ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501

NIGERIAN JOURNAL OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY (NIJEST)

https://www.nijest.com

Volume 2 | Number 2 | October 2018

www.nijest.com

NIGERIAN JOURNAL OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY (NIJEST)

https://www.nijest.com

Nigerian Journal of Environmental of Environmental Sciences and Technology (NIJEST)
Journal available online at http://www.nijest.com **Vol 2 No. 2 October 2018**

ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 137 - 147

Level of Awareness and Use of the Different BIM Software Packages in the Nigerian AEC Industry

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ABSTRACT

This study considered the extent of use of Building Information Modelling (BIM), in the Architecture, Engineering and Construction Industry (AEC) in Nigeria. The factors influencing the level of adoption of BIM and the barriers to the adoption of BIM in the AEC industry in Nigeria was investigated. The data collection technique used was the survey method, which involved the administration of structured questionnaires to 100 professionals in the AEC industry in Nigeria in the three main cities of Lagos, Port Harcourt, and Abuja. The data was analysed using Statistical Package for the Social Sciences (SPSS). The result shows that most professionals in the AEC Industry are aware of the use of BIM in the AEC Industry and a lot of professionals have also engaged in the use of BIM tools. It also shows that the BIM tools are mostly used for activities in the design stage such as design, visualization and drafting but, are least used for maintenance activities. The major barriers to the adoption of BIM in the AEC Industry in the study include, lack of training and education on BIM use, technical challenges associated with adoption of BIM, the complicated nature and processes involved in BIM use, inadequate government support for BIM use in the AEC Industry and general resistance to change by people in the AEC Industry. The study recommends that in order to achieve critical mass adoption of BIM and its benefits maximized in the AEC Industry in Nigeria there is a need for sensitization on the benefits of BIM and training of students and professionals in the industry on the use of BIM.

Keywords: Barriers, Adoption, Industry, Sensitization, Benefits

1.0. Introduction

Building information modeling (BIM) has been a growing development within the past few years in the construction industry. The use of BIM has provided a means for increasing total project quality, providing accurate scheduling timetables, yielding quantity takeoffs, and diminishing total project costs (Eastman *et al*., 2008). The Architecture, Engineering, and Construction (AEC) industry has long sought techniques to decrease project cost, increase productivity and quality, and reduce project delivery time. BIM offers the potential to achieve these objectives (Nadeem *et al*., 2008). Building Information Model is primarily a three dimensional digital representation of a building as well as its intrinsic characteristics that contains information like architectural design model, construction model, schedule model (4D), cost model (5D), fabrication model and operation model, useful within the construction project industry. BIM is also the process and practice of virtual design and construction throughout the building lifecycle (Hergunsel, 2011).

It is however important to note that Building Information Model is not the same as Building Information Modelling. Building Information Model is a collection of interlinked domain models, sharing all the necessary information for design, construction and maintenance of the building whereas, Building Information Modeling (BIM) is not just a digital model but a process of creating and applying it to the design, planning and execution of construction work (Berard, 2012). Simply

put, Building Information Modeling is a process of developing Building Information Model. Generally, BIM is more than drawings - it is a data repository for building design, construction and maintenance information combined in one convenient model to be shared with all the stakeholders. It is a technology as well as a process and can display the entire life cycle of a building project (Gardezi *et al*, 2014).

Quantities and shared properties of materials can be extracted easily. Scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities. BIM also prevents errors by enabling conflict or 'clash detection' whereby the computer model visually highlights to the team where parts of the building (e.g. structural frame and building services pipes or ducts) may wrongly intersect (Srivastava, 2016). BIM helps to reduce information loss which occurs when a design project is transferred from design team, to construction team and to building owner/operator, by allowing each group to add to and reference back to all information they acquired during their period of contribution to the BIM model. This can yield benefits to the facility owner or operator (Srivastava, 2016). Dynamic information about the building, such as sensor measurements and control signals from the building systems, can also be incorporated within BIM software to support analysis of building operation and maintenance as described by (Liu and Akinci, 2009).

There is a general lack of studies on the adoption of BIM in the AEC industry in Nigeria. A recent study by Ezeokoli *et al*. (2016) looked at the factors affecting the adaptability of BIM for construction projects. However, their study was only focused on Anambra State. This study aims to look at the adoption of BIM in the AEC industry in Nigeria, with a view to suggesting how to achieve a critical mass uptake.

2.0. Methodology

The survey method was adopted, through the administration of structured questionnaire to respondents to enable the researchers to reach a large number of the target population in a very short time and ensure uniformity in questions posed to the respondents. Data were collected from surveys of architects, engineers, contractors and other allied professionals in the AEC industry in Nigeria, for three main cities - Lagos, Port Harcourt, and Abuja. Sampling size ranged from (60-70) participants in Lagos (15-20), participants in Abuja and (10-15) participants in Port-Harcourt. These were randomly selected and more participants were selected from the City of Lagos due to proximity to researchers and accessibility. Although 120 questionnaires were distributed to respondents in the three aforementioned Cities, only 100 questionnaires were retrieved. This represents 83% response rate. However, 98% of the retrieved questionnaires were valid and were analysed with, the use of Statistical Package for the Social Sciences (SPSS).

3.0. Results and Discussion

3.1. Role of the respondents in the AEC industry

Table 1 shows the result of the analysis of data of the respondents' role in the AEC industry.

Table 1: The respondents' role in the AEC Industry

Role of the Respondents	Frequency (n=98)	Percent
Architect	40	40.8
Builder	4	4.1
Engineer	30	30.6
Contractor	3	3.1
Construction/Project manager	2	2.0
Quantity surveyor	14	14.3
Facility managers	3	3.1
Estate Surveyor	3	3.1
Academic Staff	1	1.0

Source: Researchers' field survey

It is evident from Table 1 that the highest number of respondents in the survey were architects, who constitute around 41% of those sampled, followed by engineers 31%, and quantity surveyors 14%, respectively. The least was those in the academics, who represent about one percent of the participants in this research. The result shows that, majority of professionals in the AEC industry in Nigeria participated in this research.

3.2. The respondents' organizations

Table 2 shows the different types of organizations the respondents were employed in at the time of the survey. Examination of the result (Table 2) reveals that around 44.4% of the respondents were employed in consulting firms, 36.4% were employed in academic/research institutions, 9.1% in client organizations and another 9.1% were employees of construction firms. However, only around one percent of the participants indicated that they were employees of Government Ministries/Parastatals/Departments. This result clearly shows that the highest number of participants in this research were employees of consulting firms, while the least number were employees of government institutions.

Table 2: The respondents' organizations

Role of the Respondents	Frequency (n=98)	Percent
Academic reseacrh Institution	36.4	36.36
Consulting firm	44.4	44.44
Contractor	9.1	9.09
Client Organisation Government	9.1	9.09
Ministry/Parastatal/Department	1	1.01

Source: Researchers' field survey

3.3. Highest educational qualification of the respondents

The result on the respondents highest educational qualifications are displayed in Table 3.

Table 3: Respondents' highest educational qualification

Role of the Respondents	Frequency (n=98)	Percent
Master's	43.4	44
Ph.D Degree	10.1	10
Postgraduate Diploma	2	2
Others	1	1
National Diploma	2	2
Higher National Diploma	11.1	11
Bachelor Degree	29.3	30

Source: Researchers' Field Survey

It can be seen in Table 3 that around 44% of the respondents are Master degree holders, 30% of them had bachelor degree, while 11% and 10% had Higher National Diploma (HND) and Ph.D. respectively. The result also shows that National Diploma holders constitute around 2% of the sample and another 2% of the participants were those who had Postgraduate Diploma as their highest educational qualification. This result indicates that the highest number of those who took part in the survey had master's degree, while the least had unclassified qualifications. It is therefore evident from the data in Table 3 that the respondents in the survey are highly educated individuals.

3.4. Professional registration status of the respondents

Regarding the professional registration status of the respondents, Figure 1 shows the distribution of the participants in the research according to their professional registration status. From the result displayed in Figure 1, it is evident that a majority of the respondents were not registered by the different professional bodies in Nigeria at the time of the survey. However, 23% of the respondents were registered with the Architects Registration Council of Nigeria (ARCON), 17% were registered with the Council of Registered Engineers of Nigeria (COREN), while 2% were registered by Estate Surveyors and Valuers Registration Board of Nigeria (ESVRABON). This result suggests that most of those sampled in this study were yet to secure full registration with respective bodies established to regulate the practice of their different professions in Nigeria. This means that a majority of

participants in this research are not licensed to practice their different professions they were trained to practice, suggesting that they are not professionals in other fields.

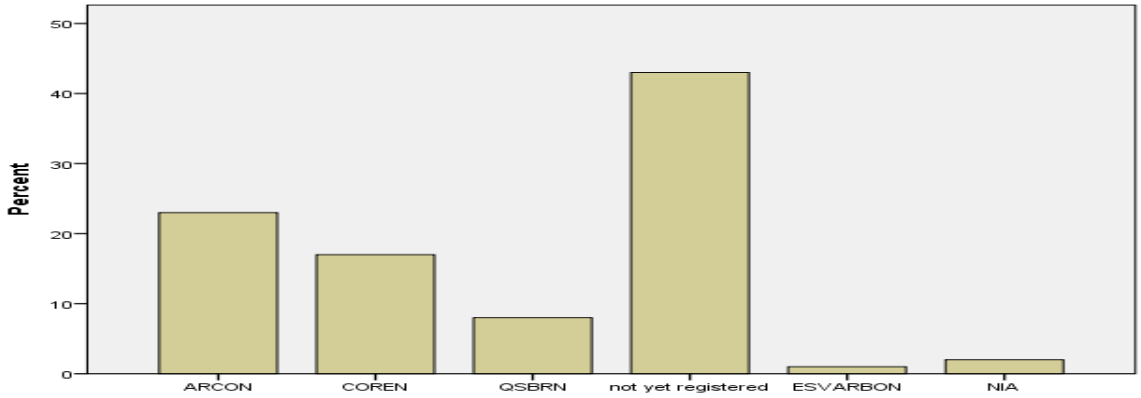

Figure 1: Professional registration status of the respondents
Source: Researchers' Field Survey

3.5. Years of practical experience in the industry

The researchers also collected data on the number of years of practical experience of the respondents in the survey. The result is as shown in Figure 2.

