified effects associated with GF

Statistics

		on Peeling of Paints	Damp Walls	Cracks	Sand-crate Blocks	Bricks
N	Valid	103	103	103	103	103
	Missing	0	0	0	0	0
Mean		3.7282	2.6214	3.1359	3.1845	2.6602
Median		4.0000	3.0000	3.0000	3.0000	3.0000
Mode		4.00	3.00	4.00	3.00	2.00
Std. Deviation		.95172	1.11247	1.22113	1.05484	1.11631
Skewness		-.262	-.029	-.199	-.583	.407
Std. Error of Skewness		.238	.238	.238	.238	.238

From table 5.28 the level of importance placed on each factor as deteriorative effects caused by GF had peeling of paints with the highest mean average of 3.7282, sand-crate blocks 3, 1845, cracks 3.1359, brick 2.6602 and damp walls 2.6214. From this representation using the mean average, bricks and damp walls are not significantly impacted by GF thus performance requirement might not be necessary for those factors. Although, the use of brick could be preferable material as compared to sand crate blocks. In addition, paints used for buildings in GF areas should be resistant to the effect of constant heat and deposition of chemical substances that might cause a reaction of deterioration such as peeling or flaking of paints. Furthermore, the level of skewness shows that the normality curve is negative and the mean conversely is less than the mode.

5.6.10 Impact of GF on Roofing Materials Used in the NDAN

The choice of material and material quality accelerate the level of deterioration noticeable. In the NDAN different materials although similar in raw material type are available in the market with different brand names. Information gathered from this section helps with the development of a solution that will help buildings. It was therefore pertinent to ask questions based on materials available in the ND area. As already discussed in chapter 3, countries like the UK as illustrated in table 3.2 and 3.3 provided specification of different types of roofing materials including roofing members. Thus question relating to roofing material types and the impact of GF was posed to respondents and from analysis table 5.29 and figure 5.18 shows results.

Table 5.29: Impact of GF on Roofing Materials

Effect of GF on Roofing Materials	Very Low Effect	low Effect	Moderate Effect	High Effect	Very High Effect
Asbestos Roofing Sheets	14.60%	29.10%	43.70%	3.90%	8.70%
Thatch Roofing Sheets	21.40%	12.60%	13.60%	29.10%	23.30%
Corrugated Roofing Sheets	2.90%	15.50%	4.90%	25.20%	51.50%
Aluminium Roofing Sheets	15.50%	30.10%	18.40%	14.60%	21.40%
Slate Roofing Sheets	21.40%	33.00%	26.20%	10.70%	8.70%

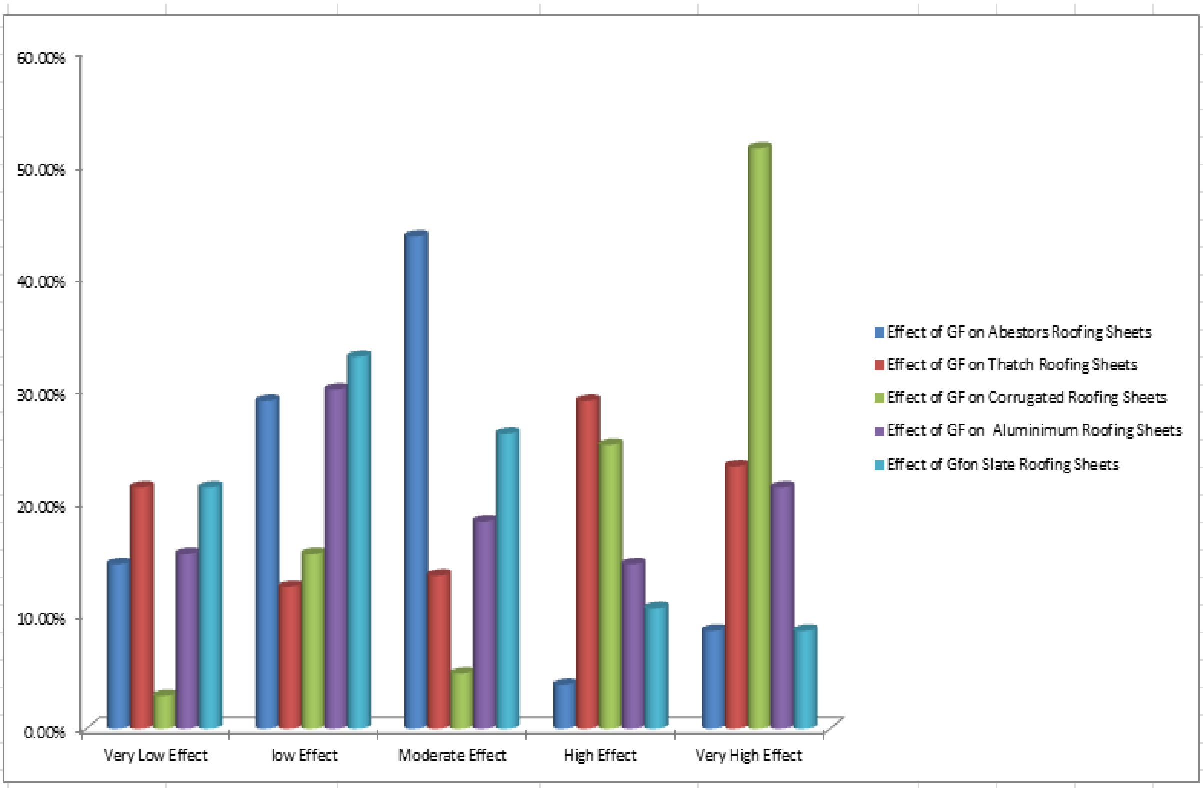


Figure 5.18 Graphical Representation of the Effect of GF on Selected Roofing Materials

Table 5.29 and figure 5.18 both represents the analysis from the question on the effect of GF on identified roofing types used in the ND area.

Five roofing material types were identified and include asbestos, thatch, corrugated zinc, aluminium, and slates. Results showed that the GF effect on asbestos roofing sheets had 14.60% very low effect, 29.10% low effect, 43.70% moderate effect, 3.90% high effect and 8.70% very high effect. Although asbestos is no longer recommended as a material type but still used in construction around the study area. During the face-to-face interview, professionals gave their reasons for asbestos preference as compared to zinc roofing material thus; interviewee 2 stated that;

Interviewee 2

"Aside from its health effect, asbestos roofing materials have stood the test of time because roofs with asbestos as roofing sheets are still functional as compared to corrugated roofing sheets".

More so, ***interviewee 7*** stated that

"There is no point discussing asbestos as roofing material because it also leads to carcinogenic effects and when combined with what the world is saying about air pollution then ND has a big pandemic waiting to unfold".

In addition, interviewee 6 mentioned that the "The ND is destined for extinction"

While, Thatch Roofing Sheets indicated a 21.40% very low effect, 12.60% low effect, 13.60% moderate effect, 29.10% high effect and 23.30% very high effects. However according to comment from semi structured interview participant comment with regards to thatch roof is stated below;

Interviewee 2

"Thatch roofing cannot be recommended for construction of public schools due to its low life span; however, I think that there should be government sponsored research on how this material could be more durable rather than relying on imported materials".

Factor 3 in the table was the impact of GF on zinc also referred to as corrugated iron sheets (CIS) roofing material, the analysis showed 2.90% very low effect, 15.50% low effect, 4.90% moderate effect, 25.20% high effect and 51.50% very high effect. Also, Aluminium Roofing Sheets showed 15.50% very low effect, 30.10% low effect, 18.40% moderate effect, 14.60%

high effect and 21.40% very high effect. Contrarily, Slate Roofing Sheets revealed 21.40% very low effect, 33.00% low effect, 26.20% moderate effect, 10.70% high effect and 8.70% very high effect. However, when these same questions were asked during the interview session, interviewee comments were as stated below;

***Interviewee 1, 2, 6 started below comments**;*

"High defects of zinc roofing material corrode in less than two years of its installation".

Interviewee 2 noted that

"Zinc Material is not a material that should be used for public buildings because the corrosion rate increases the high rate of leakages affecting both roofing members and ceiling boards with evidence of brownish discolouration on the ceiling boards".

Interviewee 6

"Around Calabar here in Akwa Ibom state Zinc show signs of decolouration and corrosion in less than one year after installation".

Interviewee 3 started below comments;

"I did carry out a study on the effect of rainfall around Ahoda-west local Government area of Nigeria and the Ogba-Egbma Local Government area and the study found out that there is acid rain in the NDA. And because of the oxidisation process, a material such as zinc corrugated roofing sheets corrodes faster than estimated lifespan of more than 30years. Even the aluminium roofing sheets also tend to change its colour having patches of blackish or brownish discoloration effect. This effect could also be noticed in distance less than 200m even with vertical flare station in the Ogba-Egbma LGA"

"Roofs should be done with high quality aluminium because even aluminium roofing sheets also tends to change it colour having patches of blackish or brownish discoloration effect"

With slates having a more positive result which means that its use is highly recommended, ***interviewee 4*** during a section with in commented that;

"although Slates has not shown any corrosion or any other effects since its use in the past seven years because it is a new material that is now used by most private individuals that can afford it but clear observation from a property developed and managed by his firm in town in close proximity to GF sites had recently noticed patches of discolouration on the roofing materials. He observed that though slates come in dark (mostly black) colours, traces of ash coloured patches are now evidently seen on the roofing materials"

Following the above analysis, it is evident that GF has a negative impact on building materials more specifically on the external façade which is the main concentration of this study. It was also evident that although newer materials such as slates are gradually been introduced in the construction industry, observations from one of the interviewees show that precautions need to be taken while specifying any material type.

Furthermore, having discussed and identified factors that should be taking into consideration for materials during design, selection, and construction of schools in the VGF. It is pertinent that the fourth main objective of this research which was to examine the criteria used for the ventilation system in schools in the ND. Although this has been discussed in chapter 2 and 3 of this study, further explication was necessary as to gather essential information for the design of solution development.

5.7 Perception of BEF on the Impact of GF on IAQ

Professionals over the years have attributed different factors to poor IAQ ranging from building materials, finishing, paintings, decorating materials to space, size and the number of people inside a given a space. However, they have relentlessly avoided the adequate consideration of ambient air as its effects on indoor air. Although the orientation of both windows and doors openings for natural ventilation system has been proven help the filtration of clean air. However, to a great extent, the probability of achieving clean indoor air in the highly polluted environment is unrealistic if there are no filtration measures or system used in purifying or filtrating air to make the indoor air clean. These arguments have fostered newer technologies and materials that could help in generating clean air indoor (See table 3.5 for some of the newer technologies and figure 3.3 for the material used for filtering polluted air). Furthermore, laws, regulations and building codes are being updated either by approbation due to the integration of nations as a global community by WHO, UN, Eurocode, ASTMI. Yet these improvements made due to the importance of indoor quality are rarely considered in Nigeria and in the ND. Again the impact of poor IAQ recently is becoming a crucial point of consideration and research has shown that it affects the performance of children academically in schools hence countries like the UK and the USA has developed IAQ guideline used in schools as a check and to confirm and monitor the quality of air in schools. Based on the literature already reviewed in chapters 2 and 3, the amount of anthropogenic substances released in the air around the NDAN due to GF activities, observation that some of these flaring sites are located close to schools as illustrated in figure 2.4 in chapter 2, the use of open ventilation system also illustrated in figure 3.7. All prove that the understanding and the emphasis of nations with the similar environmental condition to provide indoor air inside buildings is yet to be considered a fundamental problem to the growth and performance of children in the ND. This, therefore, paved the way to initiate questions in both the open ended questionnaire and the face–to-face interview, to understand if there is a problem with GF as it relates to indoor air having observed that open ventilation system is the main form of indoor air. The need to explore further from professionals to see if their likely observed or noted impact of GF on the health of the occupants and what methods of ventilation systems are used to provide clean IAQ. Again, questions asked were used to further provide evidence for the significance of the study, meeting research objectives and answering some questions posed in chapter one of the study.

5.7.1 Impact of Gas Flare on Air Quality

Knowing from the literature that internal air inhaled causes many fatal diseases leading to death in most circumstances thus, it was vital to know the opinion of professionals and their perceived impact of GF on IAQ.

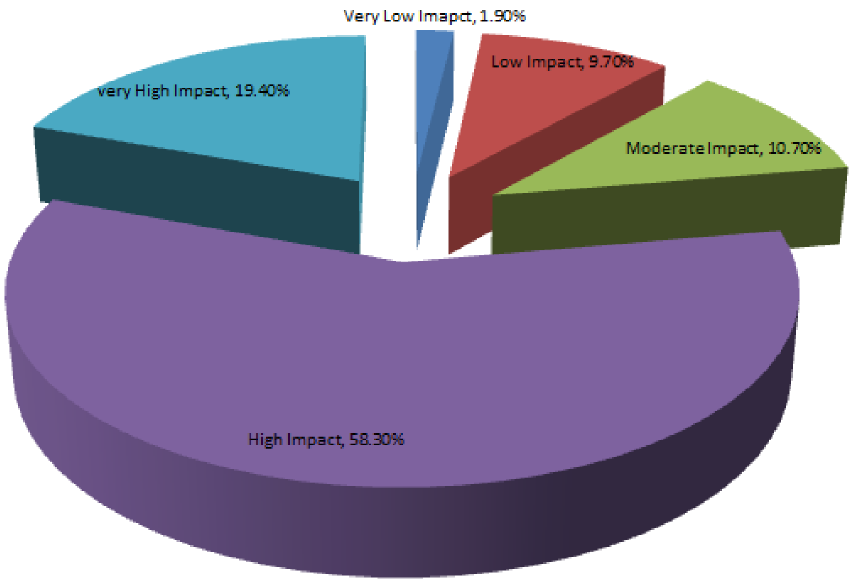


Figure 5.19: Impact of GF on Air Quality

When participants were asked to indicate their perception of the impact of GF on IAQ, results from the analysis showed in figure 5.19 indicates that 58.3% noted that GF had high impact, 19.4% very high impact and 10.7% a moderate impact with 9.7% low and 1.9% very impacts. This means that IAQ as earlier reviewed in literature is an important factor that leads to health implications, absenteeism and other vices have already discussed are some of such impacts. Therefore, it is important that during design, professionals engaged construction activities should have attributes of the specification that deals with clean air quality.

The importance of IAQ was clearly seen as an important aspect of the environment because when asked the similar question during the interview section, some interviewees made these comments:

Interviewee 8 *"Nobody ever talks about air quality standards or whether the air around where schools are sited is of good quality"*

Interviewee 5 *"It is a shame that professionals here in Nigeria do not talk about IAQ as nobody measures it also. As an architect who has practiced for over 30 years here in the ND, I have never seen air quality measured or considered during construction but I think it is a very serious aspect of construction that has to be looked at if and when constructing around the GFA"*

5.7.2 Effective Air Quality Standard for Public Schools in the Vicinity of GF

Based on the importance of clean indoor air, countries all over the world use codes, standards, regulations adaptable in their respective countries, in some countries like the USA, different states have different guidelines produced to meet those environment specific needs. In the UK, the London sustainability exchange has the specific provision in the school curriculum to teach about the importance of clean air. Similarly, the EPA 2013 is a framework providing an outline in achieving clean air in schools while ASHRAE recommended an acceptable ventilation rate of 6.7 to 7.41.s- person and guidelines for different pollutants have also been produced by different countries. International standards such as WHO and FEPA are some of the guiding standards used to base clean air quality standard to be achieved. However, this is not the case for Nigeria though the second largest emitter of anthropogenic gases through GF, which leads to the question 8 in the open-ended questionnaire survey.

Following analysis of the questionnaire, table 5.30 and chart on figure 5.20 shows the level of response given by all the participants with reference to what IAQ standard that could be effectively used in public school construction around GFAN.

Table 5.30 Effective Air Quality Standards for Schools in Vicinity of GF

Effective Air Quality Standards	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%

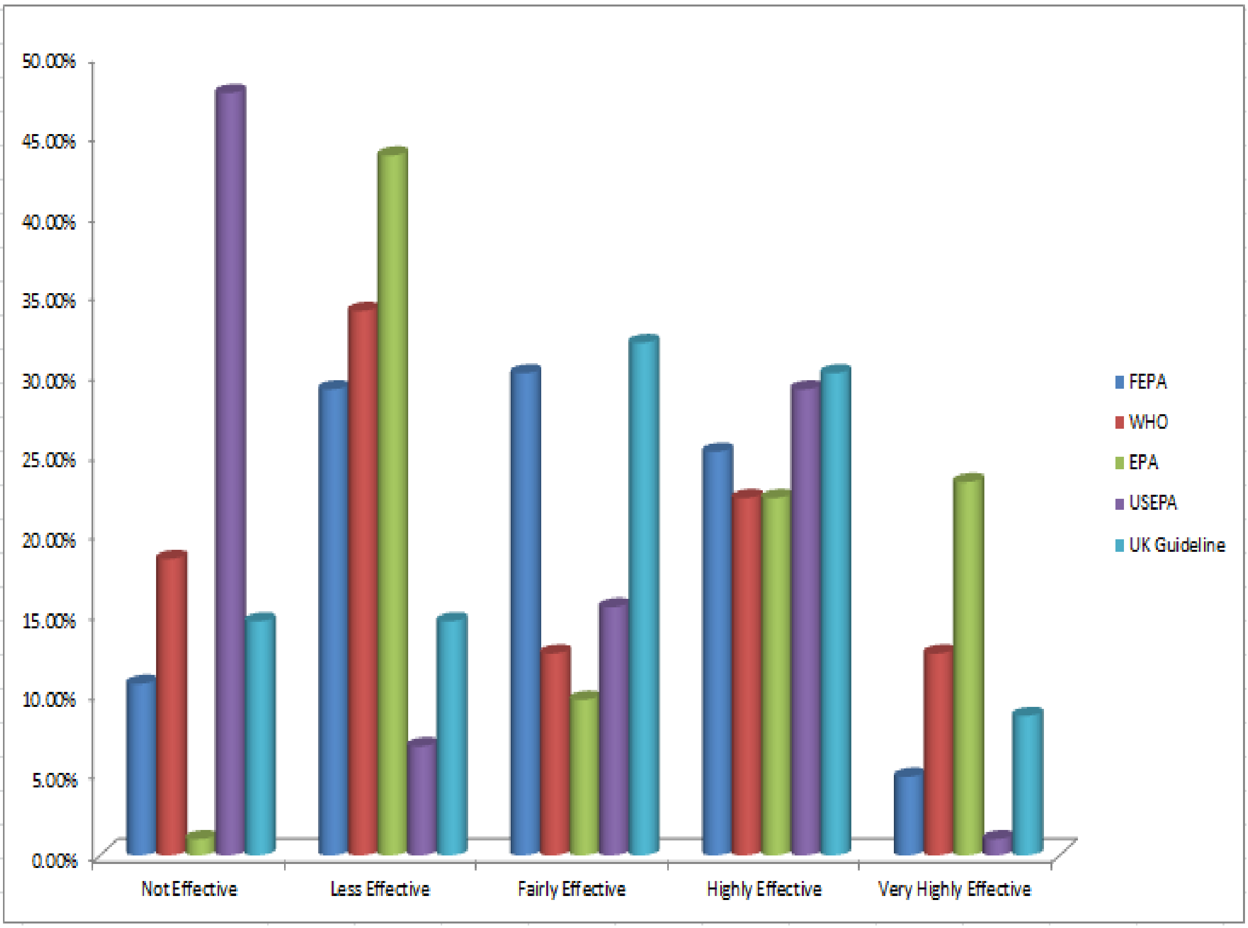


Figure 5.20 Effective Air Quality Standard for Public schools in the Vicinity of GF

Following table 5.30 and figure 5.20, shows selected air quality guidelines published to enable countries to understand and used as a guide for allowable air that will enable clean indoor air.

The result from the analysis as shown in table 5.20 revealed 10.70% not effective, 29.10% less effective, 30.10% fairly effective, 25.20% highly effective and 4.90% very highly effective of the choice of FEPA standards. WHO as an effective standard to adopt from 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, comparing the two standards, professionals in the NDA aligned more with the FEPA standards. Despite this alignment, the EPA analysis revealed a 1.0% 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% of not effective showed 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. From the above analysis, the best IAQ standard preferred by professionals is the UK guideline for schools. This also supports comments from a professional in the interview session noting that standards adopted in Nigeria are handed down from the British system;

Interviewee 9 *"Well I will say that there are IAQ standards because it is the prototype of the UK Guideline which to my mind is similar to the WHO air quality standard. But the functionality of it is what I cannot say because if these standards are there then I do not think it is used because no rightful thinking man will allow schools or people to live around GFA even up to 500km away but here schools are even built close to such flare stacks. Again like the NBC our constant copying or adopting standards from the British standards without recourse to our immediate environment is a factor that renders laws and standards ineffective".*

In addition, most interviewees recounted that the FEPA standard used in Nigeria more than 20decades old and should not be the case as laws are constantly evolving to meet present day needs.

Interviewee 4 **commented that;**

Why the country is still bent on using the FEPA standards still amazes him because information and current guidelines on air quality in areas like the ND should have been well developed by NESARA and EGASPIN. He continued by noting that some of the limits provided in such documents are different from that of the FEPA standard used in the country and somehow close to what is obtained in developed countries guidelines.

Therefore from analysis and comments from interviewees, it is clear that information on air quality should be aligned more with developed nation's limits rather than what is obtained in the FEPA standards. This also needs to the studying understanding the effect of these emissions on the performance of pupils.

5.7.3 The Effect of GF on the Performance of Schoolchildren

As part of the research and major factor to the relevance of this study is the impact of GF on the performance of children. Recent studies showed that poor academic performance of children has been linked to poor air quality and un-wellness hence the need to pose a question in the questionnaire survey that will help provide a concise agreement to literature particularly because these effects are not documented in the Nigeria context.

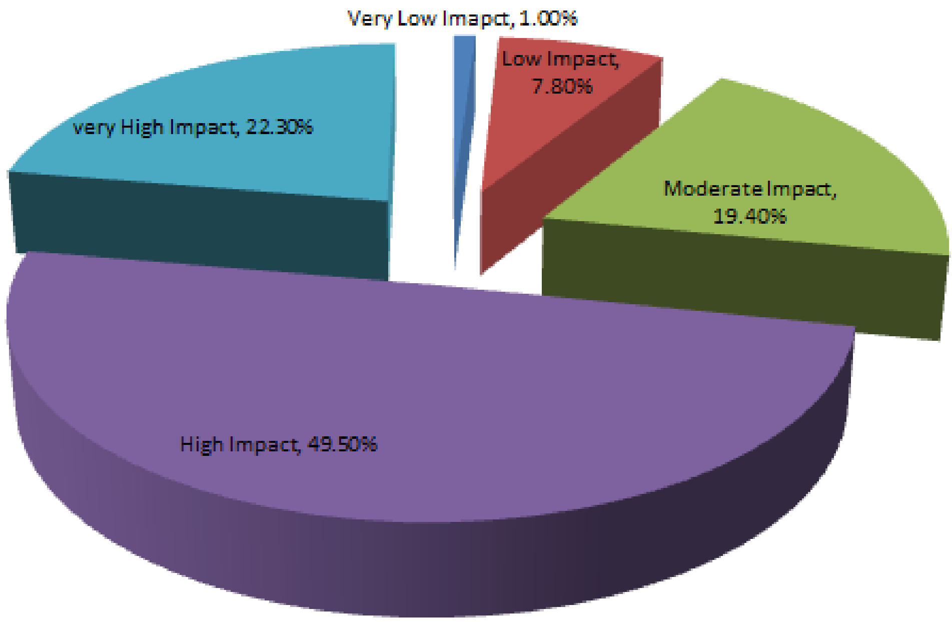


Figure 5.21 Effect of Gas Flare on the Performance of Children

The question on the effect of GF on the performance of schoolchildren was analysed and figure 5.21 shows that all respondents agreed that GF affects the performance of schoolchildren.

As indicated in the figure, 22.30% responses showed a very high effect, 49.50% high effect, 19.40% moderate effect 7.80% less effect and 1.00% no effect. This shows that penetration of flared gases into classrooms do more damage not only o the building fabrics but also to the performance of schoolchildren academically.

5.7.4 Health Impact of GF on Pupils and Staffs

In addition to the impact of GF on the academic performance of schoolchildren, the health effect is also crucial to this research as discussed in chapters 2, 3 and as illustrated table 2.5-2.7. Indications from information gathered from literature showed that the health of schoolchildren was also a factor that raised concern hence the question of the impact of GF on the health of children and staffs. A result of analysis is represented in figure 5.22;

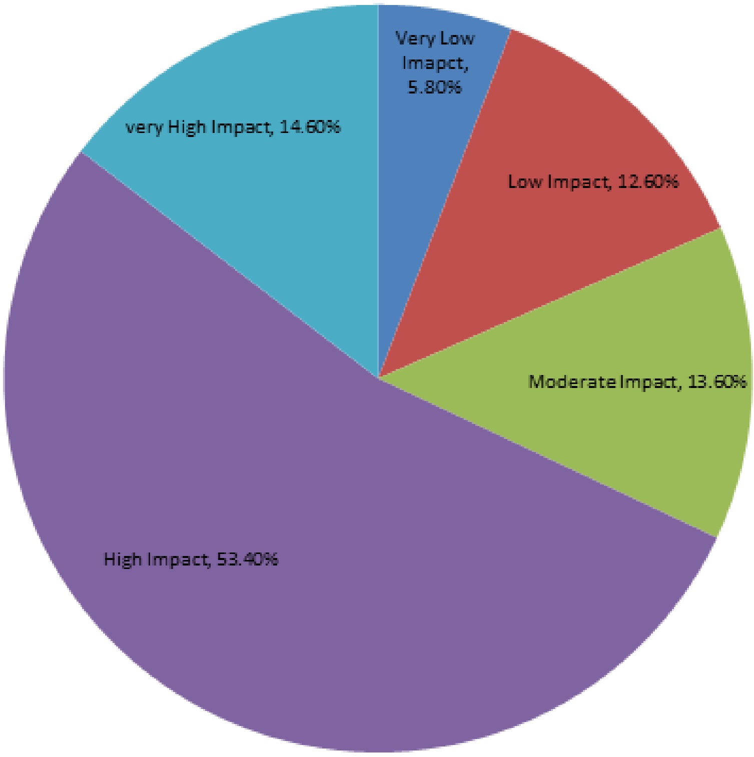


Figure 5.22 Health Impact of GF on Schoolchildren

The results from analysis of the health impact of GF on schoolchildren and staffs as indicated in figure 5.22 showed that 14.60% respondents noted that it had very high impact, 53.40% high impact, 13.60% moderate impact, 12.60% less impact and 5.80% no impact. This reveals that GF not only has the adverse impact on building fabric, the performance of children but also the health of all occupants of such building.

5.7.5 Types of Ventilation Systems

The quest for newer technologies to help in the clean indoor air has continued to pave way over the recent years; countries are beginning to develop materials and means of achieving clean indoor air. This because clean indoor depends on the ambient air around such environment and the ventilation system used. This, therefore, led to the quest to find out the type of ventilation systems used in Nigeria, this is to show if there are other types of ventilation system used in providing clean indoor air.

Again knowing that advances are made for the use of air purifiers as the alternative and a means to clean indoor air, the question was asked on ventilation systems used in providing IAQ in schools around GF areas of NDAN.

The results as illustrated in table 5.31 and figure 5.23 shows responses from analysis indicating the general method used in providing the clean indoor area around the study area.

Table 5.31: Types of Ventilation systems used in the Niger Delta

Types of Ventilation systems	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	78.00%	20.00%	2.00%	0.00%	0.00%
Ceiling Fans	0.00%	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%

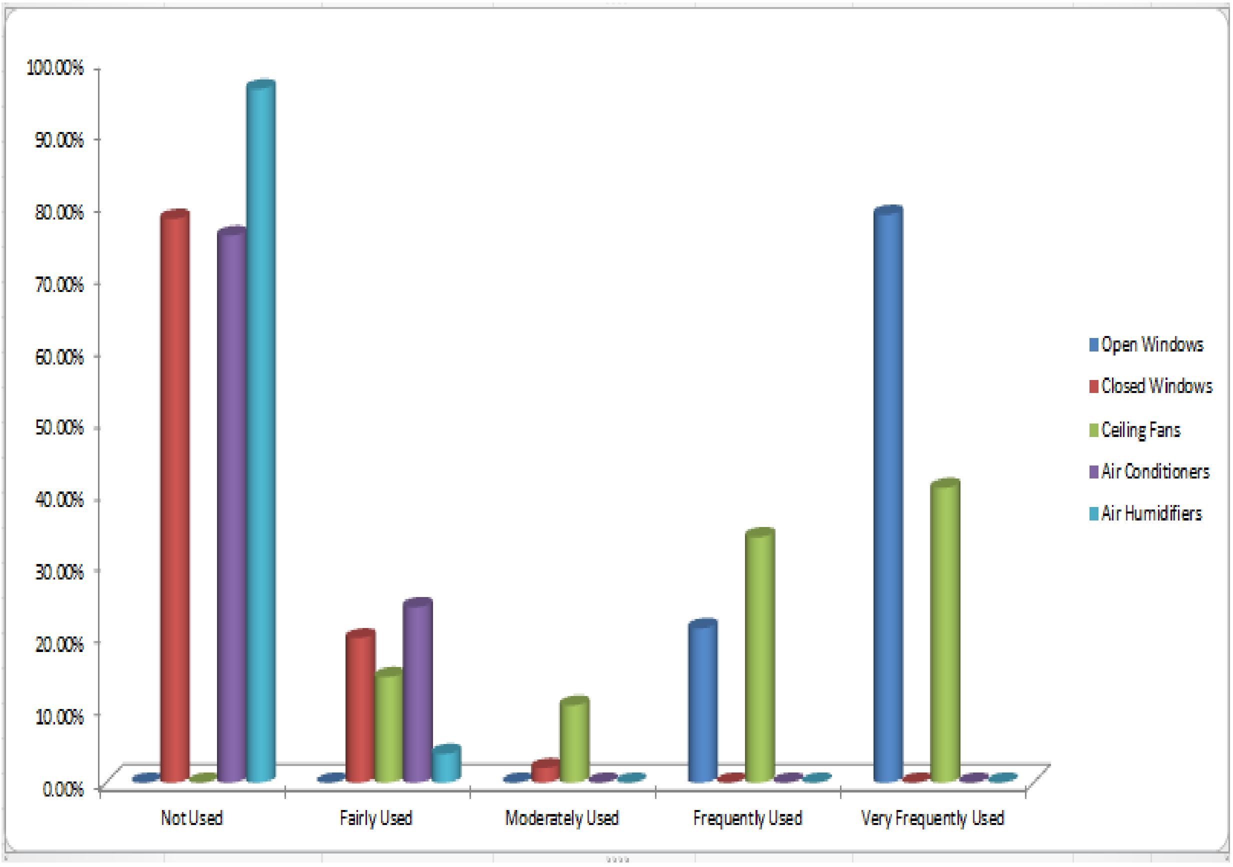


Figure 5.23: Ventilation System Used in Public schools in the Vicinity of GF

Both table 5.31 and figure 5.23 both represent findings from analysis on the types of ventilation systems used in the Gf of Nigeria.

The analysis revealed that open windows are generally an accepted method of providing indoor air as 21.4% responded indicated that open windows are frequently used and 78.6% very frequently used the method with 0% moderately, fairly and not used the method. Both closed windows and air humidifiers were not used at all as all respondents indicated 0% not used in their respective questionnaires. However, ceiling fans had 14.6% as fairly used, 10.7% moderately used, 34.0% frequently used and 40.8% very frequently used showing that ceiling fans were used in combination with the open windows. In addition, the air conditioning had 75.7% as not used and 24.3% fairly used ventilation system and 0% moderately, frequently and very frequently used indications. Following the results from open ended questionnaire, schools buildings constructed around the NDA adopts the natural ventilation system through open door and windows as a way of providing clean air. Furthermore having posed the same question in the interview section, responses from ***interviewees 5*** is as follows;

"Electricity is a major setback in the choice of any mechanical purifier because you need to consider energy sources that can be used and in Nigeria, communities, where these gases are flared most times, do not have national grid lines not to mention power itself. But as a form of betterment to the living conditions of local residents around GF, a system that can filter outdoor air will be a brilliant step to achieving IAQ"

Interviewee 7

Without electricity or energy, as it is now referred, there is no point discussing mechanical ventilation system, innovations should be set on using natural system after all plants are natural air filters or purifies if you like"

Interviewee 1 *commented as follows,*

"The use of open windows seems to be the right and cheap method of allowing air into the building. However, whether such air is clean enough to be inhaled is not the question or concern of the government who provides the schools mainly for the under privileged who might not be able to send their wards to private schools where air conditioners as a source of air".

Furthermore, *interviewee 10* commented as follows with regards to air humidifiers;

Air conditioners perform some level of air purification and could be grouped as air humidifier but as to the usability in public schools that is not foreseeable in the nearest future unless the future generation will provide such privileges in public schools

Therefore, from the analysis, it is clear that air around the study area impacts on both health of the schoolchildren and their academic performance. The open ventilation system used is also a contributing factor why the air inhaled inside of the classroom is poor. There is a significant need to consider ventilation system that can help provide clean indoor air for pupils who spend 80% of their active time in schools.

5.8 Summary of Chapter

This chapter looked at the second block of the DSM, giving a summary of the initial findings as illustrated a figure 5.1 above and it also described in full detail the process required in further explicating research problem while also meeting and achieving objectives three and four as stated in chapter one of this study. A discuss of the data analysis method was carried and results analysed and interpreted using graphs and figures were necessary to show information that is clear and easy for readers to understand. The further illustration was used where comments from analysis using Nvivo was required. Sample of questionnaires and interviews analysed is attached as Appendix G and H. From the analysis it is apparent that GF impact adversely on both the building fabric and the quality of air leading to poor IAQ affecting both the health and performance of children academically in school. From the results, all respondents who participated in both the questionnaire and semi structured interview section indicated that GF has the adverse impact on PSBs and that the NBC is not effective with its codes functionally outdated and ineffective. This means that even though professionals are conversant with construction the impediment posed by the limitations caused by the economic activities carried out in the region and the provisions in NBC adds to the problem. Therefore, there is the need to provide PS that will help professionals in the BE to design and construct schools in the vicinity with such environmental challenges. The requisite information necessary for the design of the proposed PS as clearly defined in chapter 3 includes codes, laws, regulations, and specification requirement requisite for school construction and material selections. This will then provide bases for design and development of a solution that can solve the problem.

CHAPTER 6. DESIGN AND DEVELOPMENT OF THE PERFORMANCE SPECIFICATION

6.1 Introduction

This chapter deals with design and development of a solution that will help to solve the problem of poor IAQ due to the infiltration of ambient air and retain the longevity of the external façade of PSBs. Discussions from chapters 2, 3, and information analysed in chapter 5 based on field data collected from professionals around the study area showed that there was the need to develop a solution that can help solve present problem. This chapter specifically adopts framework as adjusted in figure 1.2 and the method as illustrated in figure 5.3 as proposed by Johannesson and Perjons (2012). It deals with the third block, which represents the third stage, and process like the other block. Although, this stage allows the researcher's initiative and creative thinking to integrate and produce a solution, which could be a design, blue print, program or a prototype depending on the researcher's interest. The solution designed and developed should provide the needed information that resolves the problem explicated. For the purposes of this study, the developed PS will provide the needed information for designing, material selection and constructing PSBs in the NDA. The designed PS took into consideration the immediate environmental factor that reduces the durability of material and IAQ. Using a combination of WHO guidelines, British standards, European Standards and American Society for Testing and Material standards, that meets environmental conditions in the ND Area of Nigeria.

6.2 Design and Development of the Performance Specification

From literature, we already know that there are anthropogenic substances emitted in the environment and a summary of these substances as illustrated in figure 5.1 and 5.2 in chapter 5. In addition, pictorial evidence, illustrated in Figures 2.6, 2.7, 2.9 -2.14, shows some of the adverse effects that arise on building fabric around NDA due to flaring. Analysis from interview and questionnaire survey showed that the lack of interest in IAQ and the inadequate nature of NBC push the need for PS that will help professionals in the study area. The major facts of the PS are to provide answers that will solve the following summarised issues:

1. The open ventilation system with any form of purification system used around the vicinity of GF allows the infiltration of polluted air inhaled by children who spend 80% of their activity time in schools.
2. The inhaled air could lead to several diseases and impact on the academic performance of schoolchildren as studies have shown.
3. The noise pollution resultant from the furnace of and rumblings from the pipe and stack pipe is an added adverse effect of GF.
4. The heat generated from the GF is enough to cause discomfort and lack of concentration as demonstrable in figure 2.7 in chapter 2 where even female schoolchildren show their inner vest and the males their bare body on the field in order to cool down.
5. That building around the GF vicinity commonly shares the same deterioration ranging from discolouration, corrosion, flaking of paints and cracks.

Upon gaining knowledge about the exposure for some specific gases as a result of constant exploration, invention, and development to satisfy man's need, health and environmental concerns have seen innovations a great magnitude. Therefore, it is pertinent to discuss these substances that affect IAQ along with other significant factors that impact the durability and longevity of buildings. These form the inherent elements in the designed PS.

6.3 Indoor Air quality (IAQ)

According to Yang and Clements-Croome (2012) clean indoor air providess wellness and efficiency for occupiers of PSBs. Poor environments in schools cause ill health, low performance and poor attendance of students. The high rate of mortality in children has been linked to poor air inhalation, which arises from different mixtures of substances due to industrial and other activities, for example, GF in the case of NDAN. The significance of clean air in schools led to the use of different measures and equipment to provide clean air. However, many existing schools use space-conditioning systems and conventional mixed ventilation systems not designed to filter pollutants and fail to provide clean IAQ. In most cases, these contribute to increases in the polluted air due to the materials used for both construction and finishing of such buildings. However, the current use of advanced, hybrid and mechanical ventilation systems that are produced to specification, provided by international and developed nations as fit for specific environments, has been said to produce clean air and increase optimal student and teacher performance. In addition, advancement in natural purification systems has provided alternatives for clean indoor air although this depends on the location, orientation and design type employed. Thus, schools in developed and developing nations have mirrored limits of hazardous substances to those of the WHO, EPA, BS/EN, although country and environment specific criteria, in some cases like the USA, are tailored to suit their specific environmental and climatic needs. Based on this, it is, therefore, pertinent to design a PS for schools in NDAN as a means to maintain clean air as determined by the best standards from WHO/BS/EN on air quality standards. However, designing this PS requires an understanding of such substances that cause the problems aforementioned in this research.

6.3.1 Carbon monoxide (CO)

According to Schulte (1963), carbon monoxide has been a toxicological problem to man wherever it is found. He noted that the problem of CO started from the first time man was exposed to fire and has increased tremendously over time. It is a gaseous substance produced by an incomplete combustion of carbonaceous substances. Following this notion of inhalation through incomplete combustion, Stewart opined that human beings are continuously exposed to small quantities of CO and this small amount of exposure can clinically lead to a significant reduction in the oxygen carrying capacity of the blood. It is a colourless, non-irritant, odourless and tasteless toxic gas. Common symptoms include a headache, lethargy/fatigue, nausea, dizziness, and confusion. A victim may also suffer from shortness of breath, cardiac palpitations, convulsion and paralysis, loss of consciousness, coma, and eventually death (see table 6.1 of the possible effect of exposure to CO).

Table 6.1: Effect of CO on Schoolchildren

1	Headache	2	Difficulty in coordinating
3	Dizziness	4	Difficulty in breathing
5	Irritability	6	Chest pain
7	Confusion/memory loss	8	Cerebral edema
9	Disorientation	10	Convulsion/seizures
11	Nausea and vomiting	12	Coma
13	Heart attack	14	Death

Source: Prockop and Chichkova (2007)

Following table 6.1, Prockop and Chichkova (2007) affirmed that exposure to CO is the common cause of human injury. They also observed that due to its tasteless, odourless and colourless nature, it has been overlooked. For instance, (Stewart, 1976) observed that although the permitted limit for clean air quality was not observed, enforcement of sanctions and actions due to nonadaptation of limits were relaxed due to national energy crisis thus, placing populace on high health risk. However, over the year's different, a wide range of organisations like the United Nations (UN), WHO, FEPA, and developed and developing nations including public and private corporations have observed the negative effect of the inhalation of CO and have constantly tried to reduce limits to the lowest minimum. Nevertheless, the good common way of preventing this poisonous substance from causing health and other related havoc is the use of common sense by avoiding open flames like flaring, and rather harness it for other economic purposes. This has fallen short of the alternatives available to industries, countries, and corporations emitting CO. In the NDAN, it is a continuous emission process because the economy of the country strives on oil exploration and exploitation. Moreover, the means of exploration is through an oil venting system as already discussed in chapter 2 even though she is a member of IPCC and GFFCR.

Based on the serious health implications suffered and its effects, more significantly, on vulnerable people such as children whose immune systems are not strong enough to withstand or avert intoxication. And the complexity of the diseases arising from CO inhalation with a toxic effect on the cardiovascular system of individuals led to different IAQ and ventilation systems guide for schools around the world. Accordingly, Townsend and Maynard (2002) affirmed recent works' suggesting that constant exposure to CO that produces only mild symptoms endangers the central nervous system. This assertion has led to people paying attention to what they called "infractions of human beings". However, this initiative and moves to safeguard schoolchildren are far-fetched both in Nigeria as a country and around the NDA even though it has been recognised that the development of standardisation and limitation reduces the risk of the negative effects of these toxins on humans and the environment. Although table 6.1 displays a number of effects on the inhalation of CO, the extent of the effect depends on the amount of inhalation as illustrated in table 6.2.

Table 6.2: Level of CO Concentration, Inhalation and Symptoms

CONCENTRATION	SYMPTOMS
35 ppm (0.0035%)	A headache and dizziness within six to eight hours of constant exposure
100 ppm (0.01%)	A slight headache in two to three hours
200 ppm (0.02%)	A slight headache within two to three hours; loss of judgment
400 ppm (0.04%)	A frontal headache within one to two hours
800 ppm (0.08%)	Dizziness, nausea, and convulsions within 45 min; insensible within 2 hours
1,600 ppm (0.16%)	A headache, increased heart rate, dizziness, and nausea within 20 min; death in less than 2 hours
3,200 ppm (0.32%)	A headache, dizziness, and nausea in five to ten minutes. Death within 30 minutes.
6,400 ppm (0.64%)	A headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes.
12,800 ppm (1.28%)	Unconsciousness after 2–3 breaths. Death in less than three minutes.

Source: Rajiah and Mathew (2011)

Table 6.2 summarises the effect of the different CO limits when inhaled. Having listed the level of symptoms associated with different levels of concentrations of CO and inhalation, the people of NDAN suffer most of these symptoms on a daily basis. This is because from experiments carried out by the National Environmental Standards Regulation Enforcement Agency (NESREA) it could be confirmed that the Federal Capital of Nigeria Abuja, with no industrial activities, has a CO level of about 37%. While (Ede and Edokpa, 2015) stipulated that the level of CO is about 400ppm and above depending on the area in the NDA.

CO affects the capability of the blood to carry oxygen, causing hypoxia, which reduces the functioning of the heart muscles. This led to different organisations having to consider introducing limits to its inhalation at which point no damage or adverse health effect could be caused to both the health of people and the environment. For instance, the Occupational Safety and Health Administration's (OSHA) permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air (55 milligrams per cubic meter (mg/m^3)) at an 8-hour time-weighted average (TWA) concentration. While the National Institute for Occupational Safety and Health (NIOSH) recommended an exposure limit (REL) for carbon monoxide of 35 ppm (40 mg/m(3) at an 8-hour TWA and 200 ppm (229 mg/m^3) as a ceiling, their limit is based on the risk of cardiovascular effects. The American Conference of Governmental Industrial Hygienists (ACGIH) assigned carbon monoxide a threshold limit value (TLV) of 25 ppm (29 mg/m^3) as a TWA for a normal 8-hour workday and a 40-hour workweek. Their limit is based on the risk of elevated carboxyhaemoglobin levels. However, WHO recommended its limits pegged at 100 mg/m^3 (87 ppm) for 15 min, 60mg/m^3 (52 ppm) for 30 min, 30mg/m^3 (26 ppm) for 1 hr, 10 mg/m^3 (9 ppm) for 8 hr and 7 mg/m^3 (6 ppm) for 24 hr period. This recommendation made by WHO is applicable to the US, UK, EU and even most developing countries like Brazil yet Nigeria has not implemented this in her procedures and regulations regardless of the high level of CO emission.

6.3.2 Particulate Matter ($PM_{2.5}$ & PM_{10}):

It is a mixture of solid particles and liquid droplets found in the air. These particles include dust, dirt, soot, and smokes that are large or dark enough to be seen with the naked eye and others so small and colourless that they can only be spotted using an electron microscope. Hence, they have been divided into two;

- PM_{10}: inhalable particles, with diameters that are generally 10 micrometres and smaller; and
- $PM_{2.5}$: fine inhalable particles, with diameters that are generally 2.5 micrometres and smaller.

A clear understanding of these two types is to see the $PM_{2.5}$ as a single strand of hair. The average human hair is about 70 micrometres in diameter – making it 30 times larger than the largest fine particle. They come in many sizes and shapes and can be made up of hundreds of different chemicals with reactions from sulphur dioxide and nitrogen usually emitted from power plants, construction sites, unpaved roads, fields, smokestacks, and fires.

PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs.

Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as, lung cancer. Similarly, $PM_{2.5}$ is the main cause of reduced visibility (haze) in parts of the United States as affirmed in the EPA report. Health and other effects of PM include, but not limited to, the following as tabulated in 6.3;

Table 6.3: Health Effects of PM

1	Premature death in people with heart or lung disease	2	Nonfatal heart attacks
3	Irregular heartbeat	4	Aggravated Asthma
5	Decreased lung function	6	Irritation of the airways
7	Difficulty in breathing	8	Coughing
9	Visibility impairment	10	Reduction in life expectancy

Source: Kim, Kabir et al. (2015)

Table 6.3 summaries the effects that arise from the inhalation of PM. People with heart or lung diseases, children, and older adults are the most likely to be affected by this particular pollution exposure.

Aside from its health implication the constant emission of PM affects the environment causing the under listed defects:

- Making lakes and streams acidic
- Changing the nutrient balance in coastal waters and large river basins
- Depleting the nutrients in soil
- Damaging sensitive forests and farm crops
- Affecting the diversity of ecosystems
- Contributing to acid rain, which is the major cause of decolouration and corrosion of roofing materials with pictorial evidence illustrated in 2.9-2.11.

According to reports from WHO and other organisations, PM is the deadliest type of gaseous pollutant emitted into the environment that causes both health and environmental problems hence different countries have guidelines and limitations for PM as illustrated in table 6.4.

Table 6.4: PM Limits of Different Countries

S/No	Country	limits	PM_{10}	$PM_{2.5}$
1	Australia	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	None 50µg/m^3 None	8µg/m^3 25µg/m^3 None
2	China	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	70µg/m^3 150µg/m^3 None	8µg/m^3 25µg/m^3 None
3	European Union	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	40µg/m^3 50µg/m^3 35µg/m^3	25µg/m^3 None None
4	Hong Kong	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	50µg/m^3 100µg/m^3 9µg/m^3	35µg/m^3 75µg/m^3 9µg/m3
5	Russia	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	40µg/m^3 60µg/m^3 None	25µg/m^3 35µg/m^3 None
6	United State	Yearly average Daily average (24-Hour) Allowed number of exceeding per year	None 150µg/m^3 1	12µg/m^3 35µg/m^3 Not applicable

Source: Authors Compilation

PM represents a complex mixture of organic and inorganic substances hence its deadly nature with the possibility of causing death and serious diseases such as cardiovascular and chronic pulmonary diseases. However, Nigeria has no current limits for PM even though a recent monitoring by the federal ministry of environment and pollution control pegged the PM level in Port Harcourt, the capital of Rivers and Abia state, at 68µg/m^3 192µg/m^3 and 78µg/m^3 926µg/m^3 for PM_{10} and $PM_{2.5}$ respectively. Nevertheless, the current agitation and Stop Soot Campaign by different organisations and individuals in Rivers State mean that the estimation could be higher as the general populace are noticing the impact. Although most developed and some developing countries have different limits to PM, the WHO observed that criteria and measurement systems used by each country affect the adaptability of such limits. Hence, the recommended limits should be $PM_{2.5}$ @ 10µg/m^3 annual mean and 25µg/m^3 for a 24-hour mean in addition to an assigned PM_{10} @ 20µg/m^3 annual mean and 50µg/m^3 24-hour mean, according to the WHO.

6.3.3 Ozone (O_3)

Ozone (O_3) is a reaction from primary air pollutants in the atmosphere such as oxygen and water. It is a colourless to pale blue unstable toxic gas with a pungent odour and powerful oxidizing properties, formed from oxygen by electrical discharges or ultraviolet light. It is a very high oxidizer, which causes damage to mucous and respiratory tissues in man. It is a primary irritant and affects essentially the eyes and respiratory system. O_3 gases have increased during the last century (Nigeria Natural Gas Strategy, 2002; Nwaichi and Uzabona, 2011). As a result, these cause immediate heat waves and are noted to be a contributor to global warming and greenhouse effect.

This is because unlike other gases, its atmospheric lifetimes of days and weeks permit it to travel in a wider scale referred to as long-range transport (WHO, 2005). In addition, O_3 is noted to be present in and around industrial areas and traffic-congested environments reacting under the influence of sunlight. Therefore, countries like Nigeria and the NDA with two main seasons of rainy and dry, with a temperature of 13 – $14,000_o^C$ (Abdulkareem, et al. 2012) is presumed to have air pollution due to O_3 concentration. Excessive ozone in the air can have a marked effect on human health as illustrated in table 6.5

Table 6.5 Effect of O_3 on Human Health

1	Pulmonary system effects	2	Cardiovascular system effect
3	Time series mobility effects	4	Time series mortality effect
5	Reduced lung function	6	Development of atherosclerosis
7	Development of asthma	8	Reduction of life expectancy
9	Development of Bronchitis	10	Development of heart attack

Source: WHO 2005

In Table 6.5 are listed the health effects of O_3 when present and inhaled as provided by the WHO. Its danger to health and reduced life expectancy led to allowable limits in any particular environment being set by organisations such as WHO, USEPA, and EU who has carried out immense research on O_3's negative effects. For instance, USEPA scientists propounded that vulnerable people such as schoolchildren can be adversely affected by ozone levels as low as 40nmol/mol, while in the EU it was presented at a level of 60mmol/mol which is the equivalent of $120_{\mu g}/m^3$. It is the proposed limit allowable before any adverse effect can be said to occur. However, in countries like Australia, the O_3 level exceeds 120µg/m3 on 8hour limits reaching up to 310µg/m^3 while in Cairo it exceeds 150µg/m^3.