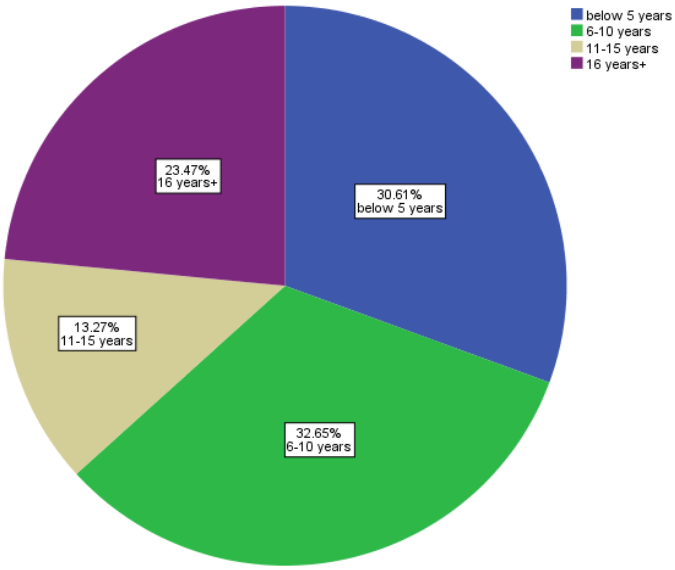

Figure 2: Years of practical experience
Source: Researchers' Field Survey

The result in Figure 2 shows that around 31% of the respondents have less than 5 years of practical experience in the field, around 33% had practical experience of between 6 years and 10 years, 13% have between 11 years and 15 years practical experience, while around 24% had over 15 years of practical experience. This result suggests that a high majority of the participants have over years of practical experience in the field. Therefore, they can be considered well experience individuals who are qualified to provide reliable data for this research.

3.6. Respondents' role in their organizations

Table 4 shows the result of the respondents' specific roles in their different organizations. From Table 4 it is evident that around 18% of the respondents were architects, 9% were academic Staff and Managing Directors, while the least number of them were, Principals & Lecturers, Quantity Surveyors, Principal Officers, Managers, Industrial Trainees and Consultants. This result shows that the participants in the research were drawn from the different cadres of employees in the different organizations.

Table 4: Respondents' role in their organizations

Role	Frequency	Percent
Academic Staff	9	9.0
Architect	18	18.0
Assistant Quantity Surveyor	4	4.0
Civil Engineer	3	3.0
Consultant	1	1.0
Consulting Electrical Engineer	2	2.0
Deputy Manager	2	2.0
Design Engineer	2	2.0
Director	5	5.0
Electrical Engineer	2	2.0
Estate Officer	2	2.0
Facility Manager	7	7.0
Industrial Trainee	1	1.0
Junior Engineer	2	2.0
Manager	1	1.0
Managing Director	9	9.0
Partners	7	7.0
Principal & Lecturer	1	1.0
Principal Officer	1	1.0
Property Management Officer	2	2.0
Quantity Surveyor	1	1.0
Senior Officer	4	4.0
Site/Structural Engineer	2	2.0

Source: Researchers' Field Survey

3.7. Numbers of offices the respondents' organizations have in Nigeria

The study also investigated the number of offices the respondents' organization have in Nigeria. The result is as presented in Figure 3.

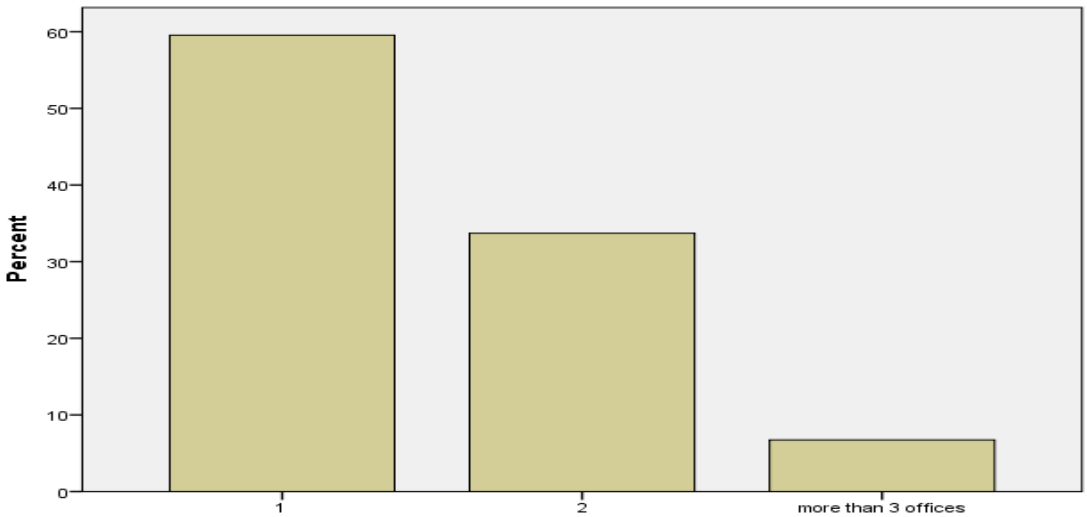

Figure 3: The number offices respondents' organizations have in Nigeria
Source: Researchers' Field Survey

From the result in Figure 3, it is evident that most of the respondents' organizations had one office in Nigeria; about 34% had 2 offices, while 7% of the respondents' organizations had more than 3 offices in Nigeria. Based on this result, it can be inferred that most of the organizations where the respondents were employed can be regarded as Small, Medium and Micro-Sized Enterprises (SMMEs).

3.8. Sex of the Respondents

The result on the sex of the respondents reveals that majority 82 (82%) of the respondents were male, while 18 (18%) were female. This result is understandable as the AEC industry is usually and known to be male dominated globally.

3.9. Use of BIM-based software package

From data collected and as represented in (Figure 4), the level of awareness of the use of BIM in the AEC industry is very high. In addition to investigating the level of awareness of the use of BIM in the architecture, engineering and construction industry, the respondents were also asked to indicate whether they had used any BIM software package in their work. The result is as presented in Figure 4. It is evident from the result (Figure 4) that of the 96 respondents who are aware of BIM, 74 (77%) of them indicated that they use BIM-based software package relating to their field, while 22 (23%) of them had never used any BIM software package in their work.

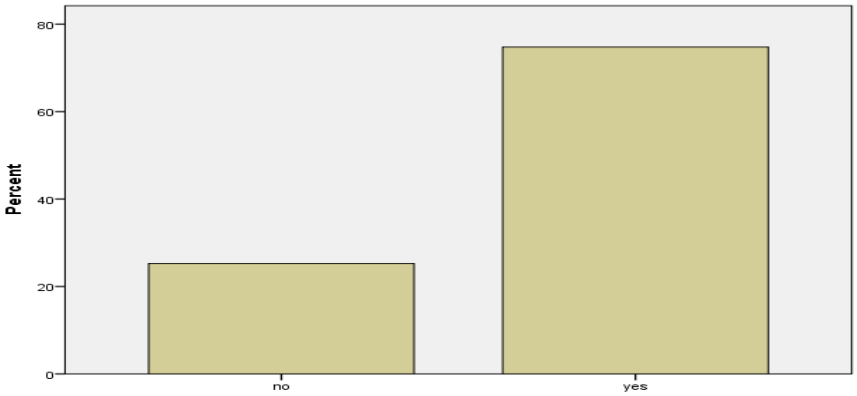

Figure 4: Use of BIM-based software package
Source: Researchers' Field Survey

The result in Figure 4 clearly shows that majority of the participants have used one BIM software package or the other in their works. This suggests that there is a high level of adoption of BIM among the respondents in the survey.

3.10. The Different BIM Software Packages used by the Respondents

The result of the different BIM software applications used by the respondents is also presented in Table 5. It is evident in Table 5 that a majority (81%) used Autodesk Revit Architecture, followed by around 34% who used AUTOCAD, 21.4% that used Graphisoft ArchiCAD and 14% that used Autodesk Revit Structure. The least, around one percent used Bentley Architecture, Bentley Structural and StaadPro respectively. This result is an indication that the most commonly used BIM software by the participants of this research is Autodesk Revit Architecture. This is not a surprise as many of the participants are architects.

Table 5: BIM software packages used by the respondents

BIM software packages	Frequency	Percent
Autodesk Revit architecture	57	81.4
Autodesk Revit structure	10	14.3
Autodesk Revit MEP	9	12.9
Bentley Architecture	1	1.4
Bentley structural	1	1.4
Graphisoft ArchiCAD	15	21.4
Telka	4	5.7
Digital Project Designer	2	2.9
AutoCAD	24	34.3
3dsMax	2	2.9
Master Bill	2	2.9
Staad pro	1	1.4

Source: Researchers' field survey

3.11. Stages in AEC work where BIM is used

The respondents were asked to identify the stages in their works where they use BIM. The result in Table 5 shows that around 72 (94%) of them said they use BIM at the design stage, 20% use it at project execution stage, 13% at renovation and around 7% use it at operation stages. However, around 5.2% indicated that they used BIM at the maintenance stage of their projects. It is evident from

the result in Table 6 that most of the respondents use BIM most at the design stage and least at the maintenance stage. This suggests that most of the respondents see BIM mainly as a design tool.

Table 6: Stages in construction practices where BIM is used

Stages	Frequency	Percent
Design	72	93.5
Execution	15	19.5
Operation	5	6.5
Maintenance	4	5.2
Renovation	10	13.0

Source: Researchers' field survey

3.12. Extent of use of BIM in executing design tasks

The study also investigated the extent of use of BIM in executing different aspects of design tasks by the respondents. From the result in Table 7 it is evident that most of the respondents strongly agree to the use of BIM in detail design, most of the respondents also strongly agree to the use of BIM in visualization, most of the respondents agree to the use of BIM in drafting, most of the respondents are undecided in the use of BIM in fabrication/shop drawings, most of the respondents strongly agree to the use of BIM in design review, most of the respondents agree to the use of BIM in design auditing and most of the respondents Strongly agree to the use of BIM in site utilization planning. This clearly shows that most of the respondent use BIM in executing various design tasks.

Table 7: Execution of task in design stage

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Detail Design	Count	9	4	6	29	35
	Percent	10.8	4.8	7.2	34.9	42.2
Visualization	Count	4	9	8	25	37
	Percent	4.8	10.8	9.6	30.1	44.6
Drafting	Count	4	11	6	35	23
	Percent	5.1	13.9	7.6	44.3	29.1
Fabrication/Shop Drawings	Count	8	12	23	17	21
	Percent	9.9	14.8	28.4	21.0	25.9
Design Reviews	Count	9	6	14	22	29
	Percent	11.3	7.5	17.5	27.5	36.3
Design Auditing	Count	9	0	23	27	17
	Percent	11.8	0.0	30.3	35.5	22.4
Site Utilization Planning	Count	4	11	16	22	24
	Percent	5.2	14.3	20.8	28.6	31.2

Source: Researchers' Field Survey

3.13. Extent of Use of BIM in Analysis Related Tasks

The result in Table 8 is the extent of use of BIM in executing analysis related tasks by the participants in the research.

Table 8: Extent of use of BIM in analysis related tasks

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Analysis of potential failures, leaks, evacuation plans	Count	10	18	19	16	14
	Percent	13.0	23.4	24.7	20.8	18.2
Building system analysis	Count	7	5	25	29	13
	Percent	8.8	6.3	31.3	36.3	16.3
Simulation	Count	6	19	19	30	4
	Percent	7.7	24.4	24.4	38.5	5.1
Energy analyses	Count	13	9	20	26	6
	Percent	17.6	12.2	27.0	35.1	8.1
Building performance analysis	Count	19	6	26	18	11
	Percent	23.8	7.5	32.5	22.5	13.8
Interrogation of different models	Count	2	25	11	30	10
	Percent	2.6	32.1	14.1	38.5	12.8

Source: Researchers' Field Survey

It is evident from Table 8 that, only 30 (39%) of the BIM users claimed that they use BIM in the analysis of potential failures, leaks and evacuation plan, around 53% use BIM to conduct building systems analysis, 44% use it for simulation, while around 43.2% use BIM for energy analysis. The result further shows that around 36.3% use BIM to conduct building performance analysis and 51.3% use BIM to interrogate different building models. It is clear from this result that comparatively, in terms of analyses, a majority of the users seems to use BIM in executing activities related to building systems analyses and building performance analysis, while just about one-third of the respondents used BIM to identify and analyse potential failures, leaks and evacuation plan in buildings. Therefore, it can be inferred form this result that, the participants in the research, used BIM more for building systems and performance analyses than any other types of analyses.

3.14. Extent of use of BIM in project cost analysis

Regarding the extent of use of BIM in project cost analysis, the result is as shown in Table 9.

Table 9: Use of BIM in project cost analysis

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Quantity take-off	Count	10	14	15	22	19
	Percent	12.5	17.5	18.8	27.5	23.8
Cost estimating	Count	7	10	22	24	18
	Percent	8.6	12.3	27.2	29.6	22.2

Source: Researchers' Field Survey

From the results in Table 9, it can be observed that most (51.3%) of the respondents use BIM in Quantity take-off and around 52% of them used it in Cost Estimating. This suggests that a little above average of those who indicated that they have used BIM, used it to execute task associated with project cost estimating and analysis.

3.15. Extent of use of BIM in e-procurement

The study also investigated the extent of use of BIM in supporting the execution of e-procurement tasks by the respondents. The result is as presented in Table 10.

Table 10: Extent of Use of BIM in e-procurement

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Create material ordering, fabrication and delivery schedules for all building components(i.e. construction sequencing)	Count	15	3	17	31	14
	Percent	18.8	3.8	21.3	38.8	17.5
Electronic (e-) procurement	Count	15	1	25	18	19
	Percent	19.2	1.3	32.1	23.1	24.4

Source: Researchers' Field Survey

From the result in Table 10, it can be observed that whereas most (56.3%) of the respondents indicated that, they used BIM to create material ordering, fabrication and delivery schedules for all building components, around 48% said they used BIM in e-Procurement activities. This means that most of the respondents do not use BIM to support the execution of e-Procurement activities.

3.16. Extent of use of BIM in executing renovation/maintenance tasks

Table 11 is the display of the result on the use of BIM in renovation and maintenance tasks by the respondents. It can be seen in Table 11 that whereas a majority (64%) of the respondents claimed to use BIM to support the execution of tasks related to renovations, space planning and maintenance operations, around 52% said that, they use BIM for maintenance scheduling. This result suggests that most of the participants in this research actually use BIM to support the execution of tasks associated with renovation and maintenance of buildings and related facilities.

Table 11: The Use of BIM in Maintenance Operation

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Renovations, space planning and maintenance operations	Count	5	8	16	30	21
	Percent	6.3	10.0	20.0	37.5	26.3
Maintenance scheduling	Count	9	6	23	23	18
	Percent	11.4	7.6	29.1	29.1	22.8

Source: Researchers' Field Survey

3.17. Extent of Use of BIM in Sundry Tasks

On the extent of use of BIM to support the execution of several other tasks like information integration, problem recording, conflict, interference and collision detection; code validation; cross-discipline coordination of tasks and tracking of problem resolution, the result is as presented in Table 12.

Table 12: Execution of sundry activities

Task		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Information integration	Count	16	8	13	25	12
	Percent	21.6	10.8	17.6	33.8	16.2
Problem Recording	Count	11	8	25	19	10
	Percent	15.1	11.0	34.2	26.0	13.7
Conflict, interference and collision detection (i.e. clash detection)	Count	14	11	26	23	7
	Percent	17.3	13.6	32.1	28.4	8.6
Code Validation	Count	18	7	15	22	15
	Percent	23.4	9.1%	19.5	28.6	19.5
Cross-discipline coordination of tasks	Count	15	12	14	26	13
	Percent	18.8	15.0	17.5	32.5	16.3
Tracking of problem resolution	Count	4	18	22	21	8
	Percent	5.5	24.7	30.1	28.8	11.0

Source: Researchers' Field Survey

From the results in Table 12, it is evident that, half (50%) of the respondents agreed that they use BIM in information integration, 40% used it in problem recording; 37% in detecting conflict, interference and collision, 48.1% use BIM in code validation; around 49% use BIM in cross-discipline coordination of tasks, while around 40% of the respondents indicated that they use BIM in tracking problem resolution. This result means that whereas the use of BIM to integrate information appears to be common amongst those sampled in the survey; the use of BIM in problem recording, conflict, interference and collision detection; code validation; cross-discipline coordination of tasks and tracking of problem resolution is not very popular among the respondents in the survey. In fact, only around 37% of the users indicated that they use BIM in detecting conflict, interference and collision (i.e. clash detection) while 40% use BIM in tracking problem resolution.

3.18. Discussion

BIM software packages used in the Nigerian AEC industry:

Ezeokoli *et al*. (2016), observed that compatibility between software platforms, level of knowledge awareness, structure/culture of the industry, non-availability of the appropriate technology and infrastructure, and cost of implementation, individual/personal disposition and lack of BIM standards/guidelines are the reasons why most BIM potential remains untapped in Anambra State.

Twelve BIM software packages were investigated. The result revealed that the most commonly used BIM software package by the respondents is Autodesk Revit Architecture. This is followed by AUTOCAD, Graphisoft ArchiCAD and Autodesk Revit Structure respectively. This result is an indication that AUTODESK Revit Architecture is the most common BIM package used in the Nigerian AEC. The emergence of Autodesk Revit Architecture, AUTOCAD, Graphisoft ArchiCAD and Autodesk Revit Structure as the most commonly used BIM packages in this research did not come as a surprise because, majority of the respondents in the survey are architects, engineers and quantity surveyors and these packages are mostly used by these professionals in the AEC industry.

Extent of use of BIM in the Nigerian AEC industry:

From the result of the analysis of the data obtained from the field work, it was observed that, of the 96 respondents who are aware of BIM, 74 of them, representing around 77% claimed that they actually use BIM in their different fields. This suggests a very high percentage of BIM adoption in the Nigerian AEC industry. It also suggests that high level of awareness of BIM can also translates to high level of adoption of BIM in the industry. Regarding the extent of use of these software packages in the various stages of work in the AEC industry, the study found out that although, it appears that the respondents use BIM across the various stages of project execution, there is a predominant use of BIM at the design stage. This is followed by the use of BIM at the execution stage as well as maintenance/renovation stage. However, in spite of the enormous benefits of BIM at the operational stage of buildings as noted by Srivastava (2016), it is obvious from this study that BIM is rarely used in the operation stage of constructed facilities in the study area.

On the use of BIM tools for specific assignments, the study found the use of BIM in detail design, visualization, drafting, preparation of fabrication/shop drawings, design review, design auditing and preparation of site utilization planning to be very common among the respondents. This means that there is predominant use of BIM as design and drafting tool among the respondents. Further, in the use of BIM to support the execution of analysis-related tasks, it was also observed that there is predominant use of BIM in building systems and performance analyses as indicated previously by (Liu and Akinci, 2009). However, in spite of the benefits of BIM in clash detection as explained by Srivastava (2016), only about one-third of the respondents used BIM to identify and analyse potential failures, leaks and evacuation plan in buildings. In addition, the study found extensive use of BIM in project cost analysis and estimation; and in maintenance/renovation work, but very low utilization of BIM in e-Procurement and other **s**undry activities like in tracking problem resolution and clash detection.

4.0. Conclusion

Based on the findings, the following conclusions are arrived at. There is a high level of awareness of BIM in the Nigerian AEC industry. There is also a high level of use of BIM software packages among the participants of this research. The most commonly used BIM software packages by the respondents are; the Autodesk Revit Architecture, AUTOCAD and Graphisoft ArchiCAD.