O_3 reacts with other gases such as Nitrogen oxides, a major source of serious health impact; this led the WHO to provide the O_3 limit as a uniform guideline for countries to adapt from its limits. However, the WHO also recognises that the guideline provided might not be accepted as a universal standard because some policy makers and countries might lower or increase their limits based on the level of pollution. Furthermore, the physical, economic, social and cultural environment, as well as, the vulnerability of children might affect limits of some countries For instance, in developing nations, the significant emission of O_3 is attributable to a combination of megacities economic activities as observed in the air quality global update report (Krzyzanowski and Cohen, 2008). In addition, a climate that favours photochemical reactions such as GF in the NDA produces higher levels of O_3. Based on research from different countries, O_3 level rises above 400µg/m^3 and health consequences are noticeable on exposure at 120µg/m^3 however, WHO set a limit lower than that set by both the USA and EU at 100µg/m^3. Knowing it's in the ND is increasing due to GF, the limit set by WHO becomes the adopted reference for the PS.

6.3.4 Nitrogen oxide (NOx)

It is reddish-brown gas with a pungent odour; it is part of a group of gaseous air pollutants produced as a result of flaring, fossil fuel combustion processes, and road traffic. It is a combination of nitrogen and oxygen and its presence in the air contributes to the formation and modification of other air pollutants, such as ozone and particulate matter as already discussed. Two of the most poisonous gases of nitrogen oxides are nitric oxides and nitrogen dioxide both of which are non-flammable and colourless to brownish at room temperature. However, nitric oxide is a sharp sweet-smelling gas at room temperature while nitrogen dioxide has a strong, harsh odour, in a liquid form at room temperature seen as a reddish-brown gas.

NOx is released into the air from the exhaust of motor vehicles, the burning of coal, oil, GF or natural gas, and during processes such as welding, electroplating, engraving, and dynamite blasting. They are also produced commercially by a reaction between nitric acid and metals or cellulose. Exposure to high levels of these gaseous pollutants can cause serious health issues and may lead to death. Some of these health issues are illustrated in table 6.6;

Table 6.6: Health Effect of NO_X

1	Collapse/Fainting	2	Rapid Burning and Swelling of Tissues in the Throat and Upper Respiratory Tract
3	Difficulty Breathing	4	Throat Spasms
5	Building-Up of Fluid in the Lungs	6	Interfere with the Blood's Ability to Carry Oxygen Through the Body
7	Headache	8	Fatigue
9	Dizziness	10	Blue Colour of the Skin and Lips
11	May Cause Genetic Mutations	12	Damage a Developing Foetus
13	Decrease Fertility In Women	14	Lead to Permanent Lung Damage
15	Unconsciousness	16	Vomiting
17	Mental Confusion	18	Damage to the Teeth

Table 6.6 lists eighteen health effects due to the inhalation of NO_X. In addition, apart from causing serious health conditions, which could lead to death in a worst-case scenario, NOx, when combined with VOCs, form ground-level ozone, or smog.

The Sulphur dioxide and nitrogen oxides present in the vicinity react with precipitation and oxygen in the atmosphere to form acid rain resulting in colossal damage on roofing materials such as decolouration and corrosion; some of the defects observable from pictorial evidence during field work was illustrated in figures 2.9-2.11.
NOx have several commercial applications; it is used in the production of nitric acid, lacquers, dyes, and other chemicals. Also, it is used in rocket fuels, nitration of organic chemicals, and the manufacture of explosives. Yet, these substances that can be harnessed for economic purposes are wasted in the NDAN.

Due to its health hazards, limits to NOx tolerance level, as the forerunner of a range of secondary pollutants, was set by the WHO at NOx $40\mu g/m^3$ annual mean $200\mu g/m^3$ 1-hour mean. Nevertheless, a 2016 update of NOx limits by the WHO observed that Indoor concentrations of NOx are also subject to geographical, seasonal and diurnal variations. Differences in the indoor concentrations in various countries are mainly attributable to differences in the type of industrial, economic and social activities. Therefore, it is pertinent that countries should set limits based on the best suitable, in reducing health or environmental risks thus, for this study the WHO was adapted.

6.3.5 Sulphur dioxide (SO_2)

Sulphur dioxide is a gas, which is the main component of air pollution aside from PM. It is invisible and has a nasty, sharp smell reacting readily with other substances to form harmful compounds, such as sulphuric acid, sulphurous acid, and sulphate particles. The presence of SO_2 in the air as a major pollutant is due to its source wherein 99% of the SO_2 in the air is caused by human activity. Modern development through industrial activities and materials processing such as the generation of electricity from coal, oil or gas and industrial activities of burning fossil fuels are the main sources of SO_2. Although many developed nations have reduced the use of materials that contribute to emissions and pollution activities like driving eco-friendly cars rather than reliance on petrol and diesel; the use of alternative methods of flaring, rather than open air burning; and the use of electric systems of cooking rather than wood. Developing nations like NDAN have continued to carry out their major economic operations through open air burning, constantly leaving sulphuric pollution in the environment. However, its presence indoor has been noted to be low due to absorption on clothes, furniture, ventilation systems, and walls. Nevertheless, in the exception where indoor sulphuric gas is present, the level of exposure as in the case of natural ventilation systems through window and door openings results in poor indoor air and the associated health issues. Therefore the presence of SO_2 outside and the infiltrated inside the building through air movement cause health risk.

The health implication of SO_2 was observed to have a high mortality rate as compared to PM with risks to the respiratory system and functioning of the lungs as well as other diseases. These can be divided into short and long term adverse health effects which can be life threatening as listed in table 6.7.

Table 6.7: Long and Short Term Effect of SO_2

SHORT-TIME EFFECT	**LONG-TERM EFFECT**
Breathing Difficulties	Chronic Bronchitis
Obstruction of Airways	Emphysema
Nose Irritation	Respiratory Illness
Throat Irritation	Aggravate Existing Heart Disease
Inflammation of the Respiratory	Premature Death
Shortness of Breath	Menstrual Disorders
Stomach Pain	Lung Disease
Convulsions	Heart Disease.
Coughing	Aggravation of Asthma
Dizziness	Mucus Secretion

Source: Petroeschevsky, Simpson et al. (2001)

Table 6.7 illustrates the effects of SO_2 on short and long-term considerations through the inhalation of this substance known to be hazardous to health.

Hospital admissions for cardiac diseases and mortality increase on days with higher SO_2 levels among children and the elderly who are the most affected as observed by Petroeschevsky, et al. (2001). Therefore, this shows that this substance easily affects the most vulnerable. Due to its experimental evidence, the WHO, in its bid to provide a guideline to help reduce the limits on gaseous pollutant in environments with health effects started from 1000μg/m^3 24-hour mean to 40μg/m^3 24-hour. And more recently has a set limit of 20μg/m^3 24-hour mean 500μg/m^3 10-minute mean, noting that SO_2 concentration of 500μg/m^3 should not be exceeded over average periods of 10 minutes duration. This is because studies indicate that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes.

In addition, when SO_2 combines with water, it forms sulphuric acid; this is the main component of acid rain, which is the cause of deforestation and deterioration in building materials such as corrosion and discolouration as already discussed. However, a reduction in the level of SO_2 shows evidence of reduced health risk such as bronchial hyper-responsiveness in schoolchildren as experiments have shown in the case of Hong Kong (Wong, et al. 1998; Wong and Wong, 2014). Therefore, it is important in the NDAN to provide SO_2 limit as an achievable consideration during design and construction of schools to reduce, if not entirely eliminate, highly dreaded nature thus, the adoption of the WHO limits as provided.

6.3.6 Benzene

Benzene, also known as benzol, is a colourless liquid with a sweet odour, highly inflammable and can be described as a VOC produced by human activities such as GF. Although it is one of the 20 most widely used chemicals in the United States to make other chemicals for the manufacturing of plastics, resins, nylon and other synthetic fibres, other uses of this gaseous substance includes, but not limited to, explosives, photographic chemicals, rubber, lubricants, dyes, adhesives, coatings, paint, detergents, drugs, and pesticides. It is used in printing, lithography, and food processing, and has also been utilized as a solvent. However, human exposure to benzene has been associated with a range of acute, long and short-term adverse health effects and diseases. For instance, breathing very high levels of benzene, or eating or drinking foods and water contaminated with high levels of benzene can cause death. Other adverse effects of its consumption include vomiting and stomach irritation. Nevertheless, small amounts of benzene, which are not harmful, can be found in fruit, fish, vegetables, nuts, dairy products, beverages, and eggs.

Benzene targets the liver, kidney, lung, heart and the brain and can cause DNA strand breaks, chromosomal damage, and have been shown to cause cancers, such as leukaemia, a fatal cancer of the blood-forming organ and aplastic anaemia. Acute exposure to benzene may cause narcosis: a headache, dizziness, drowsiness, confusion, tremors, and loss of consciousness. It is indeed a moderate eye irritant as well as a skin irritant. Although, the Agency for Toxic Substances and Disease Registry (ATSDR) in 2007 showed that the health impact of Benzene on humans is based on the dose (how much) the duration (how long) and the route of exposure, its carcinogenic nature left the WHO with an absolute limit of 'no safe level of exposure' can be recommended. This is based on continued research from notable organisations involved in air quality research stating that a Unit risk of leukaemia per 1µg/m3 is pertinent at the inhalation of Benzene.

6.3.7 Polycyclic Aromatic Hydrocarbons (PAH)

PAH is a type of VOC in a group of more than 100 different chemicals that are released from burning coal, oil, gasoline, trash, tobacco, wood, or other organic substances such as charcoal-broiled meat. Also referred to as polynuclear aromatic hydrocarbons, they occur naturally when released from forest fires and volcanoes and can be manufactured by humans like in the case of GF, driving, agricultural burning, roofing or working with coal tar products, sound- and waterproofing, coating pipes, steelmaking, and paving with asphalt. PAHs are persistent organic pollutants (POPs) which are a group of carbon-based organic chemicals highly toxic and tenacious in the environment and accumulate in the fatty tissue of living things.

Human exposure to this type of gas is through the inhalation of polluted air as that observed around NDAN. Again, like Benzene, the adverse health effects that could be encountered depends on several factors, including the amount exposed to (dose), the duration of exposure, medium of exposure and where exposure happened, as well as any other chemicals present in the same environment. PAHs are an odourless group of hydrocarbons that are largely formed by the incomplete combustion of organic materials occurring as complex mixtures rather than as individual compound. The most associated compound is Benzene and may contribute to asthma, bronchitis, and other respiratory problems. Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics, with thrombotic effects in people affected by coronary heart disease, and can cause eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers. In addition, other adverse effects include:

- Affecting the development and growth of the foetus.
- The possibility of the reduction in fertility and interference with the body's natural hormones.

Based on their carcinogenic effect, the WHO sets its limit at 0.1ng/m^3 (one Nano gram per millilitre); however, the American Conference of Governmental Industrial Hygienists set limits for the workplace at 0.2 milligrams per cubic meter (mg/m^3) and the Occupational Safety and Health Administration had their limits at 0.2 mg/$m^{3,}$ all limits allowable in 8-hour periods. Based on the limits provided for PAHs, the WHO limit was therefore adopted as the preferable limit for this study.

Following the economic engagement in the NDAN, it is obvious that the concentration of the chemicals discussed above with itemised negative health implications are due to outdoor infiltration of air into the internal area of the building. It is therefore important that PSBs should be air tight to eliminate the penetration of outdoor air.

6.4 Air tightness

According to the provisions of part L of the UK building regulation, air tightness is the resistance of the building envelope to inward or outward air leakage. Excessive air leakage results in increased energy consumption, draughty and cold buildings. It is a general descriptive term for the resistance of the building envelope to infiltration with ventilators closed, as affirmed by (Santamouris and Wouters, 2006). Accordingly, CIBSE (2005) affirmed that good air tightness is beneficial as it enables ventilation rates to be controlled more effectively. Countries like Nigeria, with the high release of hazardous substances into the immediate environment due to the method of harnessing her economic manpower, will require a high degree of air tightness during the design and construction of PSBs.

The greater the airtightness at a given pressure differences across the envelope, the lower the infiltration. This is because air infiltration is the leakage of air through cracks and gaps in a building fabric and is easily noticeable in the following areas of the building;

- Gaps between elements of the buildings, for example, floor to wall and/or wall to roof, which create a small path, but potentially around the entire perimeter of the building which is a break in the continuity at the eaves detail (between the top of the wall and the underside of the roof)
- Gaps between different parts of the air barrier, for example, the joint between membranes and boards.
- Gaps around 'penetrations' from windows, doors, and services with problems masked by suspended ceilings, bath panels, kitchen units, voids and plaster boards where the dot and dab create a small cavity that allows air to bypass any surface sealing and escape through larger openings through the structure
- Gaps around 'awkward' details, which is where the air barrier is interrupted by complicated structural members or elements of the fabric. These require attention at the design stage to identify ways of minimising these interruptions or introducing methods for bridging them to maintain continuity.

It is important for buildings to have sufficient purpose-provided ventilation. According to the Building Services Research and Information Association (BSRIA), 'project teams should design and construct the building fabric to be reasonably airtight, and also provide natural or mechanical ventilation systems that maintain good IAQ while minimising energy use. Unwanted air leakage significantly increases the space heating demand of a building, as well as causing occupant discomfort from cold draughts. Air leakage can lead to long-term problems in the building fabric with frequent damage through the spread of water vapour resulting in interstitial condensation. Although in developed countries with cold weather conditions, air tightness is carried out to majorly save energy loss and retain heat in the internal space, however; in areas affected by atmospheric pollution, unwanted air leakage can contribute to reduced levels of IAQ as in the case of the NDAN. Using the same principles adopted and noted to be efficient, to the passive house standard, will provide the same restrictions to air leakage while, in this case, eliminating the infiltration of polluted outdoor air into the internal space of a PSB.

Therefore, based on the activities of GF, the rigidity of air tightness is a vital part in achieving secured clean air in the ND. Thus it is important that the German passive house concept is used in cases where it is crucial that infiltration of outdoor air is prohibited indoor (PHH, 2011). The main features of the German passive house concept are that the building must be airtight with 0.6 air changes per hour at 50 Pascal's pressure and a mechanical ventilation system with heat exchanger depending on the environment (Schiano-Phan, et al. 2008; Tweed and Mcleod, 2008). Although it was first used in cold environments, its effectiveness has also recently been achieved in hot and humid climates in order to save energy consumption as part of the alliance for energy consumption reduction (Omer, 2008). However, the performance of the building designed with the passive house concept for temperate climate will depend on the orientations of the building (Morrissey, et al. 2011). This will be the case where natural ventilation is a means to clean IAQ.

Leakages causing infiltration of air are most times due to materials used for construction and finishing. In addition, the total number of people in a building space results in the positive or negative impact of air tightness. Although, in the case of high concentrations of the outdoor air pollutants, blocking the air paths of the building envelope could provide safeguarding against outdoor pollution (Blondeau, et al. 2005); however, the importance of materials used in building construction is vital in order to reduce pollution. Most buildings with their design characteristics provide spaces such as an attic, basement stores, warehouses and even studios that are scarcely opened. As opined by (Sherman and Chan, 2004), such buildings in themselves may be sources of pollution because of mold or toxic materials.

Again, noise pollution could arise due to air infiltration, which in legal terms, is referred to as nuisance and deters the ability of the pupil to concentrate; neither does it allow teachers to communicate properly. Contrarily, the significance of air tightness in a building does not mean a total discomfort of occupants, in this case, schoolchildren. This is because, studies show that reduced airing reduces the academic performance of children (Wargochi et. al 2002; Seppanen et.al 2006 as cited in Chatzidiakou, et al. 2012). Equally, (Bakó-Biró, et al., 2012) noted in their research that the high level of a downside effect of low airing and its negative impact on children with the memory task, spoken capability to identify words and non-words is pertinent. Therefore, there should be a system put forward that provides comfort levels during school hours, which is left to the innovative nature of a PS that allows the designing professional the possibilities of achieving the required performance.

More recently, (Sherman and Chan, 2004; Dimoudi and Kostarela, 2009; Kauppinen and Siikanen, 2011) and much more have all noted the importance of air tightness in PSBs in different developed world nations. However, these advantages should be distinct between air leakages and ventilation as noted by (Batagarawa, 2012), in differentiating that while airing is essential, air leakage is not. Therefore, putting together all building criteria, purpose, and functions of a building with important external factors within an environment ensures that air tightness in a building envelope could be achieved.

The rationale of choosing or adapting a particular type of quality standard depends on the feasibility and economic consideration and the achievability of the limits on design and control procedures. Thus, air quality standards must be fitted to the localities and populations which they are to serve (Beard and Wertheim, 1967). Accordingly, Alshamrani, et al.(2014) affirmed in their study of Canadian schools that nearly 80 million students and teachers spend at least eight hours daily in schools which could be unhealthy and restricts their ability to learn if the IAQ is poor. This only magnifies the quote from (AStroma, 2010): *"... Buildings don't need to "breathe", only people do! Therefore, "Build Tight – Ventilate Right! ...".* Thus, the achievability of IAQ limits depends on the type of ventilation system and building materials used in any environment.

6.5 Materials

Building materials have a significant role to play in the reduction or elimination of poor outdoor air in the internal part of the building. Therefore, it is pertinent that climatic factors and immediate environmental conditions, which might have consequential effects on material durability, should be considered. For instance, the strength of materials at low and high temperatures, resistance levels to rainwater and seawater, acid and alkaline, colour resistance level and salt spray from seawater affects durability.

Furthermore, the swift advancement in manufacturing different materials creates an impending disaster to material usage, as the suitability of some materials to the specific type of construction is not properly checked. In addition, the calibration and standardisation format used by different manufacturers affects choice, usage, and durability if used in a different environment. Specific factors such as intended usage and climatic conditions should serve as criteria for the choice of material rather than cost as a factor. Consequently, it is of crucial importance to check the efficiency of materials before specifying or using them as a choice for construction in a given environment, and for this purpose the ND. Hence, construction professionals should have considerable knowledge of material quality and its durability factor before use although the selection of materials and usage may depend on long-term experience (traditional method) rather than on the understanding of the efficiency based on immediate environmental factors.

The achievability of a durable building depends on the ability to cross-check environmental characteristics and the performance criteria required before selection. Thus, materials selection represents an important strategy in building design (Akadiri, et al. 2013). This is because some materials require remedial measures and repairs although part of this default in materials has been linked to inadequate quality control measures. A significant part of the defect is based on the lack of confirmation and understanding of materials efficiency from place of production to place of usage, and environmental consideration and criteria. For instance, after exposure to pollution from GF, materials should be durable and must provide the same level of manufacturer guaranty; rather, they provide less efficiency and deterioration like corrosion, discolouration, and flaking of paints.

The most significant environmental and adaptable features on which to base material selection for any environment should include both physical and mechanical resistance levels such as weathering resistance, thermal capacity, corrosion resistance and colour resistance. Achieving these criteria mentioned depends on the amount of information available and the knowledge of materials and selection criteria. Generally, clients are not aware of such material types; thus, it is left to the construction professionals, mostly architects, as the sole decision makers on specification and material selection, to make the decision. However meeting some specific environmental conditions such as that in the NDAN requires external advantages that will be able to resist pollution and still achieve its needed function. For instance, with the constant flaring of gases in the study area, it is pertinent and very important that the external façade of buildings should be able to resist corrosion and discolouration along with the added advantage of reducing infiltration of poor IAQ. Therefore, the specification of roof and wall cladding has implications well beyond the aesthetics.

The choice of cladding can affect many aspects of the building's performance. Although innovations and manufacturing of different types of cladding materials used for construction are emerging, meeting PS will provide better functioning because developments in material technology are reflected in newer regulations and codes. This might not be reflected in a given country's building code, as that of Nigeria clearly indicates from the opinions of respondents during field survey and subsequent analysis from their responses as shown in tables 5.20 and 5.22, and figures 5.13 and 5.14 of chapter 5. Therefore, the most current standard should meet the minimum specification as prescribed by both BS/EN with consideration to immediate environmental factors applied to meet performance.

The material used for the external façade can be the source of the majority of future building problems if it is not suited for such environment. Both roofing and cladding materials used for the external façade of a building are central to other parts of the building as they interact with the outside environment, along with keeping the inside comfortable. Cladding materials should be chosen to meet climatic needs of the area and buildings and should be aligned in such a way that they are concordant to the direction of prevailing winds in order to prevent parts of the material from being blown off. In recent times, due to advancement, cladding materials used for roofing have been improved and used as walling materials hence providing the same durability and efficiency criteria and protecting the internal building fabric. Therefore, its selection criteria as the covering material should meet the crucial PS as discussed below.

6.4.1 Thermal Performance of Roof Covering

The TPRC is the ability of roofing materials to lose or gain heat at various heat exchange processes possible between a building and the external environment. Although this depends on a large number of factors, which include, in summary:

- Design variables (geometrical dimensions of building elements such as walls, roof and windows orientation and shading devices)
- Material properties (density, specific heat, thermal conductivity, and transmissivity)
- Weather data (solar radiation, ambient temperature, wind speed and humidity)
- A building's usage data (internal gains due to occupants, lighting and equipment and air exchanges.

However, the TPRC has the end means of delaying and reducing the impact of external conditions on the interior of the building through its selection and specification criteria based on immediate environmental conditions. According to Borge-Diez, Colmenar-Santos et al. (2013) in their work, they observed that during a normal sunny day in any hot dry climate, a typical roof surface can reach 37 °C above the ambient temperature; thus, showing the intensity of heat gain that can be transmitted into the building. This is why in most countries like Saudi Arabia and Dubai where the temperature level is very high, materials other than galvanized roofing sheets are used to enable an internally conducive environment.

However, the advantages of any roof on any particular building depend on several factors, including building type, load, season and most importantly the immediate climatic environment (Dabaieh, et al. 2015). Although in most cases, the emphasis is on energy efficiency, however, the end purpose is to create an indoor environment that does not require any form of the mechanical or artificial ventilation system, or even so, depending on energy. As opined by Ajibola (1997), tropical areas of the world are classified as the overheated regions and for building, purposes are divided into three, namely: Hot/warm and arid/semi - arid regions, warm and humid regions, and temperate regions of Nigeria aligned in the warm/humid region. Yet, materials used for roofing buildings in countries like Nigeria include clay, wood, bamboo, concrete, steel, glass, and shiny metals (galvanised and aluminium) (Lauber, 2005; Rahman et al., 2013), although (Berdahl, et al. 2008) noted that some materials commonly used for roofs such as galvanized iron sheets are not suitable from a thermal point of view. This is because buildings in this part of the world are constantly exposed to solar radiation and heat due to the region and furnace from GF stacks.

The fabric of the buildings should be specified to prevent or minimise heat gain. Any design of PSBs should be related closely to the immediate climatic data leading to more adequate and precise design decisions in proper terms of appropriate orientation, prevention of heat gain into spaces and better choice of building materials (Ajibola, 2001). Having that in buildings, roof covering in most cases take up more than 60–70% of the building surface (D'Orazio, et al. 2010) forming the major protector of all the other parts of the building, it is imperative that the roof should be able to absorb heat without transmitting it into the inner space. For instance, the purposes of insulation and thick roofing materials used in the developed world to retain heat internally should serve the same purpose achieved in Saudi Arabia to provide a level of cooling effect without transmitting solar radiation. Accordingly, (Sisman, et al. 2007) observed in their study that the thickness of roofing material helps with the reduction of heat gain which confirms that galvanised roofing materials allow the transmission of heat into the building causing discomfort to schoolchildren. Even from field data, as illustrated in table 5.29, slate, as a roofing material, showed more durability although its usage has not yet undergone long term stress from the impact of the environmental condition on it. But again, interviewee 4 commented positively on its durability. Therefore, any action aimed at improving the interaction between the covering and immediate environment in relation to the need for comfort should be particularly effective. The Building Schools for the Future Committee noted that schoolchildren should be comfortable during academic hours; hence, TPRC of the U-level should be $0.35 W/m^2K$ – weighted average, as adopted by BS/EU and ISO.

6.4.2 Thermal Performance of Roof lights

Natural light is best used as a form of illuminance rather than an artificial method of lighting, to reduce energy consumption. The increasing aspiration for energy liberation as driven by the environmental conscience of the newer generation and the obsession with equipoise electricity consumption has led to the widespread development of natural lighting models (Reinhart, et al. 2006). With this passion, one of the most effective ways of reducing operational energy consumption is by an improved thermal performance of the building envelope. However, unlike artificial light which can be adjusted to meet needed visual effect regardless of location, time and climatic condition, day lighting is affected by location, time and climatic and weather conditions of the place where a building is located (Rockcastle and Andersen, 2013). Therefore, location plays the major role of the choice of a lighting system.

The value of natural daylight on human performance, and thus on energy efficiency in its widest sense, cannot be measured (Barrett and Barrett, 2010). Much research has shown a strong preference for views from daylight against electric lighting in respect of the increase in students' performance and positive impact on production even among staff in other employments (Simeonova, et al. 2003; Heschong 2003; Matsuoka, 2010). Thus, widespread research links natural daylighting to tangible work place benefits, lower absenteeism, faster hospital recovery rates, and improved school exam results. Also, an increased use of daylighting strategies from a health perspective yields positive results because of its strong impact on circadian rhythms affected by environmental signals such a sunlight and temperature impacting on alertness and on sleep/wake states (Newsham, et al. 2005) . Therefore, natural lighting should be provided in all buildings.

Although windows can provide daylight to areas within 6 meters, roof lights are the only practical means of introducing daylight to any wider buildings (Kim and Kim, 2010). The most effective method of providing even and consistent daylight, particularly in large buildings, is via roof lights. They are up to three times more efficient than windows of the similar area (Fontoynont, 2014). Diffusing materials should be used wherever possible to provide even light distribution and avoid glare. However, priority should be given to daylight as the main source of light in working areas, except in special circumstances. Roof lights achieve a U-value of 2.2 W/m2K or lower (Killip, 2005); however, this depends on the area, for instance in the UK, different guidelines for U-value is obtained in different parts of the country; Scotland has the specification requirement of 2.0W/m^{2}K. The roof light area on the building is usually not more than 20% of the roof area, hence most countries, for example, in the developed world now use double and triple glazed materials, which reduce the emission of solar heat during summer. If the purpose is to achieve comfort room temperature without necessarily applying the use of artificial cooling systems, then this technique and choice of material could be used to reduce the thermal effect of the heat radiating from flaring.

However, it is possible that glare may be a problem within PSBs because visual comfort created by the brightness pattern within the interiors is dependent on the orientation of the building user (Carter, 1984). Although the time of day also affects the nature of glare that can amount to discomfort, as opined by (Kent, et al. 2015), adequate consideration should be given to roof lights bearing in mind the reflective nature of transparent roofing materials even if they are double or tripled glazed. Nevertheless, any material choice used should also provide the needed insulation from both indoor and ambient noise.

6.4.3 Indoor Ambient Noise Level/Airborne Sound Insulation

The most formal education takes place in the classroom where the learning process involves intensive verbal communication between teachers and students and among students. The productivity of this communication and the learning environment is enhanced by the acoustic conditions of the classrooms. The ability to learn or show interest in learning activities in a classroom starts from the first year of a persons' life, which is affected by the acoustic condition of the place (Nelson, et al. 2008). This also impacts on the teachers' loudness which might, in turn, lead to noise rather than increased speech intelligibility. Excessive noise levels affect not only the quality of verbal communication but also lead to serious problems in the student's intellectual development (Baranzini and Ramirez, 2005). These problems include slow language learning, difficulties in written and oral language, limitations in reading skills and in the composition of vocabulary (Francois and Vallet, 2001). Therefore, materials used for construction should be able to provide acoustic advantages. Although human behaviour might impact on indoor ambient noise generated, this, in turn, might affect the hearing ability between teacher and pupil. Nevertheless, it has been observed that most noise effects arise due to design and building related issues. Thus, Seep, et al. (2000). Indicated that the best way to resolve acoustic problems is by avoiding them in the preliminary stage, which is the design phase. The social benefit of noise reduction is an environment with at least an acceptable noise level that will help in preserving the health of its users as a whole and improve the students' scholastic performance.

In achieving this, Schools in the developed and developing worlds use and adopt standards that meet their respective requirements. For instance, in Brazil, the design of schools are made with standard adjustable modules according to the need for each school, depending on the forecast of the number of students and on the type of terrain where they are to be built (Zannin and Zwirtes, 2009). This means, the requirement of particular locations where the school will be built, plays a significant part in the design, adjustments, and provisions made to provide the required noise level.

Sound insulation should be a priority in school environments where the sources of noise cannot be altered, especially in schools affected by high levels of noise ranging from road, air, and economic and industrial activities around such environments. For example, Table 2.4 in chapter 2 shows the level of noise emitted from GF sites although as indicated in the table, the noise impact reduces as the distance increases. However, the noise level could be disruptive and affects hearing ability as listed in the same chapter and section. If a region has 7,000km long pipeline installed, in some cases, over the ground as affirmed by Mgbemena (2015) and represented in figure 2.6, the rumbling noise from such oil pipelines can only be left to one's imagination. This will lead to noise levels that can cause a lack of understanding between teachers and students. The health implication of this constant noise includes, and not limited to, headache and nervousness, which will reduce the zeal or enthusiasm to learn or even come to school at all. However, these defects could be reduced, if not eliminated, with the involvement of all the professionals and experts in construction rather than just the architect who designs and selects materials that should be used.

The application of the correct standard, materials and test options both in the interior and exterior finishes of schools will provide the required tolerable noise level in schools. Therefore, for the purposes of classroom concentration, memory gain, reading ability and attention during classroom hours, the specification level of $L_{Aeq,30mins}$ was adopted. According to Andersen and Hopkins (2005) this acoustic level provides:

(a) Clear communication of speech between teacher and student;

(b) Clear communication among students and

(c) Improves Learning and study activities

The difficulty in achieving such level of low noise depends on not only the materials used but also how well such material is used. In addition, the ability of such material to withstand sound and vibrations associated with GF could be compromised which might lead to cracks and the intrusion of ambient noise. Therefore, any material selected should be resistance to cracks.

6.4.4 Resistance to Cracks

Cracks on the building structure can arise due to movement in foundation and superstructure, the decay of building fabric, corrosion, and reverberation. Hence, effective resistance level to cracks cannot be overlooked. Cracks can be visually unattractive and disconcerting for occupants and are more of a cause for concern and if left untreated they can affect the integrity, safety, and stability of the structure (Liu and Nazaroff, 2003; Chand, 2013). Accordingly, as opined by Cheng and Chen (2011), PSBs generally lack comprehensive planning which compromises resistance to cracks;

It is imperative to understand the planning and structural characteristics of the immediate environment before the construction of PSBs. Directly and indirectly, PSBs affect the lives and health of schoolchildren, which means that several factors have to be considered when planning to carry out such development.

Due to its crucial importance, the designer who is supposedly the architect and at the same time the specifier should first consider the environmental conditions existing at the building site before designing or specifying. One of the ways of reducing cracks, as affirmed by Watt (2009), is to carry out geotechnical (soil) investigations to determine the type of foundations, type of concrete materials to be used, and the grade of concrete depending on chemicals present in the ground water and sub-soil. It is critical to know whether the professional proposed to carry out the construction has the requisite skills and experience to execute construction jobs in such environmental terrain. This is because complicated designs with dense reinforcement steel in slender sections result in poor quality construction (Watt, 2009). In addition, inadequate skills and poor experience of the professionals or contractor eventually cause deterioration of the building.

Although most PSBs are constructed with concrete and blocks, which by definition of strength and soluble nature, may be crack resilient (Gao, et al. 2013), however, cracks may result due to expansive reactions between aggregate containing active silica and alkaline derived from cement hydrations (Dias, et al. 2008) . This alkali- silica reaction results in the formation of swelling gel, which tends to draw water from other portions of concrete causing local expansion resulting in cracks in the building. Other types of chemicals on concrete that will produce cracks and cause building deterioration includes sulphate attack on cement products, carbonation in cement based materials, corrosion of reinforcement in concrete and alkali aggregate reactions. Cracks caused by corrosion and reverberation are mainly due to rumbling noise from oil exploration pipes underground and on the surface. Even though crack control measures for alkali effect could be remedied with low alkali cement - pozzolana and proper aggregates, this has seldom been promoted (Farny and Kerkhoff, 2007). More so, newer innovative systems like the Abalone shells are natural materials that have twice the toughness and high-tech of ceramics that are highly resistant to cracks as the combination of hard and elastic layers stop crack circulation (Yang, 2017). Whether at a macro or a micro level, materials respond to changes in their environment by trying to move to adjust to the environment.

This is why some countries with difficult environmental terrain tend to provide a model or a template for PSB construction (Irfanoglu, 2009). However, the NDAN, which is prone to cracks to buildings near GF, has not provided such model or criteria during design and construction. Hence, the need for adequate consideration of cracks when designing and specifying materials considering the life span of such material specified.

6.4.5 Minimum lifetime

Minimum lifetime of any construction is dependent on the material type and use of the building (Watt, 2009); hence, every building is required to have a minimum life. Every building part and material meets different minimum lifetime. Having that the roof is the main area of the building exposed to different environmental conditions and protects the other parts of the building, the minimum lifetime of roofing materials should be of utmost importance. Although the load imposed and superimposed on buildings affects the building's lifespan, materials used also play a significant role in the shelve life of the building. When specifying materials, this should be based on factors ranging from quality, material type and the standard or calibration method used by the manufacturers, which depends on the country where the material is produced.

Different building codes and specifications affect the lifespan of any building material. Therefore, it is crucial that specification should be less of costs (Chan and Tam, 2000) but more of durability and expectation to meet minimum lifetime. The immediate environmental condition plays a significant role in the level of deterioration, and with the constant emission of gaseous substances, the impact is greater on buildings, in the case of the ND. As a result, the material specifier should be able to determine the resistance level of the material type in a given environmental condition and the use of the property. Although the recent trend in PSB construction in most parts of the world is for materials to meet standards, regulations and sustainable factors with such criteria have become the bases for building approvals. Technology advancement and Manufacturers have continued to explore newer improved materials such as green roofs as being this trend. However, Nigeria is yet to tap from this important trend to meet sustainability and the MDG.

According to Wen and Kang (2001), relevance should be given to the design of buildings in multi hazard environments as there are uncertainties of severe deterioration of such buildings. PSBs are predominately used during the day and almost empty during night-time. Therefore, as opined by (Guggemos and Horvath, 2006), alternative ways of designing and building should be applied. This is because there is the need for advanced reflection of environmental limitations in decision-making over social and economic factors to help reduce the impact of environmental factors (Abeysundara, et al. 2009). The actualisation of a building that provides comfort helps with the day's activities. Recently, the agitation for the comfort level of students in school during summer times has led to the innovation and manufacture of cool roofs used in schools. This is helping to reduce energy consumption for cooling demand while providing thermal comfort and air quality indoor (Akbari, et al. 2005; Levinson, et al. 2005). Yet, Nigerian with heat higher than that of the UK and many parts of the world all year round is slow to adopt this system.

Material selection should be based on immediate environmental factors, which will help reduce poor aesthetic, and future maintenance cost to improve life span. The implication of corrosion and deterioration will lead to retrofitting due to leakages and other repairs as already identified in chapter 5 from the analysis. This can distort classes and the school calendar due to retrofitting exercise and other unquantifiable psychological and physiological effects. It could also cause injury and other health risks to schoolchildren who might be running up and down repair areas. Thus, a minimum life span, which allows a long period, should be preferable. According to the specification for roofing materials used in PSB construction in the UK, a minimum of 30 years for any material type was specified. This will provide a long- term plan for either repairs or a complete installation of a new roofing material that might provide added advantages such as an increase in the corrosion resistance level.

6.4.6 Corrosion Resistance Level

Unlike gold, which generally retains its sheen after prolonged exposure to atmospheric conditions of a place, (Berdahl, et al. 2008) noted that most durable materials are modified by deposition of ambient dust and debris, and may provide an opportunity for colonization by biological organisms such as cyanobacteria, fungi, and algae. In principle, most materials suffer some degradation upon exposure to atmospheric contents. Materials that generally disintegrate due to atmospheric moisture with particular reference to buildings are metal and are mostly used as roofing material. The most commonly known degradation is corrosion and blackening. Corrosion is the gradual degradation of a metal by a chemical, often electrochemical, reaction with the surrounding environment (Leygraf, et al. 2016). Its effect on building materials modifies the material properties such as mechanical strength, appearance, and permeability to liquids and gases. Whether a metal roofing material is a corrosion resistant in a specific environment depends on a combination of its chemical composition and the aggressiveness of the environment. This is because the corrosion processes are affected by exposure to certain substances such as sulphur, particulate matter, nitrogen, and oxygen. It is crucial when considering metal as a material for roofing that primary environmental factors and immediate atmospheric moisture content should be checked to determine the resistance level for the material to be used.

The level of substances emitted from GF is observed to accelerate air pollution and acid rain by (Nwaichi and Uzazobona, 2011). The air pollutants fall down as rain droplets, precipitation or dew acting as corrosive agents with significant oxidative stress on metallic materials (Odu, 1994; Bhatia, 2001). Similarly, its corrosive impact on metallic surfaces has been correlated with zinc (Nkwocha, 2010) and aluminium sheets of less than 0.50mm thickness as affirmed by (Potera, 2009). This confirms Ovri and Iron (2003) and Akpan (2003) and the submission from data analysis in chapter 5 using the mean average of the impact of GF on the corrosion of Zinc as compared to Aluminium roofing material; that the effect of acid rain on zinc is more rapid as compared to aluminium. Therefore, based on the immediate environmental condition of the NDAN, it is important that the type and thickness of roofing material used should be able to withstand the acidic level of atmospheric moisture contents that drop on the metal surface. Corrosion can be tolerated depending on different factors apart from thickness, function, anticipated lifespan, cost implication and design criteria; however, both over and under design can be catastrophic (Jones and Ashby, 2005;

Shreir, 2013). Over design and under design are significant factors that have to be considered as well as the materials.

Following the need to preserve the environment globally and to restrict measures produced always as a means to achieving safe environment, manufacturers through innovative technologies are developing materials that can help reduce corrosion on building materials. For instance, plastics and other types of materials are replacing metals because as stated by Revie (2008), the possibility of managing corrosion effect is one of the biggest problems in recent times. As such, local specification criteria recommended by both American, British and ASTM test control systems for resistance level of materials that can mitigate corrosion levels based on environment specific criteria as prevalent in the NDAN, should be a resistance factor of 5mpy (Millie-inch per year). Therefore, controlling corrosion should include, material selection, design base, consideration of contacts with other materials, mechanical factors, acidic level and coating materials used, as discussed below.

6.4.7 Acidic level (pH)

The pH level of the water content in any environment determines the level of acidity in such environment and research has shown that the lower the pH levels, the higher the presence of acidic formation (Bowersox, et al. 1990; Weaver, 1991; Larssen, et al. 1999). The major sources of acidic concentration in the atmosphere are through the emission of sulphur/nitrogen oxides and particulate matters causing deposition of acidic trace species on surfaces. This is both during precipitation and by turbulent gas transport and adsorption processes in the absence of precipitation. Therefore, following the discussions above, it could be said that corrosion occurs due to acid the rain on the roofing material. This is because acidified rainwater serves as oxidative agent inducing rapid corrosion of metallic roofs, especially the galvanized iron roof. Accordingly, (Fang, et al. 1990) observed in their work that the corrosion rate of aluminium roofing sheets increases as the pH level reduces following the activities of a coal-burning power station, exhaust gas from motor vehicles and factories burning fuel. It is therefore crucial that construction materials for the PSB in the NDA meet specification criteria of pH level not below 6.5. This is because corrosion is associated with pH levels below 6.5 to 7.0 with temperature playing a significant role (Salvato, et al. 2003). Therefore, the choice of 6.5 was adopted as the most probable limit associated with material selection based on the corrosion resistance factor. This is because the temperature level in the ND is constantly above 30^{o}C and the continuous emission of substances that cause acidity requires the most stringent measure.

Although the emphasis is on roofing materials, it is pertinent of note that rain droplets and other moistures from the atmospheric deposition with acidity affect other parts of the building such as mortar, paint, brick, concrete, door and window panels.

6.4.8 Corrosive Resistance Coating

According to Vernon as cited in Shreir (2013) …there are four ways or methods of preventing corrosion, which include:

Table 6.8 Four Methods of Corrosion Prevention

No.	Prevention Methods	Delimitations
1	Modification of Environment	This is not an enclosed environment where alterations or modifications can be made to alters its atmospheric content neither is possible based on the difficulties of relocating people or the flaring stack
2	Modification of the Metal	This will depend on the funds available and possible experts' knowledge necessary to modify such metals.
3	Modification of Procedure	This depends on the manufacturers and if the specifier deals directly with the manufacturer and is present when the test is carried out to show confirmation of material test.
4	Protective Coatings	Referred to as corrosive resistance coating and many research has been carried out with specification is written confirming to the level of resistance required

Source: Shreir (2013)

From table 6.8, four methods have been identified as corrosion prevention ways. Although metals corrode when there is interaction with acidic moisture, prevention methods also provide high the amount of positive confirmation of their effectiveness. However, in most cases, corrosion resistance coating help protect materials from the adverse effect that could result after a period (Shreir, 2013).   Generally, due to aesthetics and confirmation to colour trend or regulations as imposed by law, most buildings use colours that will reflect the actions or logos of the roofing company or intended use. Some colours, due to their serene characteristics, are also used not minding the possibility of such colour incompatibility with immediate environmental features. Even though, paints are known to be the best way of controlling corrosion, using resistance coating material on the roofing material will help mitigate reactions that might occur.

Innovative paints, such as in powdered form rather than liquid, are currently being manufactured (Tiwari, et al., 2014). Therefore, incorporating into the specification the performance criteria of such coating material as a way of making provision for corrosion resistance coating in an environment like the NDA will help reduce the corrosion effect. While increasing material durability and lifetime, it also reduces retrofitting cost and in general enhances the aesthetic effects, as illustrated in figures 2.9-2.11 of chapter 2.

6.5 Windows and Doors

Windows and doors are openings or spaces in the wall of a building provided to allow light, air, entrance, and exit for people in the building. Windows also help to rejuvenate people, increase their performance level, and improve health condition and life expectancy, whether it is a superficial or real window. However, (Baldinelli and Bianchi, 2014) opined that windows are commonly the weakest part of the building envelope in terms of heat, air and noise transmission. Windows bring together the widest range of functions, such as, views, daylight and sometimes ventilation, and also try to keep out glare, draughts, noise, unwanted solar radiation, dust, fumes, insects; but these must be done in a secure and manageable manner (Bordass, et al. 2001). Sometimes, its location, orientation and the material it is made of cause more harm than good. Therefore, adequate considerations should be given to the design, life span, water tightness and wind resistance level, acoustic performance, thermal transmittance, resistance to repeated opening/closing, weather-stripping, glazing and selection criteria for materials.

To specify any window or door, such material requires to meet performance such as operating forces, air permeability, weather tightness, wind resistance, repeat air permeability, resistance to vertical loads and static torsion slamming resistance and closure against obstruction, abusive forces on handles, resistance to soft and heavy body impact and resistance to hard body impact. In addition, the ability to understand climatic characteristics of a site helps with longevity and durability as explained in the subsections below.

6.5.1 Design Life Span

Like the roof, design life span of windows and doors are fundamental to the general functioning of the building. Where the design falls short based on the usability, it renders the building almost completely unfit for occupation. Therefore, PSBs should be designed for their purpose. For instance, there are particular hours in the day when doors are constantly opened or closed and particular seasonal conditions when windows are opened for air infiltration depending on location. Thus, attention should be drawn to such parts of the building that require replacement and regular servicing to avoid the general limitation of the whole building rather than the singular unit of a problem. It is crucial that account is taken of materials used for windows and doors of PSBs in respect of the wear arising due to handling take. A good understanding of the properties and limitations of the materials considered is necessary to reduce the effects of poor detailing on the design life of the structure. Following the stress level imposed on windows and doors, the department of education and skills in Ireland in 2010 recommended a minimum life of 40 years (PBU, 2012). This means that materials should be durable, conform to usage, and provide adequate space for crowd movement and emergency exit.

Most materials used for the construction of doors and windows are required to have adequate fire resistance characteristics and to provide adequate air tightness to accommodate air linkages, especially when considering immediate environmental limitations as in the NDA. Nevertheless, specifying 40 years for the design lifespan of windows and doors require taking consideration of prevailing climatic factors, resistance to water penetration, the wind, non-load bearing characteristics of enclosures, acoustics performance, thermal transmittance, resistance to opening/closing.

6.5.2 Water Tightness

Water penetration through the building envelope is a recurring problem posing a major threat to building interior and exterior (Pérez-Bella, et al. 2015). The interface between window, doors and the wall has been identified as a significant source of water penetration (Salzano, et al. 2010). As affirmed by (Chew, 2005) , among the frequency of occurrence of defects, water leakages ranked the highest with wet areas subjected to constant damp conditions. Therefore, the quality of the door and windows lies in the ability of the material in withstanding water penetration, which might be through rainfall, water splash or due to leakages.

This wetness leads to unnecessary defects through rain penetration, condensation, cracking and detachment. As observed by (Chew, et al. 2004) in their study that in the UK, water penetration accounted for almost 68% of all building defects reported. The selection of poor performance materials for high moisture conditions is usually linked to poor knowledge of material performance, the lack of database or explicit knowledge of materials and contribution from materials manufacturer/suppliers, as well as the obsolete nature of building codes used during the design stage. All these may cause designers to choose poor materials.

Nevertheless, water penetration into buildings is as a result of the lack of water-tightness which could be due to the inadequacy of waterproofing, projections, and joints.

Proper selection, detailing of a waterproofing system and sound workmanship could ensure water tightness is achieved and prolonged during construction (Kanniyapan, et al. 2015; Chew, 2004). However, studies have shown that fenestration requires the minimum water penetration resistance of windows for some types of buildings which should be 15% of the structural design failure by the American Society of Civil Engineers (ASCE 2010), although, the holding period determines the ease at which water can penetrate through the materials affecting the resistance level. As affirmed by (Lopez, et al. 2011), the associated sign of penetration and subsequent leakage is dependent on material properties (absorption, adhesion, etc.), vents, frictional losses, the flexibility of the components, and the internal pressure.

The accurate determination of a facade's water tightness performance is important for optimizing design, bearing in mind the different micro-climatic conditions. This is because the penetration of rainwater through building facades negatively affects buildings (Blocken and Carmeliet, 2004). Thus, the amount of rain diverted by wind affecting the facade provides the retaliated water supply allowing the immediate wind pressure to cause penetration through the materials (Lacasse, et al. 2005; Lacasse, et al. 2007). Therefore, the formation of rain, which is due to the cloud formation and the terrain, should be taken into consideration as in the case of the ND, which is warm and humid and has a high amount of rainfall during the raining season. The importance of water tightness in PSBs led to the selection of BS EN 12208:2000 which is equivalent to materials being impervious to water penetration, and is achievable if the wind resistance level of the external façade should conform to current codes and meet the PS requirement.

6.5.3 Wind Resistance (WR)

The wind resistance (WR) level is also a crucial criterion of water and air-penetration resistance levels will be achieved. WR is an important standard that will help to improve the performance of windows and doors since it helps to determine the appropriate level of weather tightness specific to a country. For instance, the BSI standard explains how the designed wind load should be calculated for any given location and how that design wind load is used for the appropriate selection of water tightness, air permeability and, wind resistance classes. This applies to all types of vertical windows and pedestrian door sets and includes windows in which the opening lights are not fully framed, e.g. adjustable glass louvres are represented in the BS 6375-1:2015. The indication of the explicit detailing of the WR is because windows and doors form part of the building envelope and are crucial to the general performance of buildings during difficult situations like wind storms. In addition, (Minor, 2005) affirmed that wind-borne debris is influential to the performance of windows and doors. Therefore, during design, attention should be drawn to the after-effect of the immediate environmental conditions and behaviour of the material used since the exposure of the interior of the building and its contents to wind and rain bring excessive cost during retrofitting.

According to Strachan and Vandaele (2008), double and triple glazed windows should be tested with the inner window open and the outer window closed and the test repeated with the inner window closed. The test is to confirm that the requirement meets the specification since most building code requirements for windows and doors generally follow cladding and component requirements. In addition, it helps to reduce the limitation brought about from the marketplace, because of the designer, contractor or owner, makes selections of windows and doors from the product lines available. Yet windows and doors are the second most essential parts of the external façade of buildings. Even though, (Calfee and Murchison 1998) noted that 80% of deterioration is based on the window and door failure mostly due to wind defects yet, according to Taranath (2004), there is scarcely documented evidence of wind destruction except in cases of hurricane and tornadoes.   Therefore, understanding the terrain and immediate environmental challenges suffered could help determine the window and door type that will perform the needed task and function required.

In developed countries like the UK double and triple glazed windows are essential for energy conservation. However, the most important factor for the NDAN should be the ability of selected windows and doors to withstand the wind as a medium of infiltration of water and air inside of the building. Although the two countries' PS requirements are different, the main goal here is to avoid the penetration of wind through doors and windows inside of the building. Hence, the BS EN 12211: 2000 specification was adopted to fulfil this purpose.

6.5.4 Design of Non-Loadbearing External Vertical Enclosures of Buildings

PS covering non-loadbearing vertical enclosure of a building helps the systematic process where the enclosure for a building such as windows, doors and, walls are constructed to avoid unnecessary load on the substructure. The PS requirement should include the exclusion of noise from the building for the design to meet the purpose of the construction. As opined by (Calfee and Murchison, 1998), the failure of any part of the building envelope leads to major damage to the entire building structure. Thus, precaution should be taken to design and specify non-loadbearing facades avoiding any uncalculated load on the entire building. This is because in most cases, designed loads for windows and doors are usually determined by structural analysis after the building is designed (if they are determined at all).

Although The British Standard 8200 is the code that addresses load bearing in designs (Suresh Kumar, 2000), its importance is crucial because the prospect to alter the overall construction based on window and door loads are likely not in existence. These will in the long-run effect the longevity and the durability of the entire building. As affirmed by (Marteinsson, 2003), a simple mistake always leads to a large impact. Again, according to (Calfee and Murchison, 1998), the required non-load bearing external vertical enclosure minimizes window and door loads, rather than requiring stronger units and exposing the units to higher loads, without necessarily sacrificing the building design function or performance.

To provide the relevant specification that fulfils the PS requirement to meet immediate environmental criteria requires this provision during the design, construction, and layout of windows and doors. Following the crucial and significant nature of the non-load bearing enclosure to the general building load, which could lead to major defect, the BSI in conjunction with the Euro code, has provided a building code of BS 8200.

6.5.5 Acoustic Performance

The impact of external noise on health and happiness, as well on learning, has been acknowledged by WHO guidelines; hence, noise leakage between rooms requires improved sound insulation (Woolner and Hall, 2010). In addition, (Shield and Dockrell, 2003) in their report observed that ambient noise impacts negatively on the performance of schoolchildren. Therefore, careful considerations have to be given to the factors associated with the location and subsequent construction of schools. However, according to (Seep, et al. 2000), , the best way to resolve acoustic problems is by avoiding them in the preliminary stage, which is the design phase. It is, therefore, crucial to investigate and determine appropriately at the beginning stages before construction the surrounding environment and noise level determine the material type that should be used. As observed by (Chatterjee and Chakraborty, 2012) , designers are hindered by the limited choice of materials, shortage of materials and available selections or choice; hence, they are only left with alternatives which might not be of the required standard. However, test measurement criteria, as provided by BS EN ISO 140:2006, shows that with the right test, materials that can help reduce noise through windows, doors, and roofs can be selected.

This provides more credit for the need for PS, which reduces the rigidity of prescriptive specification giving the designer an opportunity to be innovative while substituting for a better alternative. As already discussed, windows with unpleasant views impact negatively on health; as such, the European Commission recognises that environmental noise is a severe environmental problem (Miedema, 2007) . According to the Commission, people suffer from unacceptable levels of noise and are exposed to serious annoyance. Consequently, (Willich, et al. 2006) affirmed that chronic noise burden is associated with the risk of myocardial infarction with the risk closely correlated with sound levels.

GF, according to Emma (2016) and as illustrated in table 2.4 of this study, generates noise. The level of noise generated from GF is higher than traffic noise in some developed countries like Dublin (Murphy, et al. 2009). Yet, noise restrictions are introduced as legislative instruments to combat its rise cognizant of its health implications. This is far from being achieved in the NDAN as there are no guidelines to noise levels around PSBs. Therefore, the need for appropriate noise test to meet the specified standard as the requirement, and selected construction materials use, should take into consideration the immediate environment and surrounding activities.

6.5.6 Thermal Transmittance

According to (Oral, et al. 2004), windows are the weakest part of the thermal building envelope and the window design or choice affects energy consumption, both for cooling and heating demand. Furthermore, (Buratti, et al. 2012) opined that the thermal properties of transparent openings have a fundamental role in accomplishing the statutory requirements and in providing an adequate envelope of the building. However, the most important functions of the building envelope are to control physical environmental factors such as heat, light and to realise good comfort conditions for the users of PSBs.

The rate of transfer of heat from windows or doors could increase the total thermal level indoor, thus creating a level of discomfort to pupils during learning hours. Since thermal transmittance is based on total heat gained from external to internal, the immediate climatic condition and environment should be a major factor to consider before designing or selecting material types. Although in most developed countries the main aim is for materials used to retain heat inside the building as an avenue for energy savings, it is the opposite for a warm humid country. For example in Nigeria, where the heat radiation is usually high and with such immediate environmental condition, heat radiation generated from GF intensifies the total heat gain in a building.

It is important that materials used for design and construction of windows and doors should be able to reduce heat gain while providing and retaining the cool temperature inside. Considering the amount of heat that is generated from GF and the level of temperature around the ND, material selection should not include complicating factors that can affect the thermal transmittance properties. Since the thermal transmittance level is dependent on both the external and internal temperature and wind speed, care must be taken to design and use materials that will reduce heat transmittance from windows and doors through external surfaces. Therefore, the thermal transmittance level should be BS EN ISO 10077-1:2006 to help meet the requirement for resistance from heat radiation from GF.

6.5.7 Resistance to Repeated Opening/Closing

Windows and doors are openings on the wall of a building for the admission of light, air, entrance and, exit from a building, held in place by frames of different material types, mostly wooden. Recently, due to modern architecture and design most windows and some doors arranged for decoration and virtual purposes usually glazed or covered in transparent or translucent material. In addition, the impact of industries and use of construction of high rise buildings in many processes of the contemporary building has led to the use of metal frames for windows in most construction. This has made possible the use of ever-greater areas of glass often made with double or triple thicknesses separated by a vacuum for insulation (Encyclopaedia Britannica, 2016). However, many glazed windows may be opened to allow ventilation or closed to exclude extreme weather conditions and for security reasons.

Windows often have a latch or similar mechanism to lock doors. While windows can be used as decorations in a building, in building safety, doors are a key area of consideration, and so should be a fundamental part of the design with three major considerations such as safety, fire, and soundproofing. This is because, the opening of doors severally in an hour based on the time and needs of pupils requires significant consideration to safety, which might be compromised due to poor design and the lack of safe hinges to help to reduce finger trapping. In addition, doors should have a fire resistance factor to prevent smoke penetration, preventing the fire from entering into the classrooms, also serves as soundproofing material as well. Furthermore, the continuous/repeated opening and closing accelerate wear and tear and are a major factor that should be considered when specifying windows or doors for PSBs.

Avoiding collisions is another requirement for open windows, doors or ventilators designed so that projecting parts kept away from people moving around the building. More so, features should be included that guide people away from openings. Thus, the basic factor is for materials used for window and door frames and the construction to be durable and conform to BS EN 1191:2012 in order to provide the required features and durability.

6.5.8 Weather-Stripping

The importance of air tightness in an environment that is prone to poor outdoor air cannot fulfil. According to Guo et al. (2008), most poor indoor air is as a result of infiltration of ambiance inside of the building. The possibility of achieving the right indoor air depends on all the building envelope, which includes windows, and doors that could be open or closed at different times. Even though these windows and doors are designed and selected based on PS, the possibility of air leakage is pertinent hence the need for weather-stripping. The importance of additional sealing requirement for windows and doors has been in existence for over the decades based on documented evidence, and even with innovation and improved professionalism and experience in construction, it is an essential requirement. Weather-stripping materials are used to carry out sealing processes to prevent air leakages (Pease Jr David 1966). As the name implies, it is the process of sealing openings of doors and windows from air and water.

Weather-stripping of all doors and windows will help reduce the unwanted hot or cold air resulting in heat and cooling loss. To perform this function, there are requirements for solid (non-cellular) rubber used in preformed gaskets for sealing applications in buildings to provide resistance to air infiltrations, which might lead to permanent deformation, are of prime importance. The specification, as described in BS 4255-1:1986, was selected based on the importance of a sealing agent, and against negative effects. In addition, the BS provides the test requirement necessary to achieve an environmental condition based on individual parts of the building façade opening rather than generalisation, thus the durability and the single nature in which this standard describes its importance.

6.5.9 Glazing Materials

Window glazing serves an important role in buildings, which helps to enhance the quality of life. Window glass is significant because it carries positive pictures such as transparency, natural brightness, modernity, freshness and both indoor/outdoor interaction. The arrangement of window technology is under continuous evolution. This is such that highly glazed buildings have become a worldwide design trend in all buildings even with hostile climatic conditions (Hee, et al. 2015) although, this is made possible with added innovations to suit environments. However, some window types put much pressure on the global environmental issues like energy, waste and global warming; nevertheless, advanced triple glazing during the design stage helps to reduce such pressure or deterioration has been claimed (Chow, et al. 2010). To cope with sustainability and conservation needs, window glazing has been given revised identities, and a wide range of design options (Baetens, et al. 2010). Windows and doors could serve as the transparent surface of a wall, allowing pupil inside a PSB to see through and also as a form of light or illumination without additional energy consumption.

Glazing materials should transmit light but without the transmittal of thermal ultraviolet rays, which cause heat sensation and subsequent discomfort. Although doors, especially main entrance doors to PSBs with glazing materials, windows are recently fitted with glazing materials and with thermal performance are largely established according to the glazing material used along with its properties. According to (Baetens, et al. 2010), it is possible to divide the various glazing materials based on transparency (totally transparent or selectively opaque to various types of radiation and wavelengths) because the use of window materials with low glazing could create a high level of heat internally causing sweat and discomfort. Each material making up the building elements, including the internal and external materials used should have adequate thermal resistance level to achieve internal comfort. Furthermore, materials considered should be able to protect the eyes of pupils while they look through the windows. This is because both the internal and external resistance levels of any glazing material should provide the following:

- It must be shielded or protected from impact
- It should resist impact without breaking
- If it is broken on impact, it must break in a way that is unlikely to cause injury.

The importance of the safety and health of the occupants of buildings with glazing materials should meet the BS EN ISO 52022-1: 2015. The sensitivity of the eyes, when exposed to natural daylight, should be considered and provided for, reducing discomforting sensations and well-being for occupants while providing a healthier indoor environment.

6.5.10 Frame Joint Sealing Materials

The façade of any building play a significant role in the quality, whether it be the assessment of the quality of construction, design, fixtures or monitoring IAQ. Therefore, having every part of the elements necessary to meet the performance requirement of such building is key. Frame joint sealing material (FJSM) be it rubber, asphalt or bitumen all play a major role in keeping a building air and water tight (Wolf, 2015) although, Prior to the 1900's most sealants evolved from vegetable, animal, or mineral substances. Thus, they help to prevent damages with the unforeseeable consequential costs.

FJSM contribute significantly to energy-efficient and sustainable building design. Although, for FJSM to fulfil its function over the whole lifetime of a building, the selection of the right solution and the correct design, taking into account all potential influences such as environmental factors, is fundamental. FJSM pad movements between parts resulting from temperature changes, humidity, shrinkage of construction material, sound, wind and other mechanical shocks could lead to accelerated decay (Wolf, 2015). It is important that the design must include structural and processing considerations because only if the design specifications have been implemented properly can the sealant function in the long term. Furthermore, sealant compensates for tensile and compressive forces and shear loads between the joint surfaces (Wolf, 2015). This is because, joints and openings between building elements are found in different parts of a construction; for instance, between precast concrete elements in facades, around windows and doors, and at the connection between floors and walls.

FJSM is used to seal openings, joints, and gaps in buildings due to the following reasons:

- Prevent passage of media (air, water, chemicals, smoke etc.)
- Provide thermal and sound insulation
- Enhance the visual appearance of the whole construction.

The main purpose of sealants is to prevent air, water, and other environmental elements from entering or exiting a structure while permitting limited movement. Common sealants include silicone, acrylic, urethane, butyl and other polymeric types. Various formulations have been developed over the years, which meet PSs established by industry standards, as well as for the specific and unique needs of the end user. The proper application of a sealant involves, not only choosing a material with appropriate physical and chemical properties but also having a good understanding of joint design, the layer to be sealed and the performance needed.

Therefore, based on the performance required in this study, the sealant should be able to enhance adhesion and extreme resistance to outside influences and provide long-term functionality. Moreover, for achieving these advantages, the specification requirement should meet BS 6093:2006+A1:2013, which helps in the utmost exclusion of outdoor air infiltrating through openings or gaps in the building.

6.5.11 Thermal Barriers

While frame joint sealing is important to the complete elimination of the wind;, air, and water from entering the building through window and door openings mostly caused by the poor connection between openings. The need to protect indoor spaces from gains of hot air is also significant bearing in mind the immediate weather characteristics of the study area. Windows and doors generally account for approximately one-third of the exterior wall area of a building (Liu and Nazaroff, 2001). It is pertinent that all openings and joints between windows and doors should be securely fitted with thermal barriers.

Thermal barriers also referred to as thermal breaks, are insulated containers designed to keep heat out. This helps in providing a barrier to the penetration of hot air into the building to create heat gains, resulting in sweating and discomfort to pupils. To reduce air infiltration at the gap between the door and doorframe, the use of thermal barriers on windows offers such important benefits. For instance, a rise in temperature above the resistance level of construction material might lead to the intolerability of some materials leading to expansions. This will in most cases lead to buildings inability to meet the user/performance requirement. However, the use of thermal barriers - a piece of material that does not conduct heat for separating two materials that conduct heat, provides resistance to expansion.

Thermal Barriers are available in standard sizes or can be customised to suit your specific requirements. Material type ranges from polyamide or polyurethane, which is mechanical, locked into aluminium or stainless steel with performance equal to or better than wood or vinyl windows. In addition, they have the added benefit of reducing sound transmittance by dampening vibration (Ekici and Bougdah, 2003). It is pertinent to fit thermal barriers on buildings in an environment like that of NDA due to the aggressive nature of the environment; in particular, to help withstand the thermal expansion stresses associated with heating, the ability to reduce sound transmittance and vibration. Therefore, to meet this requirement the performance material chosen should meet BS EN 14024:2004.

6.5.12 Weather Tightness

Every part of the façade of a building bears a significant amount of functionality, which helps to satisfy the wholesome performance requirement of the building. The cladding system used for the walls and roofs must meet specific criteria such as weather tightness, water tightness air permeability and much more. Also, window and door joinery are required to be weatherproof to meet BS 6375-1:2015 code. The BS 6375-1:2015 is one of many important standards for those working to improve the performance of windows and doors. It provides guidance to the specifier and the manufacturer of windows and doors on an appropriate level of weather tightness. Because different locations have different wind loads, this standard provides the opportunity and method of calculating how the design wind load is used. This is for the appropriate selection of water tightness, air permeability, and wind resistance classes. Weather tightness is significant because it helps to understand air infiltration, this is because according to Sherman and Chan (2006) infiltration is the movement of air through leaks, cracks and other adventitious openings in the building envelope and depends upon the pressure across the building. Although in developed nations the most important factor is the energy loss, in the subject area, the main prerogative is the exclusion of poor ambient air from the building. This is because when poor outdoor air infiltrates into the building, the whole essence of the system providing clean indoor air is tainted. Therefore, weather tightness should be stringent as infiltration could be both liquid and in vapour form, which is a warning factor to the growth of fungus and moulds and the penetration of damp air leading to bacteriological growth. In addition, other forms of defects such as draught and noise also arise whereas tight buildings provide a level of comfort and safety. Therefore, the performance of any window or door specified for PSBs in GF vicinity should meet weather tightness criteria.

6.5.13 Thermal Comfort

An internationally accepted definition of thermal comfort, used by ASHRAE, is *'that condition of mind which expresses satisfaction with the thermal environment'* (BS EN ISO 7330). Thermal comfort Perceptions of the environment are affected by air temperature, radiant temperature, relative humidity, air velocity, activity, and clothing. According to Bluyssen (2009), the human being is a comfort seeking animal. Although thermal comfort is very important, there is no absolute standard of thermal comfort. This is not surprising, as humans can and do live in a range of climates from the tropics to high latitudes. Thus, general definitions of comfort include a sense of relaxation and freedom from worry or pain. Stoops (1994), claims that an element of thermal discomfort – thermal experience beyond the normal comfort boundaries contributes to overall well-being. However, (Nicol, 2002) holds that it will eventually be possible to produce thermal standards for buildings that do not resort to specifications of the indoor climate, but use characteristics of a building such as materials, orientation, movable shading, heating system, and controls.

Providing a thermal comfort inside a PSB is significant having that schoolchildren are prone to health defects due to factors such as thermal discomfort. Although, providing acceptable thermal comfort depends on the local environment where such school is located, for instance, Dabaieh, et al. (2015) observed that in hot dry climates, it is estimated that almost half the urban peak load of energy consumption is used to satisfy air-conditioning cooling demands. However, if buildings are designed and built to incorporate the right requirement and performance criteria occupants will be comfortable. According to Bjorn Berge (2009), building location and specification are important factors as it provides the decision on types of shading and use of high-density building materials. The concern should not cross balance between costs and expenses rather the possibility of providing comfort level within the environment where learning takes place. A more important factor to base the achievability of a good thermal comfort is the environment in which the building is situated, the anthropogenic substances that emit around it and the possibility of providing a good and conducive learning environment. Therefore, achieving good thermal comfort level requires stringent choices to be made allowing the decision between systems that will provide good thermal comfort within the learning environment.

6.5.14 Space Cooling Demand

Like thermal comfort, the space cooling demand should conform to standards. It is important that design professionals take into consideration the size of space provided and the amount of cool air required, keeping both staff and pupils in the right condition. This is to avoid the unnecessary degeneration to other forms of health challenges associated with exposure to too much cold. Although the actual cooling and comfort levels of indoor climate depend on the outdoor climate, the design initiative and material selection on all parts of the building is crucial in achieving the right cooling demand. Materials used for windows and doors should be able to provide added advantages to the required space cooling demands. The adequate installation of the right windows and doors will either reduce or increase cold air. This is because some materials are either insulators or act as active solar devices in a way to offset the insulation weakness of the building façade (Chow, et al. 2010). However, significant considerations should be given to the immediate climate and activities that generate or degenerate cooling demand.

The need for space cooling demand has led to most buildings with heat gains installing air conditioning units as alternatives or substitutes for providing cool air in most countries. Although countries like Nigeria and the NDA, with heat gains from solar radiation and GF, require such initiative, this is not the case for public schools. There is, therefore, the need for further consideration to windows and doors selection that will be able to absorb heat without transferring it into classrooms. Consequently, reduced heat gains can impacts positively on the energy consumption of other units apart from lightning (Demanuele, 2010). This might include air conditioning units and humidifiers/purifiers used to provide clean indoor environments.

Temperatures in a poorly designed building can be expected to be in excess of those outside the building during hot spells. Although most countries are adopting the use of a passive cooling system or a mixed mode system where mechanical and natural ventilation systems are used concurrently to achieve needed space cooling demand, this might be different in the NDA as the main consideration is the avoidance of the infiltration of ambient air inside of the building. This remains the case unless measures could be employed that will possibly filter the outdoor of polluted substances hazardous to health. However, while considerations are different, the principle of cooling space demand is the same as that of the required comfort level for occupants. Adopting a cooling demand not exceeding 15kWh/(m^2a) is a requirement as obtained in countries like the United Kingdom and other European countries and is adopted to provide allowable cooling space demand.

6.5.15 Selection Criteria

Selection criteria meeting the requirements of one factor do not necessarily mean that it also satisfies the requirements of another or the durability requirements of other applications. This depends on the design and performance that need to be achieved. In some buildings, especially in a cold environment, materials selection criteria aims at retaining heat thereby saving energy (Vassigh, 2011). However, for the purpose of this research, the selection criteria are for the reduction or complete elimination of outdoor air from infiltrating inside of the building. Therefore, considerations such as the level of human traffic that will be passing through classroom doors on a typical school day are significant.

It is pertinent to understand that no matter how well the door is designed and installed, it will not live up to performance expectations if its durability does not match the application requirements. The selection of materials should be carefully carried out with established criteria based on different environment and immediate climatic conditions. This is because buildings are exposed simultaneously to a large number of individual pollution sources from varying upwind distances and heights over different timescales. The relationship between these and their proportionate contribution under different circumstances governs pollutant concentrations over the building shell and the degree of internal contamination.

Internal contamination of buildings from outdoor pollution sources, therefore, depends upon:

- The pollutant dispersion processes around the buildings;
- The concentrations of pollutants at the air inlets;
- The ventilation strategy (natural, mixed-mode, mechanical);
- Pollution depletion mechanisms;
- The airtightness of the building, that is, the ability of the building envelope to prevent uncontrolled ingress of pollutants.

Many studies have even shown that health, comfort, and productivity are improved due to well-ventilated indoor environments and access to natural light (Schneider, 2002; Ander, 2003). Although windows have long been used in buildings for daylighting and ventilation, they also represent a major source of unwanted heat loss, discomfort, and condensation problems. In 1990 alone, the energy used to offset unwanted heat losses and gains through windows in residential and commercial buildings cost the United States $20 billion (one-fourth of all the energy used for space heating and cooling) (Singh and Michaelowa, 2004). Therefore, clear selection of design, window type, and material type is significant and unique to every environment and climatic condition.

In recent years, windows and doors have undergone a technological revolution. High-performance, energy-efficient window and glazing systems are now available that can dramatically cut energy consumption and pollution sources. They have lower heat loss, less air leakage, and warmer window surfaces that improve comfort and minimize condensation. These high-performance windows feature double or triple glazing specialized transparent coatings, insulating gas sandwiched between panes, and improved frames. All of these features reduce heat transfer, thereby cutting the energy lost through windows. Accordingly, Vassigh and Chandler (2011) confirmed that an integrated green and sustainable method can provide the needed performance for a building. However, to meet selection criteria, the BS

6375-1:2009 standard should be used when selecting materials, to be able to withstand environmental challenges.

6.6 Coating

It is the layer of a substance either in a liquid or powder form spread over a surface for protection from decoration, corrosion and subsequent deterioration of a covering layer (Tiwari, et al. 2014). The colour used to coat any material either increases the rate of deterioration or reduces it. For instance, (Baker, et al. 2006) observed that apart from material type, colours react easily with weathering conditions to accelerate the level of discolouration. Although the type of coating in the case of a paint depends on factors such as the type of layer, the preparation of layer before paint is applied, the formulation of the coating and the application procedure (Heckroodt, 2002) . Yet some paints used for coating have out retained their stipulated performance periods.

The type of coating used provides the required protection from weathering, climatic and environmental conditions; some of such materials used include zinc, aluminium, tin, cadmium, chrome, nickel or a combination of materials to produce the needed protection (Berge, 2009). Depending on the material type, different coating substances can be used; however, care must be taken not to cause environmental problems. Thus, the need for test classification and criteria met before selection of any material type.

Therefore, any coating material used should meet performance requirement as provided. For instance, in the case of the ND, primary data collected revealed that most roofing and wall materials used showed corrosion, discolouration and flaking of paints. Thus, in order to withstand the immediate environmental conditions, coat materials should be water resistant, resistant to carbon exposure and salt spray, and the colour tolerance should be high.

6.6.1 Water Resistance

Many buildings, both public and private, are constructed with different types of materials, ranging from wood to metals and in recent years, prefabricated materials from organic and non-organic materials are constantly explored due to the need for environmental friendly readiness/sustainability. Furthermore, such materials in most cases are required to meet functional and aesthetic criteria. This, in most instances, led to buildings using cladding panels for the façades for the external surface of walls. However, such cladding materials often serve as thermal insulators or used as suspended panels for insulators. Nevertheless, every material should be able to withstand atmospheric measures from rain and other sources that might cause negative interactions with such material.

The importance of water resistance has to do with the longevity of the material, which affects the performance requirement. As affirmed by Sakumoto, et al. (2001), water is the principal environmental factor that affects coating durability. This is crucial where such material has insulation properties and such required performance could be distorted or completely faulty. For any type of coating material to meet water resistance criteria, such material should have undergone the ASTM D2247-1:2011 test. Although the practice is that, the coating material should undergo water resistance by exposing coated specimens in an atmosphere maintained at 100% relative humidity so that condensation forms on the test specimens. Thus it is important for architects and engineers to consider critical points in the humidity profile of a building at the design stage (Gaylarde and Morton, 1999). Therefore, as opined by (Ravikumar, et al. 2012), specifiers, designers, and suppliers of materials should be conversant with these test criteria because most coating materials deteriorate due to weathering conditions. Thus, they have to be sure that manufacturers of selected materials have the required certification and stamp, and that the coating material is weather tolerable.

Since the study, the area has two seasons, namely the rainy and the dry season, although due to climate changes of which GF plays a significant part, the ND is constantly faced with rain all year round. According to the meteorological agency of Nigeria, the country faces a maximum of 275 days of rainfall ranging from 300mm to 2500mm in the ND (NiMet, 2016). With this amount of rainfall, which will contain the atmospheric mixture of emitted substances, the materials used for façade should meet water resistance criteria in order to meet the performance requirement.

6.6.2 Resistance to Carbon Exposure

The adverse effect of carbon, both on health and on building decay, cannot be over emphasised as already discussed and illustrated in Table 2.6 and 2.7 in chapter 2 of this study. Accordingly, Brimblecombe and Grossi (2009) noted that the amount of pollution in any environment affects the level of deterioration or damage suffered by building materials. Thus, exposure of building façades to carbon leads to blackening or discolouration because the perception of blackening depends on the individual and on general conditions of the local environment (Watt and Hamilton, 2003). Yet the physical and aesthetic degradation have no study being currently carried on them except that relating to the chemical and physical impact of pollutants on the building fabric (Brimblecombe and Grossi, 2005). Therefore, it is a defect that needs significant consideration during design and selection of building materials.

Façades are often described positively in terms of conceptualised human characteristics such as "cheerfulness", "attractiveness", "warmth" and "friendliness" (Ball, et al. 2000). However, the negative impact of blackening dehumanises has a general perception of uncleanliness and desolation. The recent agitation of ***"#stop the soot#"*** in the ND with residents showing pictorial evidence of carbon depositions in the environment is part of the physical defects experienced. Therefore, adequate measures should be taken when designing and selecting materials for such environments. Following empirical data collected, professionals noted that the use of dark slate, although recent, have shown durability in terms of physical discolouration and corrosion effect. Nevertheless, the interaction between coating materials used with the surrounding weather conditions might lead to faster deterioration and consequent damage to the entire façade.

According to Jacques (2000) and as illustrated in figure 6.1, there are multiple reasons why weathering tests should be done in order to find geographically suitable materials that meet the performance requirement.

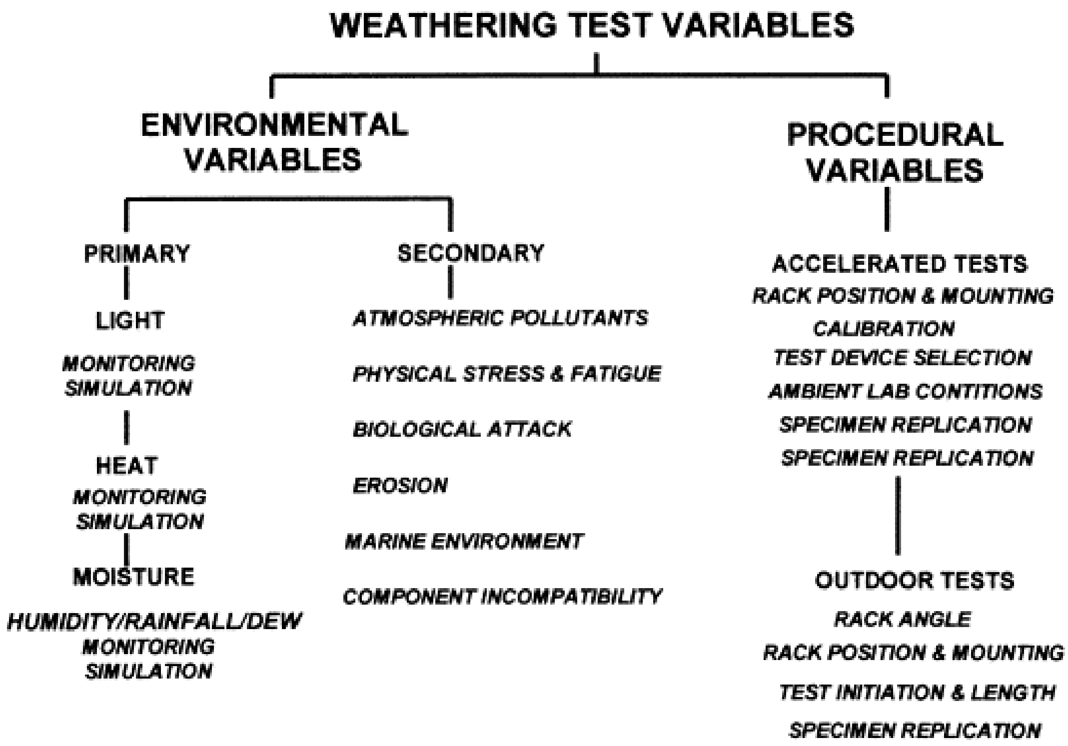


Figure 6.1: Reasons for Weathering Test
Source: Jacques (2000)

Following figure 6.1, all the listed variables affect the durability of coating materials used, therefore, coating materials used should meet ASTM D3361 / D3361M:2013 requirement. This is because the durability of any coating materials to resist deterioration caused by exposure to weather conditions such as light, heat, and water can be significant; the test requirement projected is to prompt durability, aesthetics, and changes associated with end-use conditions.

6.6.3 Resistance to Salt Spray

A salt spray carried by the wind is continuously in contact with the final finishing of any material used in constructing buildings and is usually deposited on the external façades of buildings. In most cases, the coatings are the main materials that have contact with the environment before any other material used in construction. Defects due to salt spray arise from the geographical location and the type of water that surrounds such environment. Nigeria, as a country surrounded by two main rivers, the Niger and the Benue, bordering the Gulf of Guinea, with mangrove forests and swamps, which are categorised using regular salt–water floods within most communities (Edet, 1993; Ugochukwu and Ertel, 2008). Thus, most communities in the ND have been observed to lack portable water due to the intrusion of salt spray (Oteri, 1988). Therefore, the deposition of this salt spray due to wind exchange leaves an impending deterioration if adequate care is not taken to guide against it.

Although salt spray usually affects metals, stones, cement and other material types, it has also been observed that a good corrosion resistance coating material can help resist its corrosion activity (Talbot and Talbot, 2007). According to Schürz, et al. (2010), in the last 35 years, materials such as zinc, aluminium, and magnesium alloy of which coating have been developed, although the material contained in each base coatings varies for different countries. Therefore, adequate consideration of the suitability of the base coating must be checked and monitored to be adaptable to the ND. This is because, due to the immediate conditions, coating materials can either have high corrosion resistance substances or low resistance to corrosion. Therefore, it is important that the coating material selected meets the environmental conditions in the ND and the nature of salt spray when selecting coating materials; hence, the choice of ASTM B117:2011 as a requirement for any coating material to be able to resist long-term exposure to atmospheric pressure.

6.6.4 Colour Tolerance

Coating materials are exposed to solar radiation, water, the wind, and dust when used outdoor like other materials that deteriorate due to interaction with the atmospheric content. Although chapters 2 and 3 discussed in detail, with sample pictures of discolouration caused by deposition of atmospheric content such as PM and CO regardless, the tolerance level of any colour chosen for either aesthetics purposes or unification or logo purposes, it is important to consider its characteristics during the design stage hence the criteria in the designed PS.

The main purpose here is to allow the building and the external façade retain its original colour. From field data collected and analysed in chapter 5, respondents noted that discolouration is a factor that reduces the durability of buildings in the ND. Therefore, the material selected must be able to retain its original state even with deposition of atmospheric contents. Although coating thickness decreases with increasing exposure time, such coating should retain its colour. Therefore, it is required that both suppliers and manufacturers of the coating should be clear about the performance and the suitability of such colour in an immediate environment by meeting characteristic before use. Thus, the test requirement provided by ASTM D2244:2015 states that the purchaser and the seller shall agree upon the acceptable colour tolerance because each material and condition of use may require specific colour tolerances resulting from other factors present in the environment. This clearly indicates that at the design and selection stage of materials, manufacturers, suppliers, and designers are all liable in the case of discolouration without reaching the specified life span.

Therefore, the above listed and discussed requirements will provide the needed performance criteria for PSB design and construction in the VGF in the ND area of Nigeria. A tabulated list showing the requirements and performance is illustrated in table 6.9.

Table 6.9 Specification for the Design of Public Schools in the VGF

No	Explicated Problem	Performance Requirement	Specification
PS1	Indoor Air quality Poor environments in schools cause ill health and impact on the performance and attendance of students. Many existing school space-conditioning systems using conventional mixed	Protect occupants from harm due to adverse health effect arising from poor air Improve effectiveness of learning process Reduce absenteeism Provide comfort	

	ventilation systems are not designed to filter pollutants and fail to provide the IAQ that can produce optimal student and teacher performance. Therefore, the need to provide schools with the means to maintain clean air as determined by the best standards from WHO/BS/EN on air quality standard		
PS2	Carbon monoxide (CO) Carbon monoxide (CO) is a colourless, non-irritant, odourless and tasteless toxic gas. Common symptoms include a headache, lethargy/fatigue, nausea, dizziness, and confusion. A victim may also suffer from shortness of breath, cardiac palpitations, convulsion, paralysis, loss of consciousness, coma and eventually death	Using BS EN 14626: 2012 as a standard measure for any air handling system that could achieve reduction	Protect against CO as specified by WHO: 15 minutes – 100 mg/m3 1 hour – 35 mg/ m3 8 hours – 10 mg/ m3 24 hours – 7 mg/m3
PS3	Particulate Matter ($PM_{2.5}$ & PM_{10}): PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Chronic	$PM_{2.5}$: BS EN 12341: 2014 PM_{10}: BS EN 12341: 2014	$PM_{2.5}$ 10µg/m^3 annual mean 25µg/m^3 24-hour mean PM_{10} 20µg/m^3 annual mean 50µg/m^3 24-hour mean

	exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.		
PS4	Ozone (O_3) Excessive ozone in the air can have a marked effect on human health. It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases	O_3: BS EN 14625:2012	O_3 100µg/m^3 8-hour mean
PS5	Nitrogen oxide (NO_x) Epidemiological studies have shown that symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2	NOx: BS EN 14211:2012	NO_x 40µg/m^3 annual mean 200µg/m^3 1-hour mean
PS6	Sulphur dioxide (SO_2) SO_2 can affect the respiratory system and the functions of the lungs and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels. When SO_2 combines with water, it forms	BS EN 14212:2012	SO_2 20µg/m^3 24-hour mean 500µg/m^3 10-minute mean SO_2 concentration of 500µg/m^3 should not be exceeded over average periods of 10 minutes duration. Studies indicate that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes.

	sulphuric acid; this is the main component of acid rain, which is a cause of deforestation and deterioration in building materials.		
PS7	Benzene - Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and aplastic anaemia. Acute exposure to benzene may cause narcosis: a headache, dizziness, drowsiness, confusion, tremors and loss of consciousness, moderate eye irritant and a skin irritant	BS EN 14662:2005	No safe level of exposure can be recommended. Unit risk of leukaemia per 1µg/m3 Air concentration is 6 × 10–6 The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1000 000 are 17, 1.7 and 0.17µg/m^3, respectively
PS8	Polycyclic Aromatic Hydrocarbons - Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers	BS EN 14902: 2005	1 ng/m^3 (one Nano gram per millilitre)
PS9	Air tightness - The fundamental building property that impacts infiltration caused by pressure effects of the wind and/or stack effect	Stop the uncontrolled inward leakage of outdoor air through cracks, interstices or other unintentional openings of a building	0.6 air changes per hour at 50 Pascal's pressure (ACH50)

PS10	Materials: Materials after exposure to pollution from gas flares should be durable. Therefore, the specification of roof and wall cladding has implications well beyond the aesthetics. The choice of cladding can affect many aspects of the building's performance Different types of cladding materials could be used for construction. However, it should meet the minimum standards as prescribed by both BS/EN	Durable materials that can withstand chemical influences from pollution from gas flare All materials, products and building systems shall be appropriate and suitable for their intended purpose	
Cladding materials for roofs and walls Cladding material used for the external façade of a building is there important as it interacts with the outside environment than in keeping the inside environment comfortable. The material used for the external façade can be the source of the majority of future building problems if it is not suited for such environment. cladding materials should be chosen to meet climatic needs of the area and buildings should be aligned in such a way that they are concordant to the direction of prevailing winds in order to prevent parts of the material like the roofs from being blown off			
PS11	Thermal performance of roof covering	Material should provide cool internal environment BS EN ISO 10211	0.25 W/m2K – weighted average
PS12	Thermal performance of roof lights	Material should be to provide adequate heat loss rather than heat gain BS EN ISO 10211	2.2 W/m2K – weighted average
PS13	Indoor ambient noise level/ Airborne sound insulation	(a)clear communication of speech between teacher and student (b) clear communication between students (c) learning and study activities	$L_{Aeq,30mins}$ dB
PS14	Resistance to cracks	BS EN ISO 15156-1:2015	Materials should be crack resistant
PS15	Minimum lifetime	Minimum life of the building should not be less than that specified	In PSBs, the roof deck and insulation must have a minimum lifetime of 60 years, with the roof covering lasting a minimum of 30 years for roof covering, to

			be easily overlaid, over coated, upgraded or replaced without affecting the insulation/deck below, when assessed by a competent technical professional. Evidence must be provided by the roof covering manufacturer from an independent accredited test authority or historical data that the above minimum lifetime can be achieved.
Corrosion resistance level: Corrosion is the natural degradation of a material due to its dissolution, caused by reactions with the surrounding environment. Corrosion is nature seeking to recombine elements which have been reduced to an unnaturally pure form			
PS16	Acidic level	Material below the specified acidity level should not be used	Acid (pH) level of below 6.5 should be avoided
PS17	Corrosion resistance level	Level of corrosion resistance should not exceed limit as specified	A resistance factor of 5mpy (Milli-inch per year)
PS18	Corrosive resistance Coating	BS EN ISO 14713-1:2009	Material should be able to resist corrosion as specified
Windows and doors: A space in the wall of a building to allow light and air in, allow entrance, exist and to allow people inside the building to see outside environment			
PS19	design life span	Material should achieve life span as specified	40 years
PS20	Water tightness	BS EN 12208:2000	Material should be impervious to water penetration
PS21	Wind Resistance	BS EN 12211: 2000	Materials should be able to withstand wind load
PS22	Design of non-loadbearing external vertical enclosures of buildings	BS EN 16846:2015	Able to resist impact without causing hazard
PS23	Acoustic Performance	BS EN ISO 140:2006	Should provide sound insulation
PS24	Thermal Transmittance	BS EN ISO 10077-1:2006	Should be able to have resistance to heat transfer

PS25	Resistance to repeated opening/closing	BS EN 1191:2012	The mechanical durability of constant opening of doors
PS26	Weather-stripping	BS 4255-1:1986	Should be able to prevent air from outside due to window and door leakages
PS27	Glazing materials	BS EN ISO 52022-1: 2015	Should be able to provide exposure to natural daylight without discomforting sensations of well-being for occupants while providing a healthier indoor environment
PS28	Frame joint sealing materials	BS 6093:2006+A1:2013	Material used should provide protection from outside air
PS29	Thermal barriers	BS EN 14024:2004	Materials used should be able to protect building from heat transfer
PS30	Weather tightness	BS 6375-1:2015	Materials used should be secured against rain or the wind
PS31	Thermal comfort	Materials used should not increase heat gain internally	Thermal comfort should not be more than 10% of the hours in any given year of 25^0C
PS32	Space cooling demand	Materials used should be able to conform to the cooling level required internally	Not exceeding 15 kWh/(m²a)
PS33	Selection criteria	BS 6375-1:2009	Pressure level in which material can withstand in different environment
Coating: A layer of a substance spread over a surface for protection or decoration a covering layer			
PS34	Water Resistance	ASTM D2247-1:2011	Water can cause the degradation of coatings it is important that the coating achieves a 100% performance on relative to be able to withstand defects from water

PS35	Resistance to carbon exposure	ASTM D3361 / D3361M :2013	The coating to resist deterioration of its physical and optical properties caused by exposure to light, heat, and water
PS36	Resistance to salt spray	ASTM B117:2011	Material should be able to withstand long-term atmospheric exposure
PS37	Colour Tolerance	ASTM D2244 : 2015	Coating material should be able to withstand weather conditions without losing its original colour over the stipulated time.

Source: Author's Compilation

6.7 Chapter Summary

In order to design a PSB that will help improve indoor air and longevity of the building, environment specific criteria have been considered. The performance of any building material selected during design and construction of schools in the VGF should meet the requirements discussed since the NBC mirrors that of the BSI; although falling short of current updates and amendments made to allow the specification meet modern and everyday challenges caused by man's exploits on the environment. According to Bordass, et al. (2001), prevention is better than cure. It is therefore imperative that designed buildings should conform to trending needs for sustainability and health implications. This can be made possible if current events researched and tested in developed economies are adapted to the developing economy like the Nigerian Delta environment prone to anthropogenic emissions after reviewing for appropriateness and suitability.

This chapter, in designing a PS for schools in the NDAN, has elaborated on the different pollutants from GF causing poor IAQ and provided limits of such substances allowable in order to achieve clean breathable air without health implications. It also discussed performance requirements of the external façade of PSBs for durability purposes. Although the PS and PR designed relied on primary and secondary data as illustrated in table 6.9, a confirmation of its effectiveness is carried out with professionals around the study area.

Based on the DSM adopted for this research, demonstration, also known as a weak form of evaluation, is used and constitutes the fourth stage of the process as discussed in the next chapter.

CHAPTER 7. DEMONSTRATION OF THE PERFORMANCE SPECIFICATION (ARTEFACT)

7.1 Introduction

Here, the main goal is to determine how the developed artefact can be used to solve the explicated problem by demonstrating it through a reliable research strategy. Henver (2007) noted that the design cycle, which includes the design, demonstration and evaluation steps, is where the hard work of DS research is done. The chapter will explore the need for demonstration, experiences encountered during field work, demonstration of the designed PS, the iterative steps taken to adjust the PS, feedback from the analysis and close with a summary of the chapter.

7.2 The Need for a Demonstration

According to Pries (2008), the principal aim of a demonstration is to determine how well the artefact works, not to theorise about or prove anything in the process. The aim here is focused on the ability of the designed artefact to solve problems in a real life scenario, which in turn provides a proof of concept. Although, this method centres on conditional prediction (Peffers et al. 2006), its purpose is to show that the designed artefact is functional.

However, there is the need to adjust systemically various aspects of the designed artefact and each adjustment serves as a type of testing that allows the researcher to input and redesign the artefact to suit the environment's specific needs. The expertise, knowledge, and experiences of respondents are the major contributors to the functionality of the artefact. This is because of the demonstration phase, based on multiple real-life examples, and relies on different strategies such as experimental, observational, qualitative, quantitative and benchmarking or the use of a performance measurement index.

Nevertheless, for the purposes of this chapter, an open-ended questionnaire was adopted where both qualitative and quantitative techniques were used. The qualitative content analysis technique provided the opportunity for more specifications and requirements to be developed from data as affirmed by Kondracki et al. (2002), allow insights to emerge. These emerged insights are necessary because of the possibility of adjusting the designed PS to be adaptable in a particular environment. With six options on a Likert scale of the open-ended questionnaire, the use of SPSS provides the summation of elaborate opinion and comments from professionals.

Therefore, the selection of professionals and their expertise in the area of research is a crucial factor in determining the effectiveness of the demonstration. This helps with finding the right answers for recommending solutions to the identified problem as the right expertise determines the significance of any suggestions. It remains the case because no scientific or objective data serves as the basis for proving the effectiveness of the designed PS.

7.3 Selection of Professionals for the Demonstration Phase

For the purposes of efficacy, the demonstration of the designed artefact requires consultation with relevant professionals that understand the research to provide suggestions and alter the artefact if needed. The actualisation of this phase shows the basis for proof of concept and usefulness of the PS designed. In addition, the need to gather information from experts practicing within the study area helps to provide adequate knowledge of inputs necessary for the demonstration phase. Therefore, professionals in the BE were selected based on a purposive sampling based features of a population and the aim of the study.

For special projects, the performance approach may require the creation of a new building team involving the owner and user and perhaps an expert or two on behavioural science, in addition to the traditional team of architects, engineers and builders (Hattis 1996 as cited in Foliente, Leicester et al. 1998). Rather than a fractured base information system, giving the same information to selected professionals provides an interoperability of supplying information that can work efficiently as shown in figure 7.1.

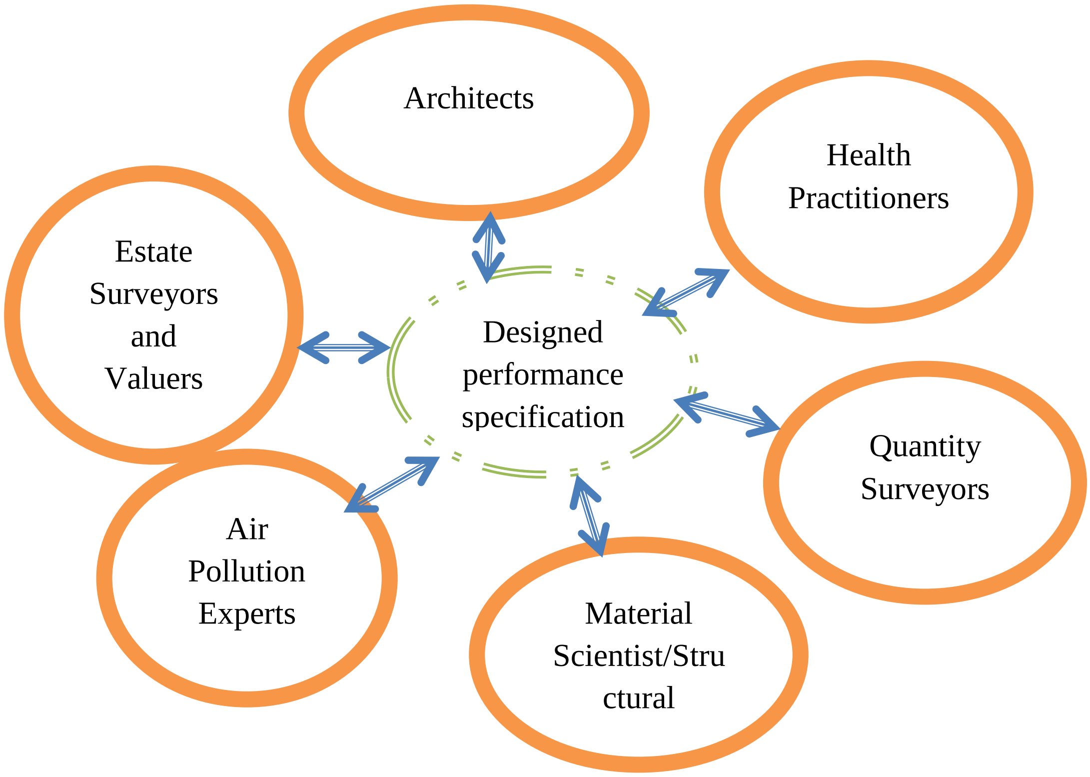


Figure 7.1: Selected professionals for Demonstration of DPS

Figure 7.1 shows the selection of the professionals for the demonstration of the designed PS. This selection was made following the subjective sampling method adopted. The same data is captured again in Table 7.1 showing the experts selected and reasons justifying their selection.

Table 7.1 Experts Selected and Reasons Justifying Selections.

No	Participants	Reasons
1	Architects	Architects work in the construction industry and are involved with designing buildings, extension or alteration, working closely with clients and users to make sure that projects designed meet their needs.
2	Health Practitioners	Are concerned with general health condition of the public and factors that affect public health, their duties include monitoring and diagnostic interpretation of illnesses, with recommendation of possible solution
3	Quantity Surveyors	Advice on the cost of projects to enhance value for money, while achieving the required standards and quality as specified by the statutory building regulation/specification document attached to design document
4	Material Scientist/Structural Engineers	They determine the structure of materials, measuring properties of materials, devising ways of processing materials, (creating materials, transforming existing materials, and making useful things out of them). They also think about how a material is suited to the purpose it serves already, and how it may be enhanced to give better performance for particular applications.
5	Air Pollution	They understand and explain different air pollutants and the effect

	Experts	on the environment and its health implication on people. They also provide expected limits of any pollutant that can cause a harmful effect.
6	Estate Surveyors and Valuers	They are land economists, suggesting land suitable for the different developmental purposes, supervision of developmental/construction works, in charge of supervision of maintenance works and custodian of land and landed properties.

From table 7.1, six different professional groups from the BE were selected with 10 open-ended questionnaires distributed to each profession totalling 60. The choice of the self-administered open-ended questionnaire was to achieve a high level of response rate as depicted by Gasquet, et al. (2001). In addition, it granted the opportunities to request, in person, for another re-administering of open-ended questionnaires where the need arose.

Furthermore, this is to give a wider perception from professionals about questions posed and allow the respondent to express an opinion without being influenced by the researcher (Foddy, 1993: 127). The advantages of open-ended questions include the possibility of discovering responses that individuals give spontaneously, thus avoiding the bias, which may result from other forms of data collection types resulting from suggesting responses to individuals. Also, open-ended questions can be used to explore different responses in addition to the close-ended questions.

In addition, Friborg and Rosenvinge (2013) affirm that this type of data collection system shows more in-depth information. Again, the demonstration of knowledge by respondents through description and explanation of their responses as opined by Popping (2015) makes it the right strategy. Since this demonstration phase is a proof of concept phase, it is significant that respondents are allowed the choice of providing their own ideologies without being controlled by closed-ended questions. Moreover, respondents have availed the opportunity to provide reasons for options ticked and if need be provide crucial information not considered during the design of the PS.

Finally, due to the uniqueness of the research and its untapped nature in the Nigerian context, there was the need to use an open-ended type of questionnaire as a motivator for experts in the demonstration of the PS.

7.4 Description of the Demonstration Process for the designed PS

This section describes the demonstration processes in three major iterations. As such, open-ended questionnaires were sent to all the professionals selected. This was to enable the selected professionals to refine, adjust and add environment specific information that will provide a complete and wholesome PS based on their professional expertise and experience in the study area. These adjustments to the designed PS provided the needed rigor, thus further justifying the choice of the DS paradigm. The overall range of features available in the open-ended questionnaires is listed in the designed PS as illustrated in table 5.3.

The PS designed provided limits to gaseous pollutants allowable indoor and the requirement for the quality of materials that can withstand environmental conditions without deterioration while reaching the specified shelf life. Following the information gathered from designed PS, the open-ended questionnaire was divided into three sections. Each section described the performance requirement accompanied by the relevant specification. The aim here was for respondents to tick from the options provided on the Likert scale the options they thought reflected their judgments. Furthermore, an opportunity to comment on the options respondents ticked was provided and if required make suggestions that could be added to the effectiveness and functionality of the designed PS. The three-iteration processes have different distinct purposes where each iteration process was adjusted based on data analysed as discussed below.

7.4.1 Iteration One

The main objectives of this first iteration were to confirm the PS designed for the ND environment and decide if there is the need for a modification of its functionality considering that the PS designed is based on standards, regulations, and codes from different countries. The ASHRAE Committee Standards of January 23, 2010 (ASHRAE, 2010) stipulate that:

- Standards and guidelines are developed for different purposes and should be interpreted with reference to the setting and purpose for which they were developed compared to that to which they are being applied.
- Not all standards and guidelines recognize the presence of susceptible groups or address typical populations found in occupancies listed in this standard.
- Most standards and guidelines do not consider interactions between and among various contaminants of concern.

- The assumptions and conditions set forth by the standard or guideline may not be met in the space or for the occupants being considered.

The above postulations were confirmed based on the results of the field-testing that determined whether additional iterations from professionals were required based on the analysis. Here, the relevance and acceptability of the designed PS were determined based on three cycles of iterations. Thus, confirming Henver (2007) who notes that the newly designed PS may have deficiencies in functionality or in its inherent qualities (e.g., performance, usability) and may limit its utility in practice. This provided an opportunity for the retesting of the designed PS through other cycles of iterations.

A. Analysis of Iteration One

The data collected was divided into three sections. The first section was based on general questions, such as the area of expertise and number of years of experience in the study area as discussed in section 7.1. The second section was designed from the PS as discussed in section 7.4.1. The third and final section provided the opportunity for the respondents to provide feedback~~s~~ and comments. Using the purposive sampling, 60 open-ended questionnaires were distributed to respondents, out of which 45 responses were returned. This represented 75% response~~s~~ rate, which took about 45 days for both distribution and recovery of the questionnaires. Figure 7.2 shows the percentage of return for each job type.

Both questions 1 and 2 are general informative questions providing necessary data that justify respondents' professions and years of experience working in the study area.