In line with the findings of this research, to achieve a critical mass adoption of BIM and maximise its benefit in the Nigerian AEC industry, there is a need for sensitization on the importance of BIM by professional associations such as the Nigerian Institute of Architects (NIA) and Nigerian Society of Engineers as well as other professional bodies in the building industry. Secondly, more institutions of higher learning need to include the use of BIM in their curriculum. There is also need for workshops, conferences and other capacity building trainings on BIM**.** Professional Associations in the AEC industry can collaborate with training Institutes and Universities to organize such trainings for Students, Professional and other stakeholders in the industry. These can help address the issue of low knowledge base and skill in BIM. Lastly, government at all levels also need to support the industry by providing sound policy framework that favours the adoption of BIM.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 148 - 159

Dynamics of Land Surface Temperature in Response to Land Cover Changes in Lagos Metropolis

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ABSTRACT

Land Surface Temperature (LST) is one of the key environmental parameters affected by land cover change. Lagos State has been experiencing an increase in surface temperature due to growing areas of impervious surfaces caused by anthropogenic urban sprawl. While the change in LST has been established, its continuous monitoring and relationship with continuing Land Cover (LC) changes have become imperative for appropriate management and policy actions. This study investigated the effect of land cover change on LST in the rapidly urbanising Lagos metropolis. Using spatio-temporal Landsat imageries with their thermal bands and ancillary data, land cover and LST changes were assessed from 1984 - 2015. The spatial patterns of LST and LC were derived to examine the response of LST to urban growth. Findings confirmed urban sprawl in previously rural areas northward of the metropolis in LGAs such as Ikorodu, Kosofe and those fringing the state's border with Ogun State. This also confirmed new growth areas as occurring west of the metropolis in Amuwo-Odofin LGA. The results further showed that the rapid urbanisation in Lagos metropolis has altered the surface thermal environment as indicated by increased LST. Built-up area and bare land accounted for the highest increase in LST (as high as 1.5℃ in some areas) while wetlands and other vegetated areas played a vital role in moderating the surface temperature in areas they still occupy. This provides reasonable evidence for the appropriate authorities to institute requisite policies and actions towards moderating urban sprawl while ramping up the development of urban green infrastructure to counter global warming.

Keywords: Landsat imageries, land cover changes, land surface temperature, urbanisation, GIS, Lagos metropolis

1.0. Introduction

In the past two decades, many studies have deployed satellite thermal remote sensing data in the derivation of land surface temperature (LST) for urban areas (Deng *et al.*, 2018; Tarawally *et al.*, 2018; Jeevalakshmi *et al*., 2017; Zaharadden *et al*., 2016; Oguz, 2013; Nwilo *et al.*, 2012; Srivastava *et al.*, 2009; David, 2008; Xiao *et al.*, 2007; Zhang *et al.*, 2006; Jimenez-Munoz and Sobrino, 2003). This is owing in part to LST being an important parameter in many environmental and climate models (Oguz, 2013). It is one of the environmental parameters affected by land cover change due to its role in the exchange of earth's surface energy, exchange of surface matter, physical and chemical processes with the atmosphere (Deng *et al.*, 2018; Butuc and Moldovean, 2012; Xiao *et al.*, 2007). At the same time, Land cover (LC) change is a significant factor affecting LST. This is because the surface characteristics, reflectance and roughness of different land cover types differ markedly thereby affecting in similar ways the LST associated with them. Intense human activities with rapid urbanization worldwide alter rapidly the land cover and thus LST. In consequence, the link between LC and LST requires to be understood in order to appreciate the ecological effects of these changes.
The relative warmth of cities has long been measured in a developing country like Nigeria through field observations of air temperature at discrete locations. Such measurements represent point

measurements not area estimates of thermal conditions (Zaharaddeen *et al*., 2016; Obinna *et al.*, 2013). However, medium resolution remote sensing data offering repetitive spatial and temporal coverage have become ready tools to document both LST and LC changes. In this regard, three methods widely used for retrieving LST from imageries include the Single-channel method, Split-window method, Temperature and Emissivity Separation (TES) method. Of these, the Single-channel method utilizes only one thermal band and thus is suitable for sensors such as Landsat TM, ETM+ and OLI, each having one thermal band (Oguz, 2013).

Lagos metropolis in Lagos State is a former Federal capital and the current economic capital of Nigeria. It is recognized as one of the megacities of the world undergoing rapid urbanization and urban sprawl (Obiefuna *et al.*, 2013). A previous study (Nwilo *et al.*, 2012) has established changing LST for the state and metropolis between 1984 and 2006. With continuing global warming coupled with unrestrained urban sprawl and in-fill, continuous monitoring to generate reliable estimates of LST and LC changes are crucial for appropriate management and policy actions at the metropolitan level for the well-being of residents of the metropolis. This study therefore investigated changes in LST and LC between 1984 and 2015 with the aim of determining their spatial distribution as well as the relationship between them.

1.1. Study area

The study area comprises of seventeen Local Government Areas (LGAs) in Lagos metropolis. A map of Lagos State showing the metropolis is shown in Figure 1. Lagos is the largest and most complex urban area in Nigeria (Kafewo, 2016). Lagos was the former capital of Nigeria and is the country's centre of commerce. The state has a very diverse and fast-growing population resulting from unrelenting migration to it from all parts of Nigeria as well as neighbouring countries. The metropolitan area of the state lies between Latitudes 6º20'00"- 6º42'10"N and Longitudes 3º02'30"-3º42'40"E. It comprises the following LGAs' – Agege, Ajeromi/Ifelodun, Alimosho, Amuwo Odofin, Apapa, Eti-Osa, Ifako/Ijaye, Ikeja, Ikorodu, Kosofe, Lagos Island, Lagos Mainland, Mushin, Ojo, Oshodi/Isolo, Shomolu, and Surulere.

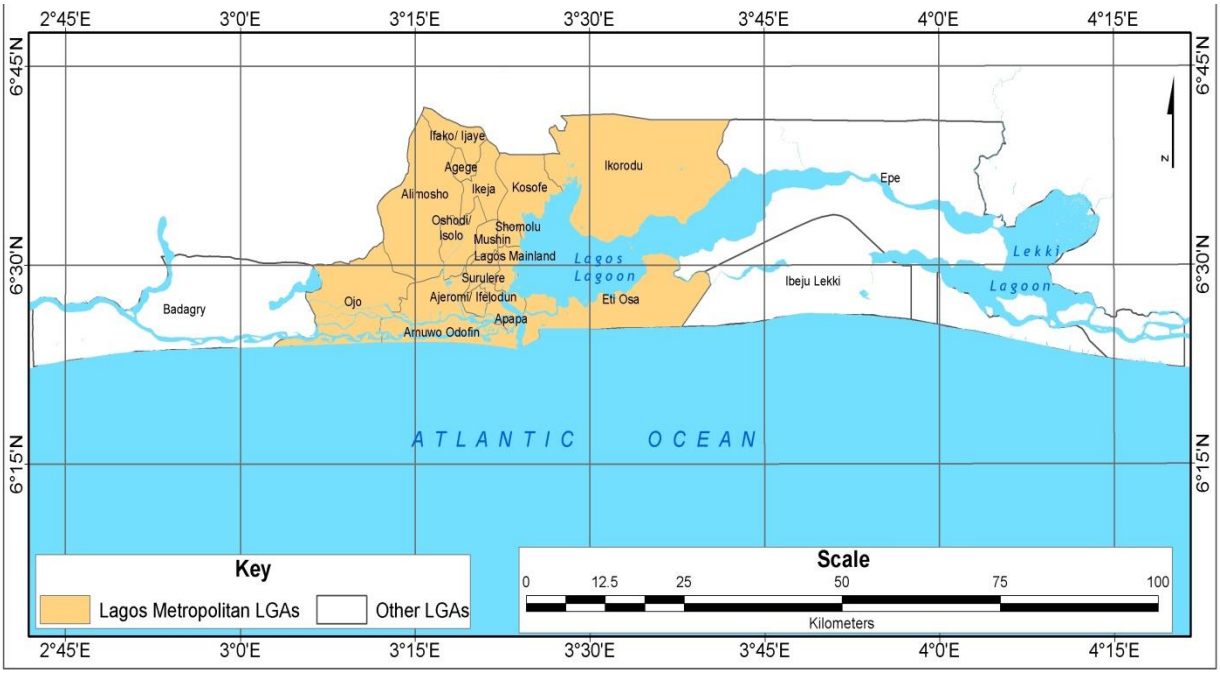

Figure 1: Map of Lagos State showing the LGAs in the metropolis.

Lagos metropolis in Lagos State is recognised as one of the megacities of the world undergoing rapid urbanisation and urban sprawl (Obiefuna *et al.*, 2013). The growth of population in the metropolis has assumed a geometrical progression, while the provision of urban infrastructure and housing to meet this demand is not at commensurate level (Olugbenga and Adekemi, 2013). Plate 1 shows a view

symptomatic of a densely built-up area in Alimosho LGA while Plate 2 illustrates the congestion and seeming inadequacy of transportation infrastructure in parts of the metropolis.

Plate 1: A view of a densely built-up area in Alimosho LGA
(Source: Business Day, 2014)

Plate 2: Commuters throng a bus park along a thoroughfare at Ifako-Ijaiye LGA
(Source: Ifako-Ijaiye LGA Online publication, 2018).

2.0. Methodology

The methodology adopted in this research consisted of data acquisition, datum harmonisation, land cover (LC) extraction, land surface temperature (LST) determination, generation of LST inventory and link with LC. These steps are discussed in the following sections.

2.1. Data acquisition

This study utilised imageries from Landsat 5 Thematic Mapper (TM) of 1984 and Landsat 8 Operational Land Imager (OLI) Thermal Infrared Sensor of 2015 acquired from the United States Geological Surveys (USGS) Global Visualisation online portal - http://glovis.usgs.gov. The Landsat mission is a joint initiative between the USGS and the National Aeronautics and Space Administration (NASA). It represents the world's longest continuously acquired collection of space-based medium-resolution land remote sensing data. A gazetteer of town and community locations was also acquired from the National Population Commission (NPopC). To overcome measurement and geometry computation difficulties, all datasets in different formats and projections were harmonized to fit into a uniform coordinate system - WGS84 UTM Zone 31N. Table 1 summarises the characteristics of the Landsat datasets used for the land surface temperature determination.