***<u>Summary of question 1</u>:** This was for respondents to tick from the list provided their designated profession (Appendix G).*

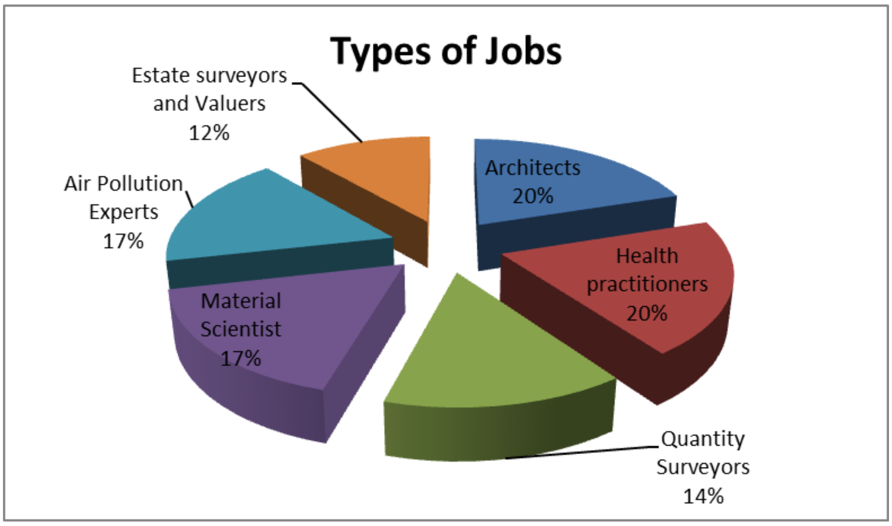


Figure 7.2: Types of Jobs

From figure 7.2 architects and health, practitioners are the highest respondents with 20% response rate each, compared to estate surveyors and valuers with the least respondents at 12%, while air pollution experts and material scientists with 17% each and quantity surveyors 14% fall in-between. This could be attributed to the number of respondents that were able to complete and return the questionnaires which might also be based on their perception and understanding of the questions. Additionally, the high percentage of responses from architects and health professionals indicates that they are conversant with the study area, issues raised and terms used in represent the questions posed. In addition to the first question, professionals were required to indicate years of experience in the GF areas of the ND. Figure 7.3 shows the results from the data analysed.

Summary of question 2: *This was for professionals to tick from the numbers provided their years of experience working in the study area (Appendix G).*

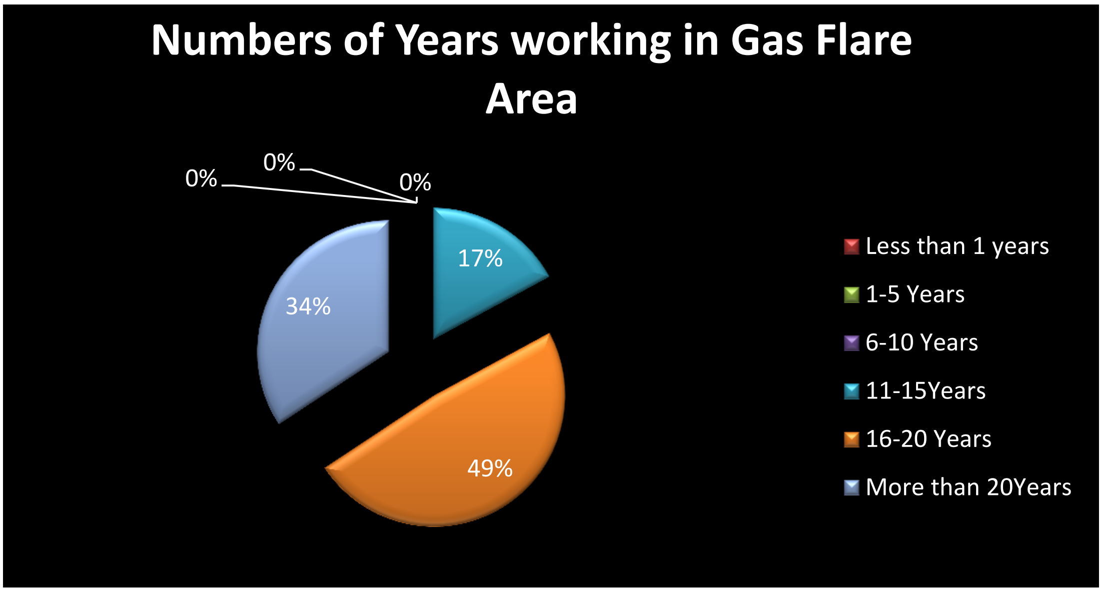


Figure 7.3 Numbers of Years Working in Gas Flare Areas

From figure 7.3, all of the respondents have been working in the research area, which shows that they are experienced and knowledgeable about the study environment. The result shows the range of the number of years working in the area as follows: 11-15 years with a 17% response rate, 16-20 years at 49% and 20 years and over at 34%.

This result provides a valid demonstration criterion of the respondents' understanding of the study area and the possibility that their responses to the questions posed were based on their experiences. Therefore, it was assumed that the information provided represents the best interpretation that can be made due to the years and wealth of expertise. The main part of the demonstration phase is the response from respondents in section B with questions 3 and 4 in a tabulated form. Table 7.2 represents the response following the analysis of the data.

Question 3: *Do you agree that limiting gaseous substances emitted from GF to the amount specified below will provide clean indoor air in schools? 1- Strongly agree; 2- agree; 3- partially agree; 4- disagree; 5- strongly disagree; 6- I Don't know*

Table 7.2 First Iterative Process for Air Quality Demonstration

Performance Requirement (RQ)	1 Strongly Agree	2 Agree	3 Partially Agree	4 Disagree	5 Strongly Disagree	6 Not Known
Carbon Monoxide (CO) -15 mins – 100 mg/m^3; -1 hour – 35 mg/ m^3; -8 hours – 10 mg/ m^3; -24 hours – 7 mg/m^3	2.2%	4.4%	4.4%	8.9%	20.0%	60.0%
Particulate Matter $PM_{2.5}$: 10µg/m^3 annual mean; 25µg/m^3 24-hour mean and PM_{10}: 20µg/m^3 annual mean; 50µg/m^3 24-hour mean	2.2%	8.9%	13.3%	-	20.0%	55.6%
Ozone Limits O_3: 100µg/m^3 8-hour mean	2.2%	11.1%	22.2%	2.2%-	6.7%	55.6%
Nitrogen Oxide NOx: 40µg/m^3 annual mean; 200µg/m^3 1-hour mean	-	2.2%	4.4%	13.3%	33.3%	46.7%
Sulphur Oxide SO_2:20µg/m^3 24-hour mean; 500µg/m^3 10-minute mean	8.9%	11.1%	8.9%	6.7%	8.9%	55.6%
Benzene 1µg/m^3 and 1 ng/m^3 (one Nano gram per milliliter)	2.2%	11.1%	2.2%	2.2%	13.3%	68.9%
Polycyclic Aromatic Hydrocarbon (PAHs)	2.2%	4.4%	4.4%%	4.4%	17.8%	66.7%

Based on the responses, and the analysis carried out, all respondents provided answers from the options, however, as illustrated by table 7.2, it showed that a substantial number of the respondents ticked the *not known* option. This is because, from the analysis of all the listed chemical substances, the *not known* option shows a significantly high response at a maximum of 68.9% for Benzene and a minimum of 46.7% for NOx. This was followed by the *strongly disagree* option with NOx having 33.3%, followed by CO and PM having 20.0% each while the least responses of *strongly disagree* at 6.7% were for O_3. The highest percentage of response for *strongly agree* was 8.9% for SO_2 and lowest of 0% for NOx response on *strongly agree* and PM had 0% responses on the *disagree* option. While analysis showed that the *not known* option had the highest response, the *strongly agree* had the least percentage response overall.

The open-ended questionnaire type chosen for this study provides an opportunity for respondents to elaborate, justify, explain and give additional information not already covered. Therefore, based on their comments, it became evident that respondents were not familiar with the limits indicated. According to them, the limits are completely different from those currently used in Nigeria as provided by the FEPA guideline of 1999. They also did not understand why such limits should be achieved and why it is a requirement because IAQ was not necessarily an important criterion during construction of PSBs in the ND. Furthermore, respondents noted that the limits provided were rather esoteric and provided a challenge for selection as it required them to look for information that justified their answers. Thus, following all their comments, it was clear that responses were not the true representation of the information needed for the purposes of the study.
Subsequent to the foregoing, the analysis for the material PS, also captured in table 7. 3 preceded by the respective question that yielded the responses as follows:

<u>Question 4:</u> *Indicate the extent to which you agree/disagree whether the listed performance requirements will meet immediate environmental criteria during the design, selection of materials and construction of public schools in the vicinity of GF?*

Table 7.3 Analysis for Material Performance Specification

S/No	Performance Requirement	1 Strongly Agree	2 Agree	3 Partially Agree	4 Disagree	5 Strongly Disagree	6 Not Known
1	Thermal Performance of Roof Covering	4.4%	6.7%	4.4%	4.4%	13.3%	66.7 %

2	Thermal Performance of Roof Lights	2.2%	6.7%	2.2%	4.4%	11.1%	73.3%
3	Indoor Sound Insulation	-	6.7%	4.4%	8.9%	11.1%	68.9%
4	Materials resistance to cracks	-	8.8%	17.8%	13.3%	13.3%	46.7%
5	Minimum Building Longevity	2.2%	11.1%	15.6%	6.7%	17.6%%	46.7%%
6	Acidic Resistance	4.4%	2.2%	13.3%	20.0%	6.7%	53.3%
7	Resistance Factor Test	6.7%	4.4%	2.2%	8.9%%	11.1%	66.7%
8	Resistance to Water Penetration	4.4%	22.2%	4.4%	4.4%	6.7%	57.8%
9	Resistance to The Wind	2.2%	8.9%	15.6%	4.4%	13.3%	55.6%
10	Resistance to Carbon meeting ASTM 2013	-	8.9%	15.6%	4.4%	11.1%	60.0%
11	Resistance to Salt Spray	-	8.9%	15.6%	4.4%	11.1%	60.0%
12	Weather-Stripping	-	13.3%	4.4%	2.2%	4.4%	75.6%
13	Meeting Glazing Need	-	8.9%	15.6%	4.4%	11.1%	60.0%
14	Frame Joint Sealing Material	2.2%	13.3%	4.4%	6.7%	13.3%	60.0%
15	Thermal Comfort	4.4%	8.8%	4.4%	11.1%	13.3%	57.8%
16	Resistance to Pressure Level	-	8.9%	6.7%	2.2%	4.4%	77.8%
17	Coating Material Resistance	4.4%	8.9%	4.4%	6.7%	8.9%	66.7%
18	Space Cooling Demand	2.2%	4.4%	6.7%	6.7%	17.9%	62.2%
19	Weather Tightness Resistance	-	11.1%	2.2%	11.1%	6.7%	68.9%
20	Resistance to Air Infiltration	4.4%	6.7%	13.3%	8.9%%	13.3%	53.3%
21	Corrosion Resistance Coating	6.7%	4.4%	11.1%	8.9%	13.3%	55.6%
22	Colour Tolerance	2.2%	6.7%%	13.3%	8.9%	8.9%	60.0%
23	Resistance of Thermal Barriers	-	15.6%	15.6%	6.7%	2.2%	57.1%
24	Acoustic Performance	6.7%	17.8%	13.3%	6.7%	4.4%	51.1%

In an effort to ascertain whether the listed Performance requirements (PR) meet immediate environmental criteria during the design, selection of materials and construction of public schools in the vicinity of GF, the immediately preceding question was posed to the respondents. Table 7.3 captures the analysis of the responses based on the various possible conditions that could result from GF. From the table, a significant number of the respondents ticked the *not known* option giving a maximum percentage response at 73.3% for PR of Thermal Performance of Roof Lights while both Materials Resistance to Cracks and Minimum Building Longevity yielded the minimum percentage of responses at 46.7%. Contrarily, the *strongly disagree* option had a maximum response of merely 17.6% for Minimum Building Longevity and 2.2% for Resistance of Thermal Barriers. Also, *disagree* option had a maximum response rate of 20.0% for Acidic Resistance and a minimum response of 2.2% for Weather-Stripping and Resistance to Pressure Level.

Besides the two extremes above, options in the questionnaire, which signify positive connotations and agreement to the designed PS, had less percentage response compared to the disagreement options. Here, the percentage of responses for *partially agrees* was at a maximum of 17.8% for Materials Resistance to Cracks and a minimum of 2.2% for 3 different PR namely: Thermal Performance of Roof Lights, Resistance Factor Test and Weather Tightness Resistance. Similarly, the *agree* option showed maximum responses at 22.2% for Resistance to Water Penetration and minimum responses rate of 2.2% for Acidic Resistance.

Finally, whereas the *strongly agree* option showed a maximum response rate of 6.7% for 3 different PR covering Resistance Factor Test, Corrosion Resistance Coating, and Acoustic Performance, the following 9 different PR had 0% minimum response based on the *strongly agree* option. They are Indoor Sound Insulation, Materials resistance to Cracks, Resistance to Carbon Meeting ASTM, Resistance to Salt Spray, Weather-Stripping, Meeting Glazing Need, Resistance to Pressure Level, Weather Tightness Resistance and Resistance of Thermal Barriers.

Again, the choice of the open-ended questionnaire provided an opportunity for respondents to give reasons for their answers. Similar to the explanations provided for question 3 already discussed, respondents' comments included the following:

- All the requirements provided were completely different from what is usually obtained by the NBC

- That building is basically constructed using available materials
- They also do not understand why the PR should be met and used during construction of schools in the ND

As stated earlier, the iterative process provides the researcher the opportunity to try out the designed PS in the form of demonstration in an actual environment. This helps to provide a very crucial and significant avenue by adjusting the designed artefact to suit the environment it is meant to serve. Accordingly, Henver (2007) who posits that feedback from the environment could be based on field-testing and a restatement of the research requirements as discovered from actual experience. However, the demonstration process adopted the open-ended questionnaire technique, which provided room for respondents to comment and provide reasons for ticking options 4, 5 and 6 in the questionnaire, which is in total disagreement of the anticipated PS. In fact, this was a very quick iteration, as respondents neither focused, in detail, on the reasons for the selection of the listed PS nor the options provided. Nevertheless, respondents gave feedback that explained their understanding of the questionnaire.

Based on the open-ended questionnaires used, experts/professionals noted that they were ignorant of the contents of the questionnaires and therefore could not respond appropriately. This could be because of a clear lack of understanding of the information posed to them within the questionnaire and therefore the need to provide further details but making sure that the questionnaire was not too lengthy and time-consuming to deter participation.

7.5. The need for Performance Specification Information Pamphlet (PSIP)

Following the outcome of the first iterative process falling short of the DS paradigm, there was the need to improve on the open-ended questionnaire as a significant number of the respondents noted that the specification requirements provided were too technical. They also requested for clarification on how these requirements were obtained. Consequently, a clear definition of terms and their effects would help in responding to questions posed. Therefore, there was a need to adopt a method that had been used to provide information for research purposes with positive outputs. Thus, a PS Information Pamphlet (PSIP) was designed as attached in Appendix J. This is similar to the leaflet information system (LIS) or drug information leaflet (DIL) used in the pharmaceutical industry as a means of providing information to patients to help them to understand the nature of the medication prescribed.

This method, although started in the USA in the 1970s, its proposal in the UK was not until 1987, when a pharmaceutical industry working group proposed that such leaflets be developed by manufacturers, and as a result, guidelines were produced (Raynor, 1998). The guidelines were based on the perception that the leaflets should be concise and understandable (Dickinson, et al. 2001). The use of the LIS or DIL showed that patients' satisfaction and use of drugs were high, indicating agreement (Ley, 1988; Vander, et al. 1991; Twomey, 2009). The benefits accumulated from this system led to its use being mandatory in the European Union (Dickinson, et al. 2001) .

Subsequently, the LIS/DIL strategy, which allows clear additional information about medication and possible side effects with its remarkable improvement, would provide the needed explanation for the respondents in this study as the responses later indicated. Adopting this method, PSIP was designed and attached to the questionnaires and re-administered to the same respondents, which formed the second iterative process.

7.5.1 Iteration Two

According to Hevner (2007), the justification for another field-testing may be that the PS inputs based on DSM had been incorrect or incomplete with the resulting artefact failing to satisfy the requirements and are inadequate to solve the problem presented. Thus, a re-administration of refined open-ended questionnaires was carried out along with PSIPs. As a result, the second iteration process administered to the same respondents provided consistency to the trend of discussions. Following formal requests made during the data collection exercise and the willingness of respondents to participate in the exercise, this second iterative process was more intense. This resulted in a range of options being ticked and more reasons provided which formed different views and suggestions leading to subsequent changes in parts of the designed PS for schools in the VGF for the ND area of Nigeria.

A. Analysis of Iteration two

The first iterative system provided little or no information that helped with the designed PS, which meant that this could not be demonstrated in any practical environment hence the need for a PSIP, which provided a clear understanding of the data collection instrument. As a result, the second iterative process was engaging and produced better results from the data analysis thus showing the practicality of the designed PS in the ND environment.

The first section of the questionnaire had the same question posed in iteration 1. Question 3 focused on IAQ implemented through another round of open-ended questionnaires with the same questions. However, this time, with a PSIP attached to the instrument for clarification and definition of terms in the PR. Consequently, the results from the analysis as illustrated in table 7.4 show more receptiveness.

<u>Question 3:</u> *indicate the extent to which you agree/disagree whether limiting gaseous substances emitted from GF to the amount specified below will provide clean indoor air in schools?*

Table 7.4 Second iterative process for Air Quality

Performance requirements for IAQ Limits	**1 Strongly Agree**	**2 Agree**	**3 Partially Agree**	**4 Disagree**	**5 Strongly Disagree**	**6 Not Known**
Carbon Monoxide (CO) -15 mins – 100 mg/m^3; -1 hour – 35 mg/ m^3; -8 hours – 10 mg/ m^3; -24 hours – 7 mg/m^3	44.4%	40.0%	6.7%	6.7%	2.2%	-
Particulate Matter $PM_{2.5}$: 10µg/m^3 annual mean; 25µg/m^3 24-hour mean and PM_{10}: 20µg/m^3 annual mean; 50µg/m^3 24-hour mean	31.1.0%	44.4%	20.0%	2.2%	2 .2%	-
Ozone Limits O_3: 100µg/m^3 8-hour mean	11.1%	46.7%	31.1%	2.2%	2.2%	6.7%
Nitrogen Oxide NOx: 40µg/m^3 annual mean; <u>200µg/m^3 1-hour mean</u>	2.2%	4.4%	6.7%	37.8%	46.7%	2.2%
Sulphur Oxide SO_2: 20µg/m^3 24-hour mean; 500µg/m^3 10-minute mean	31.1%	44.4%	11.1%	4.4%	6.7%	2.2%
Benzene 1µg/m^3 and 1 ng/m^3 (one Nano gram per millilitre)	51.1%	40.0%	4.4%	2.2%	2.2%	-
Polycyclic Aromatic Hydrocarbon (PAHs)	53.3%	37.8%	4.4%	4.4%	-	-

Table 7.4 shows the results from the respondents after the re-administration of the demonstration instrument with the PSIP attached. This second iterative process provided a more positive feedback after analysis. This showed that it was more interactive and respondents were able to make meaningful and significant inputs where necessary.

Based on the analysis, responses showed significantly positive responses from the limits provided in the table. Here, the percentage of responses for CO showed a minimum response of 0% for *not known* and maximum response of 44.4% for *strongly agrees*. Similarly, PM had a minimum response of 0% for *not known*, a maximum of 31.1% of *strongly agree* and 44.4% of *agree*. While O_3 had a minimum percentage of 6.7% of *not known* and 2.2% *strongly disagree* with a maximum of 11.1% *strongly agree* and 46.7% *agree*. Contrarily, NOx had the maximum percentage of 46.7% of *strongly disagree* and 2.2% *not known*. However, SO_2 showed from the analysis a minimum of 6.7% *strongly disagree*, 2.2% *not known* with the maximum percentage of 31.1% *strongly agree*, and 44.4% *agree*. Similarly, Benzene, with the minimum response showed 2.2% for *strongly agree* and 0% *not known*. PAHs indicated the lowest responses for *not known* and *strongly disagree* as it showed 0% respectively and had 53.3% *strongly agree* and 37.8% *agree*. These responses, as analysed, proved the justification that the PSIP provided information that enhanced and directed responses.

Comparing the first and second iteration processes, it became more evident that respondents required the leaflet that provided them with the necessary information as iteration two provided clearer responses and comments that led to the third iterative process. The information provided through the PSIP aided the respondents in making the relevant contribution to the study as they all requested to keep the pamphlet. It was believed that respondents would have made remarks on the pamphlets that might be significant to the study. However, they noted that all comments relevant to the refinement of the designed PS were stated in the open-ended questionnaires. Therefore, based on the responses and comments made, the following sub sections discuss their observations and comments.

i. Nitrogen oxides NOx:

Constituting part of the substances that are emitted from GF, NOx impact negatively on air quality and are detrimental to the environment where they can be found. It is the sum of Nitrogen oxide (NO), Nitrogen dioxide (NO_2), and the reaction between nitrogen, oxygen, and hydrocarbons that result in the formulation of NOx. Its impact on the immediate surroundings of GF sites of the ND was investigated in this study, details of which were captured earlier.

Assessing its effects on the environment, the majority of the respondents noted that the annual mean should be less than that specified in the designed PS and should reflect limits provided by the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN). According to them, serious deliberations have been ongoing on the limits as provided in the FEPA standards. These standards are known to lack improvements and hence fail to be representative of the ongoing trend in the developed world as a means of reducing GF effects. As described in chapter 2 table 2.3 and 2.5, the symptoms of bronchitis in asthmatic children increase in association with long-term exposure to NOx. Reduced lung function and growth is also linked to these substances. Furthermore, it is known to cause eye, nose and throat irritation, shortness of breath, and increased risks of respiratory infections. Its health implications can be enormous with as little as 30 minutes' exposure, hence implying a rather horrific impact on inhabitants of these GF vicinities. Thus, the limits were refined to meet EGASPIN guideline of NO_x: 40µg/m^3 annual mean; 75-113µg/m^3 1-hour mean as compared to NOx: 40µg/m^3 annual mean; 200µg/m^3 1-hour mean.

ii Lead (Pb):

During the demonstration exercise, respondents noted that the designed PS did not have lead (Pb) on it, which has greatly affected the quality of air around Nigeria's Delta region. The experts, in reference to works done by Ekpo et al. (2013); Ede and Edokpa (2015) noted that industries, together with regular petroleum exploration and exploitation, release trace metals into the atmosphere. This, therefore, steered the addition of Pb into the designed specification. However, there was the disparity in the choice of the limit to adopt. While some of the professionals had a choice of the WHO annual limit of 0.5µg/m^3, others settled for a 0.25µg/m3 based on UK limits.

Their decision was based on information such as the inhalation of Pb resulting in health risks like cognitive deficits, negative behavioural patterns (hyper activity/restlessness) and flu-like symptoms that include anorexia, vomiting, and lethargy, most especially in children. These health issues impact on their academic performance and number of out of school cases (Quillen, 1993). According to WHO (2016), it is a cumulative toxicant that affects multiple body systems, including the neurologic, hematologic, gastrointestinal, cardiovascular, and renal systems. Children are particularly vulnerable to the neurotoxic effects of Pb, and even relatively low levels of exposure can cause serious health issues and in some cases irreversible neurological damage.

The need to specify limits of the maximum allowable for Pb as a toxic chemical in an indoor environment was stressed as an imperative, especially as it affects children more than adults. Therefore, following the suggestions made on the limits and the addition of Pb, it was recommended that the requirements be considered in the design of PS for schools. Both the annual limits for WHO and UK were specified as recommended by the respondents.

Furthermore, the second section of the PS had the same question posed in iteration 1 of question 4 with a 24-numbered PR (table 7.5). They had 6 options each, ranging from *Strongly Agree* to *not known*. In addition to the open-ended questionnaire, the PSIP also provided information reflecting on this section of the questionnaire. Analysis showed a more reactive opinion from the responses as illustrated in table 7.5

<u>Question 4:</u> *Indicate the extent to which you agree/disagree whether the listed performance requirements will meet immediate environmental criteria during the design, selection of materials and construction of public schools in the vicinity of GF?*

Table 7.5 Analysis for Second Iterative Process

	Performance Requirements PR	**1 Strongly Agree**	**2 Agree**	**3 Partially Agree**	**4 Disagree**	**5 Strongly Disagree**	**6 Not known**
1	Thermal Performance of Roof Covering	24.4%	46.7%	22.2%	4.4%	2.2%	2.2%
2	Thermal Performance of Roof Lights	37.8%	42.20 %	13.3%	2.2%	2.2%	2.2%
3	Indoor Sound Insulation	53.3%	37.8%	2.2%	4.4%	2.2%	-
4	Materials Resistance to Cracks	22.2%	55.6%	13.3%	6.7%	2.2%	-
5	Minimum Building Longevity	26.7%	48.9%	13.3%	6.7%	4.4%	-
6	Acidic Resistance	28.9%	57.8%	6.7%	4.4%	2.2%	-
7	Resistance Factor	42.2%	46.7%	4.4%	4.4%	2.2%	-

	Test						
8	Resistance to Water Penetration	42.2%	46.7%	4.4%	4.4%	2.2%	-
9	Resistance to Wind	46.7%	46.7%	2.2%	-	4.4%	-
10	Resistance to Carbon meeting ASTM (2013)	31.1%	53.3%	8.9%	4.4%	2.2%	-
11	Resistance to Salt Spray	44.4%	44.4%	6.7%	4.4%	-	-
12	Weather-Stripping	48.9%	42.2%	4.4%	2.2%	2.2%	-
13	Meeting Glazing Need	37.8%	48.9%	11.1%	-	4.4%	-
14	Frame Joint Sealing Material	40.0%	48.9%	4.4%	4.4%	2.2%	-
15	Thermal Comfort	2.2%	4.4%	6.7.%	53.3%	28.9%	4.4%
16	Resistance to Pressure Level	46.7%	40.0%	8.9%	2.2%	2.2%	-
17	Coating Material Resistance	44.4%	48.9%	2.2%	2.2%	2.2%	-
18	Space Cooling Demand	4.4%	8.90%	15.6%	53.30%	15.6%	2.2%
19	Weather Tightness Resistance	28.9%	60.0%	4.4%	4.4%	2.2%	-
20	Resistance to Air Infiltration	37.80%	53.3%	4.4%	2.2%	2.2%	-
21	Corrosion Resistance Coating	40.0%	48.9%	6.7%	2.2%	2.2%	-
22	Colour Tolerance	35.6%	48.9%	6.7%	4.4%	2.2%	2.2%
23	Resistance of Thermal Barriers	40.0%	46.7%	6.7%	4.4%	-	2.2%
24	Acoustic Performance	37.8%	51.1%	6.7%	2.2%	2.2%	-

From table 7.5, all the respondents agreed to almost all the PR in the open-ended questionnaire, which might be as a result of the information provided from the attached PSIP to the instrument.

The analysis showed that for thermal performance of roof coverings set at 0.25 W/m^2K (weighted average), the responses ranged from a meagre 2.2% for *strongly disagree* to as high as 24.4% for *strongly agree* and 46.7% *agree*. *Not know* was not an option for any of the respondents. This means that 71.1% of the total respondents *agree* to this PR as specified compared to 2.2% *strongly disagreeing*.

Further analyses of the Thermal Performance of Roof Lights set at 2.2 W/m^2K (weighted average), showed that 2.2% indicated *not known* with an equal number of *strongly disagree.* However, 37.8% *strongly agreed* along with a massive 42.20% also *agreeing* which is an indication of the PS accepted by the respondents. Similar results were obtained for Indoor sound insulation meeting $L_{Aeq,30mins}$ dB requirements which revealed nil responses for *not known* and 2.2% for *strongly disagree* while, 53.3% indicated that they *strongly agreed* to the specification provided, with a further 37.8% confirming their *agreement* in similar manner. Likewise, Materials Resistance to Cracks showed 2.2% responded n*ot known* with 6.7% *strongly disagree* to PS while, 22.2% *strongly agreed* with another 55.6% opting for the *agree* option. The Designed PS for building longevity indicated yet comparatively small percentages for the *not known* and *strongly disagree* at 0% and 4.4% respectively, while 26.7% *strongly agreed* with 48.9% also generally *agreeing*. This shows that the durability of the materials used for construction is significant to its longevity, which depends on the resistance factors to atmospheric depositions.

The acidic resistance level as specified, when analysed, revealed that of the responses ticked, 2.2% represented *not known*, 4.4% *strongly disagree,* 28.9% *strongly agree* and 57.8% *agree*. The very high agreement among the respondents suggests the high level of awareness on deterioration such as corrosion caused by acidic deposition on roofing material. In this way, they affirmed their agreement with PR as the yardstick for material selection and use. This high affirmation confirms the review made in chapter 2 in the literature review section that acid rain causes corrosion. Therefore, materials used for construction in the ND should have a high level of acidic resistance.

However, the designed PS also provided a requirement for test procedure and process showing that such material meets specification. The PR of the Resistance Factor Test and from analysis 0.0% showed *not known*, 2.2% *strongly disagree* while, and a whopping 42.2% with 46.7% indicated *strongly agree* and *agreed* to the specification respectively. This result serves as a confirmation that materials should have the resistance factor test to show its suitability for the ND environment.

In addition, water has been known to pose challenges to building materials however, the use of materials that are water-resistant provides the needed preventive measure. As already discussed in chapters 2 and 6, the Nigerian environment have two seasonal periods the rainy and dry seasons. It is, therefore, pertinent that materials should be able to withstand the climatic conditions thus stressing the need to specify resistance levels for these materials. In consonance with this, the analysis for Resistance to Water Penetration requirement specified indicated 0% *not known* responses with merely 2.2% as *strongly disagree.* However, 42.2% were in favour of *strongly agree* and 46.7% *agree*. Furthermore, Resistance to Wind, which is similar, was analysed and the same results for *not known*, 4.4% for *strongly disagree* while *strongly agree* and *agree* both scored 46.7% of the respondents' chooses.

Moreover, as already discussed in chapter 6, carbon causes serious defects on building materials. Therefore, its resistance meeting ASTM (2013) open flame carbon exposure is significant as a material that is required to meet durability and longevity requirements. The analysis of these requirements revealed that none of the respondents indicated that s/he had no knowledge with 2.2% *strongly disagreeing* while 31.1% *strongly agreed* and further 53.3% *agreed* with the PR provided in the instrument. Again, resistance to Salt Spray showed none specifying *not known* while both *strongly agree* and *agree* both scored a whopping 44.4% each of affirmation by the respondents. This shows that material durability depends on the resistance factor of such materials.

Chapter 6, sub section 6.4.17 discussed the relevance of Weather-Stripping as a requirement to achieve clean indoor air. Following the analysis of its PR, none of the participants specified the *not known* option with 2.2% in *strong disagreement* while, 48.9% and 42.2% showed *strongly agreed* and *agree* to PS respectively. Thus, the acceptance of the specified PR shows that it helps to prevent infiltration of poor ambient air when used on windows and doors. The importance of windows, including its glazing requirements is vital and as already discussed in chapter 6, the health benefits and the resultant reduced cost of energy use add to this advantage. This fact is emphasised by the crucial need for brightness in some schools on the basis of which the PR for glazing materials as specified revealed nobody displaying no knowledge with only 4.4% *strongly disagree* while 37.8% chose to *strongly agree* with yet another 48.9% also choosing the *agree* option.

This study specifically aimed at improving building durability and longevity and indoor air by protecting the internal environment from infiltration of outdoor air. Therefore, every key part of a building that allows the infiltration of air associated with the designed PS, where requirement provided, should be met in order to achieve clean air. Thus, the significance of Frame Joint Sealing Material tested in the study and yielded the following response from the respondents: 0% *not known*, 2.2% *strongly disagree*, 40.0% *strongly agree* and 48.9% *agree*.

These analyses have shown that the majority of all responses showed more positive acceptance of the designed PS. However, few of them had some sort of disagreement, which compared to the number of positive acceptance, shows that the PS has been accurately designed using the right codes, regulations and standards.

In view of the above however, the PR for thermal Comfort showed that participants were not satisfied with the specification provided as reflected in the final analysis. Thus, deviating from the norm, a whopping total of 86.6% indicated their disagreement with 28.9% *strongly disagree* and 53.3% *disagree* options compared to a meagre 4.4% *not known*, 2.2% *strongly agree* and 4.4% *agree* options. Here, the open-ended questionnaire format proved its worth and accorded the respondents the opportunity to further explain their disagreement where they noted that the PS for "*Thermal comfort should not be more than 10% of the hours in any given year of 25^{0}C*". This should be changed to "*Thermal comfort should not be more than 10% of the hours in any given year of 35^{0}C*" because of the following reasons;

1. The main factors determining thermal response of a building are the heat gains and/ or losses through the various structural elements, such as walls, windows, floors, roofs, the internal loads and the rate of ventilation
2. The internal heat gains or losses depend on certain properties of the elements concerned; examples include heat gains through walls, which depend on the colour of the external superficial, heat storing capacity of the walls and their thermal resistance properties.
3. One of the factors affecting design and construction of buildings in different climatic environments is the continued thinking or thoughts of architects and designers that climate is something that is constant

4. Specialised knowledge of immediate climate are required for design and building industry to help resolve the issue of climate challenge
5. The ND area climatic condition is special and therefore should be treated as such with its immediate climatic factors used during design, construction and choice of materials
6. The thermal condition rises above 35^0C as compared to 25^0C specified hence tolerance of material and comfort of pupil should be based on the immediate weather condition. This they said will help professionals choose the materials that can withstand weather action reducing the level of deterioration that might occur due to harsh weather conditions such as discolorations, heat gains and losses.

Based on their comments, the PS was adjusted to meet this requirement. However, these adjustments are depended on the feedback from the third phase of the demonstration.

Contrarily, the PR for Resistance to Pressure Level indicated a more positive response as compared to thermal comfort. Here, the responses showed a 0% *not know*, 2.2% *strongly disagree* with 46.7% *strongly agree* and 40.0% *agree*. Similarly, PR for Coating Material Resistance indicated a 0% *not known*, 2.2% *strongly disagree* with a massive 44.4% *strongly agreed* and 48.9% *agreed* to the PS as illustrated in the PSIP which informed respondents opinion and selection. Converse to the positive notes from respondents, which correlates with disagreement for the PR of thermal comfort, responses from the analysis on the acceptability of the Space cooling demand not exceeding 15 kWh/ (m^2/a) did not meet the professionals' requirement for the study area. As a result, the analysis showed a 2.2% of respondents without any knowledge and an unparalleled 15.6% in *strongly disagreement* with a further 53.30% also *disagreeing* to the PR provided. Here again, respondents noted the following comments as reasons for holding this view and recommended that Space cooling demand should not exceeding 20 kWh/(m^2/a) based on the following reasons:

1. That children that attend these schools in most cases come from homes where space cooling is more than 15 kWh/(m^2a) and that air conditioners which serves as the cooling units in the Nigeria context is set at 16 kW/h (m^2a).
2. That the health implication of lowering the cooling space less than the generally accepted limits could lead to more out of schoolchildren cases.
3. That this means added cost to parents of school children, as they will be required to buy pullovers/sweat shirts to help keep pupils warm in the class.

4. That teachers and pupils themselves might be tempted to open windows allowing some form of heat indoors with the infiltration of ambient air indoors.
5. That increasing performance specification to a Space cooling demand not exceeding 20 kWh/ (m^2/a) will be ideal. This will allow both parents that could afford air conditioners and those that do not have air conditioners at home the same comfort without increasing health risk such as pneumonia. This suggestions and reasons led to the change to this specification criterion awaiting the third iteration.

Furthermore, responses for Weather Tightness Resistance also generated a rather normal result in line with the exposure gained from the PSIP. Therefore, the results had 0% n*ot known*, 2.2% *strongly disagree* while, *strongly agree* and *agree* both had 28.9% and 60.0% respectively. Similarly, Resistance to Air Infiltration showed 0% *not known*, 2.2% *strongly disagree* with 37.80% *strongly agree* and 53.3% *agree*. Likewise, Corrosion Resistance Coating resulted in responses with 0% *not known*, 2.2% *strongly disagree*, 40.0% *strongly agree* and 48.9% *disagree*. Colour Tolerance analysis revealed the following results: 2.2% *not known*, 2.2% *strongly disagree* on the part of those in disagreement with 35.6% *strongly agreeing* and 48.9% *agree* with the PR specified. In addition, to the positive responses already analysed, PR for the Resistance of Thermal Barriers indicated, like several others, none in strongly disagreement with 2.2% saying they had no knowledge of this while, 40.0% *strongly agreed* and further 46.7% *agreed*. Finally, the Acoustic PR showed very similar results with the *not known* and *strongly disagree* options showing 0% and 2.2% respectively while whopping 88.9% made up of 37.8% *strongly agree* and 51.1% *agree* confirmed their agreement. This showed that respondents agreed to the designed PS although they opted to have some PR altered.

Generally, there was a complete change in responses from respondents in this phase. This was because they were able to decide on the parts of the demonstration instrument that could be changed, adjusted or added to the designed PS. Thus, there was the need for another iteration process for the purposes of clarifying with the professionals based on their thoughts and suggestions. This therefore granted the opportunity for the respondents to contribute to the amended PS in the form of inputs to the open-ended questionnaire.

7.6. Iteration Three

This third iteration process was mainly for refinement and confirmation of inputs made by professionals and their acceptability of the designed PS. However, this process only considered parts of the designed PS where respondents strongly disagreed, generally disagreed and added requirements to the PR posed them. The main idea here is to analyse the inputs and comments from respondents in order to assess the level of agreement with the part of the adjusted PR based on their suggestions and inputs.

7.6.1 A. Analysis of Iteration Three

The study narrowed the questions down to the adjusted requirements for the avoidance of lengthy reading processes and the repetitive presentation of information. Thus, this iterative section was specifically for sections in the designed PS that did not meet respondents' opinion of requirements usable in the ND environment. Using the same open-ended questions, the same respondents and the analytical techniques for the first and second iteration, respondents provided the following responses to the PR as table 7.6 and 7.7 illustrates:

<u>Question 4:</u> *Indicate the extent to which you agree/disagree whether the listed performance requirements will meet immediate environmental criteria during the design, selection of materials and construction of public schools in the vicinity of GF?*

Table 7.6 Third Iteration Process for IAQ

Performance Requirements	**1 Strongly Agree**	**2 Agree**	**3 Partially Agree**	**4 Disagree**	**5 Strongly Disagree**	**6 Not Known**
Nitrogen (NOx): 40µg/m^3 annual mean; 200µg/m^3 1-hour mean	2.2%	4.4%	6.7%	37.8%	46.7%	2.2%
Nitrogen NO_x: 40µg/m^3 annual mean; 75-113µg/m^3 1-hour mean	28.9%	44.4%	22.2%	2.2%	2.2%	-
Lead (Pb) Annual limit 0.5µg/m^3 (WHO)	31.1%	53.3%	6.7%	2.2%	6.7%	-
Lead (Pb) Annual limit 0.25µg/m^3 (UK)	35.6%	55.6%	6.7%	2.2%	-	-

Table 7.6 captures the analysis for the third Iterative Process on IAQ emphasising the PR of materials impacted by NOx and Pb. Following the respondents' answers and subsequent analysis for NOx, the result shows that they *strongly agreed* at 28.9%, *agreed* at 44.4%,

partially agreed at 22.2%, *disagree and strongly disagree* having 2.2% each, with 0% *not known*. This is clearly different from responses in the second iteration as the analysis showed 37.8% of the responses *disagree* and 46.7% *strongly disagree*. Thus, confirming respondents' comments on reasons for disagreeing with the PR as discussed in the second iterative section.

Similarly, Lead (Pb), which was added during the second stage of the iterative process was returned to respondents to provide their opinion on a Likert scale just as in the case of the other substances. However, respondents indicated two different air limits from WHO and UK guidelines. These limits were represented in the open-ended questionnaire and analysis from the responses showed the ensuing results: For the WHO guideline, 31.1%, 53.3%, and 6.7% represented *strongly agree, agree, partially agree* respectively while on the contrary, 2.2%, 6.7%, and 0% opted for the *strongly disagree, disagree* and *not known* options to 0.5μg/m^3 respectively. Also, the UK guideline and limit for Pb, on the other hand, showed that 35.6% *strongly agreed*, 55.6% *agreed* and 6.7% *partially agreed*, while 2.2% *disagreed* with none *neither strongly disagreeing* nor indicating *not known* to the annual limit of 0.25μg/m^3 as specified. Subsequently, the designed PS was adjusted to include Pb with an annual limit of 0.25μg/m^3.

Therefore, these responses from a valid and complete adjustment to the specification and iteration process for the designed artefact for IAQ. This is because no additional information was provided requiring refinement and adjustment to the designed PS, thus, forming a complete process for the IAQ section of the analysis process. Subsequently, the second part of the PS on the third iterative process for materials was also analysed; the results of which are shown in table 7.7.

Table 7.7: Analysis for Third Iterative Process for Materials

Performance Requirements	**1 Strongly Agree**	**2 Agree**	**3 Partially Agree**	**4 Disagree**	**5 Strongly Disagree**	**6 Not known**
Thermal Comfort not more than 10% of the hours in any given year of 25^0C	2.2%	4.4%	6.7.%	53.3%	28.9%	4.4%
Thermal Comfort not more than 10% of the hours in any given year of 35^0C	31.1%	51.1%	13.3%	4.4%	-	-
Space Cooling Demand Space cooling demand	4.4%	8.90%	15.6%	53.30%	15.6%	2.2%

not exceeding 15 kWh/(m^2a)						
Space cooling demand not exceeding 20 kWh/(m^2a)	28.9%	53.3%	13.3%	2.2%	2.2%	-

In agreement with previous analyses, table 7.7 covers the third iterative process for materials with the responses shown in percentages. It also provides results from the analysis of the second iterative process for easy clarification of adjustments made by respondents. Again, the emphasis here is on the PR, as respondents did not agree with the PS provided. As with the IAQ, this part of the iterative process was specifically for those requirements, the specifications of which the respondents failed to agree with. This was to show the difference in responses based on the adjustment of the PR in the open-ended questionnaire.

From the analysis, *thermal Comfort not more than 10% of the hours in any given year of $35^{0}C$ compared with $25^{0}C$* as originally provided in the designed PS showed the respondents deliver a verdict of affirmation at 31.1% for *strongly agree*, 51.1% for *agree*, and 13.3% *partially agree.* On the other hand, they disapprovingly indicated their concerns at 4.4% for *disagree*ing and none for *strongly agree* and *not known*. This result was a clear manifestation that respondents agreed with the new specification provided. Similarly, the cooling space requirement provided, based on the adjustments made, showed that 28.9% of the respondents *strongly agree,* 53.3% *agree*, 13.3% *partially agree* 2.2% *disagree* and *strongly disagree* with 0% *not known*. This provided a more significant responsive rate of responses and agreement as compared to 4.4% for *strongly agree,* 8.90% for *agree*ing, 15.6% for *partially agree*, 53.30% for *disagree,* 15.6% for *strongly disagree* and finally 2.2% for *not known*.

The foregoing is therefore a confirmation that the specification for the third iteration phase is valid. Although, respondents favourably accepted the designed PS as shown in the results from the analysis, feedback was requested. The responses to this request formed the contents of section D in the open-ended questionnaire. This section as attached in Appendix L, added to this phase of the iteration, was to allow the respondents to comment on the relevance and the usefulness of the research. This is supported by Johannssen and Perjons (2012), who affirm that the demonstration phase, also referred to as a weak form of evaluation and a proof of concept, and allows the artefact designed to be tested in the specific environment.

7.6 Feedback and Analysis

Although respondents agreed generally with the PS as modified based on the first, second and third iterations, the feedback information session (denoted as question 5) was added to the open-ended questionnaire during the third iteration phase. This helped to provide a clear perception of the professionals on the designed PS. It was anticipated that their comments from question 5 would provide inputs on the effectiveness of the designed PS and justify the usefulness of the research. The major input as deduced

Table 7.8: Feedback and Analysis of Iterative Process 3

NO	Question Description	Feedback and Analysis
1	Relevance of the Research	All respondents agreed that the research is quite relevant and timely. All respondents mentioned that with the growing need for air quality and health of the child, there is urgent need to tackle these adverse effects of poor IAQ through design and construction. Respondents also noted that the current system of energy generation might hamper the practicability of some of the PS. Nevertheless, all respondents mentioned that the research is relevant and has never been thought about in Nigeria. However, the functionality of the designed artefact should be based on collaboration between the public sector and professionals during design and construction of buildings such as schools rather than leaving it in the hands of government official who might (not have innovative and updated research development/ lack innovation, research, and development) in the construction industry.
2	Usefulness of the Research	Although most respondents had answered this question as part of the answer to other questions, they, however, expressed concern that getting reversed standards, regulations/codes from international countries might prove a challenge. Again, the unskilled nature of the workforce in the country and the complexity of installing some of the innovative materials and equipment might be an added cost to construction. Hence, they expressed the desire that locally manufactured materials be explored used to satisfy the requirement as specified, with minimal importation and training needs for workers.
3	Key features that you think are important	Respondents agreed that: i. Indoor quality should be monitored during and after the construction of PSBs. ii. PS should be attached to the design documents showing all requirements, performance, and specifications. iii. Architects should not be the only ones in charge of the design and construction of buildings, but also incorporate inputs from all the other professionals/experts in the BE. iv. There should be monitoring teams specifically in charge of ensuring that the PS is carried out to the letter and where there is the need for tests to be carried out, such tests should

		be done to satisfy the requirement. v. There should be qualified specifiers as obtained in the developed world rather than leaving this responsibility solely in the hands of architects.
4	Would you consider implementing it if it were available	All the respondents agreed that if the PS were available, they would like to use it as a guide during design, construction, and management of their projects. Some respondents also agreed (offered/disclosed/showed interest) to carry out a pilot design of a PSB using the PS designed.
5	General comments	• The intensity of the research, following the iteration phases carried out by the researcher, was recommendable • Professionals in the BE should constantly be availed information regarding health implications and recommended remedial/solution based options • Every BEP with expertise in building construction should attach to their drawings/tenders a PS • The Nigerian Building code (NBC) and standards organisation of Nigeria (SON) should produce the country's own up to date standards for implementation rather than relying on international measures/regulations.

7.7 Summary

In this chapter, the process of demonstrating the designed artefact in the form of a PS for use in the ND environment was described as discussed in chapters 4 and 5. The main goal of this PS is to provide professionals in the BE with requirements that should be met during the design and construction of buildings in the vicinity of GF. This was achieved by carefully identifying the chemical substances that are associated with GF centred on the requirements from internationally developed guidelines, codes, regulations and PSs from developed countries with similar problems and through discussions with professionals practicing in the study area. Based on all information gathered, the PS for identifying the requirements for the design and construction of PSBs was designed in two major sections, the IAQ requirement, and the material requirements, although subsections were also identified.

After careful consideration of all the necessary requirements and specifications, an iterative system was used to test the effectiveness using an open-ended questionnaire distributed in three different iterative phases. During the iterative steps and processes, there were shortfalls in the PS designed which have been described in Section 6.5–6.8. While going through the design iteration cycle, the experience and knowledge of professional participants were very useful and contributed to the robustness of the PS. Comments and feedback received from respondents during demonstrations were taken into consideration while adjusting the PS. Although the design of the PS has been subjected to professional contributions where alterations and adjustments were made through iterative processes, it is necessary for an evaluation of the demonstrated artefact to be carried out. Simon (1996) describes the nature of this cycle as generating design alternatives and evaluating these alternatives against requirements until a satisfactory design is achieved. This is to establish that the efficacy and goodness of an artefact can be rigorously demonstrated by well recognized evaluation methods and also fulfil the fifth step in the DS method as discussed in chapter 4.

Although the demonstrated stage has been completed and proven effective, it is pertinent to see how well the demonstrated artefact is able to solve the explicated problem. This will be possible through the implementation of the fifth step known as the evaluation stage from the adopted DS framework as proposed by Johannesson and Perjons (2012) and used throughout this research. According to Holmström, et al. (2009), for any developed artefact to actually work, it is, of course, a proposition that should be subjected to evaluation. They further noted that without the DS, evaluative research would have nothing to assess. This is because, without the efficacy or validity of research, the process becomes inclusive and lacks reliability. Design research should not stop with design ideas. They need to be realised in gaugeable artefacts.

Thus, design ideas are elaborated and then tried out through realisation, hence the need for an interpretation of the designed PS through a method or process identified, and by so doing satisfy the DSM. Thus, for the purposes of this research, an architectural drawing of a public PSB in the vicinity of the study satisfying the required PS is used.

CHAPTER 8. EVALUATION OF THE DESIGNED PERFORMANCE SPECIFICATION (ARTEFACT)

8.1 Introduction

Although the demonstration phase of this research, also referred to as the weak evaluation phase, provided an opportunity to expose the designed PS to professionals and that allowed the needed feedbacks and suggestions. This process led to the refinement and adjustment of the designed PS to meet immediate climatic conditions based on the views of professionals in the vicinity of GF. However, it is pertinent to further carry out an evaluation of the designed PS to show its effectiveness which is greatly influenced by the willingness of participants to produce drawings as a way of testing the PS, led to this chapter. This chapter, therefore, discusses the steps taken to produce drawings from professionals in the study area.

8.2 Evaluation and the Design Science Method

According to (Frechtling 2002), evaluation can be synonymous with tests, descriptions, documents, or even management. Johnsesson and Perjons (2012) added the drawing, design, guidelines and blue prints as types of representations of evaluation. Although many definitions have been proposed and developed, a comprehensive definition presented by (Sanders, 1994) of the Joint Committee on Standards for Educational Evaluation held that evaluation is a "*systematic investigation of the worth or merit of an object*" appears more acceptable. Therefore, the whole essence of any research is the value or worth placed on it. However, in any evaluation, the design is based on some purpose and it is judged based on perceived quality or beauty (Reich and Subrahmanian, 2013). From all the definitions represented above, evaluation determines the strength, worth or beauty of the research as *c*learly illustrated in table 4.7. Both drawings and designs are types of evaluation methods that could be used for evaluation purposes. This research adopts architectural drawing as a method for the judgment of the merit of the study. The drawings represent the validity and effectiveness of the designed PS and feedback received from respondents during the third iterative step of the usability of the PS.

The Evaluation process is the core significance of the DSM, which makes it different from other research strategies/methods. The willingness of respondents to provide drawings based on the adjusted PS adds to the needed advantage and further justification of the worth of the research. The reason for evaluation through the drawing of PSBs was based on the type of testing used for simulations in IT and engineering designs. Testing, which is a form of an evaluation exercise is important because, through it, issues could be raised based on functionality, effectiveness, and reliability and can also help to find and remove errors where necessary (Myers et al., 2012). Evaluation of the PS requires communication with professionals in the research area. Here, the purpose of this chapter is to allow the users of the PS to design a PSB that justifies the designed PS.

This phase and final step of the DSM shows effectiveness and establishes some degree of confidence that the designed PS does what it is supposed to do. In addition, this evaluation phase is critical in order to prove the concept and receive acceptance from practitioners in the field while satisfying the rigors and justification of DSM. This chapter, therefore, discusses the steps taken to produce drawings from professionals in the study area. The following section presents and discusses both issues in terms of the evaluation process, results and discussions, and chapter summary.

8.3 Evaluation of Designed Performance Specification (DPS)

This is the fifth stage of the DS process adopted, as illustrated in figure 4.2 sections 4.10 and its importance is shown in table 4.6. From table 4.6, every framework, as proposed, had an evaluation process as a significant part of the developed solution. However, the evaluation approach selected should be the best suitable for the research because the final step is very crucial for the DS method since the output designed has to be returned to the environment it is meant for to try its effectiveness (Hevner, 2007). Although testing might be in a form of simulation, prototype or exemplary, such process might not necessarily be represented as a physical structure, however, the information provided should facilitate deciding on a course of action.