Table 1: Characteristics of the Landsat scenes used for LST determination

Landsat Sensor	Year	Path/ Row No	Acquisition Date	Acquisition Time (GMT + 1)
Landsat 5 Thematic Mapper (TM) – Band 6	1984	191/55	18-12-84	10:33:04 AM
Landsat 8 Thermal Infrared Sensor (TIRS) – Band 10	2015	191/55	06-01-15	11:02:59 AM

2.2. Datum harmonisation

All the layers used for the production of the land cover and land surface temperature maps were projected onto a Universal Transverse Mercator (UTM) coordinate system (Zone 31N) on WGS84 datum. This projection helped to overcome linear measurement difficulties and preserve geometric properties of the maps.

2.3. Land cover extraction

The preliminary interpretation of the Landsat imageries involved categorising the study area land cover into five classes, namely: bare land, built-up area, wetlands, mixed forests and water bodies. Next, a step-by-step process of training class selection based on the spectral signatures of each class and ancillary data was done with ENVI 5.0 software. Care was taken to avoid inclusion of mixed pixels in the training classes so as not to compromise the fidelity of the output classes. Then, supervised classification of the imageries was performed using the parallelepiped technique. The parallelepiped algorithm is a computationally efficient method of classifying remotely sensed data. It uses a simple decision rule to classify multispectral data. The decision boundaries form an *n*-dimensional parallelepiped in feature space (Kumar, 2003). If a pixel value lies above the low threshold and below the high threshold for all *n* bands being classified, it is assigned to that class. If the pixel value falls in multiple classes, ENVI assigns the pixel to the first class matched. After classification, the feature classes were transferred to ArcGIS 10.4 for editing, elimination of spurious clusters and refinement of the output.

2.4. Land surface temperature determination

This study relied on the following thermal bands – TM band 6 and TIRS band 10 for land surface temperature retrieval of Lagos State metropolis. The Digital Number values on the imagery were converted to radiance, then to at-sensor (top-of-atmosphere) brightness temperature and further, to land surface temperature (LST) in order to draw quantitative analysis from thermal remote sensing data. The procedure is as follows:

2.4.1. Conversion of digital number to spectral radiance

For Landsat 5 and 7, the formula to convert Digital Number (DN) to radiance is given by Zareie *et al.* (2016):

$$L_\lambda = \left(\frac{LMAX - LMIN}{QCALMAX - QCALMIN}\right) \times (QCAL - QCALMIN) + LMIN \quad (1)$$

where:

L_λ	Spectral radiance at the sensor's aperture (Watts/(m^2.sr.µm)
QCAL	Quantized calibrated pixel value in DN
LMIN	Spectral radiance scaled to QCALMIN
LMAX	Spectral radiance scaled to QCALMAX
QCALMIN	Minimum quantized calibrated pixel value (corresponding to LMIN) in DN
QCALMAX	Maximum quantized calibrated pixel value (corresponding to LMAX) in DN.

For Landsat 8, the following formula was used to derive the spectral radiance (USGS, 2015):

$$L_\lambda = M_L \times QCAL + A_L \quad (2)$$

where:

M_L Radiance multiplicative scaling factor for the band

A_L Radiance additive scaling factor for the band

NB: *LMIN, KMAX, QCALMIN, QCALMAX,* M_L *and* A_L *are sourced from the Landsat metadata file.*

2.4.2. Conversion of spectral radiance to top-of-atmosphere brightness temperature

After the spectral radiance, L_λ was computed; the brightness temperature at the satellite level was directly calculated by using the following approximation formula (Schott and Volchok 1985; Wukelic *et al.*, 1989; Goetz et al, 1995; Qin *et al.*, 2001; Zareie *et al.*, 2016):

$$T = K_2 / \log(1 + K_1/L_\lambda) \quad (3)$$

where:
T Top of Atmosphere Brightness Temperature (deg K)
K_1 ($Wcm^{-2}sr^{-1}\mu m^{-1}$) and K_2 (deg K) are pre-launch calibration constants.

Values for K_1 and K_2 for Landsat TM and ETM+ are shown in Table 2, while Table 3 shows the values for Landsat 8 TIRS.

Table 2: Landsat TM and ETM+ thermal band calibration constants

	Landsat 5 TM	Landsat 7 ETM+
K_1 ($Wcm^{-2}sr^{-1}\mu m^{-1}$)	607.76	666.09
K_2 (deg K)	1260.56	1282.71

(Source: Ghulam, 2010)

Table 3: Landsat 8 TIRS thermal band calibration constants

	Band 10	Band 11
K_1 ($Wcm^{-2}sr^{-1}\mu m^{-1}$)	774.89	480.89
K_2 (deg K)	1321.08	1201.14

(Source: Zhang et al., 2016)

2.4.3. Conversion of brightness temperature to land surface temperature

The equation for conversion from brightness temperature to land surface temperature follows (Weng *et al.*, 2004; Cummings, 2007; Zareie *et al.*, 2016).

$$S_T = \frac{T}{1+(\lambda \times T/\rho)\log\varepsilon} \quad (4)$$

where:
S_T Land surface temperature (deg K)
λ Wavelength of emitted radiance (11.5 μm),
ε Land surface emissivity (typically 0.95)
ρ $h * c/\sigma$ = $1.438*10^{-2}$mK (σ = Boltzmann constant = $1.38*10^{-23}$ J/K, h = Planck's constant = $6.626*10^{-34}$Js, c = velocity of light = $2.998*10^{8}$ m/s).

Finally, the land surface temperature in degrees Kelvin was converted to Celsius by subtracting from 273.15.

2.5. Generation of land surface temperature inventory and link with LC

An inventory of land surface temperature was created for the metropolis from the above steps for each period. Then, a point shapefile of 512 community locations was overlaid on the land surface temperature maps in the ArcGIS environment. Next, using the 'Extract values to Points' tool in ArcGIS Spatial Analyst, the temperature values on the maps coinciding with the community locations were extracted and appended to the attribute tables of the shapefiles. The temperatures at communities within each LGA were then averaged to generate the mean temperatures in each LGA. Similarly, the land cover classes coinciding with the community locations were extracted for a point-to-point comparison with the point temperatures. To explore the relationship between LST and LC, descriptive statistics was used. The mean LST and its standard deviation for each land cover class were calculated with the Statistical Package for Social Sciences (SPSS) for the two periods of 1984 and 2015.

3.0. Results and Discussion

Table 4 shows the coverage area of the land cover classes for 1984 and 2015 while Figures 2 and 3 show the land cover and land surface temperature maps for the same time periods respectively.

Table 4: Coverage area of land cover classes in Lagos Metropolis

S/N	Feature Class	1984		2015	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)
1	Bare land	104.58	6.55	35.48	2.19
2	Built up area	133.04	8.33	859.50	53.15
3	Water body	301.27	18.86	295.68	18.28
4	Wetlands (including mangroves and swamps)	293.13	18.35	230.21	14.24
5	Mixed forests	733.43	45.90	196.28	12.14
6	Cloud cover	32.32	2.02	-	-
Total		1597.76	100.00	1617.17	100.00

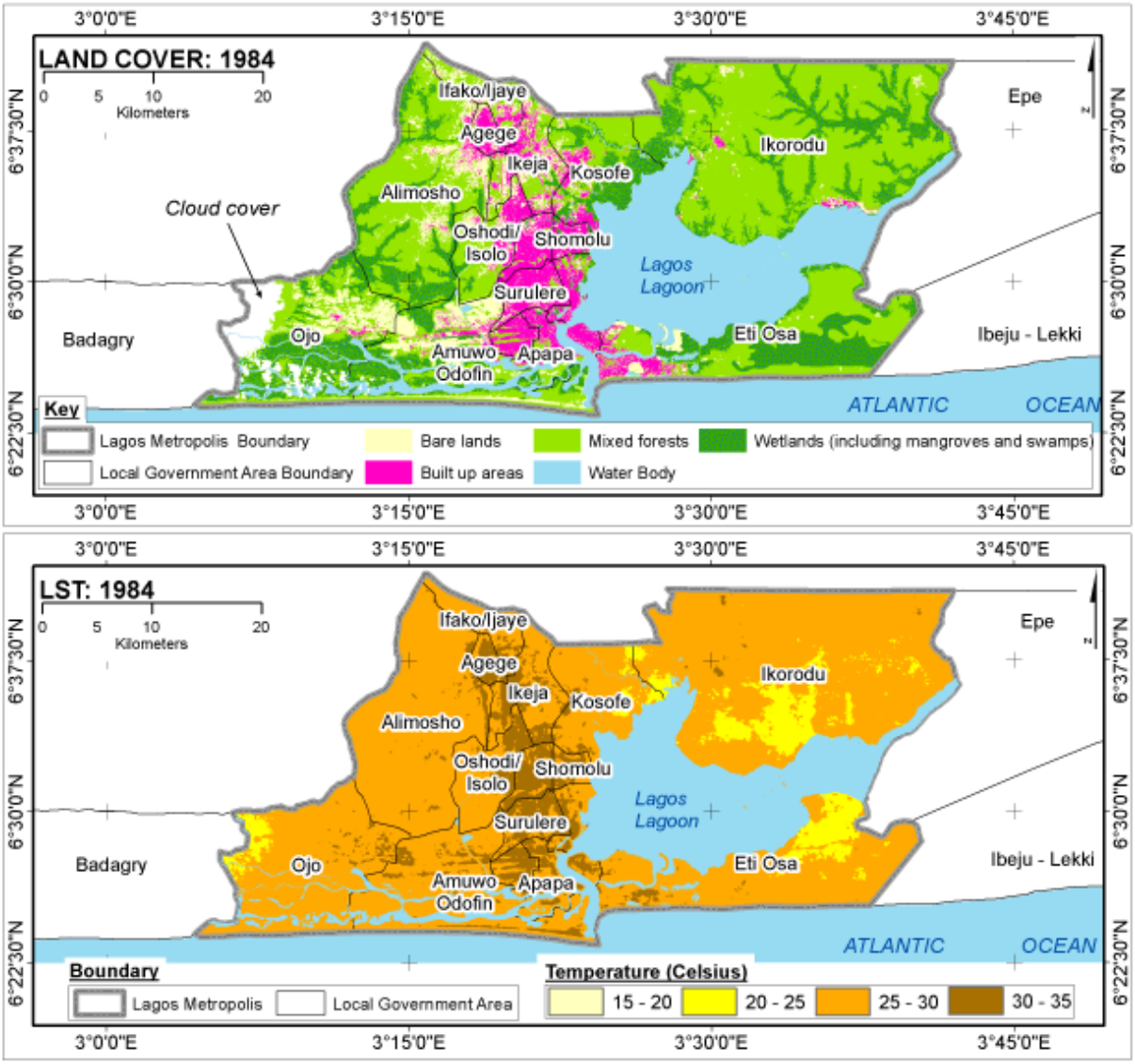

Figure 2: Lagos metropolis 1984 - Land Cover map (top); Land Surface Temperature map (bottom).

There is a general increase in the coverage of built-up area between 1984 and 2015 from 133.04km^2 to 859.50km^2, a gain of 726.46km^2 at 23.43km^2yr^{-1}. Within the same period, wetlands and mixed forests decreased from 293.13km^2 to 230.21km^2 and 733.43km^2 to 196.28km^2 respectively. There was a significant increase in the land surface area of the metropolis in 2015 perhaps due to expansion of the metropolis through land reclamation activities in the Eko Atlantic City and other areas. Within this same period (1984 – 2015), bare lands decreased from 104.58km^2 to 35.48km^2, and water bodies

decreased from 301.27km^2 to 295.68km^2. Cloud cover accounted for 2.02% of the coverage area of the imagery in 1984.

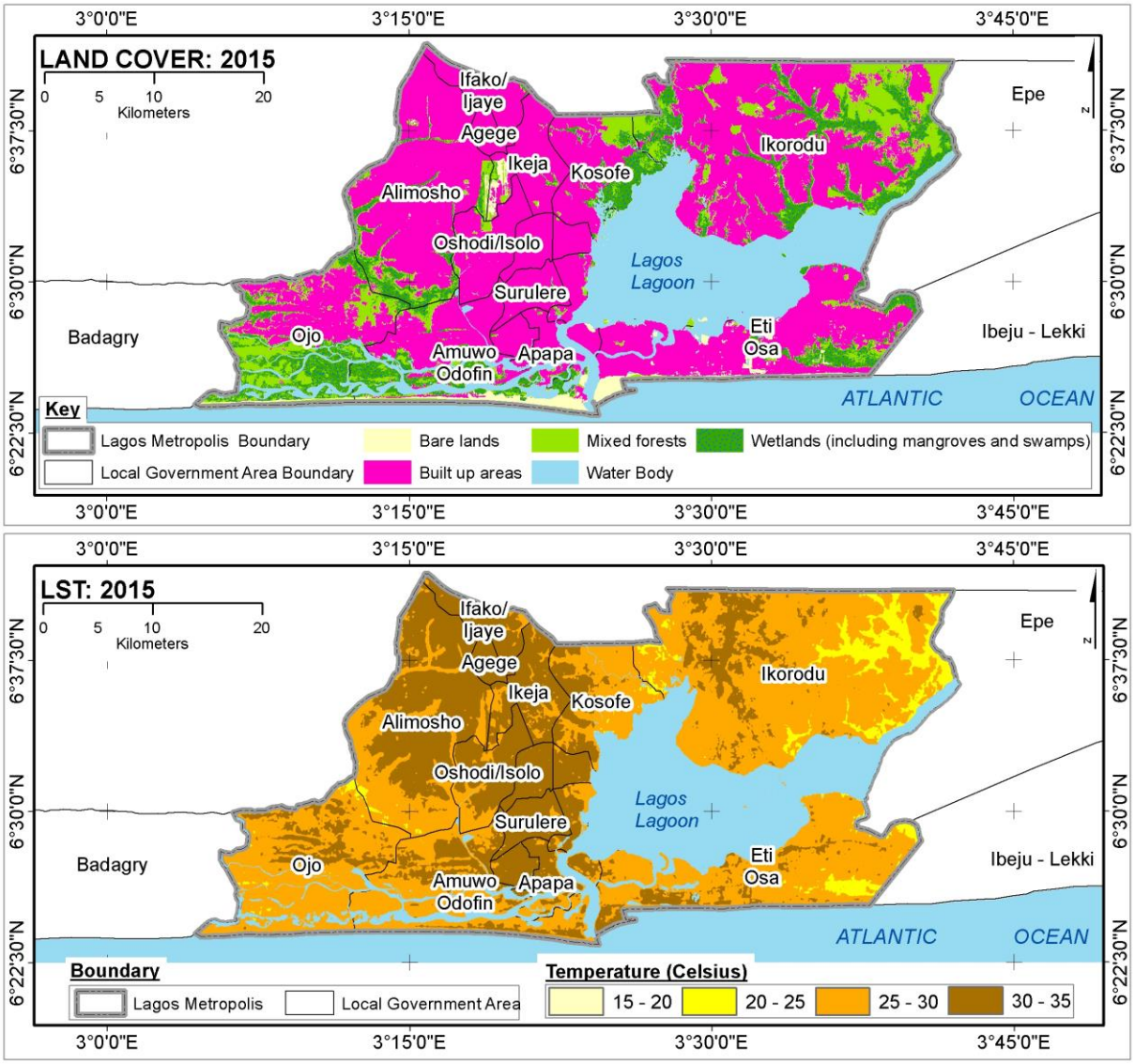

Figure 3: Lagos metropolis 2015 - Land Cover map (top); Land Surface Temperature map (bottom).

Table 5 shows the changes in mean land surface temperatures (LST) from 1984-2015 in the seventeen Local Government Areas (LGAs) of the metropolis. There is a general trend of increasing surface temperatures from 1984-2015. The highest increases in mean land surface temperature occurred in Alimosho LGA (2.812°C), Ikorodu LGA (2.320°C), Ifako Ijaiye LGA (2.314°C), and Eti-Osa LGA (2.071°C). Within the same period, the lowest increases occurred in the following LGAs: Lagos Island (0.049°C), Shomolu (0.579°C), Amuwo Odofin (0.633°C), and Lagos Mainland (0.735°C). Figure 4 presents a graphical illustration of this change in mean land surface temperatures at the various LGAs from 1984-2015.

Table 5: Mean Land Surface Temperatures in the 17 LGAs of Lagos Metropolis (1984-2015).

S/N	LGA	*N**	Mean Land Surface Temperature (°C)		B-A (°C)
			1984 (A)	2015** (B)	
1	Agege	20	30.843	32.319	1.476
2	Ajeromi/Ifelodun	15	32.108	32.978	0.870
3	Alimosho	64	28.495	31.307	2.812
4	Amuwo Odofin	31	29.283	29.916	0.633
5	Apapa	7	30.654	31.393	0.739
6	Eti-Osa	38	27.382	29.453	2.071
7	Ifako Ijaiye	9	29.158	31.472	2.314
8	Ikeja	22	30.077	31.52	1.443
9	Ikorodu	125	27.683	30.003	2.320
10	Kosofe	23	28.653	30.356	1.703
11	Lagos Island	14	30.523	30.572	0.049
12	Lagos Mainland	16	30.235	30.97	0.735
13	Mushin	23	31.51	32.282	0.772
14	Ojo	52	27.585	29.107	1.522
15	Oshodi/Isolo	25	30.803	32.054	1.251
16	Shomolu	19	31.143	31.722	0.579
17	Surulere	10	30.67	31.992	1.322

**N – No. of sample points*

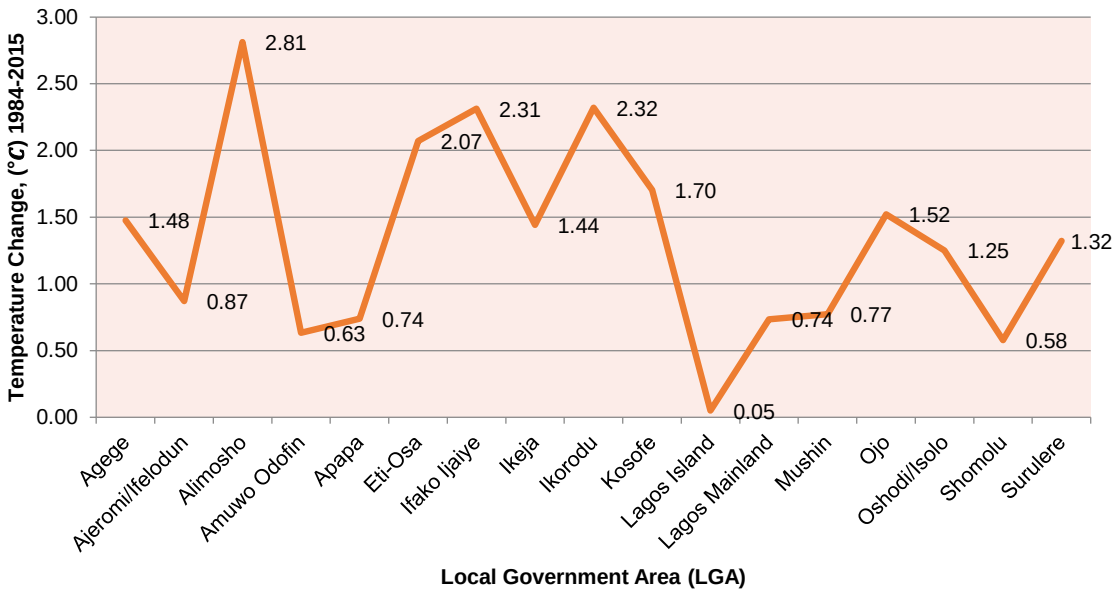

Figure 4: Change in mean land surface temperatures at LGAs from 1984-2015.