Evaluation process is the central and essential activity in conducting rigours in DS research (John Venable *et.al*. 2012), because DS is influenced by the ability to test designed solutions in a real life scenario by analytical, experimental, functionality, completeness, consistency, accuracy, performance, reliability, usability and fit for purpose (Henvar, 2004; Peffer, 2008; Jonnasson and Perjons, 2012). Moreover, accomplishing an evaluation proof is difficult because of challenges such as meeting objectivity, comparability, and traceability (Cleven, et al. 2009). However, the complexity and the rigors provide the needed satisfaction of accomplishment. It is, therefore, the choice of the researcher to adopt the use of architectural drawing, used to represent and interpret the designed PS and the suitability for the environment and for the intended purpose.

Whether an explicitly or implicitly tested approach was used, the required performance is permanently embedded in the building procedure. Therefore, it is significant that the design and construction team are able to predict, not only the performance of some parts but also how the entire building will perform when completed (Szigeti and Davis, 2001). This requires the selection of experts that represent the designed PS in a drawing hence, professional architects practicing around the research area are the best fit to provide the critical evaluation. This is because architects are both designers and specifiers in Nigeria (Folorunso and Ahmad, 2013). Thus, the designed PS was tested implicitly in the NDAN with two out of three experts who originally confirmed their willingness to participate. These architects design and construct buildings around the case study area with over twenty years' experience. Those selected, are knowledgeable and well equipped to interpret information in the PS. This gives the researcher an opportunity in providing an evidence-based evaluation to show the possibility of achieving the aim of the research.

The designed PS as tabulated in table 6.9 of this study was distributed to three architects. Although, based on time, distance and other barriers posed by the data collection that relied heavily on the goodwill of the respondents, two architects provided drawings. The drawings provided were used for evaluation purposes illustrating the effectiveness of the designed PS.

To achieve this process, a brief detailing the requirements for public schools constructions is required to provide the necessary information for the architects. This brief provided a gateway and an overall preamble to the research, and the aim it should achieve forms the next part of the discussion.

8.4 Design Brief and Performance Specification

According to Ryd (2004), a construction brief is a document showing the context and requirements for a building development. The brief forms an integral part of the design process and not just an early stage where discussions can be ignored or not taken into consideration (Blyth and Worthington, 2010). It is the document that describes requirements for a building and communicating them to other stakeholders which are significant to the effective delivery of the project (McGeorge and Palmer, 2009). Therefore, all requirements as specified in the designed PS form part of the brief, forming wholesome information necessary for such design and construction in polluted environments.

Providing a brief requires detailed instructions on what has required such the construction, purpose of use and intended expectation of the final product to achieve, thus information in table 8.1 shows the instruction as represented in the brief. The brief provides requirements and performance documented or produced as a separate document depending on the magnitude of the project such as government projects. Thus, the brief is a product of a process achieved when information provided is interpreted correctly to perform the required task.

Table 8.1 Information for Design Brief for Evaluation Purposes

Item	Description
Name of Project:	Design of public schools in the NDA of Nigeria
Aim of the Project	To develop a design for a public school in the VGF with PS developed as a proof of the viability of the designed artefact.
Intended Use of the Project:	To show as a process carried out confirming to the DS process adopted.
The Problem:	The NDA of Nigeria is the economic reserve of the nation. Oil exploration and exploitation activities are constantly carried out on daily bases. Here the cheapest means of harnessing this natural reserve is employed thereby emitting anthropogenic substances into the environment. These oil exploration activities are carried out around and within public schools, which poses both health and deteriorating effect on both users and the buildings. As a way of providing the solution to this problem, a PS has been designed and it is required that it should be used to design a school building putting into consideration all the performance requirements prescribed in the document.
Design Requirements:	A drawing designed with details as provided in the PS attached to the brief. It required that at the end of the design, information that shows filtration process employed that will provide clean indoor air is provided.

The main goal of table 8.1 was to provide a clear understanding of the requirements necessary to produce a design of a PSB. Since the brief is the basis of the decision as opined by (Winch, 2013), it is important for a clear and concise information to be provided to avoid unforeseen events. Hence, the designed PS provided the intrinsic information necessary and serving that purpose, bearing in mind that human beings do forget things not properly documented. At this stage, it is necessary to note that the main reason for choosing instantiation is to show that the designed PS will work for the designed environment. The functionality depends on the ability of the architects to produce an architectural design of public PSBs in the VGF.

In the evaluation phase, architects were met; this is after meeting with them during the demonstration phase where a formal request was made to three of them with positive responses. In addition, another request was made after the last iteration process with a brief attached to the designed PS. However, based on timeframe and discussions carried out, two out of three architects with over 20 years' worth of experience working in the research area produced the drawings. In addition, as part of the request made, the evaluators were interviewed, which involved discussions and were asked to give feedback and comments that probed their subjective view of the designed PS; although, formal evaluations are not always conducted, and when done results may not necessarily be widely known or accepted (Bovens and 't Hart, 2016). Most evaluations are carried out based on trial bases or through the expert opinions of professionals knowledgeable in such domain as in this case where architects are selected as the best fit for the purpose. The brief, in addition to the designed PS, was used to provide the drawings; though a number of problems were discovered, it was considered good as it provided another avenue for further research for valuable feedback. It also provided an opportunity for direct use by architects from the research study area of the designed PS as a test, illustrating its effectiveness.

The evaluation session took four months to complete although, from the inception and first request made during demonstration phase, it could be said that the design took approximately 13 months. This is because the task required the architects to be provided with the completely refined and adjusted PS to enable them design to meet the amended performance.

8.5 The Designed School Building Based on the PS

PSBs around the world are built in accordance with building codes, laws and regulations as practiced in such countries. In addition, in some cases regional, state or local laws affect the way buildings are constructed. In recent times, due to research and other experiments, schools and performance of schoolchildren academically are linked to so many factors, which include deteriorated buildings and poor IAQ, which is the focus of this research.

Following the need to provide a solution to this problem as present in the NDAN, the designed PS as amended through three iterative processes by specifying performance requirements, building codes, and tests required for material selection during design and construction. The designed PS provides the needed information that will improve academic performance, the health of the pupils and durability of the building, rather than BEPs relying solely on the NBC which is prescriptive in nature. Although three architects consented to produce drawings when approached, as stated earlier, two out of the three were able to produce building plans based on the request. The designed PSB consists of a floor plan, elevation (right, rear, left and approach elevations) and roof plan with purification systems adopted by each expert. The distinctive part of the two separate drawings was the process and method used in meeting the IAQ PR. For the purposes of the evaluation discussions, it will be based on the elevations provided while narrowing down discussions to the main criteria used in developed countries.

Although in recent times, the most significant criteria for the construction of PSBs is IAQ, other criteria such as lighting, acoustic and thermal comfort are significant factors to achieve the overall performance. However, these criteria will be discussed based on their relationship with the current area of concentration of the research, which is the external façade with particular reference to the cladding of the roof, walls, paints used and IAQ. Furthermore, it is important to state here that although the same brief was handed to the experts, drawings were made separately; however, when drawings were collected, the researcher found out that the two experts had used the same design type.

8.5.1 Lighting

The lighting system provided in buildings used for educational purposes requires good illuminance to enable good visibility without distorting and discomforting students' sight during school hours. Therefore, an understanding of the pattern in which the sun rises and sets is vital. Although , (Block and Bokalders, 2010) noted that the effect of direct sunlight is not wanted, the daylight it provides is wanted. However, day lighting is affected by the location, time and climate, even the weather conditions of a place where the building is located impacts on the amount of daylight (Rockcastle and Andersen, 2013). Thus, the ability of sunlight to provide day lighting depends on crucial factors already discussed in chapter 6 subsection 6.4.2 noting the immeasurable advantages of day lighting. More so, with new advancement in research and innovation, software that could measure the impact of sunlight on buildings are been developed. This requires architects and builders to be well informed and understand sunlight geometry, a basic concepts that allows design of low-energy solar-responsive buildings. For instance, Heliodons software used in the USA achieves this solar responsive design by reducing the energy demand by harvesting the winter sun for heating, by rejecting the summer sun to reduce the cooling load, and by collecting a small amount of quality daylight year-round to replace most of the electric lighting used during daylight hours (Lechner, 2014). This can effectively provide enough solar energy required in place of artificial lighting which in turn requires energy and cost effectiveness which might impact on the quality of school buildings required to meet the PS.

Lighting in schools can be provided with both natural and artificial lighting systems depending on the weather conditions and orientation of the building. Achieving the required illuminance, and as a means to meeting the PS, the two experts provided courtyard type of design. Although it was impressive that both designers thought of a similar system to achieve the PS, however, based on the information provided during the interview sessions, reasons were given which were similar. In addition, innovative systems have also added a new dimension to the way spaces like lobbies and courtyards are seen and used. For instance, in architecture, voids which were simply seen as empty spaces have been recreated and referred to as corner voids (exhaust towers) used as natural ventilation systems (NIKKEN,2013). The Home energy efficient design (HEED) provides information system freely and allows additions of high mass to temper indoor temperatures, inclusion of several Passive Heating and Cooling options available including ventilation, evaporative cooling and passive solar heating. HEED can automatically download climate data for thousands of locations around the world (Milne, 2017). This software allows the redesign and adjustments to buildings depending on the needs although, the actualisation of these innovations are based on the availability of immediate climatic information of such environments. Accordingly, The lighting system as illustrated and discussed using the floor plan as shown in figure 8.1 and 8.2 showed a courtyard system where natural lighting was used as a major source. It was also used as the design system that will reduce the amount of sunlight penetrating into parts of the building.

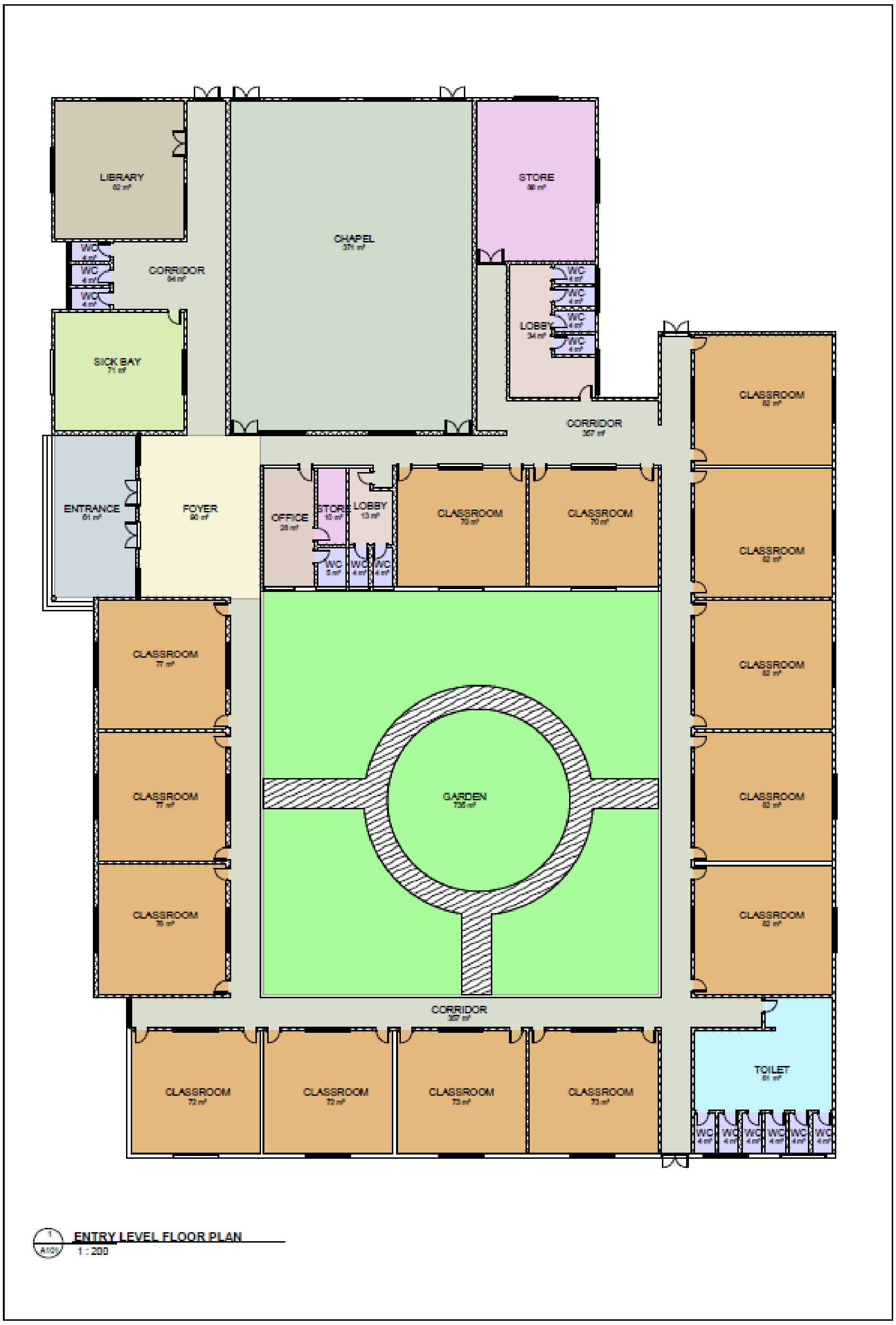


Figure 8.1Floor plan by Expert 1

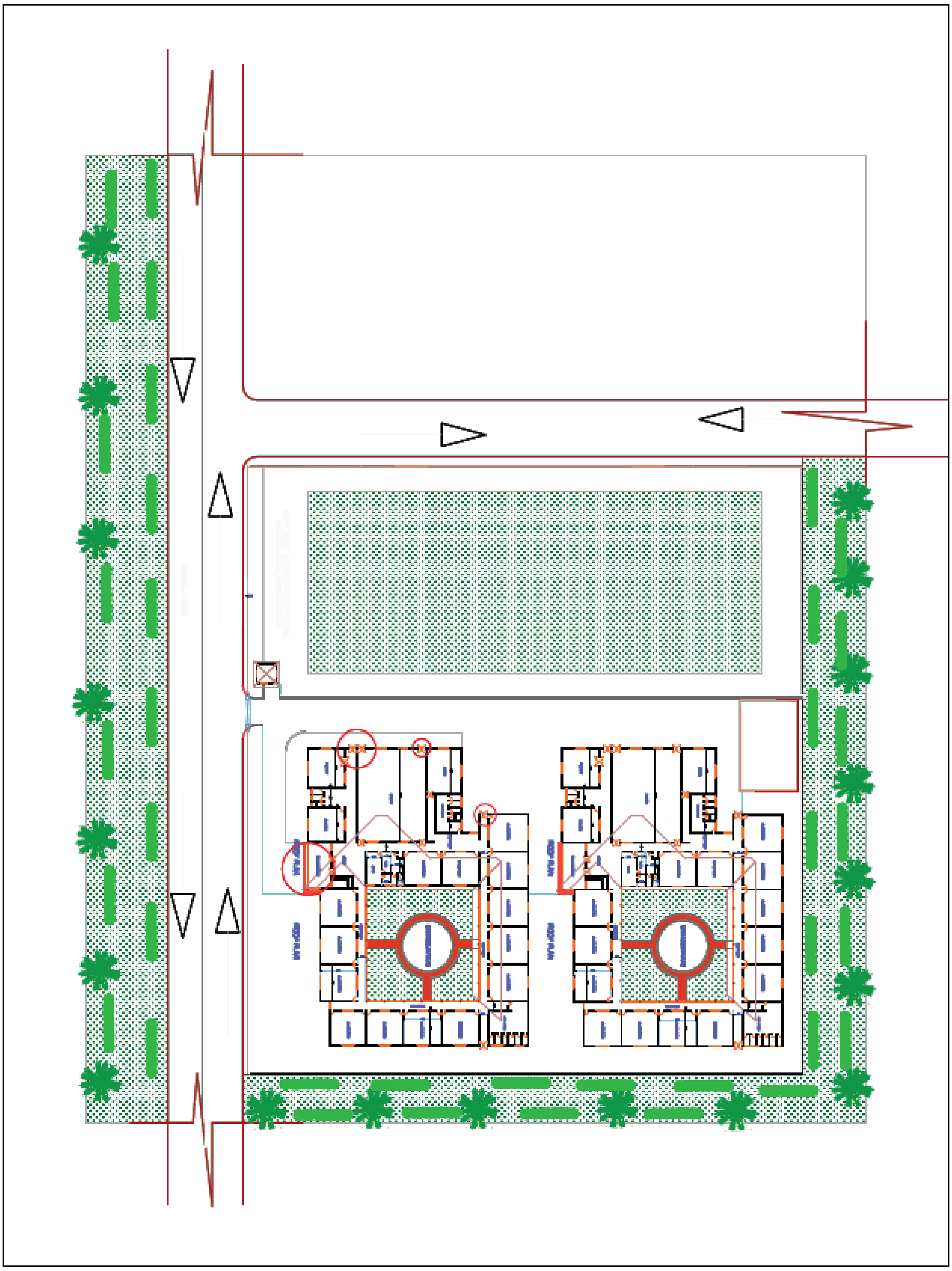


Figure: 8.2 Floor Plan by Expert 2

The floor plans designed by both experts referred to as Experts 1 and 2 show a diagrammatical representation of the entire building from the top showing the entire classrooms, toilets and the representation of the courtyard.

Schools are usually occupied during the daytime therefore, day lighting is very crucial to learning and teaching. The inadequacy of visibility through lighting provision will result in virtual impairment hence, defiling the purpose of a classroom. Energy, though used to produce light in some cases where the weather condition does not allow enough sunlight, is mostly advised as a means to meeting sustainability and performance requirement; therefore, natural lighting should be maximally utilised. Such natural day lighting provision requires the use of transparent materials for windows and doors and roofs in some cases. Here, during the evaluation stage, the architects provided windows with double glazed glass with an aluminium frame with the anti-corrosion coating.

Current studies have shown that double glazed glass~~es~~ is a step to sustainable society because it allows sunlight, provides thermal comfort and is a sound insulator thus saving energy (Block and Bokalders, 2010). Therefore, the choice of double glazed windows as provided by the experts will meet the required performance as designed in the PS. In addition, during discussions, experts noted that the choice of double glazed windows was for the purposes of reducing the radiation of external heat and noise from the furnace of the gas stack. Reduction of the heat from natural sunlight was also a priority as they noted that, the GF area of ND is not only met with radiation of open air burning of gases but also the heat from sunlight rising above 35^0 in some places.

Although windows were provided for day lighting, the open courtyard system, according to the experts, allowed illumination into every part of the building. This provided a natural lighting system which presumably would be enough to provide the needed light exposure without further installation of artificial lighting unless in rare cases where energy bulbs are installed for added illumination.

8.5.2 Acoustic Comfort

Providing a comfortable environment contributes significantly to the performance of school children and reduces absenteeism. According to the WELL Standards (2017), acoustic comfort plays a significant role in mitigating physical and psychological trauma. The discomfort is usually through the ears and can emanate from the classroom, traffic noise outside, mechanical equipment in adjacent spaces such as rumbling noise from GF around and within such vicinity.

Noise pollution is a major deterring factor to hearing, affecting both teaching and learning. It is important that both external and internal noise be considered when constructing buildings for educational purposes. External noise rising from the furnace and the rumblings from the flare stack can be a source of distraction and hearing difficulties for teachers and students. It is pertinent that the noise level is brought to the minimum as specified in chapter 7 of this research. Thus, materials used for the external façade, roofs, windows, and doors should meet the PS criteria.

In line with meeting the performance designed, experts noted that acoustic comforts were met through the choice of materials used for construction. According to them and based on the diagram as illustrated in figure 8. 3 and 8.4, noise can become a problem if buildings do not take care of echoing sounds as well, caused by too large or empty partitioned rooms. Therefore, care must be taken in the design, selection of material and construction. This is why windows have been designed as double glazed and with aluminium frames with joints properly sealed and concealed to avoid openings, which might allow the penetration of noise from external sources.

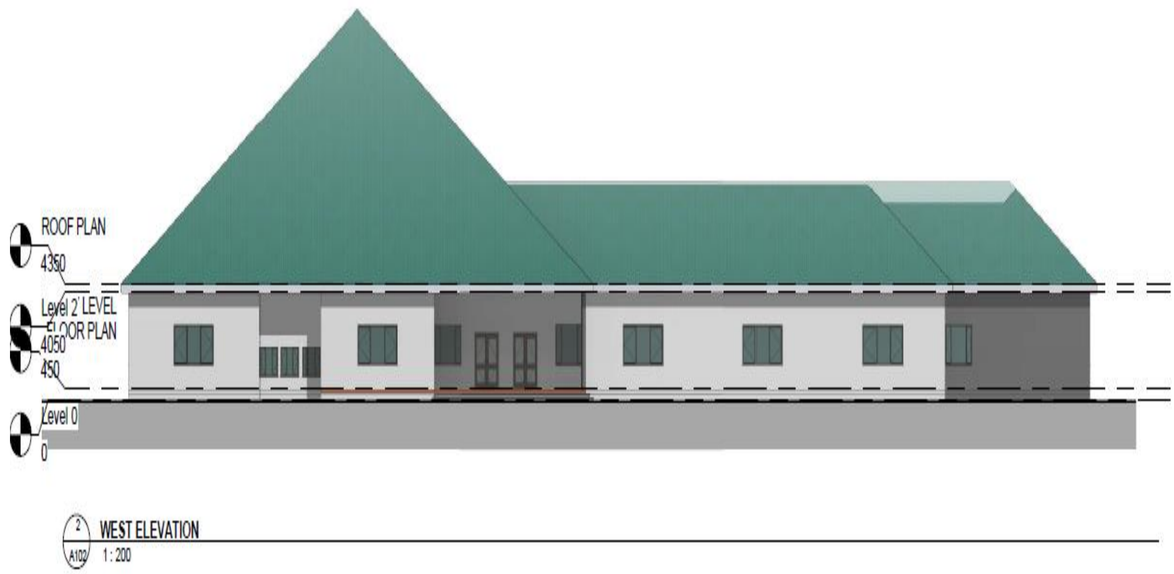


Figure 8.3 windows designed fitted with double glazed glass by Expert 1

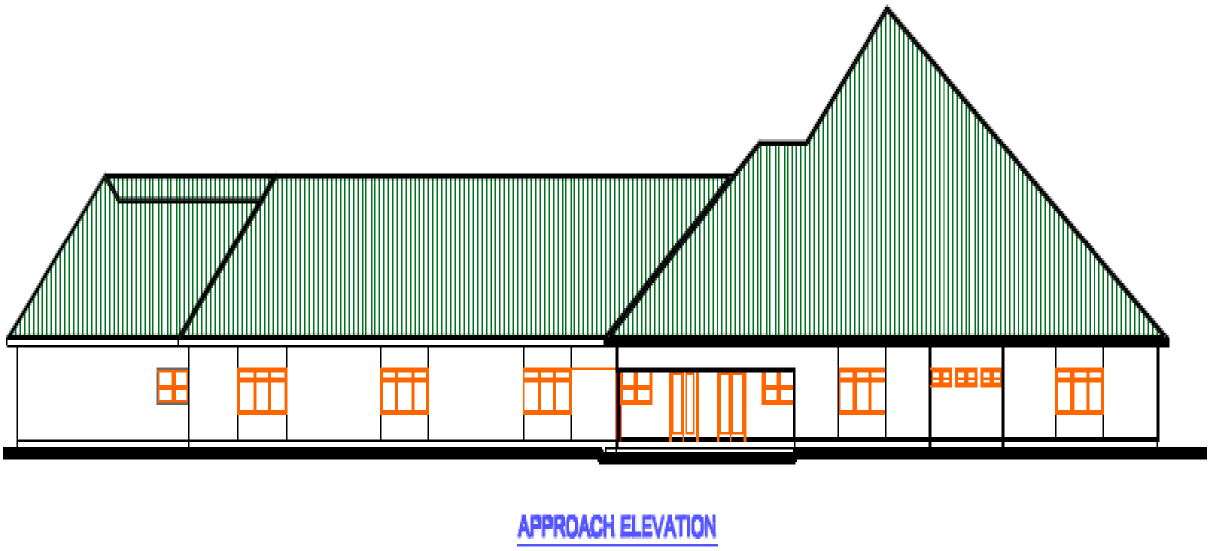


Figure 8.4 windows designed fitted with double glazed glass by Expert 2

Experts confirmed that to reduce noise from both external and internal parts of the building, blocks should be used to build both external and internal walls for the purposes of partitioning different classes. This is made evident in the thickness of the lines used to demarcate the rooms as illustrated in figure 8.1 and 8.2. According to them, it will reduce noise, withstand vibrations and rumbling noise from the pipes. Again, they noted that the use of blocks for the partitioning walls of different classes is to allow students and teachers communicate with each other without interference from adjoining classes. Furthermore, noise can also penetrate through the roof knowing that a courtyard design system was used, but experts noted that the use of building materials meeting the PS will provide the necessary resistance to noise. In addition to the external roofing, the internal part of the roof where roofing members could be seen is concealed with a ceiling material. This covers the internal part of the roof and serves as a second barrier to noise penetration either from outdoor or indoor, given the height of the building.

The pitched roof type of construction was to provide the added height in consideration of the environment. This will also allow a dripping down effect of atmospheric substances in liquid form, also allowing rainwater to wash off powder-like substance such as carbon and soot deposition on the roof. They also made reference to the recent soot deposition which is causing blackening of buildings where, even with rainfall due to the roof type, such deposition remains on the roof top. Although they informed the researcher that the colour of paint plays a significant role, they both confirmed that darker paints could be a better choice. The experts recommended that low quality emulsion paints should not be used and in fact, expert 1 noted that with his drawing, he adopted a spray paint used for metal finishing; this he said, has the properties required to meet the PS. They both agreed that paints not meeting the resistance level of alkalinity and acidity as specified should not be used or allowed in the construction market. They both noted that the corrosive nature of atmospheric gases prevailing in the ND washes off ordinary emulsion paints resulting in chalk-like stains and leading to flaking of oil paints thereby exposing the plastered wall to further weather effects.

However, discussions revealed that they both would prefer prefabricated cladding materials used presently in some privately owned buildings around cities, although the cost implications, according to them, might hinder the actualisation hence, they both used paints but insisted that it should meet the designed PS.

8.5.3 Thermal Comfort

According to ISO (2005), thermal comfort (TC) is the condition of mind which expresses satisfaction with the thermal environment. The perceptions of TC in an environment is affected by air temperature, radiant temperature, relative humidity, air velocity, activity, and clothing. TC is achieved where indoor room temperature and humidity are satisfactory. As affirmed by ISO (2005), such comfort level is acceptable given the environmental conditions considered suitable for general TC as well as those representing local discomfort. It is of great significance to build, based more on climate-adaptive systems, rather than climate-excluding systems that rely on natural and financial gains (Yang, 2017). Achieving TC depends on the system employed during design, construction and local climatic factors

In the NDAN, according to (NDDC, 2006), the climate varies from the hot equatorial forest type in the southern lowlands to the humid tropics in the northern highlands. This means that there are always hot temperatures around the region causing internal heat gain. Therefore, construction around such vicinity should consider the possibility of achieving TC in both the design, selection of materials and construction. Following this, during the evaluation process, architects informed the researcher that the use of the concrete blocks of 225mm (solid or hollow), with Portland cement used in plastering walls, and would provide the needed resistance. This, according to them, can withstand heat and serve as a resistance factor to both fire outbreaks and the heat radiating from GF. However, they noted that poorly made blocks would reduce performance, which reduces the requirement as specified and therefore opined that blocks should be supplied by a reputable block industry or should be manufactured on site with the adequate supervision of the mixture of aggregates. The choice of production of blocks for a building with a brief and attached PS should be made mandatory as noted by Expert 2, who was of a strong view that, blocks for special buildings like that of public schools where PS is required and made requisite document, blocks should be moulded on site to meet requirements. Although he added that it might delay the start and completion time for the construction of the building, he felt the delay will be worthwhile as fulfilling the performance requirement should be the actual incentive and the end reward rather than the completion period.

Following the designed PS, experts observed that the requirements for indoor thermal comfort or temperature level of 25^0c might not be achievable with selected materials during the peak period of high temperatures, which is usually from 12 noon to 3pm. They added that that would necessitate the installation of ceiling fans in addition to the cross ventilation system using openable windows on all the elevations (front, left, right and rear).

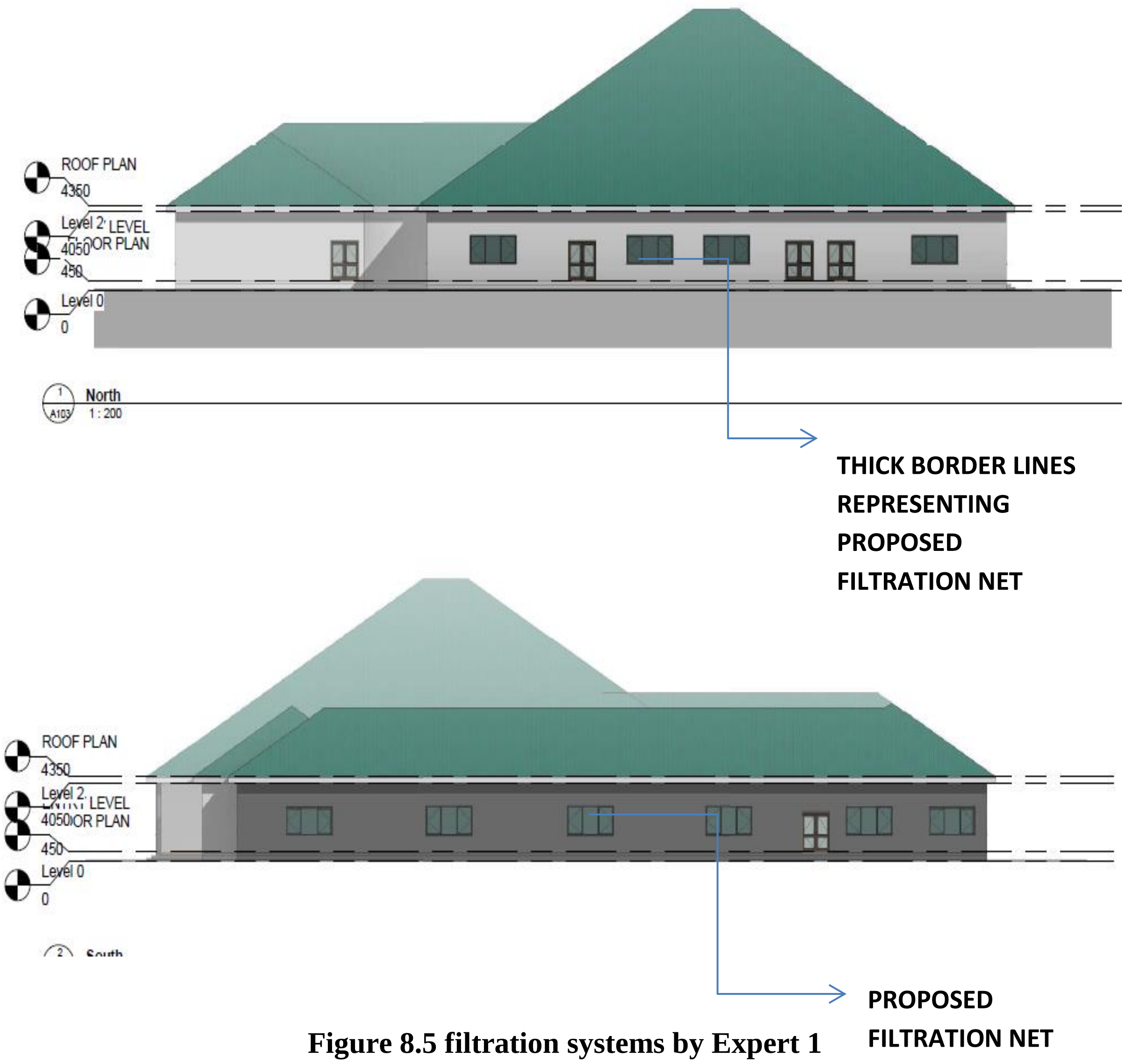
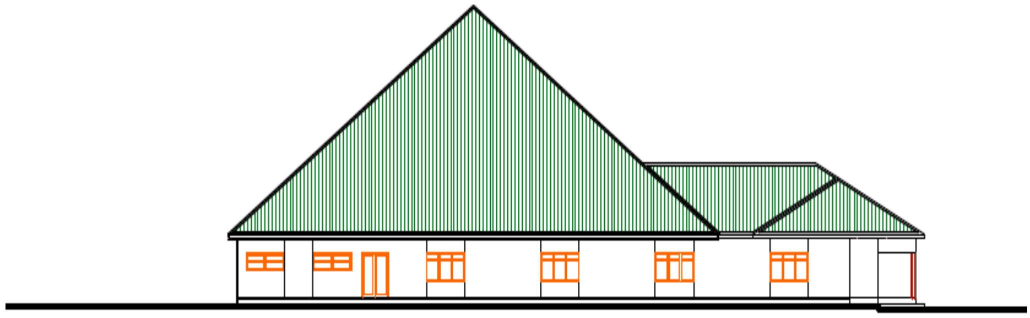


Figure 8.5 filtration systems by Expert 1



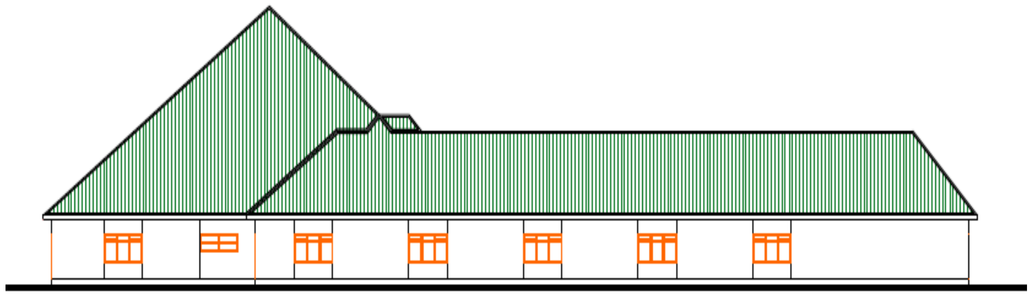


Figure 8.6 Right and left elevation as designed by Expert 2

Figures 8.5 and 8.6 show that the right and rear elevations are designed with the same shapes and sizes with that of figure 8.4 and 8.5. According to them, the same materials meeting the PS should be used. However, they clearly stated that cross ventilation systems using windows should be used if adequate air purification system as designed is employed or a decisive mechanical system should be employed.

Although they both agreed that, the problem of energy will be a devastating factor that will hinder the functionality of such equipment, they also noted that other methods that will serve the purposes of both IAQ and the ventilation system while providing the needed TC as specified. These methods have been elaborated by Yang, 2017 noting that climatic-adaptive design provides advantages such ventilation, cooling and daylighting free for occupants (pupils) for a long period of time using natural systems although architectural and engineering intelligence is essential in providing the needed requirements to meet building performance.

8.5.4 Indoor Air Quality (IAQ)

Although most indicative factors for clean indoor air are determined by the measurement of carbon monoxide (CO), it is not the only chemical substance that affects IAQ because other substances emitted have a significant effect on health. In recent times, the issue of nitrogen, sulphur and particulate matter have been researched and scientifically proven to show adverse effects leading to serious health risks as already discussed in Chapters 2 and 3. The consequences, and composition and limits allowable, all form parts of the wholesome criteria and requirement for clean IAQ.

To achieve clean IAQ, much research has been developed and is currently used in different countries and some of these innovations and strategies have been discussed in chapters 2 and 3. However, for the purposes of this research, designing a PSB to meet limits as specified by BE professionals requiring the provision of an added purification system that will stop the infiltration of ambient air into the internal part of the PSB. Following this need, professional architects, therefore, considered several factors ranging from consideration of the cost of energy and maintenance of a fully mechanical Ventilation system. They noted that the pollution from GF in the ND is very high and contains numerous anthropogenic substances hazardous to human health. Therefore, for the ND air to meet international standards as well as meet PS, a system has to be thought through that can help reduce, if not eliminate, poor indoor air.

Based on their drawings and suggested methods that will help with clean indoor air whilst reducing dependence on energy as a form of powering any system introduced, Experts 1 and 2 designed two different systems referred to as triple filtration and double filtration processes and are discussed below;

Expert 1: He clearly stated that bearing in mind the cost implication of energy provision and maintenance in the NDA, he is of the view that a triple filtration system should be employed to eliminate and purify the ambient air before it filtrates inside of the building. However, he observed that the possibility of providing the third filtration system will require the application of an innovative process. According to him, this will be through a further refining of the innovative system used for the manufacture of face masks used in countries such as China and presently in Port Harcourt, a city in the ND where a current deposition of soot and dark cloud are causing difficulties. Rather than use the popularly known mosquito net, the face mask material would be made durable and used both for the purposes of an insect preventive measure and an air filtration system. A diagrammatical representation illustrated in figure 8.7.

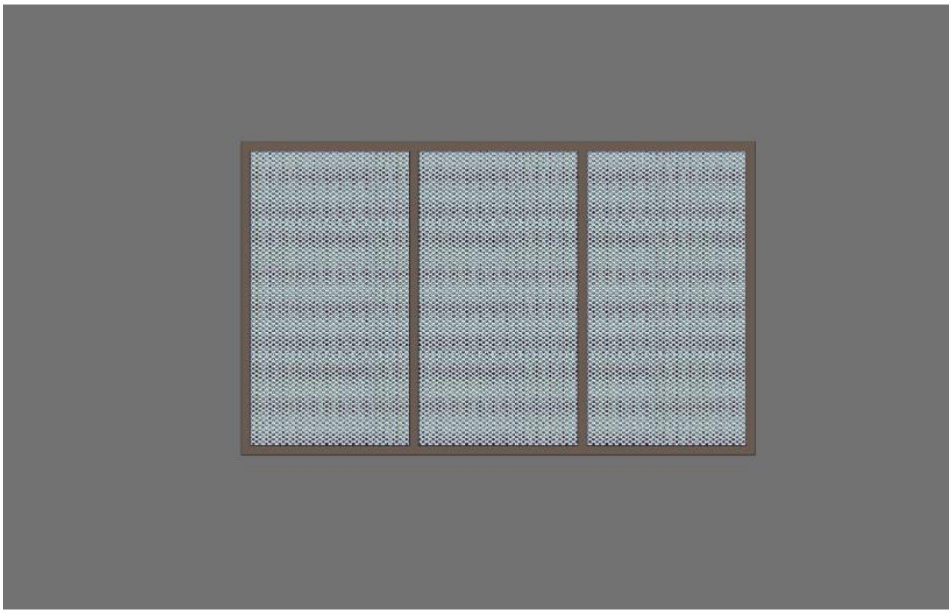


Figure 8.7: Refined Facemask Material used as the Third Filtration System Expert 1

According to the expert, the material will be placed before the double glazed windows from the external façade, which allows the vertical sliding of windows internally without obstructions. This will thereby provide clean indoor air without necessarily requiring mechanical ventilation systems. Although he noted that currently, the materials used for face mask have low resistance levels to weather conditions such as rain or water, the refined material will be made more durable to resist water from damaging it. He noted that the material should provide the much-needed support for users helping them to inhale clean air. The significance of clean air and the adverse health effects of pollution has led individuals, local, international collaborative and corporate bodies to look into natural systems and man-made products. These can be reconsidered, refined and reused for greater efficacies. For instance, in a book reviewed by Yang, 2017, stated that the Cardboard to Caviar project developed and managed to transform a low-value material into a high-value product was innovative. The book also stated that Gunther Pauli of Zeri.org achieved similar height by the transformation and creation of a man-made system that mimic the ecosystem to produce environment adaptive materials. Therefore, the refinement and use of face mask as a purification system form a part of his design and method of providing clean air. This is because expert 1 added other natural air purification methods which are basically the same as the design by Expert 2 and is illustrated in the figures 8.8 below.

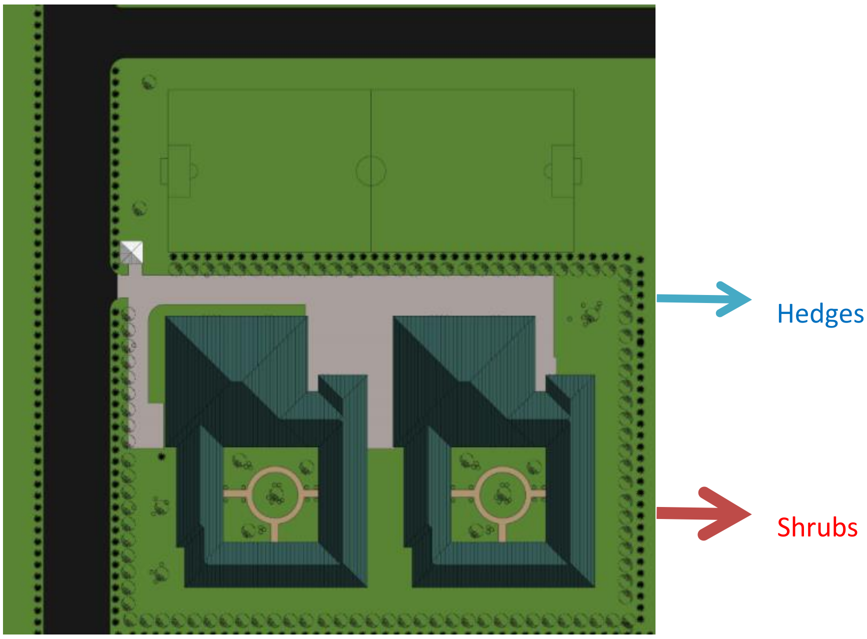


Figure 8.8: Model showing air purification system using hedges and shrubs Expert 1

From the figure, 8.8, Expert 1 indicates in the drawing the use of hedges or trees and flowers to provide the first two natural purifications before the third purification. This he said will provide the needed results of clean indoor air. Therefore, according to discussions from the expert, the triple filtration system entails; firstly hedges, secondly shrubs and thirdly refined facemask.

Expert 2: Following the design and discussions, Expert 2 designed a PSB meeting IAQ as specified in the PS with the provision of double filtration. Relying solely on natural means without additional purifiers as in the case of Expert 1, Expert 2 noted that the use of plants in an unparalleled form will reduce and eliminate poor indoor air. As illustrated in figure 8.9, all sides of the building are surrounded by plants also clearly illustrated in figure 8.2 from the floor plan design.

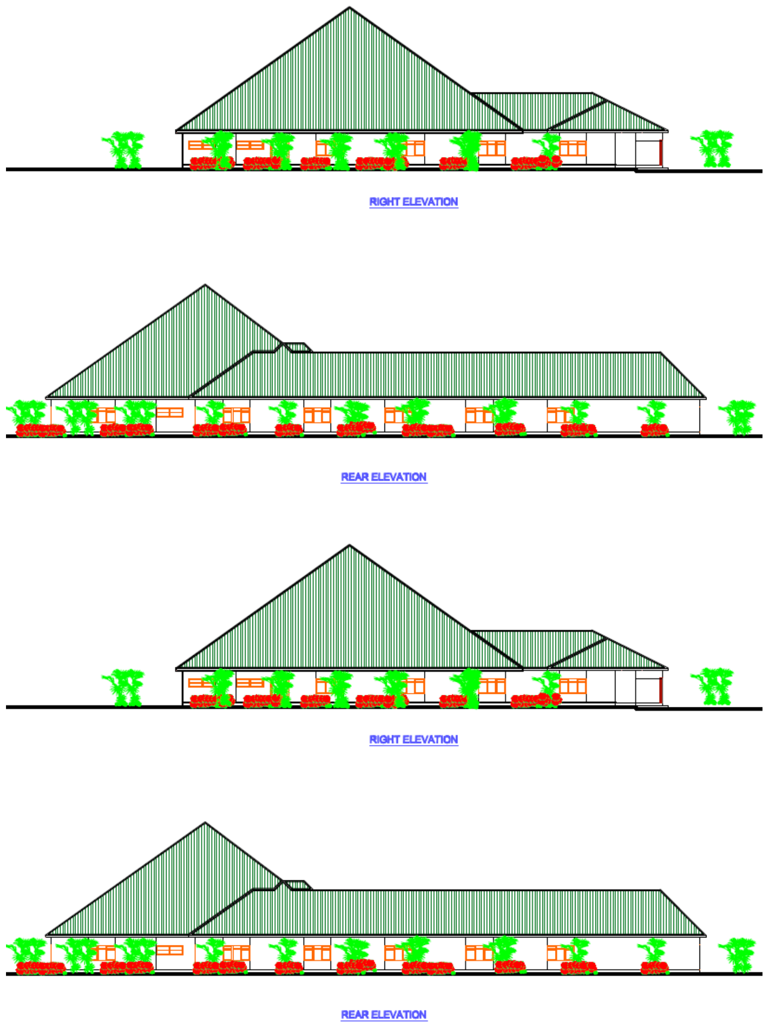


Figure 8.9: Elevations of the Building showing Double Filtration System using Hedges and Shrubs

Here the main concentration was the use of plants to provide double filtration systems. According to expert 2, the shrubs and hedges are not planted on the same parallel lines, this is clearly shown in figure 8.2.

From the above filtration system, both experts 1 and 2 used plants as filtration systems in their drawings. This system, they believe, will provide a double filtration system based on the wind direction. According to them when the wind flows through the first plants, referred to as hedges represented with trees, it breaks the speed, filters the air which, is redirected through a motion and goes through to the second filtration system referred to as shrubs (another vegetation such as flowers) represented as red plants. These shrubs filter the air again before filtrating into the buildings.

These systems employed for the provision of clean IAQ by the two experts and referred to as double and triple filtration systems can be applied barely requiring or accruing any energy cost. This, according to the Experts, is better than recommending a mechanical system which will be hindered by the challenges faced in the ND in terms of energy as affirmed in the NDDC Masterplan (NDDC, 2006). They noted that it is better to use safer processes than exploring systems that might not be utilised in the nearness of time. Although, they (the Experts) both agreed that a monitoring system has to be put in place to confirm the effectiveness of the filtration process recommended. However, the possibility of any system (mechanical or natural), depends on the air tightness of the building, which is largely dependent on leakages from opening through elevations and roofs.

8.5.5 Air Tightness

According to Part L of the UK building regulation, it is the resistance level of the building envelope to inward or outward air leakages. The possibility to achieve clean air inside PSBs depends majorly on air tightness achieved after the construction of various parts of the building envelope. This is crucial to the achievement of clean indoor air in the study area and part of the significant elements under IAQ for school construction.

According to Astroma (2010), buildings do not breathe, humans do. Human beings, therefore, form the integral factor as they occupy the building when it is finished regardless of the building type. Thus achieving air tightness as designed in the PS depends on professionals and their workers. Following discussions, both experts noted that materials used for construction are vital because they provide the needed criteria for air tightness. For instance, they confirmed that unlike the developed world where buildings are tested for air tightness, that is seldom the case in Nigeria and in the ND. Giving that any leakage might bring about an increase in the amount of ambient air filtrating inside the building, adequate caution should be taken. Here they insisted that rather than cheap labour, experienced labour should be used. This confirms the information obtained during further explication of the problem as analysed in chapter 5.

They informed the researcher that although every part of the building is important, however, based on the research requirement and the performance needed, there are critical areas where experienced workmanship should be used. Areas, where adequate care should be taken, include roofs, windows and doors, and fittings including internal wall partitioning. This is significant because as already discussed in chapter 6 subsection 6.3.8 and as affirmed by (Batagarawa, 2012), while airing is important, air leakages are not. Therefore, adequate care has to be taken in fitting and constructing the different parts of the building.

Experts noted that public buildings constructed in the ND are with blocks, plastered with Portland cement, providing a smooth finishing and rendered with paints to conceal any form of openings that would have penetrated through during block works. However, to achieve this depends on the information from the PSIP, which includes sealing materials used, thermal barriers, weather tightness and window load bearing resistance level, coating material used and resistance level to water, exposure to immediate weather condition such as carbon exposure, sea salt water spray and colour tolerance as discussed in chapter six.

The consideration of other performance requirements affirms the conception as confirmed by (Foliente, 2000) noting that the satisfaction of one performance criterion requires the satisfaction of other criteria. A building is a unit joined together by smaller entities that must meet some form of criteria or arrangement that forms it and every part is significant. Although building air tightness has its advantages, especially where it is necessary to protect indoor from ambient air, which has been categorised as polluted, as already discussed, thermal comfort of people inside of the building is vital and needs to be satisfied.

8.5.6 Thermal Comfort

As already discussed in chapter 6 section 6.4.22, humans are comfort seeking beings (Bluyssen 2009). This depends on the condition of mind expressing satisfaction with the thermal environment (BS EN ISO 7330). The possibility of satisfaction is affected by air temperature, humidity, air velocity and clothing; however, an adaptive system using building materials and the orientation of the building helps to provide significant amounts of comfort.

According to experts, as illustrated in figure 8.1 and 2, the use of the courtyard design system with open windows will provide the needed comfort. Although this depends on the time, weather condition and the season, (because Nigeria has two seasonal periods) with the current climate change, both seasons are observed all year round. This is in addition to the radiation from GF which was discussed in chapter 2 and illustrated in table 2.4 showing the level of radiation. Experts noted that in the ND, heat discomfort is usually almost unbearable from 12noon until about 3pm. Which might be due to the combination of heat radiation from GF and natural sunlight thus experts recommended that the use of plants as ventilation systems would provide cool air depending on the wind direction. However, they suggested that ceiling fans and HVAC could be installed. This electrical installation requiring the use of energy should be used when radiation from GF and the sun reaches a discomforting stage causing sweating and uneasiness, which in most cases is usually from 12 pm to 3pm.

Putting out the cooling condition required to meet the designed PS, experts noted that, it is very important that any mechanical cooling system employed should follow the information provided in the designed PS as adopting information from the manufacturers' manuals might lead to other health risks. Such health risks include cold, flu and pneumonia. Based on these health risks, Expert 2 was of the view that ceiling fans in addition to plants and open windows should provide the necessary thermal comfort level during such peak periods of high sunrise.

8.6 Adjustment during Evaluation

Although feedback was given during the demonstration phase, which provided an opportunity, interest, and willingness of architects in the study to produce drawings based on the designed PS, the evaluation stage provided another opportunity for experts who are the main users of the designed PS to provide an overall valid discussion of the usability and adaptiveness of the designed PS.

The PS was designed based on the explication of the problem, which was clearly gathered from both primary and secondary data showing that GF negatively affects building façades and IAQ. Based on the problem as clearly defined, the design of the solution relied on building codes, regulations and test procedures used in developed and developing countries to solve similar problems. This is because most problems as shown from data analysis included the lack of current codes and regulations with the NBC relying heavily on prescriptive specifications.

Due to the above, the research explored the use of updated codes meeting sustainability and well-being criteria and standards and adjusting such criteria where the requirement and performance on immediate climatic conditions are necessary. The stipulation of the performance required provided additional and intrinsic information necessary to design, select materials and construct schools in the ND. The designed PS provided performance requirements that should be met during the design and selection of materials and construction.

Based on the design, the indoor air has to meet specific limits as stated and this is depending on the choice of materials as the Experts are the sole specifiers in Nigeria and they determine the method and materials that can be used to achieve and meet the performance requirement. The need to meet this requirement and performance informed the two experts' designs of the PSB based on a natural ventilation system using double and triple filtration. Although with the current trend and the need for clean air, many innovative products, concepts, and designs are manufactured, almost all of them have merits and demerits.

Most of the demerits include the energy cost for assisting the operation of such purifiers. This was clearly a factor as both experts noticeably avoided the use of mechanical ventilation systems. This, therefore, correlates with comments from interviewee 5 during the demonstration phase from the interview session that:

"Electricity is a major setback in the choice of any mechanical purifier because you need to consider energy sources that can be used and in Nigeria, communities, where these gases are flared most times, do not have national grid lines not to mention power itself. But as a form of betterment to the living conditions of local residents around GF, a system that can filter outdoor air will be a brilliant step to achieving IAQ"

The difficulties of energy supply play a major role in the functionality of any mechanical system even in the developed world, as operation cost reduces the hour's such purifiers are allowed to run. Therefore, the experts resorted to the use of natural ventilation systems. Although Expert 1 added a third system which really does not need the use of energy unless, during the production stage, it could also serve as a mosquito net having dual purpose knowing that Nigeria is a mosquitoes infested area.

This adjustment did not change or alter the designed PS. It only provided an alternative means to achieving clean indoor air in schools. However, care has to be taking to grow and manage the plants for effective performance. More so, the experts agreed that there should be a process of effectively calculating a number of atmospheric substances indoor. This will provide the needed quantitative way to test a purification system if it is meeting the designed PS in schools in the VGF. Based on the purification system recommended and the materials meeting the performance standard, the designed PS will help professionals in the construction industry in Nigeria and in the ND in the construction of PSBs.

Another adjustment made to the designed PS was the provision made for roof lighting where the researcher recommended that materials used should provide adequate heat loss rather than heat gain meeting BS EN ISO 10211 standards. This is because the roof light area on buildings represents no more than 20% of the roof. However, day lighting is affected by the location, time and climate, even weather condition of a place where the building is located (Rockcastle and Andersen, 2013). Therefore, the complete understanding of the environment is required to minimise the use of artificial lighting. This is because natural lighting has been noted to have a high level of importance based on its value to human health and limitless performance (Barrett and Barrett, 2010). Following the discussion, the Experts noted that the use of materials that will provide day lighting in the research environment is not necessary. According to them, there is enough sunlight that will penetrate into the classrooms. This is based on the courtyard type of design, and the use of double glazed windows located in such a way that they allow the sunlight to penetrate inside of the building from all sides of the elevations as already illustrated in figures 8.1- 8.9. From their design, all sides of the elevations have windows with double glazed glasses fitted, in order to allow illumination. They, therefore, recommended that the roof should be covered with the same material.

Although the specification has been designed and architectural drawings produced as a proof of its workability and its effectiveness has been shown, it is important that the requirements specified should always be amended and updated to suit changing conditions, and advancing development and innovation. This is in line with the adjustment and the specialisation of NBS in the formation and formulation of codes and regulations that meet environmental changes (NBS, 2008). However, these adjustments should consider the immediate climatic and environmental conditions as pertains in the case of the ND.

8.7 Generalisation of Innovative Filtration System

Researchers have identified social, economic, political, environmental and technological impact of man-made exploration and exploitation for industrialisation and development on humans and the environment. This has led to various studies and innovations currently being explored, tested and used, although most are employed using mechanical systems that require the use of energy. However, some of these innovative systems have long time effects and running costs which, in most cases, outweigh its advantages. The recognition of the residual effects of these advancements has spawned the need for a natural system of innovative processes and procedures; this is in a bid to save energy, the move towards green environment and a means to achieving sustainability through the natural process.

Following the evaluation process above and the information gathered from experts, it is expected that the general consideration of this research, which is deterioration of building façades and indoor air, can be achieved if the designed PS is met.

8.8 Challenges to Evaluation

Based on the brief given to professionals in Nigeria, several major challenges were faced on the actualisation of the drawing showing the effectiveness of the designed PS in an environment such as the NDA was identified. These challenges include the need for advancement in design methods, adoption of current standards, regulations and codes, time factor, operational cost, implementation issues, Need for specifiers, lack of updating system for NBC, and fragmentation of professionals. Their main concerns are discussed below.

Table 8.2 Challenges from Evaluation

No	Challenges	Feedbacks and Comments
	Need for Advancement in Design Method	Architects noted that the most significant hindrance that poses harm, wrong specification and detailing is the slow pace in which Nigeria as a developing nation has embraced BIM and has constantly relied on traditional drafting methods with some cases of 2D and 3D and AutoCAD. According to them, it slows the pace at which design is done because every alteration requires a total redesign of a full section of a building. This makes the drawing take longer than is required and reduces the number of possible consultations for inputs from other professionals and clients on the performance required. This also reflects on the number of drawings produced and discussed, as noted that in an ideal situation every part of the building should clearly descript and discuss materials and construction procedure.
	Adoption of Current Standards	Experts noted that adoption of current standards is very important because materials are manufactured based on such standards, which meets most performance requirements. However, due to the lack of standards and the slow pace at which NBC is updated to meet changing needs, it is difficult for architects to design public schools based on codes not currently adopted in the Nigerian context. Materials used in most cases are substandard or either produced based on the standards currently in use and also provide avenues for manufacturers dumping prohibited, and not in use materials and cannot be sanctioned because of lack of updated standards
	Need for Specifiers	Though Experts were architects, it is noted that the use of just architects as both designers and specifiers makes the job less critical. Architects find it cumbersome to specify and even look out for specification requirements as provided by NBC. They, most times use their discretion and knowledge of what they remember and think it should be. However, if there were specifiers trained and knowledgeable more care will be taken to meet immediate environmental requirements.

		It is solely the responsibility and a duty that falls on the architect to specify whatever he thinks without been checked by another professional, this makes it nearly impossible for adherence or knowledge to new standards and regulations that guide material selections.
	Spacing and Ventilation	The most pressing challenge according to the architects was the possibility of achieving limits as stipulated in the designed PS. They further noted that though the provision of mechanical ventilation systems will help with thermal comfort inside of the building, the number of the pupil in a given classroom also defies the goal. They informed the researcher that public school construction is the responsibility of the government and in most cases, you find just one school that educates more than four communities. Which means that the population might either be over- estimated or under estimated because at present they the architects do not take cognisance of maximum admittance of pupils per given year. This means that pupils are put into classrooms with space definition which poses the problem for ventilation.
	Provision of Artificial Lighting	It was pointed out that although the area of research might not necessarily require artificial day lighting, in the event of thick clouds such as the one experienced in Port Harcourt due to the presence of soot, it becomes necessary that artificial day lighting using energy saving bulbs or fluorescent tubes should be fitted to produce needed illumination. They also noted that although in the developed world transparent materials such as glass, plastic roofing sheets are used on roofs adopted mainly for the provision of natural lighting, the harsh weather condition in the area of study, and the low maintenance culture defiles its purposes. However, if necessary, it was recommended that such roofing materials should be manufactured with the thickness that prevents heat radiation.
	Triple Filtration	Experts noted that further research should be undertaken on the use of face mask which will, in turn, have the dual purpose as a catalyst against mosquitos and an air purifier. This will provide an added purification system resulting to a triple filtration system following the introduction of trees (first filtration), hedges (second flirtation) and the advanced face mask which forms the third flirtation system. Rather than explore different types of purification systems that might not be adaptable in the ND environment and the energy cost associated with its operation, it is best to explore the use of face mask with no energy cost of powering the purification system. In addition, the need for the use of mechanical ventilation systems will not be necessary due to the air that will be coming from the plants used as purification systems.

		However, where such product is manufactured there will be the complete reduction in energy cost to a minimum as such usage will be for a particular pick period during the day when the heat generated cannot be absorbed by natural ventilation systems alone.
	Materials	Experts noted that most materials used in construction are imported. However, there are no stringent rules guiding the inspection of those materials and if there are, the NBC makes it almost impossible to carry out checks that meet current day regulations as used in the specification. They agreed that use of designed PS such as the one designed for this study will put more responsibility on all parties involved in the construction. This will provide additional scrutiny to material selection and use. According to them the purpose thus will be to meet PS rather than prescriptive specification as provided by the country's NBC code which fails to meet current standards and measures as seen in other parts of the world. Building materials used for school construction in an environment like that of the ND should undergo stringent inspection and tests carried out to confirm its suitability for the environment.
	Operational Cost	The physical representation of the designed PSB based on the DPS was hindered by the cost that will accrue from the actual construction. It was noted that in the future, further research should be carried out with practical construction using designed PS, where monitoring of IAQ will be carried out on the buildings as designed. This according to them will provide a complete evaluation and actual efficacy. Time as a cost was also an issue during the evaluation stage as the research was at the mercy of architects that had agreed to produce a drawing based on PS. This is made clear as 2 out of 3 architects were able to produce drawings.
	Fragmentation of Professionals	The isolation system in the construction industry makes it difficult to get unifying results, most research, and information used are individually derived either through personal efforts or through small grants, which do not provide an opportunity for advanced wholesome information. All professionals in the BE have different professional bodies without an umbrella body that can bring all of them together and information shared as that of the CIB.
	Lack of Updating System for NBC	The lack of updating system and research on new codes and standards affects the usability of the NBC as a guideline in exploring the adaptability of newer materials that are sustainable and meets environment specific criteria of GF and substances emitted causing adverse effects. Where there is an updating system, some materials used for construction in the VGF might not be present in the construction market and even if they are, they might not be

		used for public buildings like schools where stringent construction standards should be put in place.

8.8 Summary

This chapter has presented the evaluation process of the designed PS and the process undertaken to produce the drawings used for the purpose. A discussion of the need for a brief provided the requirements and instructions that should be followed in meeting the performance required. Though three architects agreed to produce drawing on making the formal request during the demonstration period, only two were able to produce drawings and discussed their choice and means to achieve the performance.

Following the need to meet significant issues as raised in the brief, the architects designed PSBs using a courtyard type of design, which according to them provides many factors that will help to satisfy the required performance standards.

Their design was used to compare with the main criteria used by most developed nations on meeting PSs for schools. This falls under the six main criteria that were discussed with consideration to the research problem of external façade of the building and IAQ. However, even if the objectives of the evaluation was achieved, the designed PS should be refined continuously, adjusted and updated to meet current requirements and codes as they change to fulfil environmental and human requirements. Furthermore, based on their design and suggested filtration systems, the initial suggestion of a mechanical purification was refined to conform to an advanced natural ventilation system. The next chapter draws the conclusion, recommendations and possibility of future research.

CHAPTER 9. CONCLUSION AND RECOMMENDATIONS

9.0 Introduction

This Chapter provides the results, contribution to knowledge, conclusions, and recommendations from the study. The chapter begins with a discussion of the main findings for each key stage of the research and follows on with a summary of the main conclusions and direction for future research. However, to achieve these results, there is the need to revisit the research aim, objectives, process and main findings and how the results met the research objectives. Limitations and opportunities for advancement from findings can be established through the generation of further research questions in the future.

9.1 Revision of the Research Aim and Process

The research commenced with a review of the literature, which provided an overview of the research problem. This overview provided a method of inquiry used to further narrow down relevant literature findings to the current study. Problems in the immediate environment were explicated using qualitative and quantitative data collection. This suggested that the deterioration of external façades of PSBs and poor IAQ is predominantly due to GF, and the prescriptive specification system provided by the NBC, which defies the innovative measure explored by the PS. Professionals noting that the effects of IAQ on the health of children in schools in the VGF have never been a concern and have been ignored when building also suggested a significant factor.

The aim of the study was to design a PS that can be used for the design, selection of materials and construction of PSBs in the VGF. Although PSBs are the primary reference point here, the effectiveness of the DSM is the usability of the solution in a wider and similar situation. The study achieved the above aim through the design, demonstration (also referred to as a weak form of evaluation) and the main evaluation of the designed PS.

The main evaluation allowed architects as experts on whom the responsibility rest because they are the designers and specifiers in the Nigerian context who design, select materials and supervise the construction of all buildings. The evaluation process was able to obtain very positive feedback from the intended users, which helped to achieve the aim of the research. However, in order to do this, the following objectives were set out as summarised:

- To identify from literature, the typology of building components in use in the ND climatic region of Nigeria;
- To identify the reported effects of GF on building components in other developing regions in general and the ND region in particular;
- To examine the effect of the current building materials and their sustainability for use in a GF environment;
- To examine the criteria used for ventilation system implored in schools in the vicinity of GF
- To design a PS for professionals in the BE meeting environment specific criteria to enable clean indoor air and durability of PSBs in the GF environment.
- To demonstrate through systematic iterative process, analysing and synthesising the designed PS and evaluate through drawings of PSBs illustrating the effectiveness in the NDAN

Additionally, the following research questions were posed;

1. Does the climatic region affect the typology of PSBs?
2. Are there reported effects of GF on building components in the ND region?
3. Is there a correlation between GF activities in an environment and the discolouration of the external/internal finishing of a building fabric?
4. Are there building materials that could be resistant to the impact of GF?
5. Are there building materials that are suitable for use in a GF environment?
6. What are the criteria used for the design of ventilation system in schools in the vicinity of GF?
7. How does an immediate environmental condition affect indoor air and PSB facades in the ND?
8. Are there robust techniques that can enhance the shelve life of building structure where metals are exposed to environmental conditions?

9. Are there possible design systems that can exclude contaminants, provide durable buildings and maintain the health of people?

10. Is there a PS guideline for professionals in the BE in GF areas that can be used to achieve better design and construction of PSBs?

9.1.1 Objective 1: To identify the typology of Public School Buildings (PSB) in use in the ND climatic region of Nigeria;

The first objective of the study was a review of the literature of the typology of building components in use in the ND area. The initial literature review from both the developed and developing worlds showed that the environmental conditions vary. This variation impacts on building materials differently thus different building components are used in each immediate climatic condition. For instance, the USA uses different building regulations, codes and guidelines from one state to another even though these states are in the same country. This is to provide, building components that will suit the immediate environmental conditions. Knowledge was gained on the system and strategies explored currently and considered in determining the environmental effects of GF activities carried out and their corrective action.

Exploring considerations from both developing and developed worlds with similar environmental defects, the review provided information that was used to explore deeper the issues focused on in the research. These issues were explored using open-ended questionnaires and semi- structured interviews which showed that Nigeria, in the ND area, depends on the NBC, which was last reviewed in 2006. In addition, the prescriptive specification nature of the NBC takes no account of the immediate environmental conditions of different regions in the country in the specification of its codes. This is because though the country's climatic conditions vary, the same NBC codes apply to all the regions.

Furthermore, it was realised from the explicated problem that there is no consideration given to IAQ during construction because nobody monitors air and its quality. The only known and used ambient air guideline in Nigeria is the FEPA standards of 1999 which provide limited information as discussed in chapter 2. Although the government constructs public schools, there are no guidelines or PS used as a professional guidance document for during design, selection of materials and construction of such buildings. Moreover, the over dependence on the NBC and the monopoly of architects doubling as both designers and specifiers in the Nigerian context, make inspection and monitoring of such construction almost impossible. In addition, the over-reliance on construction materials from different countries with different calibrations and codes makes it difficult to choose suitable materials.

Research from the developed world has shown that PS helps with the overall delivery and user satisfaction derived, whether the end user or the body providing such building. This has not been considered as a solution that can help both health and deterioration issues in buildings in Nigeria by the government, as witnessed in the ND. The review of the literature and further explication through data collection provided useful information for the design of the PS used to produce drawings for the PSB in the evaluation phase of the study.

9.1.2 Objective Two: To identify the reported effects of GF on building components in other developing regions in general and the ND region in particular

This objective was concerned with the identification of the reported effects of GF on building components in other developing regions and in the ND. To achieve this objective, relevant literature was reviewed in Chapters 2 and 3. This was followed by the collection of both quantitative and qualitative data through open-ended questionnaires and semi-structured interviews as discussed in Chapter 5. The findings of both the open-ended questionnaires and semi-structured interviews established the main issues relating to the deterioration of PSBs and poor IAQ.

Key findings drawn from this objective indicate that:

- Currently, GF results from open air burning for the exploration and exploitation of crude oil, carried out predominately in the ND at over 200 flaring sites. It is the mainstay of the Nigerian economy and ranked second highest GF country emitting more than 200 anthropogenic gases with degrading effects on buildings and humans.
- Due to the exploration and exploitation of oil and the rise in environmental awareness, BE professionals such as architects, estate surveyors and valuers, land surveyors, quantity surveyors, and health and environmentalists serves as the representative of those conversant with GF impact in the NDAN. Their levels of involvement are based on their roles, responsibilities, and information gathered during data collection in the VGF which helped to achieve some objectives of the study.
- It is also observed that the reliance on the NBC affects the type, selection of materials and construction of schools in the environment. This is because the NBC is more prescriptive in nature and does not take into consideration the immediate

environmental activities and their constituted effects on buildings and humans. This in some ways makes the architect handicapped as she is both the specifier and designer in the Nigeria context and tends to play leading roles during the design, selection of materials and construction stages.

- The issue of IAQ is completely not looked at or monitored during and after construction, which is clearly noted from data analysed as Nigeria currently uses the FEPA standard of 1999 with less information already discussed in chapter 2
- That from literature most developed countries are currently aware of the adverse effect of pollution on the environment both on buildings and indoor air and have over the years explored the use of materials that can withstand environmental challenges.
- The issue of IAQ in schools is a critical factor that has well-developed guidelines and standards including purification systems currently refined and adjusted to meet newer standards as published.
- PSBs in the NDAN are derelict in appearance, as illustrated in chapter 2, which shows pictorial evidence of a primary school in the ND. Such schools are mostly constructed with corrugated iron roofing sheets, with wooden windows and doors and finished with emulsion paints. Even where aluminium-roofing sheets are used, such materials tend to discolour within three years of installation, completely distorting its aesthetic value. Emulsion paints used are washed off and in most cases expose the plastered walls with ordinary Portland cement to atmospheric moistures, which leads to cracks and other forms of building decay.
- Apart from the architects, other BEP is the least involved in the design, selection of materials and construction projects such as schools, making it almost impossible for assimilation of important information that could be significant during design, selection of materials and construction.

9.2.3 Objective three: To examine the effect of the current building materials and their sustainability for use in a GF environment

The third objective set out using the framework of DSM was to examine the effect of current building materials and their sustainability for use in GF environments. There is little or no information with regards to PSBs and their derelict nature in the ND. From the analysis of open-ended questionnaires and semi-structured interviews, including evidence of pictures taken during the field survey, it was observed that:

- The most important factor is the implicit provision made in the NBC, which currently does not provide adequate information necessary or allow an innovative initiative to be explored by professionals. Respondents noted that they are handicapped by the provisions made in the code, which in most cases, provide an escape route for professionals who prefer to use cheap materials, which do not conform to the calibration system used in Nigeria.
- The lack of unification of calibration systems makes it almost possible to select from many products and check their sustainability and suitability of use in the ND. Professionals, therefore, adopt and use materials available in the market though they might be substandard.
- It is observed that the most frequently used roofing material is the corrugated iron roofing sheet though it shows a higher rate of deterioration, the application of slate roofing materials which currently show little deterioration effect due to GF is only being used for private residential constructions.
- It can be said that the lack of commitment shown by the Standard Organisation of Nigeria and the regulators that update and refine the NBC influence the type of materials available on the market. However, where the designed PS clearly explains the requirement and performance needed, both suppliers and professionals involved in construction will be held accountable and will readily meet client's requirements.

9.2.4 Objective four: To examine the criteria used for ventilation systems employed in schools in the vicinity of GF

The fourth object of this study was the second part of the research that dealt with IAQ and ventilation systems employed in schools in the VGF. This was achieved through evidence from primary data collection and pictures were provided. Although the research found some literature that generally discussed ventilation systems and the provision of air in buildings, none was particular about the effect on classrooms and the impacts inhaling such air. Even though chapters 2 and 3 discussed some of the factors that are associated with poor ambient air infiltrating into the building, Chapter 5 narrowed this down to the significant effects, and the key findings that address this object are as follows:

- Currently, the lack of an IAQ monitoring system in the ND and in the construction industry makes it easier for both suppliers of building materials and professionals in the BE to be absolved from any implication. Here, during the interview session, section respondents clearly stated that there is no such thing as IAQ provided or used for any form of the building. Even though there is evidence of carcinogenic effects of GF has constantly been researched and reported.

- It is also observed that simple open ventilation systems are predominately used as supply systems. Open windows and doors as illustrated in chapter 2 are the main systems of ventilation.
- The NBC provides an openable area of 4% of the floor area as ventilated space, which means that the provision made for window openings during construction without minding the total floor space for ventilation will be a maximum of 4%. This does not take into consideration the building type, construction type and the location of the building.
- From further questions posed using open –ended questionnaires, as analysed in chapter 5, ceiling fans are partially used while air conditioners are seldom used and air humidifiers/purifiers are never used in PSBs in the VGF.
- It was also observed that the lack of energy is a persisting disadvantage to the use of mechanical ventilation systems. Although this can be resolved where waste gas flared can be harnessed and converted into energy.
- It was observed that most of the schools are built in close proximity to GF stacks which impacts on the performance of pupils academically and leads to absenteeism of schoolchildren from the resultant health reasons or associated thermal comfort.

9.2.5 Objective five: To design a PS for professionals in the BE meeting environment specific conditions for durability and clean indoor air of school buildings in the VGF

The achievement of objective 3 led to the design of the PS that provided information that meets specific user requirements and allows the use of innovative materials currently being invented and manufactured to address present day environmental challenges. The literature review in Chapters 2 and 3 showed that in Nigeria and in the ND, PSBs are designed and built based on the prescriptive specifications as provided in the NBC.

Further investigation using open-ended questionnaires and semi-structured interviews as discussed in Chapter 5 showed the limitation due to current standards as provided in the NBC code. In addition, it revealed that there is no consideration given to indoor air as professionals including government officials neither talk nor provide any measure to regulate or monitor the air that infiltrates indoor.

The overall discussion provided the need to design a PS that as represented in Chapter 6. The designed PS was based on the established usefulness and positive reactions from developed nations such as the USA and UK. Its function is to provide an opportunity for innovation and use of environmentally friendly materials currently developed that meet environmental challenges such as the one in the current study.

The designed PS took into consideration the main aspects of the study, the external façade, which looked at the performance requirement enabling materials used for construction to achieve building durability and indoor air following the infiltration process of ambient air.

9.2.6 Objective six: To demonstrate the validity of the PS guideline for school buildings through systematic iterative process and evaluation using drawings

The sixth objective was achieved through a systematic and rigorous process also known as a weak form of evaluation. This was carried out with participants selected from the BE whose responsibilities and professionalism meet the requirements needed to provide proof of concept. This was carried out in the ND where the test participants were given the designed PS to provide the necessary information required to improve and refine the designed PS. This was effected through the use of open-ended questionnaires where participants were provided with additional information that helped to achieve the aim. Although the first iterative process provided less input, providing the PSIP attached to the open-ended questionnaires ensured a more realistic response.

The iterative process involved three separate processes, with analysis carried out at the completion of each process. Based on the results, the designed PS was refined (as discussed and presented in Chapter7). Overall, the test results were very encouraging. Respondents found the designed PS as an important and significant document. This was confirmed as all PSIP distributed to the respondents were retained. All respondents insisted that they were all keeping their copies because the information provided in it was useful. Furthermore, this process provided an opportunity for the evaluation experts to willingly accept to draw and design PSBs for the last process as a test of the usability.

This study set out to design a PS to serve as a document to be used in the design, selection of materials and construction of PSBs in the VGF of Nigeria. The designed PS was developed based on literature review (Chapters 2 and 3), semi-structured interviews and open-ended questionnaires data collected and analysed (Chapter 5). The designed PS was tested through a demonstration also known as proof of concept (Chapters 6 and 7). The evaluation of the designed PS was achieved through a confirmation process with selected practitioners as discussed in Chapter 8. Specifically, the evaluation of the designed PS was to produce drawings for PSBs that meet the PS. Here the main goal was to achieve the overall aim of the study, showing that the designed based PS can achieve durability, thus reducing the deterioration rate and providing clean indoor air though such buildings are located in an environment with the emission of more than 200 anthropogenic substances as already discussed in Chapter 2.

It is established that architects who are generally the evaluation experts and predominately the specifiers and designers in the Nigerian context, confirmed that the designed PS is comprehensive. They also noted that it provides the opportunity and allows innovative thinking and exploration, thus meeting environmental challenges and should be adopted as a guide to designing buildings in other parts not included in this study. Although challenges were encountered as discussed in section 8.7, experts were satisfied and keen to use the designed PS information in place of the NBC that they are currently using.

9.3 Limitation of this Research

The research had some limitations, as follows:

Information constraints: due to the novelty of the study area, there were limited data available from the study environment. This made it more cumbersome and time-consuming for the researcher to gather more data inductively using both qualitative and quantitative techniques.

Research participant's constraint: Although the initial data collection process had many professionals willing to participate in the exercise as well as in the demonstration as discussed in chapters 5 and 7, the evaluation had limited number of users able to provide the required information by representing the designed PS in architectural drawings of a school. This was due to the small number of experts willing to perform this task, as according to them, it takes approximately four to five months to put together a drawing that meets clients' requirement.

A short period of demonstration and evaluation sessions: This research was bound by the strict requirements as it was subjected to formal approvals at designated milestones. Although the demonstration and evaluation sessions were carried out accordingly, the sessions depended on the availability of the demonstrators and expert evaluators involved in this research. However, the demonstration and evaluation sessions though were achieved by designing the PS, and architects as experts produced the drawings of PSBs to meet the performance requirement. Time limitations restricted the researcher to the number of respondents that returned the demonstration questionnaires and the two architects that were able to produce the architectural drawings for the PS.

The study only considered external facades and ambient air infiltrating inside classrooms and did not consider furniture and other indoor facilities. Due to the wide range of issues covered by both external façades and IAQ, this study is limited to those consequences that heighten deterioration and cause infiltration of polluted air because of GF.

There was no ventilation rates measurement, neither was there any use of air monitoring system for IAQ as none is currently employed in the study area. There was no material test carried out on the rate of corrosion caused by acid rain and deterioration of other atmospheric depositions based on a number of anthropogenic substances emitted due to GF in the immediate environment.

In the analysis of the questionnaires and interviews, responses from professionals as selected were used without inputs from users of such buildings (pupils and teachers). This is based on the point that the PS relies on inputs from BE in the developed world making it a wholesome document for the anticipated users of the designed PS.

In this study, the ventilation effectiveness was assessed based on visual observation of the proximity of GF sites to schools, researcher's involvement in environmental pollution assessment due to oil spillages and responses from respondents working in the study area. The study did not consider any other pollution source from building materials, coal burning or traffic. It is generally accepted that pollution from GF is enough to cause both building deterioration and health impact affecting both academic performance and absenteeism.

The designed PS, though was used to produce a building as discussed in Chapter 8, no real life construction was undertaken to prove its effectiveness. The facemask filtration system recommended forming the triple filtration system was also not tested for effectiveness. Both the triple filtration and double filtration systems designed to meet the PS provided some challenges as experts were not able to provide concrete affirmation to their design, as there were no test procedures carried out thus the solutions are assumed to provide an effective filtration system

9.4 Contribution to Knowledge

The novel contribution of this research presented in terms of PS document rather than prescriptive specification as provided by the NBC. This will help professionals design, select materials and construct more durable buildings that will reach their shelve life and provide clean indoor air even if the open ventilation system is used in such vicinity. The demonstration process with iterative steps provided a valid and rigorous test by different professionals from the BE knowledgeable in construction who have been working in the study area for lengthy periods. This provided an opportunity for experienced and professional input into the designed PS that helped to refine it in meeting current environmental needs and requirements.

Furthermore, the use of architects as experts for the evaluation process as the main users of the designed PS makes robust and effective proof of the concept. This research has demonstrated that the designed PS, when used, can enhance the design, selection of materials and construction type used in polluted environments like the ND. While also improving the information base of users of the designed PS as well as refining the ability of BEPs in making well-informed decisions while designing, selecting materials and constructing buildings around VGF.

This would enhance buildings' durability and the quality of air inhaled and subsequently improves the possibility of refining and updating the NBC. This research also clearly supports the inputs made by professionals in the ND of Nigeria and their contributions in the refinement of the designed PS. Since the designed PS was developed based on the direct refinement from practicing BE experts in the ND area of Nigeria and has been evaluated by real users of the designed PS practicing in the Nigeria ND, its design can consequently be said to be effective.

In addition, the thesis also presents a novel contribution by reviewing and producing various themed areas and bodies of knowledge including, GF and its effect, environmental degradation due to GF, PS, IAQ and purification systems. Moreover, in order to accomplish the research, the following main activities were carried out:

(1) Gaining an understanding of the environmental issues due to GF and of the existing approaches in addressing those issues;
(2) Gaining an understanding of the impact building codes and regulations have on the design of buildings to meet environmental challenges
(3) The role of BEPs on achieving clean indoor air
(4) Looking at the concept of a PS as a means to the design, selection of material and construction of PSB since, the designed PS was based on the performance requirements from practicing BE experts;
(5) The testing of the designed PS by architects who are the real users of the PS and also work in the study environment;

Therefore, the design of the PS benefited from different theoretical and practical lenses and expertise. Finally, one of the strengths of the DSM is relying on its epistemology of "knowing through making". Obviously, this research integrated for the first time the external building façade and clean indoor air for the purpose of providing BEPs with more effective, environment-specific and considerable means of averting environmental pollution. This is in line with the aims of DSR which is to "produce and apply knowledge of tasks or situations in order to create effective artefacts" for improving practice (March and Smith, 1995). As a result, this research produce totally new information aimed at environmental performance requirement and specification for building design, material selection and construction in the VGF.

Although, there are many innovative filtration systems both mechanical and natural explored in countries with current research interest, this is made apparent during the data collection process. Along the process, this research identifies a satisfactory number of, and suitable innovative systems and strategies to clean indoor. One of the important contributions is that the evaluators explore natural systems of ventilation through triple and double filtration processes using an improvised face mask as a filtration system. This is providing a ground breaking marvel that could change and help the filtration of poor indoor air around the NDA. The second important contribution is the dual-purpose possibility of the improvised face mask used as both a filtration system and an insect prevention net. The third important contribution is the use of hedges and shrubs in a non-parallel sequence as a filtration process, thus deemed to be important in enhancing and achieving clean air.

Additionally, through the evaluation process in this research, it was found that the courtyard system of school construction provides the necessary requirement in the designed PS. The courtyard allows the provision of required sunlight thus delivering adequate day lighting which might achieve the necessary illuminance during school hours without necessarily using artificial forms of lighting. It also provides the medium of heat exchange to make the classroom thermally comfortable during school periods unless in peak times when ceiling fans can be used to provide the required comfort level as already discussed in chapter 6 and7. From this research, materials imported can be checked and monitored while, suppliers, designers, and clients can also be made accountable in respect of performance to meeting the specification provided in the designed PS. These would offer some tangible help for future development by manufacturers who are specialise in construction materials to be environmentally cautious and considerate when producing materials for construction in areas like the ND. In addition, it provides a whole new process of design, selection of materials and construction process for schools and other types of buildings as well.

9.5 Recommendations for Future Research

Actual replication and proactive use of the designed PS will provide the concrete realisation of the efficacy of the research while also offering the needed opportunity for the manufacture of materials necessary to achieve performance requirements. However, owing to the constraints of no measurement and monitoring of indoor air or pro-active inspection and monitoring of materials used for construction of schools, many simplifications and assumptions were made. Thus, the study is not perfect and therefore, the following recommendations are hereby suggested;

9.5.1 Full Measurement

Owing to the difficulty or the non-existence of air monitoring devices or procedures in schools in the NDAN, it was necessary to extrapolate from all chemical substances affecting indoor air through infiltration of air flow movement in the VGF. Schools around the ND use open windows and doors as ventilation systems where mechanical systems such as ceiling fans and air conditioners are hardly used as discussed and analysed in chapter 5. The quality of air in such schools was not measured; neither were the impact of adjoining factors that cause air pollution such as furniture, biomass and fumes from vehicles were considered. Thus, it is recommended that in future a full monitoring device may be used to conduct full-scale measurements rather than relying on expert’s points of view and experience alone. This will provide the required information by considering the adverse effects that the total emissions cause on the buildings and health of schoolchildren. However, the discussion was based on data gotten from literature and responses from respondents without carrying out any test on building materials and monitoring indoor air in such schools. Thus, it is recommended that, tests should be carried out on external materials used to monitor indoor air and measured with ambient air because of the infiltration system and ventilation system used.

9.5.2 Triple Natural ventilation

Based on the comments made by architects during the evaluation process, it was noted that energy is the main challenge that will hinder the supply of electricity to power artificial ventilation systems. Therefore, out-of-the box recommendation of the possible refinement of the face mask used in China and other countries with severe air pollution can be researched, refined, manufactured and used to filter the ambient air. Thus, windows and doors can be opened without the infiltration of polluted air into the building while also serving a dual process of insect prevention. This, according to the architect, will provide clean air, and work as a natural system and mosquito net without any cost incurred from installation and operation of any mechanical ventilation. Therefore, it is recommended for material scientists and other building material manufacturers to consider exploring this material as means for achieving a dual-purpose benefit.

9.5.3 Indoor Air Quality (IAQ)

The major outdoor source of indoor air pollutants in the study area is GF. The severity of these substances emitted, deposited, and inhaled in the study area was evaluated through psychosocial perception only. Even though, it is difficult to ascertain the quantity of chemicals in an indoor environment, information from reputable organisations such WHO, EPA and UN shows that the study area is surrounded by poor air quality. Therefore, it is recommended to ascertain the amount of GF substances inhaled indoor and the level of exposure to such buildings that leads to deterioration to determined using scientific methods.

9.5.4 Thermal Comfort (TC)

This study focussed on two aspects; deterioration of external building façades and IAQ. However, thermal comfort (TC) is one of the major parameters for consideration in buildings' indoor environment. Owing to scope and data constraint, though the present study included TC in the research no measurements were carried out. Nevertheless, it was suggested that a mixed methods could be adopted. This is when the heat radiation is very intense and at such times, TC through natural ventilation systems will be inadequate. This is because the heat inside will be high and during that period, the use of air humidifiers or air conditioners, which in most cases has a level of air purification mechanisms, can be used. It is hoped that new research could explore the use of facemasks or a mixture of artificial and natural ventilation systems, which could help reduce poor IAQ in GF areas of the ND. There is the need for the development of a system that will aid specification, which the PS could be updated regularly to meet international standard on IAQ, code and regulation amendments.

9.5.5 Building Deterioration

The reliability of the descriptions and pictures provided in chapters 2 and analysis in chapter 5 depends mainly on the existing building and information from professionals in the study area. In the present study, tests on the corrosion rate, discolouration of roofing materials on corrugated zinc roofing material, flaking of paints and cracking on walls of PSBs, are not considered. The level of the impact of atmospheric substances that accelerate the deterioration rate may likely be due to the effect of some and not all the substances as discussed in chapters 2 and 3. Therefore, it is recommended that, such materials that show deterioration rate should be tested against the atmospheric substances for more stringent performance requirements rather than an assumed acidity level, which might be lower or higher than specified.

9.6 Conclusion

The adverse effects of poor IAQ and the durability of external façades of buildings have increasingly become a reoccurring decimal in all areas of research, for instance, sustainability, resilience and now intelligent/smart city, all require satisfactory consideration and implication of all materials and provisions for air quality. Therefore, this research addressed two research problems, firstly the deterioration rate of the external façade and secondly the determination of the impact of GF on IAQ on PSBs and pupils, with the aim of designing a PS to help combat the effect of GF on the external façade and IAQ of schools in the ND area of Nigeria. Adopting a DSM, the demonstration of the designed PS shows that it is not possible to achieve improved building information from prescriptive specification rather adopting PS with requirements meeting environmental challenges provide advantages that resolves issues such as the research problem.

Through the design of a PS, it was demonstrated that it is possible to support BEPs with additional information and documents which will provide information during design, selection of materials and construction of buildings in the VGF. Also, it can be concluded that the DSM was appropriate for the chosen type of research and future research in the BE within the construction industry may refer to this process.

The main conclusions from the problem analysis were that the provision of NBC lacks updated information as used in the developed world, however, the introduction of PS leads to the use of innovative materials that could reduce the impact of GF on buildings. It was also noted that in Nigeria, IAQ is yet to be an important issue in the construction industry as nobody, even the professionals look at it, neither is there a monitoring system provided to check if indoor air is clean. Since open doors and windows are predominately used for PSB construction. It also emerged that the absence of a uniform calibration system impacts on the possibility of inspecting materials imported and used in the construction industry as most building materials are calibrated based on the country of origin. In addition, since the architect solely has the responsibility as both the specifier and the designer, it makes it more difficult to inspect and check if requirements meet standards or performance as it is in their duty to discharge such services.

During the exploration of potential solutions following the information from findings in the VGF, the research designed the PS based on current procedures, process, and requirements including codes and regulations and information from data collected and analysed. This can help improve the durability and longevity of PSBs thereby improving on the aesthetics. It also emerged that though the ND environment is polluted, specifying limits of substances allowable to meet clean indoor air will help protect the health of vulnerable schoolchildren. Using rigorous iterative processes, the solution designed was refined and adjusted to meet the immediate environmental criteria of the ND, such as the cooling requirement, thermal comfort level and the limits to NOx, were all adjusted based on professional opinion. The significance of the selected method provided another opportunity to test the designed solution. This was also carried on in the research domain area and was evaluated by the users of the solution. In addition, as means for testing the designed solution, evaluation was carried out and experts with more than twenty years wealth of experience in the ND area were used for this test. The professionals used the designed solution to produce architectural drawings, which showed proof of concept, and that by using the PS, buildings can meet longevity standards and improve on indoor air. The emergent was the design of PSBs using courtyard type of design, which provides adequate day lighting that might not require artificial lighting but where necessary energy bulbs could be used is seen as efficient and appropriate for the study area. It also emerged that the natural ventilation system using vegetation planted in a non-parallel form can purify the ambient air before it enters indoors to be inhaled. It also emerged that face masks can be improved on and used as a purification system to achieve a dual purpose; as an insect prevention net and an air purifier.

In conclusion, the designed PS can play an important role in the design, selection, and construction of schools in the NDAN where GF occurs on a daily base. One of the main contributions of this research is that the designed PS was commended and potentially accepted by all the participants because all the PSIPs attached to the demonstration questionnaires were retained by the participants. This provides an opportunity to expand and continue the research into this subject in the future as already discussed in section 9.6. By working further in this particular area, it might be possible to produce updated PS to meet other aspects of buildings. The outcome of this study is significant to all BEPs not just architects as an input towards the new design, selection of building material and construction of buildings in the VGF.

References

Abdulkareem, A. and A. Kovo (2006). "Simulation of the viscosity of different Nigerian crude oil." Leonardo Journal of Sciences **8**: 7-12.

Abdulkareem, A. S., et al. (2012). Oil Exploration and Climate Change: A case study of heat radiation from gas flaring in the Niger Delta area of Nigeria. Sustainable Development-Authoritative and Leading Edge Content for Environmental Management, InTech.

Abeysundara, U. Y., et al. (2009). "A matrix in life cycle perspective for selecting sustainable materials for buildings in Sri Lanka." Building and Environment **44**(5): 997-1004.

Action, E. R. (2005). "Friends of the Earth Nigeria (2005)." Gas flaring in Nigeria: a human rights, environmental and economic monstrosity.

Actions, E. R. (2005). Gas flaring in Nigeria: A human rights, environmental and economic monstrosity. Amsterdam, The Netherlands, Environmental Rights Action/ Friends of the Earth.

Adejimi, A. (2005). Poor building maintenance in Nigeria: Are Architects free from blames. Being paper presented at the ENHIR international conference on "Housing: New challenges and innovations in tomorrow's cities" in Iceland.

Adenuga, O. A. (2013). "Factors Affecting Quality in the Delivery of Public Housing Projects in Lagos State, Nigeria." International Journal of Engineering and Technology **3**(3): 332-344.

Agbola, T. and T. Olurin (2003). "Landuse and Landcover change in the Niger delta." Excerpts from a Research Report presented to the Centre for Democracy and Development.

Aghalino, S. (2009). "Gas Flaring, Environmental Pollution and Abatement Measures in Nigeria, 1969-2001." Journal of Sustainable Development in Africa **11**(4): 219-238.

Aibinu, A. A. and H. A. Odeyinka (2006). "Construction delays and their causative factors in Nigeria." Journal of Construction Engineering and Management **132**(7): 667-677.

Air, P. (2015). "Reviews and General Information on Air Purifiers." from http://www.plentyair.com.

Ajao, E. and S. Anurigwo (2002). "Land-based sources of pollution in the Niger Delta, Nigeria." Ambio: 442-445.

Ajibola, K. (1997). "Ventilation of spaces in a warm, humid climate—Case study of some housing types." Renewable energy **10**(1): 61-70.

Ajibola, K. (2001). "Design for comfort in Nigeria—a bioclimatic approach." Renewable energy **23**(1): 57-76.

Akadiri, P. O. (2015). "Understanding barriers affecting the selection of sustainable materials in building projects." Journal of Building Engineering **4**: 86-93.

Akadiri, P. O., et al. (2013). "Multi-criteria evaluation model for the selection of sustainable materials for building projects." Automation in Construction **30**: 113-125.

Akbari, H., et al. (2005). "Cool colored roofs to save energy and improve air quality." Lawrence Berkeley National Laboratory.

Aken, J. E. v. (2004). "Management research based on the paradigm of the design sciences: the quest for field-tested and grounded technological rules." Journal of management studies **41**(2): 219-246.

Akeredolu, F. and J. Sonibare (2004). "A review of the usefulness of gas flares in air pollution control." Management of Environmental Quality: An International Journal **15**(6): 574-583.

Akobundu, A. N. (2014). "Impact of Gas-Flaring on the Quality of Rain Water, Groundwater and Surface Water in Parts of Eastern Niger Delta, Nigeria." Journal of Geosciences and Geomatics **2**(3): 114-119.

Akuaka, M. U. (2012). "Neglecting the public and focusing on the private:" The situation of education in Nigeria"."

Alaba, o. O. (2014). "the effect of gas flare in the health and buildings of the indigene in oil producing communities ". Retrieved 25/11/2014, 2014, from http://www.slideshare.net/arcfemi/gas-flaring.

Alder, L. (2000). "common indoor pollutants: sources and Helath impacts." Retrieved 4/11/2014, 2014, from http://www2.ca.uky.edu/hes/fcs/factshts/HF-LRA.161.PDF.

AlSehaimi, A., et al. (2012). "Need for alternative research approaches in construction management: Case of delay studies." Journal of Management in Engineering **29**(4): 407-413.

Alshamrani, O. S., et al. (2014). "Integrated LCA–LEED sustainability assessment model for structure and envelope systems of school buildings." Building and Environment **80**: 61-70.

Amaratunga, D., et al. (2002). "Quantitative and qualitative research in the built environment: application of “mixed” research approach." Work study **51**(1): 17-31.

Ana, G. R. (2011). "Air Pollution in the Niger Delta Area: Scope, Challenges and Remedies." The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources, InTech—Open Access Company, Rijeka: 182-198.

Ander, G. D. (2003). Daylighting performance and design, John Wiley & Sons.

Andersen, A. and C. Hopkins (2005). "Sound Measurements and Natural Ventilation in Schools." International Journal of Ventilation **4**(1): 57-69.

Andersen, R., et al. (2012). Efforts to reduce flaring and venting of natural gas world-wide, Norwegian University of Science and Technology, Trondheim.

Andersen, R. D., et al. (2012). Efforts to reduce flaring and venting of natural gas world-wide. TPG 4140 – Natural Gas. Trondheim, Norwegian University of Science and Technology, .

Anejionu, O. C. D., et al. (2015). "Detecting gas flares and estimating flaring volumes at individual flow stations using MODIS data." Remote Sensing of Environment **158**: 81-94.

Argo, J. (2001). Unhealthy Effects of Upstream Oil and Gas Flaring: A report prepared for Save our Seas and Shores (SOSS) for presentaiotn before the Pubcli Review Commission into Effects of Potential Oil and Gas Exploration, Drilling Actvities within Licenses 2364, 2365, 2368.

ASCE, A. S. o. C. E. (2010). Minimum design loads for buildings and other structures. Virginia American Society of Civil Engineers.

ASHRAE (2016). The Standards for Ventilation and Indoor Air Quality: Ventilation for Acceptable Indoor Air Quality Alanta The American Society of Heating, Refrigeration and Air-Conditioning Engineers

ASHRAE, A. S. o. H., Refrigerating and Air-Conditioning Engineer (2010). Ventilation for Acceptable Indoor Air Quality. Atlanta.

ASTM, A. s. f. T. a. M. (2011). Standard Practice for Operating Salt Spray (Fog) Apparatus, ASTM.

ASTM, A. S. f. T. a. M. (2015). Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates, ASTM**:** 11.

ASTM, T. A. S. f. T. a. M. (2013). Standard Practice for Unfiltered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings, ASTM**:** 5.

AStroma (2010). "Air Tightness Compliance." Retrieved 24/11, 2016, from http://docplayer.net/23937232-Air-tightness-compliance.html.

Atuma, M. I. and V. N. Ojeh (2013). "Effect of Gas Flaring on Soil and Cassava Productivity in Ebedei, Ukwuani Local Government Area, Delta State, Nigeria." Journal of Environmental Protection **4**(10).

Awofadeju, A., et al. "Evaluation of Locally Produced and Imported Reinforced Steel Rods for Structural Purposes in Nigerian Market."

Ayeni, A. J. and M. A. Adelabu (2011). "Improving learning infrastructure and environment for sustainable quality assurance practice in secondary schools in Ondo State, South-West, Nigeria." International Journal of Research Studies in Education **1**(1).

Baetens, R., et al. (2010). "Properties, requirements and possibilities of smart windows for dynamic daylight and solar energy control in buildings: A state-of-the-art review." Solar Energy Materials and Solar Cells **94**(2): 87-105.

Baiche, B., et al. (2006). "Compliance with building regulations in England and Wales." Structural Survey **24**(4): 279-299.

Baker, L. and H. Bernstein (2012). "The impact of school buildings on student health and performance." The Center for Green Schools.

Baker, M. J. (2000). "Writing a literature review." The Marketing Review **1**(2): 219-247.

Bakó-Biró, Z., et al. (2012). "Ventilation rates in schools and pupils' performance." Building and Environment **48**: 215-223.

Baldinelli, G. and F. Bianchi (2014). "Windows thermal resistance: Infrared thermography aided comparative analysis among finite volumes simulations and experimental methods." Applied Energy **136**: 250-258.

Ball, J., et al. (2000). "Stone cleaning: comparing perceptions with physical and financial implications." Journal of Architectural Conservation **6**(2): 47-62.

Barab, S. and K. Squire (2004). "Introduction: Design-Based Research: Putting a Stake in the Ground." The Journal of the Learning Sciences **13**(1): 1-14.

Baranzini, A. and J. V. Ramirez (2005). "Paying for quietness: the impact of noise on Geneva rents." Urban studies **42**(4): 633-646.

Barrett, A. M. (2009). "The education Millennium Development Goal beyond 2015: prospects for quality and learners." Bristol,, UK: EdQual. EdQual working paper **13**.

Barrett, P. and L. Barrett (2010). "The potential of positive places: senses, brain and spaces." Intelligent Buildings International **2**(3): 218-228.

Barrett, P. S., et al. (2015). Clever classrooms: Summary report of the HEAD project, University of Salford.

Bassuoni, M. and M. Nehdi (2009). "Durability of self-consolidating concrete to different exposure regimes of sodium sulfate attack." Materials and structures **42**(8): 1039-1057.

Batagarawa, A. (2012). "Benefit of conducting energy calculations in the built environment of nigeria."

Baumüller, H., Donnelly Elizabeth, Vines Alex And Weimer Markus, Chatham House, United Kingdom (2011). The Effects Of Oil Companies' Activities On The Environment, Health And Development In Sub-Saharan Africa. Belgium, Directorate-General For External Policies Of The Union

Bazeley, P. (2007). QUALITATIVE DATA ANALYSIS WITH NVIVO, JSTOR.

Beard, R. and G. Wertheim (1967). "Behavioral impairment associated with small doses of carbon monoxide." American Journal of Public Health and the Nations Health **57**(11): 2012-2022.

Berdahl, P., et al. (2008). "Weathering of roofing materials–an overview." Construction and Building Materials **22**(4): 423-433.

Berdahl, P., et al. (2008). "Weathering of roofing materials – An overview." Construction and Building Materials **22**(4): 423-433.

Berge, B. (2009). The ecology of building materials, Routledge.

Berhane, K., et al. (2014). "Longitudinal effects of air pollution on exhaled nitric oxide: the Children's Health Study." Occupational and environmental medicine: oemed-2013-101874.

Bhatia, S. (2001). "Environmental pollution and control in chemical process industries." Khanna ub,, Delhi: 365-391.

Bichard, E. and A. Kazmierczak (2012). "Are homeowners willing to adapt to and mitigate the effects of climate change?" Climatic Change **112**(3-4): 633-654.

Blaikie, N. (2009). Designing Social Research. Cambridge.

Block, M. and V. Bokalders (2010). The Whole Building Handbook:" How to Design Healthy, Efficient and Sustainable Buildings", Routledge.

Blocken, B. and J. Carmeliet (2004). "A review of wind-driven rain research in building science." Journal of Wind Engineering and Industrial Aerodynamics **92**(13): 1079-1130.

Blondeau, P., et al. (2005). "Relationship between outdoor and indoor air quality in eight French schools." Indoor Air **15**(1): 2-12.

Bluyssen, P. M. (2009). The Indoor Environment Handbook: How to make buildings healthy and comfortable, Routledge.

Blyth, A. and J. Worthington (2010). Managing the brief for better design, Routledge.

Bordass, B., et al. (2001). "Assessing building performance in use 2: technical performance of the Probe buildings." Building Research & Information **29**(2): 103-113.

Borgatti, S. (2005). "Introduction to grounded theory." Retrieved May **15**: 2010.

Borge-Diez, D., et al. (2013). "Passive climatization using a cool roof and natural ventilation for internally displaced persons in hot climates: Case study for Haiti." Building and environment **59**: 116-126.

Bovens, M. and P. ‘t Hart (2016). "Revisiting the study of policy failures." Journal of European Public Policy **23**(5): 653-666.

Bowersox, V. C., et al. (1990). "Acid rain, a world-wide phenomenon: a perspective from the united states." International Journal of Environmental Studies **36**(1-2): 83-101.

Bradshaw, V. (2010). The building environment: Active and passive control systems, John Wiley & Sons.

Branham, D. (2004). "The wise man builds his house upon the rock: The effects of inadequate school building infrastructure on student attendance." Social Science Quarterly **85**(5): 1112-1128.

Brimblecombe, P. and C. M. Grossi (2005). "Aesthetic thresholds and blackening of stone buildings." Science of The Total Environment **349**(1–3): 175-189.

Brimblecombe, P. and C. M. Grossi (2009). "Millennium-long damage to building materials in London." Science of the Total Environment **407**(4): 1354-1361.

Broere, W. (2008). "The elusive goal to stop flares." Shell World.