Table 6 shows the coverage of built-up area and bare land in the four LGAs with highest temperature changes from 1984-2015. In the table, positive values indicate a net gain while negative values indicate a net loss. The highest increase in built-up area was in Ikorodu LGA (220.53km^2). Similarly, the lowest decrease in bare lands occurred in the same Ikorodu LGA (3.42km^2). Alimosho LGA had the highest loss of bare lands (15.53km^2).

Table 6: Coverage of Built-up area and bare land in the four LGAs with highest temperature changes (1984-2015).

S/N	LGA	Bare land Area (km^2)		Area of change (km^2)	Built up area Area (km^2)		Area of change (km^2)
		1984	2015		1984	2015	
1	Alimosho	16.84	1.31	-15.53	4.10	146.13	142.04
2	Eti-Osa	6.85	13.41	6.55	9.06	126.09	117.02
3	Ifako Ijaiye	6.78	0.01	-6.77	3.21	25.82	22.61
4	Ikorodu	3.91	0.49	-3.42	2.27	222.80	220.53

Tables 7 and 8 show the descriptive statistics of the mean LST and standard deviation for each LC class for both 1984 and 2015 respectively. In 1984, the mean temperatures for each land cover class

are namely: bare land (29.61°C), built-up area (30.69°C), wetlands (27.92°C) and mixed forests (27.63°C). In 2015 they were: bare land (29.78°C); built-up area (30.92°C), wetlands (27.20°C), and mixed forests (27.48°C). The mean LST for all land cover types in 1984 was 28.98°C while it was 30.68°C in 2015 indicating an increase of 1.7°C in mean LST over the metropolis.

Table 7: Descriptive statistics of Land cover and LST relationship – **1984**

		LST (°C)				
LC Class	*N**	Mean	Std. Deviation	Std. Error	Min.	Max.
Bare land	52	29.61	0.995	0.138	26.90	31.59
Built-up Area	187	30.69	1.155	0.085	26.25	32.86
Wetlands	53	27.92	1.598	0.219	25.56	32.13
Mixed Forests	220	27.63	1.424	0.096	23.75	30.41
Total	512	28.98	1.934	0.085	23.75	32.86

N - No. of sample points.*

Table 8: Descriptive statistics of Land cover and LST relationship – **2015.**

		LST (°C)				
LC Class	*N**	Mean	Std. Deviation	Std. Error	Min.	Max.
Bare land	4	29.78	1.156	.578	28.55	31.34
Built-up Area	475	30.92	1.194	.055	26.79	33.40
Wetlands	18	27.20	.916	.215	25.76	29.08
Mixed Forests	15	27.48	1.149	.297	26.21	30.26
Total	512	30.68	1.477	.065	25.76	33.40

N - No. of sample points.*

The land cover change in the period under study is in tandem with findings of rapid urbanization in earlier studies on the area by Obiefuna *et al.* (2013), and Okude and Adelumiluyi (2006). It also affirms that most of the urban development occurred on areas of ecological assets of wetlands and mixed forests as these witnessed massive decline. In 1984, areas with temperature of 30–35°C were mainly already built-up LGAs of Apapa, Ikeja, Somolu, Surulere and Agege. The average temperature range for other LGAs was 25–30°C. However in 2015, the temperature range of 30–35°C has spread to hitherto rural LGAs which have become built-up such as Alimosho, Eti-osa, Ifako Ijaiye and Ikorodu. Table 5 further shows that generally surface temperature increased across the entire metropolis in 2015 with the exception of Lagos Island LGA. Also, it indicates that the already built-up LGAs in 1984 such as Shomolu and Apapa recorded a minimum LST change of about 0.58°C in 2015. The increase in the mean LST of 1.7°C in 2015 over the previous period further points to a warming surface temperature across the metropolis. The relationship between LC change and LST is revealed as highlighted in Tables 7 and 8. Four LGAs' (Alimosho, Eti-osa, Ifako Ijaiye and Ikorodu) with temperature range of 25-30°C in 1984 have all gained over 2°C in 2015 just as their built-up areas and impervious surfaces grew by at least 8-10 times in the same period. Moreover, this relationship is further exposed by the mean LST of both the built-up area and bare land. The mean LST for built-up area with its high anthropogenic activities and high albedo is higher than that of other LC classes in the two periods. In displaying an increase of 0.23°C in 2015, it signifies that aside global warming; this is closely aligned with the rapidly expanding metropolis. The mean LST of ecological assets of mixed forests and wetlands which were even lower than the average mean LST in 1984 further dropped lower than this mean in 2015. With lower albedo, this suggests that their moderating effect on surface temperature should be increased in the metropolis through more open space and green infrastructure projects.

4.0. Conclusion

The study has investigated changes in LC and LST between 1984 and 2015 through the use of remote sensing data**.** It established that rapid urbanization is continuing in the metropolis mostly on the fringe and rural LGAs' where land is expectedly cheaper. Also, it established that surface temperature is generally rising in the metropolis in the study period. Additionally, it established that the areas of increased LST in the metropolis coincided with areas of rapid increase in built-up area. Increased surface temperature across the metropolis therefore necessitates the suggestion for the state authorities

to ramp-up the development of the city's open space and urban green infrastructure projects which appear to have stalled in recent years. The findings on increasing LST require to be validated with in-situ measurements stretching over a number of years. Also, in-situ measurements of LST in areas of industrial cluster such as Apapa, Ijora Ilupeju and Ikeja are important towards determining the contribution of these clusters to overall LST of the metropolis especially in view of the dwindling manufacturing activities.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 160 - 170

Determination of Heavy Metals in Sawdust Particles, Distribution in Soil and Accumulation in Plants at Ahiaeke Timber Market in Umuahia, Nigeria

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ABSTRACT

Farmers are constrained to farming on lands adjoined to sources of pollution without considering the health implications of consuming crops grown on such lands. The main route of entry of heavy metals in human body is via ingestion of food contaminated with heavy metals. Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. This, therefore, necessitated the determination of heavy metals in sawdust, distribution in soil and accumulation in plants at Ahiaeke timber market in Umuahia, Abia State. The study assessed metals (chromium [Cr], zinc [Zn], cadmium [Cd], and copper [Cu]) in sawdust particles, their distribution in soil and accumulation in plants. The highest concentration of Zn (51.00±1.84 mg/kg) and Cr (0.170±0.014 mg/kg) was observed at the sawdust dump 2, Cu (8.24±0.60 mg/kg) was highest at sawdust dump 1 while Cd (4.72±0.071 mg/kg) was highest at sawdust dump 3. The values of the highest concentration of Zn (119.7±7.02 mg/kg), Cu (75.85±4.80 mg/kg) and Cd (22.39±3.30 mg/kg) in soil were observed in 0-10 cm depth at the distance of 20 m. The values of Zn (119.7±7.02 mg/kg) and Cd (22.39±3.30 mg/kg) in soil is above the maximum permitted levels of 60 mg/kg (Zn) and 0.1 mg/kg (Cd) established by the Codex Alimentarius Commission. The highest concentration of Zn (34.70±7.05 mg/kg), Cu (5.34±0.11 mg/kg) and Cd (2.94±0.515) in plants was assimilated by Centrosema pubescence. The level of Cd in plants is well above the permissible limit (PL) 0.3 mg/kg set by FAO/WHO for vegetables and herbs. Consumption of such contaminated C. pubescence can be a route of entry of Cd in grazing animals' vis-à-vis the people who depend on such herbivores for protein.

Keywords: Sawdust, Heavy metals, Soil, Plants, Distance, Depths

1.0. Introduction

The environment is continuously being contaminated by various human activities, such as industrial production, agricultural processes, and mineral exploitation, food processing, commercial, social, and domestic activities that generate contaminants like heavy metals. The release of heavy metal is of great concern all over the world since metal are non-biodegradable (Wu and Zhang, 2010) and cannot be detoxified and removed by metabolic activities once they are available in the environment. This can result to the building-up of toxic levels in terrestrial and aquatic ecosystem. Metals such as zinc (Zn), copper (Cu), manganese (Mn), iron (Fe), and nickel (Ni) are required by living organism to support their metabolic function but are toxic when they exceed their normal threshold in soil through external addition. Non-essential metals such as lead (Pb), chromium (Cr), mercury (Hg) and cadmium (Cd) are not needed for growth of living organisms (Kabata-Pendias, 2011).

Plants growing on metal contaminated soil tend to absorb metals from soil solution via the roots and translocate it to the stems and the leaves. Their (metals) chemical form in soil can strongly influence their uptake by plants (Pitchell and Anderson, 1997) through the roots (either as mobile ions present in the soil solution) (Davies, 1983) or through foliar absorption (Chapel, 1986) resulting in

bioaccumulation of the elements in plants tissues (Amusan *et al*., 2005). This however, is dependent on the type of metal, plant species and plant part (Juste and Mench, 1992). The exploitation of such trees at maturity and subsequent processing at timber markets will result to release of metal in form of dust particles in the environment. The increasing demand for wood as building material, for furniture purposes, sculptural work, and in various industries vis-à-vis poor planning and ineffective implementation of budget allocation for waste collection and disposal by the Government has resulted to high volumes of sawdust waste at dumpsites in Umuahia timber market. The decomposition of the sawdust may culminate to contamination of the immediate surroundings via leaching of metals and other chemical pollutants into the soil. The concomitant effect is possible ecological imbalance and deterioration in the quality of plant products around the vicinity. Similarly, it may result to bioaccumulation of metals in plants; hence culminate to bio magnification in food chain via herbivorous animals and man that depend on such plants for food and medicine.

Heavy metal toxicity has proven to be a major threat and there are several health risks associated with it (Mathew *et al*., 2014) which include hyperkeratosis, loss of skin pigmentation, cancers of the skin, bladder, and lung (WHO, 2001), vomiting, diarrhea, abdominal cramps, liver and kidney damage (Plunkett, 1987), impair reproduction and abnormal development of children, nervous and immune systems, dental and skeletal fluorosis (Finkelman, 2007). Quite a number of studies on sawmilling and/or wood processing activities have been carried out in terms of the health effects of workers of the sawmills (Boateng and Amedofu, 2004; Ugheoke *et al*, 2006; Oke and Oyedare, 2006; Arimoro *et al*, 2007; Verma *et al*, 2007; Lasode and Balogun, 2010; Bello and Mijinyawa, 2010; Edith and Nkwocha, 2012), heavy metals in sawdust particles (Nwajei and Iwegbue, 2007; Ncube and Phiri, 2015) and soil (Ezekiel *et al*., 2013). Literature search show that no work has been done on metal accumulation in plants at timber market or sawmills. This study, therefore, attempted to fill this gap by investigating heavy metal distribution in soil and accumulation in plants at Ahiaeke timber market, Nigeria. The specific objectives were to identify some metals in sawdust, their distribution in soil at various depths and distances and accumulation in plant species around the timber market sawdust dumpsite.