Brown, G. (2013). Accelerating Progress to 2015 Nigeria. A report series to the UN special Envoy for Global Education. UK, United Nations.

Bruce, N., et al. (2000). "Indoor air pollution in developing countries: a major environmental and public health challenge." Bulletin of the World Health Organization **78**(9): 1078-1092.

Bruce, N., et al. (2014). "WHO indoor air quality guidelines on household fuel combustion: Strategy implications of new evidence on interventions and exposure–risk functions." Atmospheric Environment.

Brunekreef, B. and S. T. Holgate (2002). "Air pollution and health." The Lancet **360**(9341): 1233-1242.

Bryman, A. (2003). Quantity and quality in social research, Routledge.

Bryman, A. (2012). Social research methods, Oxford university press.

BSI, B. S. I. (2009). Performance of windows and doors. Classification for weathertightness and guidance on selection and specification. UK, BSI**:** 24.

BSI, T. B. S. I. (2005). Ambient air quality. Standard method for measurement of benzene concentrations. Pumped sampling followed by thermal desorption and gas chromatography. UK, BSI.

BSI, T. B. S. I. (2012). Ambient air. Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence. UK, BSI

BSI, T. B. S. I. (2012). Ambient air. Standard method for the measurement of the concentration of ozone by ultraviolet photometry. UK, BSI.

BSI, T. B. S. I. (2012). Ambient air. Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence. UK, BSI.

BSI, T. B. S. I. (2013). Designing for material efficiency in building projects —Part 1: Code of practice for Strategic Definition and Preparation and Brief. UK, BSI Standards Limited.

BSI, T. B. S. I. (2014). Ambient air Standard gravimetric measurement method for the determination of the PM10 or PM2,5 mass concentration of suspended particulate matter. UK, BSI Standards Limited

BSI, T. B. S. I. (2015). Photocatalysis. Batch mode test methods. Part 1. Measurement of efficiency of photocatalytic devices used for the elimination of VOC and odour in indoor air in active mode. BSI.

Burke, M. (2007). "Making choices: research paradigms and information management: Practical applications of philosophy in IM research." Library review **56**(6): 476-484.

Busch, J. F. (1992). "A tale of two populations: thermal comfort in air-conditioned and naturally ventilated offices in Thailand." Energy and buildings **18**(3): 235-249.

Butt, T., et al. (2010). Sustainable development and climate change induced obsolescence in the built environment. International Sustainable Development Research Conference, Hong Kong, China, May.

Byrne, M. (2001). "Grounded theory as a qualitative research methodology." AORN Journal **73**(6): 1155-1156.

Caldwell, B. (2010). Beyond positivism, Routledge.

Calfee, R. D. and W. W. Murchison (1998). "Demystifying window and door selection for single-family homes in high-wind environments." Journal of Wind Engineering and Industrial Aerodynamics **77**: 97-106.

CAMPBELL, P. (2012). More criticism in pipeline for Shell over handling of Niger Delta spillages. Daily Mial.

Caracelli, V. J. and J. C. Greene (1993). "Data analysis strategies for mixed-method evaluation designs." Educational evaluation and policy analysis **15**(2): 195-207.

Carcary, M. (2009). "The research audit trial–enhancing trustworthiness in qualitative inquiry." The Electronic Journal of Business Research Methods **7**(1): 11-24.

Cartegena, A. (2014). "cladding that eats pollution." 2014, from tectonicablog.com

Carter, D. (1984). "The lighting of the St. Mary's School, Wallasey." Building and environment **19**(4): 209-215.

Chan, A. P. and C. Tam (2000). "Factors affecting the quality of building projects in Hong Kong." International Journal of Quality & Reliability Management **17**(4/5): 423-442.

Chand, S. (2013). "Cracks in building and their remedial measures."

Charmaz, K. (2011). "Grounded theory methods in social justice research." The Sage handbook of qualitative research **4**: 359-380.

Chatterjee, P. and S. Chakraborty (2012). "Material selection using preferential ranking methods." Materials & Design **35**: 384-393.

Chatzidiakou, L., et al. (2012). "What do we know about indoor air quality in school classrooms? A critical review of the literature." Intelligent Buildings International **4**(4): 228-259.

chemeng (2011). "Adopting Sustainability In All Aspects Of Chemical Engineering." Retrieved 30 June, 2014, from http://sustainablechemeng.blogspot.co.uk/2011/05/shell-nigeria.html.

Chen, J. and C.-s. Poon (2009). "Photocatalytic construction and building materials: From fundamentals to applications." Building and Environment **44**(9): 1899-1906.

Cheng, M.-Y. and C.-S. Chen (2011). "Optimal planning model for school buildings considering the tradeoff of seismic resistance and cost effectiveness: a Taiwan case study." Structural and Multidisciplinary Optimization **43**(6): 863-879.

Chew, M., et al. (2004). "Maintainability of wet areas of non-residential buildings." Structural Survey **22**(1): 39-52.

Chew, M. Y. L. (2005). "Defect analysis in wet areas of buildings." Construction and Building Materials **19**(3): 165-173.

Chow, T.-t., et al. (2010). "Innovative solar windows for cooling-demand climate." Solar Energy Materials and Solar Cells **94**(2): 212-220.

Clancy, L., et al. (2002). "Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study." The Lancet **360**(9341): 1210-1214.

Clark, G. L. (1998). "Stylized facts and close dialogue: methodology in economic geography." Annals of the association of American Geographers **88**(1): 73-87.

Clements-Croome, D., et al. (2008). "Ventilation rates in schools." Building and Environment **43**(3): 362-367.

Clements-Croome, D. J., et al. (2008). "Ventilation rates in schools." Building and Environment **43**(3): 362-367.

Cleven, A., et al. (2009). Design alternatives for the evaluation of design science research artifacts. Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology, ACM.

Committee, H. o. C. E. a. S. (2007). Sustainable Schools: Are we building schools for the future? London. **1**.

Conceição, E. and M. Lúcio (2006). "Air quality inside a school building: air exchange monitoring, evolution of carbon dioxide and assessment of ventilation strategies." International journal of ventilation **5**(2): 259-270.

Connell, A. F. and W. R. Nord (1996). "The bloodless coup: The infiltration of organization science by uncertainty and values." The Journal of Applied Behavioral Science **32**(4): 407-427.

Corbin, J. and A. Strauss (2014). Basics of qualitative research: Techniques and procedures for developing grounded theory, Sage publications.

Creswell, J. (2002). Research Design Qualitative, Quantitative, and Mixed Methods Aproaches. India, Sage.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches, Sage publications.

Creswell, J. W. and V. L. P. Clark (2007). "Designing and conducting mixed methods research."

Creswell, J. W. and A. Tashakkori (2007). "Editorial: Differing perspectives on mixed methods research." Journal of mixed methods research **1**(4): 303-308.

Cross, N. (2006). Designerly ways of knowing, Springer.

Crossan, F. (2003). "Research philosophy: towards an understanding." Nurse researcher **11**(1): 46-55.

CRS, C. R. S. (2008). Nigeria: Current Issues. L. Ploch.

Curtis, D. M. (1986). "Comparative Tertiary petroleum geology of the Gulf Coast, Niger, and Beaufort-Mackenzie delta areas." Geological Journal **21**(3): 225-255.

D. Calfee, R. and W. W. Murchison (1998). "Demystifying window and door selection for single-family homes in high-wind environments." Journal of Wind Engineering and Industrial Aerodynamics **77–78**: 97-106.

D'Orazio, M., et al. (2010). "The effects of roof covering on the thermal performance of highly insulated roofs in Mediterranean climates." Energy and Buildings **42**(10): 1619-1627.

Dabaieh, M., et al. (2015). "Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings." Energy and Buildings **89**: 142-152.

Dahiru, D., et al. (2014). "A Study of Underpinning Methods Used in the Construction Industry in Nigeria." Small **2**: 9.1.

Dai Guoying, X. P. W. Y. (2004). "DISCUSSION ON REVIEW OF SEISMIC FORTIFICATION OF TALL BUILDINGS WITH DESIGN BEYOND THE CODE LIMITS [J]." China Civil Engineering Journal **1**: 000.

Daoud, O. E. (1997). "Problems with specification writing in the Middle East." Technology, Law and Insurance **2**(4): 179-185.

DEfRA, D. f. E. F. a. R. A. (2013). UK air quality. D. f. E. F. a. R. A. defra. UK.

Devins, D. and J. Gold (2002). "Social constructionism: a theoretical framework to underpin support for the development of managers in SMEs?" Journal of small business and enterprise development **9**(2): 111-119.

DfCLG, D. f. c. a. L. G. (2014). "Building control performance standards." Retrieved 23/12, 2014, from www.gov.uk.

DfE, D. f. E. (2016). Guidelines on ventilation, thermal comfort and indoor air quality in schools. London.

DfES, D. f. E. a. S. (2006). "Building Bulletin 101 Ventilation of School Buildings." Retrieved October 21, 2014.

Dias, C. M. R., et al. (2008). "Long-term aging of fiber-cement corrugated sheets – The effect of carbonation, leaching and acid rain." Cement and Concrete Composites **30**(4): 255-265.

Dickinson, D., et al. (2001). "Patient information leaflets for medicines: using consumer testing to determine the most effective design." Patient Education and Counseling **43**(2): 147-159.

Dickson, U. J. and E. I. Udoessien (2012). "Physicochemical studies of Nigeria's crude oil blends." Petroleum & Coal **54**(3): 243-251.

Dictionary, O. E. (2008). Oxford English dictionary online, Oxford University Press, Oxford, UK http://www. oed. com.

Dimoudi, A. and P. Kostarela (2009). "Energy monitoring and conservation potential in school buildings in the C′ climatic zone of Greece." Renewable Energy **34**(1): 289-296.

DoD, D. o. D. (2009). Guide for Performance Specifications SD-15.

Dolman, A. J., et al. (2010). "A Carbon Cycle Science Update Since IPCC AR-4." Ambio **39**(5/6): 402-412.

Dong, G. H., et al. (2014). "Ambient air pollution and the prevalence of obesity in chinese children: The seven northeastern cities study." Obesity **22**(3): 795-800.

Duke, B. "Development, Pollution and the Environment in Developing Countries." Retrieved 14/11, 2014, from http://web.stanford.edu/.

Durán-Narucki, V. (2008). "School building condition, school attendance, and academic achievement in New York City public schools: A mediation model." Journal of environmental psychology **28**(3): 278-286.

Eastman, W. N. and J. R. Bailey (1996). "Epistemology, action, and rhetoric: Past and present connections." The Journal of Applied Behavioral Science **32**(4): 455-461.

Ede, P. N. and D. O. Edokpa (2015). "Regional Air Quality of the Nigeria's Niger Delta." Open Journal of Air Pollution **4**(01): 7.

Edet, A. (1993). "Groundwater quality assessment in parts of Eastern Niger Delta, Nigeria." Environmental Geology **22**(1): 41-46.

EFA, E. F. o. A. (2001). The Right to Breathe Healthy Indoor Air in Schools. M. Franchi. Helsinki, Finland.

Eisenhardt, K. M. and M. E. Graebner (2007). "Theory building from cases: Opportunities and challenges." Academy of management journal **50**(1): 25-32.

Ekici, I. and H. Bougdah (2003). "A review of research on environmental noise barriers." Building Acoustics **10**(4): 289-323.

Ekpoh, I. J. and A. E. Obia (2010). "The role of gas flaring in the rapid corrosion of zinc roofs in the Niger Delta Region of Nigeria." The Environmentalist **30**(4): 347-352.

Elvidge, C. D., et al. (2009). "A fifteen year record of global natural gas flaring derived from satellite data." Energies **2**(3): 595-622.

Emam, E. A. (2016). "Environmental Pollution and Measurement of Gas Flaring."

Emmitt, S. (2001). "Observing the act of specification." Design Studies **22**(5): 397-408.

Emmitt, S., et al. (2008). Specifying Buildings: A Design Management Perspective, Butterworth Heinemann.

EPA, U. N. E. P. (2013, 15/8/2013). "Air Pollution and the Clean Air Act." Retrieved 30/10/2014, 2014, from http://www.epa.gov/air/caa/.

EPA, U. N. E. P. A. (2008). Care for Your Air: A Guide to Indoor Air Quality, EPA.

ESCAP, U. N. E. a. S. C. f. A. a. t. P. U. (2012). Integrating Environmental Sustainability and Disaster Resilience in Building Codes. Bangkok 10200, Thailand.

Exponent (2010). "Architectural Applications." Retrieved 13/11/2014, 2014, from http://www.exponent.com/architectural-applications/.

Fang, H. H. P., et al. (1990). "Corrosion of construction metals under simulated acid rain/fog conditions with high salinity." Water, Air, and Soil Pollution **53**(3): 315-325.

Farny, J. A. and B. Kerkhoff (2007). "Diagnosis and Control of Alkali-Aggregate Reactions in Concrete."

Feilzer, M. Y. (2010). "Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm." Journal of mixed methods research **4**(1): 6-16.

Fellows, R. (2009). "Advanced Research Methods in the Built Environment." Construction Management and Economics **27**(6): 605-609.

Fellows, R. F. and A. M. Liu (2015). Research methods for construction, John Wiley & Sons.

FEPA, F. E. P. A. (1999). Review of the National Policy on Environment. Abuja

FGN, C. o. t. F. r. o. N. (1999). Constitution of the Federal Republic of Nigeria. Abuja, Federal Ministry of Information and National Orientation, Federal government of Nigeria.

FGN, F. R. o. N. (2006). National Building Code. ENVIRONMENTAL AND GENERAL BUILDING REQUIREMENTS.

Flyvbjerg, B. (2006). "Five misunderstandings about case-study research." Qualitative inquiry **12**(2): 219-245.

Foliente, G., et al. (1998). "Development of the CIB proactive program on performance based building codes and standards." BCE Doc **98**: 232.

Foliente, G. C. (2000). "Developments in performance-based building codes and standards." Forest Products Journal **50**(7/8): 12.

Folorunso, C. O. and M. H. Ahmad (2013). "Parameters for building materials specifications in Lagos, Nigeria." SAGE Open **3**(3): 2158244013497724.

Fontoynont, M. (2014). Daylight performance of buildings, Routledge.

Fowler, F. J. (2014). Survey research methods, Sage publications.

Francois, D. and M. Vallet (2001). "Noise in schools." World Health Organisation—Regional Office for Europe Pamphlet no **38**.

Frechtling, J. (2002). "The 2002 User-Friendly Handbook for Project Evaluation."

Friborg, O. and J. H. Rosenvinge (2013). "A comparison of open-ended and closed questions in the prediction of mental health." Quality & Quantity **47**(3): 1397-1411.

Fujishima, A., et al. (2000). "Titanium dioxide photocatalysis." Journal of Photochemistry and Photobiology C: Photochemistry Reviews **1**(1): 1-21.

Fukuchi, T. and K. Ueno (2004). "Guidelines on acoustic treatments for school buildings proposed by the Architectural Institute of Japan." Proc. 18th Int'l Cong. Acoust.(Kyoto) **2**: 909-910.

Gao, J., et al. (2005). "Experiences with 3D and 4D CAD on building construction projects: Benefits for project success and controllable implementation factors." Construction Informatics Digital Library, w78.

Gao, J., et al. (2014). "Ventilation system type, classroom environmental quality and pupils' perceptions and symptoms." Building and Environment **75**: 46-57.

Gao, J., et al. (2013). "Durability of concrete exposed to sulfate attack under flexural loading and drying–wetting cycles." Construction and Building Materials **39**: 33-38.

Gasquet, I., et al. (2001). "Impact of reminders and method of questionnaire distribution on patient response to mail-back satisfaction survey." Journal of clinical epidemiology **54**(11): 1174-1180.

Georghiou, L. (2003). Evaluating foresight and lessons for its future impact. Second International Conference on Technology Foresight.

Georghiou, L., et al. (2010). "Assessing the impact of the UK's evolving national foresight programme." International Journal of Foresight and Innovation Policy **6**(1): 131-150.

Gervet, B. (2007). "Gas flaring emission contributes to global warming." Renewable Energy Research Group, Lulea University of Technology, Lulea, Sweden.

GFDRR, G. F. f. D. r. a. R. I. a. (2009). Guidance Notes on Safer School Construction, The World Bank.

Giunta, F. J. and A. M. Ramirez (1991). "Avoiding defective specifications." Civil Engineering **61**(9): 70.

Glaser, S. D. and A. Tolman (2008). "Sense of sensing: from data to informed decisions for the built environment." Journal of infrastructure systems **14**(1): 4-14.

Godish, T. and J. S. Fu (2003). Air quality, CRC Press.

Godoi, R., et al. (2009). "Indoor air quality assessment of elementary schools in Curitiba, Brazil." Water, Air, & Soil Pollution: Focus **9**(3-4): 171-177.

Goldkuhl, G. (2012). Design research in search for a paradigm: Pragmatism is the answer. Practical Aspects of Design Science, Springer**:** 84-95.

Gray, D. E. (2014). Doing Research in the Real World. United Kingdom, SAGE.

Greenwood, D. J. and M. Levin (2006). Introduction to action research: Social research for social change, SAGE publications.

Grimm, N. B., et al. (2008). "Global change and the ecology of cities." science **319**(5864): 756-760.

Gross, J. G. (1996). Developments in the application of the performance concept in building. Proc. 3rd CIB-ASTM-ISO-RILEM International Symposium.

Group, T. w. B. (2016). Zero Routine Flaring by 2030.

Gruner, K. E. and C. Homburg (2000). "Does customer interaction enhance new product success?" Journal of business research **49**(1): 1-14.

Guggemos, A. A. and A. Horvath (2006). "Decision-support tool for assessing the environmental effects of constructing commercial buildings." Journal of Architectural Engineering **12**(4): 187-195.

Haines, A., et al. (2007). "Policies for accelerating access to clean energy, improving health, advancing development, and mitigating climate change." The Lancet **370**(9594): 1264-1281.

Hasabnis, N., et al. (2015). Checking correctness of code generator architecture specifications. Proceedings of the 13th Annual IEEE/ACM International Symposium on Code Generation and Optimization, IEEE Computer Society.

Haverinen, U., et al. (1999). "An approach to management of critical indoor air problems in school buildings." Environmental Health Perspectives **107**(Suppl 3): 509.

Health, C. o. E. (2004). "Ambient air pollution: health hazards to children." Pediatrics **114**(6): 1699-1707.

Heckroodt, R. O. (2002). Guide to the deterioration and failure of building materials, Thomas Telford.

Hee, W., et al. (2015). "The role of window glazing on daylighting and energy saving in buildings." Renewable and Sustainable Energy Reviews **42**: 323-343.

Heschong, L. (2003). "Heschong Mahone Group.“." Windows and Offices: A Study of Office Worker Performance and the Indoor Environment.” California Energy Commission: Pacific Gas and Electric Company. Fair Oaks, California.

Hevner, A. R. (2007). "A three cycle view of design science research." Scandinavian journal of information systems **19**(2): 4.

Hevner, A. R. and S. T. March (2003). "The information systems research cycle." Computer **36**(11): 111-113.

Hibbard, S. and A. Onwuegbuzie (2012). Trends of mixed methods designs in evaluation studies: From 2003 to 2011. annual meeting of the American Educational Research Association, Vancouver, BC.

Hoch, C. J. (2002). "Evaluating plans pragmatically." Planning theory **1**(1): 53-75.

Hoek, G., et al. (2008). "A review of land-use regression models to assess spatial variation of outdoor air pollution." Atmospheric Environment **42**(33): 7561-7578.

Hoey, B. A. (2000-2015). "What is Ethnography?". Retrieved 20/11/2015, 2015.

Holden, M. T. and P. Lynch (2004). "Choosing the appropriate methodology: understanding research philosophy." The marketing review **4**(4): 397-409.

Holmström, J., et al. (2009). "Bridging practice and theory: a design science approach." Decision Sciences **40**(1): 65-87.

Hondros, C. (2011). A retrospective in pictures. The Guardian.

Huang, Y.-C. T. and M. Al-Hegelan (2012). "Adverse Effects of Outdoor Air Pollution." Clinical Pulmonary Medicine **19**(1): 14-20.

Hubka, V. and W. Ernst Eder (1987). "A scientific approach to engineering design." Design studies **8**(3): 123-137.

Hughes, J. A. and W. W. Sharrock (1997). "The philosophy of social research."

Huovila, P. and J. Leinonen (2001). "Managing performance in the built environment." Paper CLI **18**.

Hyde, R. (2013). Climate responsive design: A study of buildings in moderate and hot humid climates, Taylor & Francis.

Ibem, E. O. and E. B. Aduwo (2013). "Assessment of residential satisfaction in public housing in Ogun State, Nigeria." Habitat International **40**: 163-175.

ICIBSE (2016). "Primary evidence – primary schools from 1976 and 2016 go head-to-head." Retrieved 7/01/2018, 2018, from https://www.cibsejournal.com/general/primary-evidence-primary-schools-from-1976-and-2016-go-head-to-head/.

Ihejiamaizu, E. (1999). "Socio-economic Impact of Oil Industry Activities on the Nigerian Environment: the case of Ebocha Gas Plant and Brass Terminal." International Journal of Tropical Environment **1**(1): 38-51.

Iloh, C. and W. Tierney (2014). "Using ethnography to understand twenty-first century college life." Human Affairs **24**(1): 20-39.

Ilstedt, S. and J. Wangel (2013). "Designing sustainable futures." Nordes **1**(5).

Imbabi, M. and A. Peacock (2003). Smart breathing walls for integrated ventilation, heat exchange, energy efficiency and air filtration. Invited paper, joint ASHRAE/CIBSE conference, Edinburgh.

Industry, F. (2002). "MARKET REPORT: Consumer Water & Air Purification Systems." Filtration Industry Analyst **2002**(10): 14.

Irfanoglu, A. (2009). "Performance of Template School Buildings during Earthquakes in Turkey and Peru." Journal of Performance of Constructed Facilities **23**(1): 5-14.

Isikdag, U., et al. (2012). "Building information modelling." Construction innovation and process improvement: 399-403.

Ismail, O. S. and G. E. Umukoro (2012). "Global Impact of Gas Flaring." Energy & Power Engineering **4**(4).

ISO, I. O. f. S. (2005). Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. Switzerland.

Ite, A. E. and U. J. Ibok (2013). "Gas flaring and venting associated with petroleum exploration and production in the Nigeria's Niger Delta." American Journal of Environmental Protection **1**(4): 70-77.

Ite, A. E., et al. (2013). "Petroleum Exploration and Production: Past and Present Environmental Issues in the Nigeria's Niger Delta." Nature **1**(4): 78-90.

IWBI, I. W. B. I. (2016). The WELL Building Standard. Washington, DC, Delos Living LLC.

Jacques, L. F. E. (2000). "Accelerated and outdoor/natural exposure testing of coatings." Progress in Polymer Science **25**(9): 1337-1362.

Järvinen, P. (2007). "Action research is similar to design science." Quality & Quantity **41**(1): 37-54.

Jelle, B. (2012). "Accelerated climate ageing of building materials, components and structures in the laboratory." Journal of Materials Science **47**(18): 6475-6496.

Jike, V. T. (2004). "Environmental degradation, social disequilibrium, and the dilemma of sustainable development in the Niger-Delta of Nigeria." Journal of Black Studies **34**(5): 686-701.

Jimoda, L. (2012). "Effects of particulate matter on human health, the ecosystem, climate and materials: A review." Facta universitatis-series: Working and Living Enviromental Protection **9**(1): 27-44.

Johannesson, P. and E. Perjons (2012). "A design science primer."

Johannesson, P. and E. Perjons (2012). "A design science primer." Unpublished Manuscript, February **25**.

JONES, B., et al. (2007). Air quality measured in a classroom served by roof mounted natural ventilation windcatchers, Heliotopos Conferences Limited.

Jones, D. R. and M. F. Ashby (2005). Engineering materials 2: an introduction to microstructures, processing and design, Butterworth-Heinemann.

Joseph, P. and S. Tretsiakova-McNally (2010). "Sustainable non-metallic building materials." Sustainability **2**(2): 400-427.

JSCQB, J. S. C. o. t. Q. o. B. (2002). Inquiry into the Quality of Buildings. Sydney, New South Wales Parliament Legislative Assembly.

Julius, O. O. (2011). "Environmental impact of gas flaring within Umutu-Ebedei gas plant in Delta State, Nigeria." Archives of Applied Science Research **3**(6): 272-279.

Kagioglou, M., et al. (2000). "Rethinking construction: the generic design and construction process protocol." Engineering construction and architectural management **7**(2): 141-153.

Kanniyapan, G., et al. (2015). "Façade Material Selection Criteria for Optimising Building Maintainability." Jurnal Teknologi (Sciences & Engineering) **75**(10): 17-25.

Karimipanah, T., et al. (2007). "Investigation of air quality, comfort parameters and effectiveness for two floor-level air supply systems in classrooms." Building and Environment **42**(2): 647-655.

Kauppinen, T. and S. Siikanen (2011). Improvement of energy efficiency: the use of thermography and air-tightness test in verification of thermal performance of school buildings. SPIE Defense, Security, and Sensing, International Society for Optics and Photonics.

Keller, M. R., et al. (1990). "Gas flaring method and apparatus."

Kent, M., et al. (2015). "Temporal variables and personal factors in glare sensation." Lighting Research and Technology: 1477153515578310.

Kheirandish-Gozal, L., et al. (2014). "Preliminary functional MRI neural correlates of executive functioning and empathy in children with obstructive sleep apnea." Sleep **37**(3): 587-592.

Killip, G. (2005). "Built fabric and building regulations." Background Material F **40**.

Kim, J.-L., et al. (2005). "Current asthma and respiratory symptoms among pupils in relation to dietary factors and allergens in the school environment." Indoor air **15**(3): 170-182.

Kim, J. T. and G. Kim (2010). "Overview and new developments in optical daylighting systems for building a healthy indoor environment." Building and Environment **45**(2): 256-269.

Kim, K.-H., et al. (2015). "A review on the human health impact of airborne particulate matter." Environment international **74**: 136-143.

Knight, A. and L. Ruddock (2009). Advanced research methods in the built environment, John Wiley & Sons.

Knizhnikov, A. and N. Poussenkova (2009). "Russian associated gas utilization: problems and prospects." World Wildlife Federation-Russia-Institute of World Economy and International Relations.

Kolfschoten, G. L. and G.-J. De Vreede (2009). "A design approach for collaboration processes: A multimethod design science study in collaboration engineering." Journal of Management Information Systems **26**(1): 225-256.

Koskela, L. (1992). Application of the new production philosophy to construction, Stanford University Stanford, CA.

Krzyzanowski, M. and A. Cohen (2008). "Update of WHO air quality guidelines." Air Quality, Atmosphere & Health **1**(1): 7-13.

Kuechler, B. and V. Vaishnavi (2008). "On theory development in design science research: anatomy of a research project." European Journal of Information Systems **17**(5): 489-504.

Lacasse, M., et al. (2007). Results on assessing the effectiveness of wall-window interface details to manage rainwater. 11th Canadian Building Science and Technology Conference, Banff Canada.

Lacasse, M., et al. (2005). Assessing the effectiveness of wall-window interface details to manage rainwater. 10th Canadian Conference on Building Science & Technology, Ottawa, May.

Ladan, S. I. (2013). "Examining Air Pollution and Control Measures in Urban Centers of Nigeria." International Journal of Environmental Engineering and Management **Volume 4**.

Lam, P. T., et al. (2007). "International treatise on construction specification problems from a legal perspective." Journal of Professional Issues in Engineering Education and Practice **133**(3): 229-237.

Lam, P. T. I., et al. (2010). "Factors affecting the implementation of green specifications in construction." Journal of Environmental Management **91**(3): 654-661.

Larssen, T., et al. (1999). "Acid deposition and its effects in China: an overview." Environmental Science & Policy **2**(1): 9-24.

Lawal, T. and A. Oluwatoyin (2011). "National Development in Nigeria, issues, challenges and prospects." Journal of Public Administration and Policy Research **3**(9): 237-241.

Lawson, B. (2006). How designers think: the design process demystified, Routledge.

Le Quéré, C., et al. (2014). "Global carbon budget 2014." Earth System Science Data Discussions **7**(2): 521-610.

Lechner, N. (2014). "Daylighting is Mostly Sunlighting." 2018, from http://www.heliodons.org/index.html.

Lee, A. and P. Barrett (2003). Performance Based Building: first international state-of-the-art report, CIB.

Lee, A. S. and J. V. Nickerson (2010). Theory as a case of design: lessons for design from the philosophy of science. System Sciences (HICSS), 2010 43rd Hawaii International Conference on, IEEE.

Levinson, R., et al. (2005). "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements." Energy Policy **33**(2): 151-170.

Ley, P. (1988). Communicating with patients: Improving communication, satisfaction and compliance, Croom Helm.

Leygraf, C., et al. (2016). Atmospheric corrosion, John Wiley & Sons.

limits, C. (2013). "REDUCING AN IMPORTANT GAS FLARE IN NIGERIA." Retrieved 30 June, 2014, from http://www.carbonlimits.no/.

Liu, D.-L. and W. W. Nazaroff (2001). "Modeling pollutant penetration across building envelopes." Atmospheric Environment **35**(26): 4451-4462.

Liu, D.-L. and W. W. Nazaroff (2003). "Particle penetration through building cracks." Aerosol Science & Technology **37**(7): 565-573.

Lobo, C., et al. (2006). Performance-based specifications for concrete. Building Integration Solutions**:** 1-13.

Loe, J. S. and O. Ladehaug (2012). "Reducing gas flaring in Russia: Gloomy outlook in times of economic insecurity." Energy Policy **50**: 507-517.

Loesch, J. and D. Hammerman (2013). "Private/public partnerships to ensure building code compliance." Facilities.

Lohmann, L. (2009). "Neoliberalism and the calculable world: The rise of carbon trading." Upsetting the offset: the political economy of carbon markets, London: Mayfly books: 25-40.

Lopez, C., et al. (2011). "Water penetration resistance of residential window and wall systems subjected to steady and unsteady wind loading." Building and Environment **46**(7): 1329-1342.

LSX, L. S. E. (2013). "Cleaner Air 4 Primary Schools Toolkit." Retrieved 09/06, 2014, from http://www.lsx.org.uk/whatwedo/CleanAir4Schools_page3504.aspx.

Lucas W. Davis (2008). "The Effect of Driving Restrictions on Air Quality in Mexico City." Journal of Political Economy **116**(1): 38-81.

Lukka, K. (2003). "The constructive research approach." Case study research in logistics. Publications of the Turku School of Economics and Business Administration, Series B **1**(2003): 83-101.

Maass, P. (2009). "Scenes From the Violent Twilight of Oil." Foreign Policy(174): 106-119.

Mac-Ikemenjima, D. (2005). E-Education in Nigeria: Challenges and prospects. A Paper presented at the 8 th UN ICT Task Force Meeting. Dublin, Ireland.

Madu, A., et al. (2011). "EXTENT OF HEAVY METALS IN OIL SAMPLES IN ESCRAVOUS, ABITEYE AND MALU PLATFORMS IN DELTA STATE NIGERIA." Journal of Agriculture & Environmental Studies **2**(2).

Madureira, J., et al. (2015). "Indoor air quality in schools and its relationship with children's respiratory symptoms." Atmospheric Environment **118**: 145-156.

Malumfashi, G. I. (2007). "Phase-out of gas flaring in Nigeria by 2008: The prospects of a multi-win project." Petroleum training journal **1**(1).

Manzo, L. C. (2003). "Beyond house and haven: Toward a revisioning of emotional relationships with places." Journal of environmental psychology **23**(1): 47-61.

March, S. T. and G. F. Smith (1995). "Design and natural science research on information technology." Decision support systems **15**(4): 251-266.

Mark Saunders, et al. (2012). Research methods for business students, Harlow : Pearson

Marteinsson, B. (2003). "Durability and the factor method of ISO 15686-1." Building Research & Information **31**(6): 416-426.

Matsuoka, R. H. (2010). "Student performance and high school landscapes: Examining the links." Landscape and Urban Planning **97**(4): 273-282.

Mavrogianni, A. and D. Mumovic (2010). "On the use of Windcatchers in schools: Climate change, occupancy patterns, and adaptation strategies." Indoor and Built Environment **19**(3): 340-354.

May, P. J. (2003). "Performance-based regulation and regulatory regimes: the saga of leaky buildings." Law & Policy **25**(4): 381-401.

McConnell, R., et al. (2002). "Asthma in exercising children exposed to ozone: a cohort study." The Lancet **359**(9304): 386-391.

McDaniel, M. and B. A. Tichenor (1983). Flare efficiency study, US Environmental Protection Agency, Industrial Environmental Research Laboratory.

McGeorge, D. and A. Palmer (2009). Construction Management: New Directions, John Wiley & Sons.

MDGs, M. D. G. (2000). "GOAL 2: ACHIEVE UNIVERSAL PRIMARY EDUCATION." Retrieved 25 June, 2014, from http://www.un.org/millenniumgoals/education.shtml.

Mehta, P. K. and R. W. Burrows (2001). "Building durable structures in the 21 st century." Indian Concrete Journal **75**(7): 437-443.

Meier, H. W. and D. J. Wyatt (2008). Construction specifications : principles and applications, Clifton Park, N.Y. : Delmar Learning.

Meinhold, B. (2013). "Urgent architecture; 40 sustainable housing solutions for a changing world." Reference and Research Book News **28**(2).

Mgbemena, O. O. (2015). "EVALUATION OF SOME OIL COMPANIES IN THE NIGER DELTA REGION OF NIGERIA: AN ENVIRONMENTAL IMPACT APPROACH." International Journal of Environment and Pollution Research.

Miedema, H. M. (2007). "Annoyance caused by environmental noise: elements for evidence-based noise policies." Journal of social issues **63**(1): 41-57.

Mills, G. (2007). "Cities as agents of global change." International Journal of Climatology **27**(14): 1849-1857.

Milne, M. (2017). "ENERGY DESIGN TOOLS: New Non-Residential Energy Tool SBEED." Retrieved 20/01, 2018.

Minor, J. E. (2005). "Lessons learned from failures of the building envelope in windstorms." Journal of Architectural Engineering **11**(1): 10-13.

Miske, C., et al. (2014). Towards a More Cognitively Effective Business Process Notation for Requirements Engineering. DESRIST.

Mitchell, G. (2015). "Use of interviews in nursing research." Nursing Standard **29**(43): 44-48.

Mohammed, M. A., et al. (2013). Simulation of Natural Ventilation in Hospitals of Semiarid Climates for Harmattan Dust and Mosquitoes: A Conundrum. Proceedings of the 13th Conference of International Building Performance Simulation Association, August.

Moja, T. (2000). "Nigeria education sector analysis: An analytical synthesis of performance and main issues." World Bank Report.

Moje, E. B., et al. (2000). "Commentary: Reinventing Adolescent Literacy for New Times: Perennial and Millennial Issues." Journal of Adolescent & Adult Literacy: 400-410.

Mollaoglu-Korkmaz, S., et al. (2013). "Delivering Sustainable, High-Performance Buildings: Influence of Project Delivery Methods on Integration and Project Outcomes." Journal of Management in Engineering **29**(1): 71-78.

Moore, G. T. and J. A. Lackney (1993). "School design: Crisis, educational performance and design applications." Children's Environments: 99-112.

Morrison Ifeanyi, A. and O. Vincent Nduka (2013). "Effect of Gas Flaring on Soil and Cassava Productivity in Ebedei, Ukwuani Local Government Area, Delta State, Nigeria." Journal of Environmental Protection **2013**.

Morrissey, J., et al. (2011). "Affordable passive solar design in a temperate climate: An experiment in residential building orientation." Renewable Energy **36**(2): 568-577.

Morse, J. M. (1991). "Strategies for sampling." Qualitative nursing research: A contemporary dialogue: 127-145.

Mumovic, D., et al. (2009). "Winter indoor air quality, thermal comfort and acoustic performance of newly built secondary schools in England." Building and Environment **44**(7): 1466-1477.

Murphy, E., et al. (2009). "Estimating human exposure to transport noise in central Dublin, Ireland." Environment International **35**(2): 298-302.

Murthy, D. N. P., et al. (2008). "Performance and Specification in the Front-end Phase." Product Reliability: Specification and Performance: 91-119.

Mustapha, B. A., et al. (2011). "Research| Children's Health." Environmental health perspectives **119**(10): 1479.

NBS, N. B. o. S. (2016). SELECTED BASIC PUBLIC EDUCATION STATISTICS IN NIGERIA 2013 - 2014. Nigeria.

NBS, N. B. S. (2008). NBS Educator Specifications: an introduction, NBS.

NBS, N. B. S. (2013). "Specification Survey 2013." Retrieved October 2014, from http://www.thenbs.com/.

NDDC, N. D. D. C. (2006). THE REGIONAL DEVELOPMENT MASTER PLAN. Nigeria.

Neidell, M. J. (2004). "Air pollution, health, and socio-economic status: the effect of outdoor air quality on childhood asthma." Journal of Health Economics **23**(6): 1209-1236.

Nelson, E. L., et al. (2008). "Background noise levels and reverberation times in old and new elementary school classrooms." Journal of Educational Audiology vol **14**: 2007.

NESREA, N. E. S. a. E. A. (2010). "National Policy on Enivironmnent." Retrieved 06/11/2014, 2014, from http://www.nesrea.gov.ng/policy.

Newsham, G. R., et al. (2005). "Lighting quality research using rendered images of offices." Lighting Research and Technology **37**(2): 93-112.

Nicola Cheetham, et al. (2012). Delivering Vertical Greening.

Niehaves, B. (2007). "On epistemological pluralism in design science." Scandinavian Journal of Information Systems **19**(2): 7.

NIKKEN (2013). "Stable natural ventilation in high-rise tenant office buildings." NIKKEN SEKKEI **16**(16).

NiMet, N. M. A. (2016). 2016 SEASONAL RAINFALL PREDICTION (SRP). Nigeria, Nigerian Metrological Agency.

Nkwocha, E. E. and E. C. Pat-Mbano (2010). "Effect of Gas Flaring on Buildings in the Oil Producing Rural Communities of River State, Nigeria." African Research Review **4**(2).

NNPC, N. N. P. C. (2014). 2014 Annual Statistical2014 Statistical Bulletin. Nigeria, Nigerian National Petroleum Cooperation.

Noor, K. B. M. (2008). "Case study: A strategic research methodology." American journal of applied sciences **5**(11): 1602-1604.

Nwaichi, E. and M. Uzazobona (2011). "Estimation of the CO_2 level due to gas flaring in the Niger Delta." Research Journal of Environmental Sciences **5**(6): 565.

Nwanya, S. C. (2011). "Climate change and energy implications of gas flaring for Nigeria." International Journal of Low Carbon Technologies **6**(3): 193-199.

Nwaugo, V., et al. (2006). "Effect of gas flaring on soil microbial spectrum in parts." African Journal of Biotechnology **5**(19).

O'Connor, A.-M. (2010). Mexico City drastically reduced air pollutants since 1990s. The Washington Post. US, Washington Post**:** 2.

O'Connor, J. T., et al. (1991). "Improving highway specifications for constructibility." Journal of Construction Engineering and Management **117**(2): 242-258.

O., A. A. (2013). "Negative Effects of Gas Flaring: The Nigerian Experience." Journal of Environment Pollution and Human Health **1**(1): 6-8.

O'Brien, R. (2001). "An Overview of the Methodological Approach of Action Research." Retrieved 20/11/2015, 2015, from http://www.web.ca/~robrien/papers/arfinal.html

Obaje, N. G. (2009). Geology and mineral resources of Nigeria, Springer.

Obi, C. (2009). "Nigeria's Niger Delta: Understanding the complex drivers of violent oil-related conflict." Africa Development **34**(2).

Obia, A. E., et al. (2011). "The influence of gas flare particulates and rainfall on the corrosion of galvanized steel roofs in the Niger Delta, Nigeria." Journal of Environmental Protection **2**(10): 1341.

Obia, A. E., et al. (2011). "The Influence of Gas Flare Particulates and Rainfall on the Corrosion of Galvanized Steel Roofs in the Niger Delta, Nigeria." Journal of Environmental Protection **2**(10).

Odia, L. and S. Omofonmwan (2007). "Educational system in Nigeria: Problems and prospects." Journal of social science **14**(1): 81-86.

Odu, C. (1994). "Gas flare Emissions and their Effects on the Acidity of Rain Water in the Ebocha Area." Univer-sity of Ibadan, Ibadan.

Odu, C. (1994). "Gas Flare Emissions and their Effects on the Acidity of Rainwater in the Ebocha area." A Paper presented in the Department of Agronomy University of Ibadan, Nigeria, 10p.

Ofoegbu, F. (2004). "Teacher Motivation: A Factor for Classroom Effectiveness and School Improvement in Nigeria." College Student Journal **38**(1): 81.

Ogbonda, U. J. and B. Erik (2017). "EXAMINING THE STATE OF PUBLIC SCHOOLS IN THE GAS FLARING AREAS OF NIGERIA." ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY **08**(04): 4574-4579.

Ogbonda, U. J. and Y. Ji (2017). A critique of the ventilation system used for public schools around gas flaring sites in the Nigeria Niger Delta Area. Healthy Building Lublin Poland.

Ojeh, V. N. (2012). "Sustainable Development and Gas Flaring Activities: a Case Study of Ebedei Area of Ukwuani LGA, Delta State, Nigeria." Resources and Environment **2**(4): 169-174.

Ole Fanger, P. (2006). "What is IAQ?" Indoor Air **16**(5): 328-334.

Olowoporoku, A., et al. (2011). "Towards a new framework for air quality management in Nigeria." Air Pollution XIX **147**: 1.

Olufowobi, M. and O. Adenuga (2012). "TOWARDS THE SPECIFICATION OF WINDOWS SIZES FOR NATURAL VENTILATION IN CLASSROOMS IN A WARN CLIMATE, NIGERIA." Journal of Building Performance **3**(1).

Olusola, B. S. and O. Akintayo (2009). "An assessment of failure of building components in Nigeria." Journal of Building Appraisal **4**(4): 279-286.

Omer, A. M. (2008). "Renewable building energy systems and passive human comfort solutions." Renewable and Sustainable Energy Reviews **12**(6): 1562-1587.

Omuta, G. E. D. (1986). "Minimum versus affordable environmental standards in third world cities: An examination of housing codes in Benin City, Nigeria." Cities **3**(1): 58-71.

Oni, S. I. and M. A. Oyewo (2011). "Gas flaring, transportation and sustainable energy development in the Niger-Delta, Nigeria." Journal of Human Ecology **33**(1): 21-28.

Onwuegbuzie, A. J. and C. Teddlie (2003). "A framework for analyzing data in mixed methods research." Handbook of mixed methods in social and behavioral research **2**: 397-430.

Oral, G. K., et al. (2004). "Building envelope design with the objective to ensure thermal, visual and acoustic comfort conditions." Building and Environment **39**(3): 281-287.

Orubu, C. (2002). "Oil Industry activities, Environmental Quality, and the Paradox of Poverty in Niger Delta." The Petroleum Industry, the Economy and the Niger-Delta Environment.(Eds), Orubu, CO, Ogisi, DO and Okoh, RN: 17-31.

OSHA, O. S. a. H. A. (2011). Indoor Air Quality in Commercial and Institutional Buildings. U. S. D. o. Labor.

Osuji, L. C. and G. O. Avwiri (2005). "Flared Gases and Other Pollutants Associated with Air Quality in Industrial Areas of Nigeria: An Overview." Chemistry & Biodiversity **2**(10): 1277-1289.

Oteri, A. U. (1988). "Electric log interpretation for the evaluation of salt water intrusion in the eastern Niger Delta." Hydrological sciences journal **33**(1): 19-30.

Oviasuyi, P. and J. Uwadiae (2010). "The dilemma of Niger-Delta region as oil producing states of Nigeria." Journal of Peace, Conflict and Development **16**(1): 10-126.

Owoeye, J. S. and P. O. Yara (2011). "School facilities and academic achievement of secondary school agricultural science in Ekiti State, Nigeria." Asian social science **7**(7): 64.

Ozga, I., et al. (2011). "Diagnosis of surface damage induced by air pollution on 20th-century concrete buildings." Atmospheric Environment **45**(28): 4986-4995.

Pachauri, R. K., et al. (2014). "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change."

Pahl, G. and W. Beitz (2013). Engineering design: a systematic approach, Springer Science & Business Media.

Parker, R. (2008). Roof covering in schools. S. a. F. D. Department for Children. Nothingham, DCSF.

Pathirage, C., et al. (2011). "The role of philosophical context in the development of theory: Towards methodological pluralism." The Built & Human Environment Review **1**.

Pathirage, C., et al. (2012). "Managing disaster knowledge: identification of knowledge factors and challenges." International Journal of Disaster Resilience in the Built Environment **3**(3): 237-252.

PBU, P. a. B. U. (2012). Planning & Design Guidelines Primary & Post Primary School Specialist Accommodation for Pupils with Special Educational Needs. E. a. Skills. Ireland, Planning and Building Unit.

Pearson, S. R. (1970). Petroleum and the Nigerian economy, Stanford University Press.

Pease Jr David, H. (1966). Weather stripping, Google Patents.

Peffers, K., et al. (2012). Design Science Research Evaluation. Design Science Research in Information Systems. Advances in Theory and Practice: 7th International Conference, DESRIST 2012, Las Vegas, NV, USA, May 14-15, 2012. Proceedings. K. Peffers, M. Rothenberger and B. Kuechler. Berlin, Heidelberg, Springer Berlin Heidelberg**:** 398-410.

Peffers, K., et al. (2007). "A design science research methodology for information systems research." Journal of management information systems **24**(3): 45-77.

Pegas, P. N., et al. (2010). "Outdoor/indoor air quality in primary schools in Lisbon: a preliminary study." Quimica nova **33**(5): 1145-1149.

Pérez-Bella, J. M., et al. (2015). "Improvement alternatives for determining the watertightness performance of building facades." Building Research & Information **43**(6): 723-736.

Peterson, J., et al. (2007). "Minimize facility flaring." Hydrocarbon Processing **86**(6): 111-115.

Petroeschevsky, A., et al. (2001). "Associations between outdoor air pollution and hospital admissions in Brisbane, Australia." Archives of Environmental Health: An International Journal **56**(1): 37-52.

PHH, P. H. I. (2011). "What is passivehaus." Retrieved 2015, 5/10/2015, from http://www.passiv.de/English/PassiveH.HTM.

Pietarinen, A.-V. (2006). Signs of logic, Springer.

Pink, S. and K. Leder Mackley (2014). "Re-enactment methodologies for everyday life research: art therapy insights for video ethnography." Visual Studies **29**(2): 146-154.

Poindexter, P., Meraz, Sharon, & Weiss, Amy Schmitz. (2008). Women, Men, and News: Divided and Disconnected in the News Media Landscape: Taylor & Francis Group, . New York, Routledge.

Popping, R. (2015). "Analyzing open-ended questions by means of text analysis procedures." Bulletin of Sociological Methodology/Bulletin de Méthodologie Sociologique **128**(1): 23-39.

Potera, C. (2009). "Air pollution: the oxidative punch of wildfires." Environmental Health Perspectives **117**(2): A58.

Prior, J. J. and F. Szigeti (2003). "Why all the fuss about performance based building." International Council for Research and Innovation in Building and Construction-PeBBu Thematic Network.

Prockop, L. D. and R. I. Chichkova (2007). "Carbon monoxide intoxication: an updated review." Journal of the neurological sciences **262**(1): 122-130.

Proctor, S. (1998). "Linking philosophy and method in the research process: the case for realism: Adopting o realist approach can help researchers to design and execute a study that does nor exclude vital segments of data, argues Sue Proctor." Nurse Researcher **5**(4): 73-90.

Quillen, T. (1993). "...about lead poisoning." Nursing **23**(8): 26.

Rabinowitz, P. M., et al. (2014). "Proximity to natural gas wells and reported health status: Results of a household survey in Washington County, Pennsylvania." Environmental health perspectives: 9-17.

Rajiah, K. and E. M. Mathew (2011). "Clinical manifestation, effects, diagnosis, monitoring of carbon monoxide poisoning and toxicity." African journal of pharmacy and pharmacology **5**(2): 259-263.

Randall, D., et al. (2007). "Ethnography and How to Do It." Fieldwork for Design: Theory and Practice: 169-197.

Randolph, J. J. (2009). "A guide to writing the dissertation literature review." Practical Assessment, Research & Evaluation **14**(13): 1-13.

Ravikumar, H., et al. (2012). "Biodegradation of paints: a current status." Indian Journal of Science and Technology **5**(1): 1977-1987.

Raynor, D. (1998). "The influence of written information on patient knowledge and adherence to treatment." Adherence to treatment in medical conditions: 83-111.

Rees, N. (2016). "Clear the air for children: the impact of air pollution on children."

Reeves, S., et al. (2008). "Qualitative research methodologies: ethnography." BMJ **337**.

Reich, Y. (2013). "Designing science." Research in Engineering Design **24**(3): 215-218.

Reich, Y. and E. Subrahmanian (2013). "Philosophy of design, science of design, engineering (of) design: what is your choice?" Research in Engineering Design **24**(4): 321-323.

Reinhart, C. F., et al. (2006). "Dynamic daylight performance metrics for sustainable building design." Leukos **3**(1): 7-31.

Remenyi, D., et al. (2004). Adding Something of Value to the Body of Theoretical Knowledge? European Conference on Research Methodology for Business and Management Studies, Academic Conferences Limited.

Remenyi, D. and B. Williams (1998). Doing research in business and management: an introduction to process and method, Sage.

Revie, R. W. (2008). Corrosion and corrosion control, John Wiley & Sons.

Riedy, C. (2009). "The influence of futures work on public policy and sustainability." foresight **11**(5): 40-56.

Rivas, I., et al. (2014). "Child exposure to indoor and outdoor air pollutants in schools in Barcelona, Spain." Environment International **69**(0): 200-212.

Robinson, H. S. and J. Scott (2009). "Service delivery and performance monitoring in PFI/PPP projects." Construction Management and Economics **27**(2): 181-197.

Robinson, J., et al. (2011). "Envisioning sustainability: Recent progress in the use of participatory backcasting approaches for sustainability research." Technological Forecasting and Social Change **78**(5): 756-768.

Robinson, L. and T. Robinson (2009). "An Australian approach to school design."

Rockcastle, S. F. and M. Andersen (2013). Celebrating Contrast and Daylight Variability in Contemporary Architectural Design: A Typological Approach. LUX EUROPA.

Rösch, C., et al. (2014). "Relationship between sources and patterns of VOCs in indoor air." Atmospheric Pollution Research **5**(1).

Ryd, N. (2004). "The design brief as carrier of client information during the construction process." Design Studies **25**(3): 231-249.

Sakumoto, Y., et al. (2001). "Durability evaluation of intumescent coating for steel frames." Journal of materials in civil engineering **13**(4): 274-281.

Salthammer, T. (2011). "Critical evaluation of approaches in setting indoor air quality guidelines and reference values." Chemosphere **82**(11): 1507-1517.

Salvato, J. A., et al. (2003). Environmental engineering, John Wiley & Sons.

Salzano, C. T., et al. (2010). "Water penetration resistance of residential window installation options for hurricane-prone areas." Building and Environment **45**(6): 1373-1388.

Samet, J. M., et al. (2000). "The national morbidity, mortality, and air pollution study." Part II: morbidity and mortality from air pollution in the United States Res Rep Health Eff Inst **94**(pt 2): 5-79.

Sanders, J. R. (1994). "The Joint Committee on Standards for Educational Evaluation.(1994)." The program evaluation standards: How to assess evaluations of educational programs.

Sanoff, H. (2001). "School Building Assessment Methods."

Santamouris, M., et al. (2011). "Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions." Solar Energy **85**(12): 3085-3102.

Santamouris, M. and P. Wouters (2006). Building ventilation: the state of the art, Routledge.

Saunders Mark *et* al (2009). Research methods for business students. Italy, Pearson Education India.

Saunders, M. N. (2011). Research methods for business students, 5/e, Pearson Education India.

Schiano-Phan, R., et al. (2008). 432: The Passivhaus standard in the UK: Is it desirable? Is it achievable?, PLEA.

Schneider, M. (2002). "Do School Facilities Affect Academic Outcomes?".

Schulte, J. H. (1963). "Effects of Mild Carbon Monoxide Intoxication." Archives of Environmental Health: An International Journal **7**(5): 524-530.

Schürz, S., et al. (2010). "Chemistry of corrosion products on Zn–Al–Mg alloy coated steel." Corrosion Science **52**(10): 3271-3279.

Seep, B., et al. (2000). "Classroom Acoustics: A Resource for Creating Environments with Desirable Listening Conditions."

Sexton, M., et al. (2005). "The relationship between performance-based building and innovation: An evolutionary approach." Performance Based Building: 37.

Sharif, R. (1983). The Status of Building Specifications in the Arab World. Building Codes and Specifications for the Arab World, Springer: 27-43.

Sherman, M. H. and W. R. Chan (2004). "Building airtightness: research and practice." LBNL report **53356**.

Sherman, M. H. and W. R. Chan (2006). "Building air tightness: research and practice." Building Ventilation: the state of the Art: 137-162.

Shi, H., et al. (2008). An integrated modeling tool to simulating effect of natural ventilation on indoor air quality and room thermal conditions. The First International Conference on Building Energy and Environment.

Shield, B. M. and J. E. Dockrell (2003). "The effects of noise on children at school: a review." Building Acoustics **10**(2): 97-116.

Shih, F. J. (1998). "Triangulation in nursing research: issues of conceptual clarity and purpose." Journal of advanced nursing **28**(3): 631-641.

Shreir, L. L. (2013). Corrosion: corrosion control, Newnes.

Simeonova, M., et al. "Lighting Research Center Rensselaer Polytechnic Institute, Troy, NY 12180."

Simeonova, M., et al. (2003). "Application of colored LEDs for retail display windows." Journal of the Illuminating Engineering Society **32**(1): 52-62.

Simon, H. A. (1996). The sciences of the artificial, MIT press.

Sims, G. and W. Broughton (2009). Chapter 56: Codes and standards. ICE manual of Construction Materials: Volume II: Fundamentals and theory; Concrete; Asphalts in road construction; Masonry, Thomas Telford Ltd**:** 655-666.

Singh, I. and A. Michaelowa (2004). Indian Urban Building Sector: CDM Potential through Engergy Efficiency in Electricity Consumption, HWWA Discussion paper.

Sisman, N., et al. (2007). "Determination of optimum insulation thicknesses of the external walls and roof (ceiling) for Turkey's different degree-day regions." Energy Policy **35**(10): 5151-5155.

Slaughter, R. (2009). "The state of play in the futures field: a metascanning overview." foresight **11**(5): 6-20.

Smedje, G. and D. Norbäck (2000). "New ventilation systems at select schools in Sweden—effects on asthma and exposure." Archives of Environmental Health: An International Journal **55**(1): 18-25.

Smith, S. (2008). "School Building Quality and Student Performance in South Carolina High Schools: A Structural Equation Model."

Snow, D. A., et al. (2003). "Elaborating analytic ethnography linking fieldwork and theory." Ethnography **4**(2): 181-200.

Sobanke, V. O., et al. (2012). "Technological Capability in Metal Fabricating Firms in Southwestern Nigeria." American Journal of Industrial and Business Management **2**(04): 176.

Solov'yanov, A. (2011). "Associated petroleum gas flaring: Environmental issues." Russian Journal of General Chemistry **81**(12): 2531-2541.

Spengler, J. D. and Q. Chen (2000). "Indoor air quality factors in designing a healthy building." Annual Review of Energy and the Environment **25**(1): 567-600.

Srebric, J. (2011). "Ventilation performance prediction." Building Performance Simulation for Design and Operation: 143-179.

Stewart, R. B. (1976). "The Development of Administrative and Quasi-Constitutional Law in Judicial Review of Environmental Decisionmaking: Lessons from the Clean Air Act." Iowa L. Rev. **62**: 713.

Strachan, P. and L. Vandaele (2008). "Case studies of outdoor testing and analysis of building components." Building and Environment **43**(2): 129-142.

Stringer, A., et al. (2012). "Schools design quality: A user perspective." Architectural Engineering & Design Management **8**(4): 257-272.

Stringer, E. T. (2007). Action Research. Los Angeles, SAGE Publications, Inc.

Description based on print version record.

Suresh Kumar, K. (2000). "Pressure equalization of rainscreen walls: a critical review." Building and Environment **35**(2): 161-179.

Suri, H. (2011). "Purposeful sampling in qualitative research synthesis." Qualitative Research Journal **11**(2): 63-75.

Sykorova, I., et al. (2011). "Carbon air pollution reflected in deposits on chosen building materials of Prague Castle." Sci Total Environ **409**(21): 4606-4611.

Szigeti, F. and G. Davis (2001). "Functionality and Serviceability Standards: Tools for stating functional requirements and for evaluating facilities." Federal Facilities Council, in Learning From Our Buildings: A State-of-the-Art Practice Summary of Post-Occupancy Evaluation, National Academy Press, Washington, DC.

Takeda, H., et al. (1990). "Modeling design process." AI magazine **11**(4): 37.

Talbot, D. E. and J. D. Talbot (2007). Corrosion science and technology, CRC press.

Taranath, B. S. (2004). Wind and earthquake resistant buildings: structural analysis and design, CRC press.

Tashakkori, A. and J. W. Creswell (2007). Exploring the nature of research questions in mixed methods research, Sage Publications Sage CA: Los Angeles, CA.

Tawari, C. and J. Abowei (2012). "Air Pollution in the Niger Delta Area of Nigeria." International Journal of Fisheries and Aquatic Sciences **1**(2): 94-117.

Taylor, D. B. (2007). "A brief guide to writing a literature review." Writing in the Health Sciences: a comprehensive guide **1**(1).

The Joint Contracts Tribunal, B. D. P. J. (2001). The JCT guide to the use of performance specifications. London, RIBA Publications.

Thomas, G. and D. James (2006). "Reinventing grounded theory: Some questions about theory, ground and discovery." British Educational Research Journal **32**(6): 767-795.

Tiwari, A., et al. (2014). Intelligent coatings for corrosion control, Butterworth-Heinemann.

Toles, M. and J. Barroso (2014). "Qualitative Approaches to Research." Nursing Research: Methods and Critical Appraisal for Evidence-Based Practice: 109.

Townsend, C. and R. Maynard (2002). "Effects on health of prolonged exposure to low concentrations of carbon monoxide." Occupational and Environmental Medicine **59**(10): 708-711.

Tweed, A. C. and R. Mcleod (2008). "Meeting the 2011 zero carbon buildings target for Wales using the Passivhaus standard."

Twomey, C. (2009). "An analysis of patient information leaflets supplied with medicines sold by pharmacists in the United Kingdom." Library and Information Research **25**(80): 3-12.

Ubani, E. and I. Onyejekwe (2013). "Environmental impact analysis of gas flaring in the Niger delta region of Nigeria." American J. of Scientific and Industrial Research **4**(2): 246-252.2013.

UBEC (2010). MINIMUM STANDARDS FOR BASIC EDUCATION IN NIGERIA U. B. E. Commission. Nigeria, UNEC.

Ugochukwu, C. N. and J. Ertel (2008). "Negative impacts of oil exploration on biodiversity management in the Niger De area of Nigeria." Impact assessment and project appraisal **26**(2): 139-147.

Uline, C. and M. Tschannen-Moran (2008). "The walls speak: The interplay of quality facilities, school climate, and student achievement." Journal of Educational Administration **46**(1): 55-73.

UN, U. N. (2015). "Millennium development goals." United Nations. Available online: http://www. un. org/millenniumgoals/(accessed on 23 August 2011).

UNESCO (2013/14). Teaching and learning: Achieving quality for all. France, United Nations Educational, Scientific and Cultural Organization.

UNESCO, E. (2007). Global Monitoring Report 2008: Education for All by 2015. Will We Make It, Paris, UNESCO.

Unicef (2016). Pollution: 300 million children breathing toxic air - UNICEF report. Clear the air for children

The impact of air pollution on children. D. Anthony. New York, NY 10017, USA, UNICEF.

Urwick, J. (2002). "Determinants of the private costs of primary and early childhood education: findings from Plateau State, Nigeria." International Journal of Educational Development **22**(2): 131-144.

Urwick, J. and S. U. Junaidu (1991). "The effects of school physical facilities on the processes of education: A qualitative study of Nigerian primary schools." International Journal of Educational Development **11**(1): 19-29.

Vaishnavi, V. and W. Kuechler (2007). "Introduction to Design Science Research in Information and Communication Technology." Design science research methods and patterns: innovating information and communication technology: 20.

Vaishnavi, V. K., et al. (2009). Towards design principles for effective context-and perspective-based web mining. Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology, ACM.

Valkokari, K. (2014). "Road-mapping the business potential of sustainability within the European manufacturing industry Author (s) Valkokari, Katr."

Van Aken, J. E. (2005). "Valid knowledge for the professional design of large and complex design processes." Design Studies **26**(4): 379-404.

Van Aken, J. E. and G. Romme (2009). "Reinventing the future: adding design science to the repertoire of organization and management studies." Organization Management Journal **6**(1): 5-12.

Vander Stichele, R. H., et al. (1991). "Attitude of the public toward technical package inserts for medication information in Belgium." Annals of Pharmacotherapy **25**(9): 1002-1006.

Vaughan, E. L. (2016). "ELEMENTARY SCHOOL ". Retrieved 13/12, 2016, from https://www.wbdg.org/building-types/education-facilities/elementary-school.

Venable, J. (2006). The role of theory and theorising in design science research. Proceedings of the 1st International Conference on Design Science in Information Systems and Technology (DESRIST 2006), Citeseer.

Visscher, H. and F. Meijer (2006). Building regulations for housing quality in Europe. ENHR conference 2006: Housing in an expanding Europe. Theory, policy, implementation and participation, Ljubljana, July 2-5, Urban Planning Institute of the Republic of Slovenia.

Volland, G. (2014). "Exposure Analysis for Indoor Contaminants." Regulatory Toxicology: 277-288.

von Alan, R. H., et al. (2004). "Design science in information systems research." MIS quarterly **28**(1): 75-105.

Waller, L. G. (2013). "Interviewing the surveyors: factors which contribute to questionnaire falsification (curbstoning) among Jamaican field surveyors." International Journal of Social Research Methodology **16**(2): 155-164.

Walliman, N. (2011). Research Methods: the basics. Abingdon, Oxon, Routledge.

Watkiss, P., et al. (2006). Damage Costs for Air Pollution.

Watt, D. S. (2009). Building pathology: Principles and practice, John Wiley & Sons.

Watt, J. and R. Hamilton (2003). "The soiling of buildings by air pollution." Air Pollution Reviews. The Effects of Air Pollution on the Built Environment **2**: 289e334.

Weaver, M. E. (1991). "Acid Rain and Air Pollution vs. the Buildings and Outdoor Sculptures of Montréal." APT Bulletin **23**(4): 13-19.

Weber, R. (2003). "Still desperately seeking the IT artifact." MIS quarterly **27**(2): 183-183.

Weli, V. E. and O. Adekunle (2014). "Air Quality in the Vicinity of a Landfill Site in Rumuolumeni, Port Harcourt, Nigeria." Journal of Environment and Earth Science **4**(10): 1-9.

Wen, Y.-K. and Y. Kang (2001). "Minimum building life-cycle cost design criteria. I: Methodology." Journal of Structural Engineering **127**(3): 330-337.

Whitehead, T. L. (2005). "Basic classical ethnographic research methods." Ethnographically Informed community and cultural assessment research systems.

WHO, W. H. O. (2002). Reducing Risks, Promoting Healthy Life. Geneva.

WHO, W. H. O. (2014). "Air Pollution." Retrieved 31/10/2014, 2014, from http://www.who.int/topics/air_pollution/en/.

WHO, W. H. O. (2014). Air quality deteriorating in many of the world's cities.

Wieringa, R. J. (2014). Design science methodology for information systems and software engineering, Springer.

Willich, S., et al. (2006). "Noise burden and the risk of myocardial infarction." European heart journal **27**(3): 276-282.

Winch, G. M. (2013). "Escalation in major projects: Lessons from the Channel Fixed Link." International Journal of Project Management **31**(5): 724-734.

Wolf, A. (2015). Considerations for Prolonging the Working Life of Sealed Exterior Building Joints. Durability of Building and Construction Sealants and Adhesives: 5th Volume, ASTM International.

Wong, C., et al. (1998). "Comparison between two districts of the effects of an air pollution intervention on bronchial responsiveness in primary school children in Hong Kong." Journal of Epidemiology & Community Health **52**(9): 571-578.

Wong, T. W. and A. H. Wong (2014). "The public health challenges." Routledge Handbook of Global Public Health in Asia: 310.

Woolner, P. and E. Hall (2010). "Noise in schools: a holistic approach to the issue." International journal of environmental research and public health **7**(8): 3255-3269.

WorldBank (2011). Gas Flarring Reductions Aviods 30 Million Tons of Carbon Dioxide Emissions in 2020. M. Rios. Washington.

WorldBank (2013). Population ages.

Worzala, E. and S. Bond (2011). "Barriers and drivers to green buildings in Australia and New Zealand." Journal of Property Investment & Finance **29**(4/5): 494-509.

Yang, T. (2017). A whole-system approach to high-performance green buildings, Taylor & Francis.

Yang, T. and D. J. Clements-Croome (2012). Natural Ventilation natural ventilation in Built Environment natural ventilation in-built environment. Encyclopedia of Sustainability Science and Technology, Springer New York**:** 6865-6896.

Ye, Q. and E. C. Economy (2013). "China's environmental future." McKinsey Quarterly(3): 40-41.

Yin, R. K. (2009). Case Study Research: Design and Methods. 4. udgave, Sage Publications.

Yin, R. K. (2013). Case study research: Design and methods, Sage publications.

Yip, M. and P. Madl (2002). Air Pollution in Mexico City, University of Salzburg, Austria.

Zamawe, F. (2015). "The implication of using NVivo software in qualitative data analysis: Evidence-based reflections." Malawi Medical Journal **27**(1): 13-15.

Zande, R. V. (2011). "Design Education Supports Social Responsibility and the Economy." Arts Education Policy Review **112**(1): 26-34.

Zannin, P. H. T. and D. P. Z. Zwirtes (2009). "Evaluation of the acoustic performance of classrooms in public schools." Applied Acoustics **70**(4): 626-635.

Zhao, R. and Y. Xia (1998). Effective non-isothermal and intermittent air movement on human thermal responses. Proc. of Roomvent.

Zolfani, S. H. and E. K. Zavadskas (2013). "Sustainable development of rural areas' building structures based on local climate." Procedia Engineering **57**: 1295-1301.

Appendix A

List of Publications

Ogbonda, U.J & Bichard E (2015)An Approach for Examining the State and Value of Public Schools in the Gas Flaring Areas of Nigeria; African Real Estate (Afres) Conference 31st August to 5th October 2015, Kumasi, Ghana

Ogbonda, U.J (2016) "Design Performance Specification for Resilient School buildings in the Vicinity of Gas Flaring in the Niger Delta Area of Nigeria" Publication of research preamble in the University of Salford Urban Processes, Resilient Infrastructure Sustainable Environment (UPRISE).

Akujuru. V & Ogbonda U.J (2016) Rationalising the Contemporary Issues in the Valuation of Land for Infrastructural Development in Nigeria. Donnish Journal of Environmental Studies Vol 3, Issue, 01, pp. 001-007

Ogbonda, U.J & Bichard E (2017) Examining the State of Public Schools in the Gas Flaring Areas of Nigeria. Asian Journal of Science and Technology Vol. 08, Issue, 04, pp.4574-4579

Ogbonda U.J. & Yingchun Ji (2017) Critique of the Ventilation System Used for Public Schools around Gas Flaring Sites in the Nigeria Niger Delta Area; Healthy Building (ISAQ) Conference 2nd -5th July 2017, Lublin Poland

Ogbonda U.J. & Yingchun Ji (2017) Criteria for Public School Construction in Polluted Environment: A Case of the Niger Delta Area of Nigeria; International postgraduate research (IPGRC) Conference Salford UK

Ogbonda U.J., Yingchun Ji, Paul Coates & Erik Bichard (2017) The Impact of Gas Flare on Oil Fields' Environments; Academicsera International Conference on Multidisciplinary Research & Practice (ICMRP) 28-29 October Canada

Ogbonda U.J. & Yingchun Ji (2017) The effect of gas flares on the health of schoolchildren in the Niger delta area of Nigeria. International Journal of Humanities and Social Science Research Vol. 03; Issue, 08, pp. 10-15

Appendix B

The incomplete information on the amount of GFper company exploring Oil in the ND

10—Year Gas Production vs Flared by Company (mscf)

COMPANY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
JOINT VENTURE:											
SHELL											
GAS PRODUCED	740,302,238	671,326,319	735,315,476	763,905,871	800,689,383	455,894,266	777,170,431	864,835,618	848,333,416	599,410,787	681,782,525
GAS FLARED	275,248,361	216,876,732	163,405,866	96,967,320	97,879,670	77,819,939	103,477,380	85,333,761	62,258,849	45,613,944	51,915,284
% OF GAS FLARED	37.18	32.31	22.22	12.69	12.22	17.07	13.31	9.87	7.34	7.61	7.61
MOBIL											
GAS PRODUCED	392,065,111	446,743,226	491,110,702	464,537,142	427,115,491	427,919,671	479,251,266	278,267,754	396,961,650	442,279,916	498,281,731
GAS FLARED	174,859,914	179,534,640	201,026,922	183,528,046	130,586,764	122,567,197	122,745,744	66,088,196	73,594,937	43,869,959	42,863,531
% OF GAS FLARED	44.60	40.19	40.93	39.51	30.57	28.64	25.61	23.75	18.54	9.92	8.60
CHEVRON											
GAS PRODUCED	209,897,271	238,352,653	235,249,063	191,186,784	243,040,550	166,573,783	194,327,349	266,330,614	246,142,456	238,507,252	295,989,619
GAS FLARED	125,087,325	136,523,011	192,602,299	162,780,356	142,625,580	112,931,552	118,309,010	105,289,859	83,505,632	67,137,729	53,624,369
% OF GAS FLARED	59.59	57.28	81.87	85.14	58.68	67.80	60.88	39.53	33.93	28.15	18.12
TOTAL E & P											
GAS PRODUCED	209,208,860	207,893,532	218,968,851	289,817,162	320,372,686	302,772,348	277,253,720	260,372,978	223,020,171	212,999,376	216,964,029
GAS FLARED	47,752,399	29,840,233	64,224,402	33,842,081	35,758,806	26,825,119	30,475,487	28,853,296	26,087,338	30,192,077	22,783,191
% OF GAS FLARED	22.83	14.35	29.33	11.68	11.16	8.86	10.99	11.08	11.70	14.17	10.50
NAOC											
GAS PRODUCED	433,997,252	429,003,689	423,716,209	320,927,714	293,668,636	272,334,581	441,864,139	470,413,456	470,413,456	317,176,081	407,714,508
GAS FLARED	178,670,250	161,837,476	109,926,431	108,696,157	96,353,534	71,103,491	102,888,514	219,000,564	57,317,015	42,513,538	35,785,398
% OF GAS FLARED	41.17	37.72	25.94	33.87	32.81	26.11	23.29	46.55	12.18	13.40	8.78
TEXACO											
GAS PRODUCED	13,721,063	7,366,467	5,941,278	2,479,303	4,803,727	7,085,828	7,683,657	6,492,267	4,325,610	5,451,064	4,805,489
GAS FLARED	13,605,041	7,251,079	5,828,277	2,421,926	4,746,874	6,999,689	7,553,166	6,407,635	4,192,499	5,113,373	4,428,580
% OF GAS FLARED	99.15	98.43	98.10	97.69	98.82	98.78	98.30	98.70	96.92	93.81	92.16
PAN-OCEAN											
GAS PRODUCED	27,265,601	27,067,500	3,944,139	-	21,752,432	207,473	8,082,809	12,737,108	3,372,789	NOT AVAILABLE	866,274
GAS FLARED	25,967,694	25,779,438	3,756,324	-	21,211,546	201,909	6,796,633	3,806,306	2,324,147	NOT AVAILABLE	435,274
% OF GAS FLARED	95.24	95.24	95.24	-	97.51	97.32	84.09	29.88	68.91	-	50.25
JVC SUB - TOTAL											
GAS PRODUCED	**2,026,457,396**	**2,027,753,386**	**2,114,245,717**	**2,032,853,975**	**2,111,442,905**	**1,632,787,949**	**2,185,633,371**	**2,159,449,794**	**2,192,569,548**	**1,815,824,476**	**2,106,404,175**
GAS FLARED	**841,190,984**	**757,642,609**	**740,770,521**	**588,235,886**	**529,162,773**	**418,448,895**	**492,245,933**	**514,779,616**	**309,280,417**	**234,440,620**	**211,835,626**
% OF GAS FLARED	**41.51**	**37.36**	**35.04**	**28.94**	**25.06**	**25.63**	**22.52**	**23.84**	**14.11**	**12.91**	**10.06**
PRODUCTION SHARING:											
ADDAX											
GAS PRODUCED	38,036,721	46,481,560	54,580,697	68,093,192	83,876,751	72,678,580	84,989,027	75,305,694	67,386,027	46,211,847	54,685,267
GAS FLARED	28,204,432	36,112,453	46,268,969	58,549,342	73,028,019	58,614,336	64,920,466	54,764,734	47,811,514	31,532,670	35,600,676
% OF GAS FLARED	74.15	77.69	84.77	85.98	87.07	80.65	76.39	72.72	70.95	68.24	65.10
ESSO											
GAS PRODUCED	N/A	N/A	N/A	28,310,626	75,260,666	110,648,124	104,990,025	59,287,658	139,600,203	112,226,569	109,580,927
GAS FLARED	N/A	N/A	N/A	2,070,036	3,865,012	11,537,590	7,379,772	2,616,846	15,917,915	9,336,930	4,517,188
% OF GAS FLARED	-	-	-	7.31	5.14	10.43	7.03	4.41	11.40	8.32	4.12
NAE											
GAS PRODUCED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	844,973	1,301,980	6,569,520	4,210,165
GAS FLARED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	783,486	801,960	4,918,770	710,467
% OF GAS FLARED	-	-	-	-	-	-	-	92.72	61.60	74.87	16.88
SNEPCO											
GAS PRODUCED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	36,503,491	58,842,827	31,930,952	51,003,930
GAS FLARED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4,225,429	4,378,484	4,588,362	915,456
% OF GAS FLARED	-	-	-	-	-	-	-	11.58	7.44	14.37	1.79
SEEPCO											
GAS PRODUCED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	508,847	755,489
GAS FLARED	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	287,827	160,266
% OF GAS FLARED	-	-	-	-	-	-	-	-	-	56.56	21.21

Source: NNPC (2014)

APPENDIX C

Tabulated List of All Laws Relating to Gas and Air Pollution

No.	YEAR	POLICY/LAW/REGULATIONS	DESCRIPTION
1	1969	Petroleum Act law	which vested the ownership and control of all petroleum resources in the Federal Government of Nigeria
2	1969	Petroleum (Drilling and Production) Regulation	Essentially for crude oil production
3	1956 1995	Oil Pipeline Act	This is essentially for crude oil and petroleum product operations
4	1973	Petroleum Amendment Decree	Allowed the use of associated gas without payment of royalties.
5	1979	Associated Gas Re-injection Decree 99	Stated that companies producing oil should have stopped flaring the associated gas by 1984, except those with a special permission of the Minister of Petroleum and Resources.
6	1985	Associated Gas Re-injection Amendment Decree 7	Introduced a fine (proportional to the amount of gas flared) to those fields where the authorities had not granted the permission of flaring)
7	1990	The Nigerian LNG fiscal incentives, guarantees and Assurance Act	Specific to Nigerian Liquefied Natural Gas project in Bonny Island. Its incentives and guarantees have constitutional implications
8	1991	Effluent Limitation Regulations 1991 (DPR)	
9	1992	Associated Gas Framework Agreement (AGFA)	This is Introduced as part of fiscal incentives for the utilization of natural gas.
10	1995	Oil and gas pipeline regulations	Petroleum transportation and storage regulation
11	2003	National Energy Policy	To ensure optimal, adequate, reliable and secure and utilisation in the country
12	2004	National oil and gas policy	Provides policy framework for a liberalised and functional gas industry, especially the domestic gas utilisation.
13	2005	Downstream gas bill	Proposed to implement the liberalisation of the domestic gas market
14	2008	Nigerian Gas Master Plan (NGMP)	To ensure – Domestic gas supply - Gas infrastructure blueprint - Gas price policy
15	2008 2008	National domestic gas supply and pricing regulation National Domestic Gas Supply and Pricing Policy	An extended legal and policy framework to implement NGMP
16	2012	Petroleum Industry Bill	A comprehensive legal framework for exploitation of petroleum product including gas

Appendix D

Consent form for participation

Manchester
M5 4wt
Tel: +447884519645
Email: U.J.Ogbonda@edu.salford.ac.uk
11th March 2015

CONSENT FOR RESEARCH INTERVIEW PARTICIPATION
RE: SPECIFICATION FOR THE DESIGN OF PUBLIC SCHOOL BUILDINGS IN THE VICINITY OF GAS FLARING IN THE NIGER DELTA AREA OF NIGERIA
Dear Sir,

I am a PhD research student in the school of Built Environment, University of Salford Greater Manchester, United Kingdom. I am currently undertaking research on the effect of gas flare on roofing materials and indoor air quality of public school buildings in the Niger Delta area of Nigeria. It is the anticipation of the researcher that the outcome will provide professionals in the built environment specialised in construction of buildings a guideline in material choice while providing clean air quality for public school building users thereby increasing learning ability.

The aim of research is concerned with corrosion, blackening, discolouration, deterioration of external façade and internal air quality of public school building in the vicinity of gas flaring (air pollution) in Nigeria. The data collection method will be through a semi-structured interview and it is expected to last for an hour.

I would be very grateful if you could confirm your interest and willingness to participate in this research as your participation will contribute immensely to this study and timely completion of the PhD programme.

This research will not disrupt your working environment and all information collected as part of the data for this research purpose will remain confidential, as your identity will be anonymous. This shall remain same both in this research and in any publications. However, you are a liability to withdraw from participation in this research and future publications.

For further inquiry or clarifications, you can contact me through the above address or my supervisor Professor Erik Bichard (E.Bichard@salford.ac.uk).

Yours faithfully,

Uche J. Ogbonda

Appendix E

RESEARCH PARTICIPATION CONSENT FORM

TILTLE: SPECIFICATION OF THE DESIGN OF PUBLIC SCHOOL BUILDINGS IN THE VICINITY OF GAS FLARING IN THE NIGER DELTA AREA OF NIGERIA

Name of Research: Uche J. Ogbonda

Tick as appropriate (√)

s/n		Yes	No
1	I confirm that I have read and understood the information sheet for the above study and what my contribution will be		
2	I have been given the opportunity to ask questions about the study		
3	I agree to take part in the interview		
4	I understand that the information provided will only be kept for the duration of this research		
5	I understand that the information provided will be confidential and any information about me will not be disclosed to a third party		
6	I agree to the interview being tape recorded		
7	I understand that my participation is voluntary and that i can withdraw from the research at any time without giving any reason and any information provided destroyed immediately		
8	I agree to digital images being taken during the research exercises		
9	I agree to take part in the above study		

Name of participant: ………………………………………………………………………………………….

Signature: ………………………………………………………………………………………….

Date: ………………………………………………………………………………………….

Appendix F

Ethical Approval for Data Collection Purposes

Academic Audit and Governance Committee

University of Salford MANCHESTER

College of Science and Technology Research Ethics Panel (CST)

To **Ogbonda Uche Joyce (and Prof Erik Bichard)**

cc: **Professor Hisham Elkadi, Head of School of SOBE**

Chapter 10. **From** **Nathalie Audren Howarth, College Research Support Officer**

Date **24/04/2015**

Subject: **Approval of your Project by CST**

Project Title: **Specification for the resilient design of school buildings in the vicinity of gas flaring in the Niger Delta Area of Nigeria**

REP Reference: **CST 15/14**

Following your responses to the Panel's queries, based on the information you provided, I can confirm that they have no objections on ethical grounds to your project.

If there are any changes to the project and/or its methodology, please inform the Panel as soon as possible.

Regards,

Nathalie Audren Howarth
College Research Support Officer

Appendix G

QUESTIONNAIRE SURVEY

Title of Project: Specification for the resilient design of school buildings in the vicinity of gas flaring in the Niger Delta Area of Nigeria

Name of Researcher: Uche J. Ogbonda

Name of Supervisor: Prof. Erik Bichard

Co-supervisor: Dr. Paul Coats

Aim: The aim of this research is to design a performance specification for public buildings in the VGFs in the Niger Delta Area of Nigeria.

The questionnaire is targeted at professionals in the built environment involved in public building constructions around gas flaring areas as well as those in the ministry of housing and development who deal construction approvals.

Confidentiality: All information provided will be treated in strict confidence and your identity and anonymity is guaranteed. Results will only be published in aggregate form and used strictly for the purpose of this research only. Any acknowledgement of you or your organisation will be made subject to your agreement. The questionnaire is estimated to take between 20-25 minutes to complete.

About this research: The research aims at producing benchmarks that will help reduce deterioration rate in public school buildings while achieving clean indoor air quality for children schooling around gas flaring environment of the Niger Delta Area of Nigeria.

Section A - Identification of building materials: The aim of this section is to show how knowledgeable participants are and to show if there are any impact of gas flaring on materials used for construction

Q1. How would you rate your knowledge of construction materials used in Public Buildings?

	1 Not Knowledgeable	2 Low knowledge	3 Moderate knowledge	4 Highly knowledgeable	5 Very highly knowledgeable

Q2. How would you rate the quality of materials used for construction of public schools in Nigeria in relation to international standards:

	1 Very Poor quality	2 Poor quality	3 average quality	4 good quality	5 very good quality

Q3. What factors influence the quality of materials used for construction in public schools from the following;

	1 Least influential	2 Low influential	3 Moderately influential	4 Highly influential	5 Very Highly influential
Finance					
Specifications from Nigerian Building Code (NBC)					
Politics					
Lack of expertise					
Availability					
Unconcerned attitude					

Q4. In your opinion, what are the causes of defects in public school buildings in the Niger Delta? 1-never; 2-rarely; 3-sometimes; 4-often; 5-always *(please tick as appropriate)*

	Corrosion					Blackening					Discolouration					Deposition of Debris					Leakages				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Weather condition																									
Low quality material																									
Poor workmanship																									
Material type																									

No maintenance culture																									
'I don't care attitude'																									

Q5. What factors influence the quality of materials used for construction in public schools from the following;

	1 Least influential	2 Low influential	3 Moderately influential	4 Highly influential	5 Very Highly influential
Finance					
Specifications from Nigerian Building Code (NBC)					
Politics					
Lack of expertise					
Material costs					
Availability					
Unconcerned attitude					

Q6. In your view, what factors influences the effectiveness of Nigerian Building Code (NBC)

	1 Not influential	2 Low influence	3 Moderately influential	4 Very influential	5 Very highly influential
Lack of awareness of NBC					
Inadequate provisions in NBC					
Lack of current regulations					
No unified calibration with imported materials					
No enforcement team					

Q7. In your opinion, rate the efficiency of imported building materials in reducing the impact of gas flares in public school buildings:

	1 Not efficient	2 Low efficiency	3 Moderately efficient	4 Very efficient	5 Very high efficiency

UK imported alternative building materials					
US imported alternative building materials					
China imported alternative building materials					
Locally manufactured materials					

Q8. Rate the influence of the listed factors on the selection of construction method and types of material used for public school buildings:

	least influential	slightly influential	somewhat influential	very influential	extremely influential
Funds					
Policies					
Building codes					
Material availability					
Lack of skilled labour					
Lack of unskilled labour					

Q9. In your opinion, what is the impact of gas flare on building fabric?

	1 Very Low impact	2 Low impact	3 Moderate impact	4 High impact	5 Very High impact
Corrosion					
Blackening					
Discolouration					
Dry and wet rot					
Leakages					
Painting peeling					
Damp walls					
Cracks					

Q10. What impact does gas flaring have on the following roofing materials?

	1 Very Low impact	2 Low impact	3 Moderate impact	4 High impact	5 Very High impact
Thatch					
Asbestos					
Zinc					
Aluminium					

Section two (B) The impact of gas flare on indoor air quality: the aim of the section is to find out if gas flare impact on health and ventilation system used for clean air in public school buildings

Q11. What are the impacts of gas flaring on the indoor air quality of schools on the occupants?

	1 Very Low impact	2 Low impact	3 Moderate impact	4 High impact	5 Very high impact

Q12. What available standard of air quality do you consider effective for public schools buildings?

	1 Not effective	2 Less effective	3 Fairly effective	4 Highly effective	5 Very highly effective
FEPA					
WHO					
EPA					
USEPA					
UK guideline					

Q13. What are the impacts of gas flaring on performance of schoolchildren around the vicinity of gas flaring?

	1 Very Low impact	2 Low impact	3 Moderate impact	4 High impact	5 Very high impact

Q14. In your opinion, do you think that gas flaring has any impact on the health of schoolchildren and staffs in such vicinity?

	1 Very Low impact	2 Low impact	3 Moderate impact	4 High impact	5 Very high impact

Q15. What ventilation systems are used to control the indoor air quality in gas flaring vicinity?

	1 Not used	2 Fairly used	3 Moderately used	4 Frequently used	5 Very frequently used
Open windows					

Closed windows					
Ceiling fans					
Air conditioners					
Air humidifiers					

SECTION C: GENERAL INFORMATION: The aim of this section is to have general background information of respondents and their knowledge of the research intent.

*In each of questions, 16-18, please tick **one box** only*

Q16. Please state your current job title:
[ ] Architect/Designer
[ ] Estate Surveyor and Valuer
[ ] Urban and Regional planners
[ ] Quantity surveyor
[ ] Land Surveyors
[ ] Environmentalist
Q17. Number of years in the profession/occupation: [ ] Less than 1 year [ ] 1-5 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years [ ] More than 20 years

Q18. How long have you been working or living around gas flaring areas: [ ] Less than 1 year [ ] 1-5 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years [ ] More than 20 years

Thank you for taking the time to complete this questionnaire

Appendix H

Face-to-Face Interview Guide Questions

A: ***Gas Flaring***
The aim of this section is to understand the perception of interviewees about gas flaring

1. What is your understanding of gas flaring?
2. Do you think that gas flaring has any environmental impact? Ff – could you mention some of these impacts
3. How do you ascertain that these impacts are as a result of gas flaring
4. Are there other significant issues that you think are as a result of gas flaring
5. Are you aware of any intervention measure to reduce gas flaring?
6. In your opinion, do you think that Nigeria will stop gas-flaring to a sustainable method? FF - where in the future do you think this might be achieved?
7. Does gas flaring impact on the indoor air quality?
8. Do you think that additional measures should be taken to provide clean indoor air quality? FF – what additional measures would you recommend

B: ***Building Materials***
The aim of this section is to understand the perception of participants on the effect of gas flaring on building materials

1. In your opinion, do you think gas flare causes acid rain?
2. What impact does acid rain have on building materials
3. Do you think that these impacts are observable in public school buildings? FF- do you think these impacts are because of the materials used?
4. Do you think that improvements in material selection and use will reduce such impacts
5. Do you think there are sufficient building materials law that guides against sub-standard materials
6. Do you think that the built environment professionals should be integrated into the construction process of public schools
7. Do you think a specification guideline should be enacted that gives a comprehensive data as a model to follow in the construction of public schools?
8. What material type do you recommend to be used in public school construction
9. Do you think that the use of sub-standard materials is because of financial incapacitation?
10. What other reasons can you give for the use of sub-standard materials in building?

Any other comments/contribution you consider necessary will be appreciated.

Appendix I

Open-ended questionnaire for Demonstration Purposes

Title of Project: Specification for the design of school buildings in the vicinity of gas flaring in the Niger Delta Area of Nigeria

Name of Researcher: Uche J. Ogbonda

Name of Supervisor: Prof. Erik Bichard

Co-supervisor: Dr. Paul Coats

Aim: To design Performance Specification for school buildings in the vicinity of gas flares in the Niger Delta Area of Nigeria.

The questionnaire is targeted at professionals in the built environment involved in public building constructions around gas flaring areas as well as those in the ministry of housing and development who deals with construction approvals.

Confidentiality: All information provided will be treated in strict confidence and your identity and anonymity is guaranteed. Results will only be published in aggregate form and used strictly for the purpose of this research only. Any acknowledgement of you or your organisation will be made subject to your agreement. The questionnaire is estimated to take between 30-35 minutes to complete.

About this research: The research aims at producing benchmarks that will help reduce deterioration rate in school buildings while achieving clean indoor air quality for children schooling around gas flaring environment of the Niger Delta Area of Nigeria.

GENERAL INFORMATION: the aim of this section is to have general background information of respondents and their knowledge of the research intent.

*In each of questions, 1-3, please tick **one box** only*

Q1. Please tick your profession

[ ] Architect
[ ] Health practitioners
[ ] Quantity surveyor
[ ] Material scientist
[ ] air pollution expert
[ ] Estate surveyors and Valuers

Q2. Number of years in the profession/occupation: [ ] Less than 1 year [ ] 1-5 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years [ ] More than 20 years

Q3. How long have you been working or living around gas flaring areas: [ ] Less than 1 year [ ] 1-5 years [ ] 6-10 years [ ] 11-15 years [ ] 16-20 years [ ] More than 20 years

Section B: The aim of this section is to demonstrate the designed artefact by determining the views of professionals.

Q4. Do you agree that limiting gaseous substances emitted from gas flare to the amount specified below will provide clean indoor air in public schools? 1- Strongly agree; 2- agree; 3- partially agree; 4- disagree; 5- strongly disagree; 6- I Don't know

Factor Base/Criterion	1	2	3	4	5	6
Carbon dioxide CO 15 minutes – 100 mg/m3; 1 hour – 35 mg/ m3; 8 hours – 10 mg/ m3; 24 hours – 7 mg/m3						
Particulate matter PM $PM_{2.5}$: 10µg/m^3 annual mean; 25µg/m^3 24-hour mean PM_{10}: 20µg/m^3 annual mean; 50µg/m^3 24-hour mean						
Ozone O_3: 100µg/m^3 8-hour mean						
Nitrogen oxides NO_x: 40µg/m^3 annual mean; 200µg/m^3 1-hour mean						
SO_2: 20µg/m^3 24-hour mean; 500µg/m^3 10-minute mean						
Benzene Avoid unit risk of leukaemia per 1µg/m3						
Polycyclic Aromatic Hydrocarbons (PAHs) 1 ng/m^3 (one Nano gram per millilitre)						

Q4b: If you have ticked options 4 and5 kindly state your reasons and likely suggestions you might have:---

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Q5. Adopting 1- Strongly agree; 2- agree; 3- partially agree; 4- disagree; 5- strongly disagree; 6- I Don't know; State whether the listed factors are achievable during design and construction of public schools in the vicinity of gas flaring?

Thermal performance of roof coverings 0.25 W/m2K – weighted average	1	2	3	4	5	6
Thermal performance of roof lights 2.2 W/m2K – weighted average						
Indoor sound insulation meeting $L_{Aeq,30mins}$ dB requirement						
Materials should be Resistant to cracks meeting BS EN ISO 15156-1:2015 standard						
Building longevity should a be minimum of 60 years						
Materials should have 5.6 acidity resistance level						
A resistance factor of 5mpy (Milli-inch per year) standard						
Materials should be impervious to water meeting BS EN 12208:2000 standard						
Materials should be resistant to wind meeting BS EN 12211: 2000 standard						
Materials should be resistant to carbon to meet ASTM D3361 / D3361M :2013 standard						
Materials should be resistant to salt spray meeting ASTM B117 :2011 standard						
Weather-stripping should meet BS 4255-1:1986 requirement						
Glazing materials should meet BS EN ISO 52022-1:2015 requirement						
Frame joint sealing materials should meet BS 6093:2006+A1:2013						
Thermal comfort should not be more than 10% of the hours in any given year of 25^0C						
Pressure level in which material can withstand in different environment should meet BS 6375-1:2009						
Coating material should be able to withstand weather conditions without losing its original colour over the stipulated time as						

required in ASTM D2244 : 2015 standards						
Space cooling demand not exceeding 15 kWh/(m²a)						
Weather tightness should meet BS 6375-1:2015 standard						
Do you agree that air tightness of 0.6 air changes per hour at 50 Pascal's pressure (ACH50) is adequate?						
Corrosive resistance Coating meeting BS EN ISO 14713-1:2009 standard						
Do you agree that colour tolerance should meet ASTM D2244: 2015						
Thermal barriers should meet BS EN 14024:2004						
Acoustic performance should meet BS EN ISO 140:2006						

2b: If you have ticked options 4 and 5 kindly state your reasons and likely suggestions you might have: ---
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Appendix J

Performance Specification Information Pamphlet

University of Salford
MANCHESTER

Specification for the design of schools in the vicinity of gas flaring in the Niger Delta area of Nigeria

PhD research work for demonstration purposes

Ogbonda Uche Joyce

Introduction

This pamphlet is designed to further explain the salient points about the potential specification for the design of schools in the vicinity of gas flaring in the Niger Delta area of Nigeria as part of an ongoing PhD research project. It is hoped that this explanation will help you appreciate the consequences of choosing any preferred option(s) as illustrated in the attached questionnaire. Kindly peruse this pamphlet and answer the questions in the attached questionnaire.

Specification for the design of schools in the vicinity of gas flaring in the Niger Delta area of Nigeria

No	Explicated Problem	Performance Requirement	Specification
SP1	<u>Indoor Air quality</u> Poor environments in schools cause ill health, performance and attendance of students. Many existing school space-conditioning systems using conventional mixed ventilation systems are not designed to filter pollutants and fail to provide the indoor air quality that can produce optimal student and teacher performance. Therefore, the need to provide schools with the means to maintain clean air as determined by the best standards from WHO/BS/EN on air quality standard	Protect occupants from harm due to adverse health effect arising from poor air Improve effectiveness of learning process Reduce absenteeism Provide comfort	
SP2	Carbon monoxide (CO) Carbon monoxide (CO) is a colourless, non-irritant, odourless and tasteless toxic gas. Common symptoms include	Using BS EN 14626: 2012 as a standard measure for any air handling system that could achieve reduction	Protect against CO as specified by WHO: 15 minutes – 100 mg/m3 1 hour – 35 mg/ m3

	headache, lethargy/fatigue, nausea, dizziness and confusion. A victim may also suffer from shortness of breath, cardiac palpitations, convulsion, paralysis, loss of consciousness, coma and eventually death		8 hours – 10 mg/ m3 24 hours – 7 mg/m3
SP3	Particulate Matter ($PM_{2.5}$ & PM_{10}): PM affects more people than any other pollutant. The major components of PM are sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, ($\leq PM_{10}$), which can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer.	$PM_{2.5}$: BS EN 12341: 2014 PM_{10}: BS EN 12341: 2014 (BSI 2014)	$PM_{2.5}$ 10µg/m^3 annual mean 25µg/m^3 24-hour mean PM_{10} 20µg/m^3 annual mean 50µg/m^3 24-hour mean
SP4	Ozone (O_3) Excessive ozone in the air can have a marked effect on human health. It can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases	O_3: BS EN 14625:2012	O_3 100µg/m^3 8-hour mean
SP5	Nitrogen oxide (NO_x) Epidemiological studies have shown that symptoms of bronchitis in asthmatic	NOx: BS EN 14211:2012	NO_x 40µg/m^3 annual mean 200µg/m^3 1-hour mean

	children increase in association with long-term exposure to NO_2. Reduced lung function growth is also linked to NO_2		
SP6	Sulphur dioxide (SO_2) SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes. Inflammation of the respiratory tract causes coughing, mucus secretion, aggravation of asthma and chronic bronchitis and makes people more prone to infections of the respiratory tract. Hospital admissions for cardiac disease and mortality increase on days with higher SO_2 levels. When SO_2 combines with water, it forms sulphuric acid; this is the main component of acid rain, which is a cause of deforestation and deterioration in building materials.	BS EN 14212:2012	SO_2 20µg/m^3 24-hour mean 500µg/m^3 10-minute mean SO_2 concentration of 500µg/m^3 should not be exceeded over average periods of 10 minutes duration. Studies indicate that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 as short as 10 minutes.
SP7	Benzene Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and a plastic anaemia. Acute exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion,	BS EN 14662:2005	No safe level of exposure can be recommended. Unit risk of leukaemia per 1µg/m3 Air concentration is 6 × 10–6 The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1000 000 are 17, 1.7 and 0.17µg/m^3,

	tremors and loss of consciousness, moderate eye irritant and a skin irritant		respectively
SP8	Polycyclic Aromatic Hydrocarbons Short-term exposure to PAHs also has been reported to cause impaired lung function in asthmatics and thrombotic effects in people affected by coronary heart disease, eye irritation, nausea, vomiting, and diarrhoea. Long-term exposure to PAHs has been reported to have an increased risk of skin, lung, bladder, and gastrointestinal cancers	BS EN 14902: 2005	1 ng/m^3 (one Nano gram per millilitre)
SP9	Air tightness The fundamental building property that impacts infiltration, caused by pressure effects of the wind and/or stack effect	Stop the uncontrolled inward leakage of outdoor air through cracks, interstices or other unintentional openings of a building	0.6 air changes per hour at 50 Pascal's pressure (ACH50)
SP10	Materials: Materials after exposure to pollution from gas flares should be durable. Therefore, specification of roof and wall cladding has implications well beyond the aesthetics. The choice of cladding can affect many aspects of the building's performance Different types of cladding materials could be used for construction. However, it should meet the minimum standards as prescribed by both BS/EN	Durable materials that can withstand chemical influences from pollution from gas flare All materials, products and building systems shall be appropriate and suitable for their intended purpose	

	Cladding materials for roofs and walls Cladding material used for the external façade of a building is important as it interacts with the outside environment and keeps the inside environment comfortable. The material used for the external façade can be the source of the majority of future building problems if it is not suited for such environment. cladding materials should be chosen to meet climatic needs of the area and buildings should be aligned in such a way that they are concordant to the direction of prevailing winds in order to prevent parts of the material like the roofs from blowning off		
SP11	Thermal performance of roof covering	Material should provide cool internal environment	0.25 W/m2K – weighted average
SP12	Thermal performance of roof lights	Material should be to provide adequate heat loss rather than heat gain	2.2 W/m2K – weighted average
SP13	Indoor ambient noise level/ Airborne sound insulation	(a)clear communication of speech between teacher and student (b) clear communication between students (c) learning and study activities	$L_{Aeq,30mins}$ dB
SP14	Resistance to cracks	BS EN ISO 15156-1:2015	Materials should be crack resistant
SP15	Minimum lifetime	Minimum life of the building should not be less than that specified	In school buildings, the roof deck and insulation must have a minimum lifetime of 60 years, with the roof covering lasting a minimum of 30 years for roof covering, to be easily overlaid, over coated, upgraded or replaced without effecting the insulation/deck below, when assessed by a competent technical professional. Evidence must be provided by the roof covering manufacturer from an independent accredited test authority or historical data that the above minimum lifetime can be achieved.
	Corrosion resistance level: Corrosion is the natural degradation of a material due to its dissolution, caused by reactions with the surrounding environment. Corrosion is nature seeking to recombine elements which have been reduced to an unnaturally pure form		
SP16	Acidic level	Material below the specified	Acid (pH) level of below

		acidity level should not be used	5.6 should be avoided
SP17	Corrosion resistance level	Level of corrosion resistance should not exceed limit as specified	A resistance factor of 5mpy (Milli-inch per year)
SP18	Corrosive resistance Coating	BS EN ISO 14713-1:2009	Material should be able to resist corrosion as specified
	Windows and doors a space in the wall of a building to allow light and air in, allow entrance, exist and to allow people inside the building to see outside environment		
SP19	design life span	Material should achieve life span as specified	40 years
SP20	Water tightness	BS EN 12208:2000	Material should be impervious to water penetration
SP21	Wind Resistance	BS EN 12211: 2000	Materials should be able to withstand wind load
SP22	Design of non-loadbearing external vertical enclosures of buildings	BS EN 16846:2015	Able to resist impact without causing hazard
SP23	Acoustic Performance	BS EN ISO 140:2006	Should provide sound insulation
SP24	Thermal Transmittance	BS EN ISO 10077-1:2006	Should be able to have resistance to heat transfer
SP25	Resistance to repeated opening/closing	BS EN 1191:2000	The mechanically durability of constant opening of doors
SP26	Weather-stripping	BS 4255-1:1986	Should be able to prevent air from outside due to window and door leakages
SP27	Glazing materials	BS EN ISO 52022-1: 2015	Should be able to provide exposure to natural daylight without discomforting sensations of well-being for occupants while providing a healthier indoor environment
SP28	Frame joint sealing materials	BS 6093:2006+A1:2013	Material used should provide protection from outside air

SP29	Thermal barriers	BS EN 14024:2004	Materials used should be able to protect building from heat transfer
SP30	Weather tightness	BS 6375-1:2015	Materials used should be secured against rain or wind
SP31	Thermal comfort	Materials used should not increase heat gain internally	Thermal comfort should not be more than 10% of the hours in any given year of 25^0C
SP32	Space cooling demand	Materials used should be able to conform to the cooling level required internally	Not exceeding 15 kWh/(m^2a)
SP33	Selection criteria	BS 6375-1:2009	Pressure level in which material can withstand in different environment
	Coating: A layer of a substance spread over a surface for protection or decoration a covering layer		
SP34	Water Resistance	ASTM D2247-1:2011	Water can cause the degradation of coatings it is important that the coating achieves a 100% performance on relative to be able to withstand defects from water
SP35	Resistance to carbon exposure	ASTM D3361 / D3361M :2013	The coating to resist deterioration of its physical and optical properties caused by exposure to light, heat, and water
SP36	Resistance to salt spray	ASTM B117 :2011	Material should be able to withstand long-term atmospheric exposure
SP37	Colour tolerance	ASTM D2244 : 2015	Coating material should be able to withstand weather conditions without losing its original colour over the stipulated time