2.0. Methodology

2.1. Description of study area

The study was carried out at the Ahiaeke timber market located at Ahiaeke in Umuahia North, Abia State, Nigeria. Ahiaeke lies on latitude 05° 29' to 05° 42' N and longitude 07° 24' to 07° 33' E, and it is located on the low land rainforest zone of Nigeria (Keay, 1959). The area has two distinct seasons in a year which are the wet season and the dry season. The rainy season covers a period of seven months from April to October, while dry season last for four months from November to March each year with an average rainfall of 2238 mm per year (Ogbonna and Nzegbule, 2009). Its minimum and maximum temperature is 23 and 32 °C, respectively and a relative humidity of 60-80 % (Ogbonna and Nzegbule, 2009) while the estimated terrain elevation above sea level is 155 m. Agriculture is the major occupation of the people where over 70 % of the population engages in subsistent farming and the main food crops grown are yam, maize, cassava, cocoyam, banana, plantain, palm tree and raffia palm.

2.2. Sawdust analysis of the timber market

A reconnaissance survey was carried out prior to sample collection at the timber market. This was to identify the location of the sawdust waste dumps and plant species commonly found at the site. Three sawdust waste dumps (1, 2, and 3) were located at the Ahiaeke timber market. Sawdust particles were collected randomly from fifteen different sampling points in four cardinal points (i.e. three sampling points each at north (N), south (S), east (E), west (W), and at the centre (C) of the dumps from each dump. Samples from each particular sawdust dumps (e.g. 15 sampling points at N, S, E, W, and C dumpsite 1) were placed (about 2 kg) in large, well cleaned cellophane bags (of Abia State Environmental Protection Agency (ASEPA) and transferred to the laboratory for pre-treatment and analysis. The sawdust was sieved through 0.2 mm sieve, and sawdust that passed through the sieve was kept in a refrigerator prior to digestion. A 2 g of the sieved sawdust was weighed and digested in acid mixture prepared from 15 ml nitric acid and 3 ml perchloric acid. The solutions were kept on a

hot plate at 130 °C for 2 hrs. The clear digest was slowly evaporated and on cooling, the solution was filtered and the filtrate was diluted to 25 ml using deionized water. The concentrations of chromium (Cr), zinc (Zn), cadmium (Cd), and copper (Cu) in the digested samples were determined using flame Atomic Absorption Spectrophotometer, AAS (PG Instrument, model: Pg-500, UK)) after calibrating the equipment with different standard concentrations.

2.3. Soil analysis of the experimental site

Soil samples were collected randomly from eight different sampling points at 0-10, 11-20, and 21-30 cm soil depth with well cleaned Dutch soil auger in four cardinal points (i.e. two sampling points each at north (N), south (S), east (E) and west (W) of 20, 40, 60 and 80 m from the centre of the sawdust wastes dumps. The control sample was collected in a 5 year upland bush fallow about 500 m from the dump sites where there was no visible source of contamination. Samples from each particular soil depth (e.g., 0-10 cm at N, S, E and W) were placed in cellophane bags (about 20 g), labelled well, and were transferred to the laboratory for pre-treatment and analysis. Samples from the same soil depth were bulked together to give composite samples which were homogenized and air-dried in a circulating air in the oven at 30 °C to a constant weight and passed through a 2 mm sieve. Sub-samples from the composite samples were then digested. About 10 ml of nitric acid was added to 2 g of air dried and processed soil in a 100 ml beaker and the mixture was reacted and heated by the addition of 3 ml of perchloric acid, allowed to stand for 15 min. The mixture was digested by heating gently at low temperature on a hot plate and allowed to cool for 5 minutes. The digest was then filtered with Whatman No. 41 filter paper into 50 ml standard flask. The suspension was filtered into 50 ml standard flask and diluted with de-ionized water to 100 ml mark. The concentrations of chromium (Cr), zinc (Zn), cadmium (Cd), and copper (Cu) in the digested samples were determined using flame Atomic Absorption Spectrophotometer, AAS (PG Instrument, model: Pg-500, UK)) after calibrating the equipment with different standard concentrations. The calibration curves were prepared from standards by dissolving appropriate amounts of the metal salts in purified nitric acid, diluting with deionized water and storing as stock solutions in a quartz flask.

2.4. Plant sampling and analysis of metals

In this study, plant sampling for determination of heavy metals content in plants was carried out on individual plant species that had up to five (5) number of occurrence in each of the distances (20, 40, 60 and 80 m) at the sawdust waste dumpsite and control site. Fresh leaves were sampled from different shoots and parts of different plant species 4-5 years of age. The leaves of *Eleusine indica* L. (goose grass, Family-Poaceae), *Sida rhombifolia* L. (arrow leaf sida, Family- Malvaceae), *Amaranthus spinosus* L. (spiny amaranth, spiny pigweed or thorny amaranth, Family-Amaranthaceae) and *Centrosema pubescence* Benth (centro, butterfly pea, Family- Fabaceae) were collected randomly in the month of August separately from each individual plant using well-cleaned secateurs at the various distances at the sawdust dumpsite (20, 40, 60 and 80 m) and control site (a 5 year upland bush fallow that is 500 m from the dump site where there was no visible source of contamination). Three replicates of each plant species were collected and mixed separately to obtain composite samples. These samples were well labelled and transferred to the laboratory for pre-treatment and analysis. The plant samples were cleaned sequentially with deionized water to remove dust, pollens and debris and oven dried at 60 °C for 72 hrs. Thereafter, the leaf samples from each separate plant species were milled with Thomas Wiley milling machine (Model ED-5 USA) to fine powder. The procedure described by Kakulu and Jacob (2006) but slightly modified was used for digestion of plant samples. A 5 ml of 4:1 mixture of concentration of $HN0_3$:HCl_4 was added to 2 g of plant sample and the mixture was heated at 105 °C for an hour to dryness on a hot plate, allowed to cool and made up to the mark of 50 ml volumetric flask with 1M HNO_3. The solution was centrifuge for 30 minutes and transferred to sampling bottle for analysis. Triplicate digestion of each sample was carried out and blanks were prepared from only reagents without sample to check for background contamination by the reagents. Appropriate quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were carefully handled to avoid cross-contamination. Glassware was properly cleaned, and reagents used were of analytical grades. Deionized water was used throughout the study. Working standard solutions of chromium (Cr), zinc (Zn), cadmium (Cd), and copper (Cu) were prepared from the stock standard solutions containing 1000 ppm of element in 2N nitric acid. Calibration and measurement of elements were done on flame Atomic Absorption

Spectrophotometer, AAS (PG Instrument model: Pg-500, UK). A blank reading was also taken and necessary correction was made during the calculation of concentration of various elements.

2.5. Experimental design and data analysis

A 4 x 3 factorial experiment in Randomized Complete Block Design (RCBD) in three replicates in soil depth was used. Data collected from this study was subjected to 2-way Analysis of Variance (ANOVA) using Statistical Analysis System (SAS) version 9 to test the significance of difference in total mean concentration in sawdust, soil and plant samples and means separated using Duncan Multiple Range Test (DNMRT) at 0.05 probability level test. The correlation of heavy metals was analysed using Pearson correlation analysis.

3.0. Results and Discussion

3.1. Metal concentration (mg/kg) in sawdust

The values of the concentration of metals in samples of sawdust collected from the three (3) sawdust dumps is presented in Table 1. Sawdust concentrations of all metals were raised to different levels and the significant differences was evidenced amongst the three sawdust dumps at Ahiaeke. Wood processing at the timber market resulted to generation of metal contaminated sawdust that are dumped within the vicinity. The value for the highest concentration of Zn (51.00 ± 1.84 mg/kg) was recorded at sawdust dump 2 and the value is significantly ($P < 0.05$) higher than values recorded for Zn at sawdust dump 3 (44.83 ± 0.3535 mg/kg) and sawdust dump 1 (41.06 ± 0.226 mg/kg). The metal analyses of sawdust particles revealed the following properties presented in Table 1. The high value of Zn at sawdust dump 2 suggest that the sawdust were generated from trees that grew on soil rich in Zn. Plants growing on metal contaminated soil may take up metals from soils and translocate it to the stem.

Table 1: Metal concentration (mg/kg) in sawdust

Sawdust dumpsite	Zn	Cu	Cd	Cr
1	41.06 ± 0.226^{b}	8.24 ± 0.6^{a}	3.715 ± 0.219^{b}	0.084 ± 0.0085^{b}
2	51.00 ± 1.84^{a}	6.84 ± 0.37^{a}	3.895 ± 0.4313^{b}	0.17 ± 0.014^{a}
3	44.83 ± 0.3535^{b}	7.82 ± 0.4^{a}	4.72 ± 0.071^{a}	0.125 ± 0.0071^{ba}

Mean in the same column followed by the same letter are not significantly different (p<0.05) according to DMRT
Values are mean ± standard deviation of 3 replications

It also suggests that the sawdust at the three dumps (i.e. 1, 2 and 3) were generated from trees that grew on different sites in the wild forest or exotic plantations thus, the differences in the values of Zn at the three sawdust dumps. The values of Zn in sawdust dumps at Ahiaeke timber market range from 41.06±0.226 to 51.00±1.84 mg/kg which is higher than 3.54 ± 0.28 mg/kg in pine wood briquette made from planer shavings and sawdust from high quality pure pine wood (Swietlik *et al*., 2014).

The value for the highest concentration of Cu (8.24 ± 0.60 mg/kg) was recorded at dump 1 but the value is statistically equal ($P > 0.05$) to its corresponding values at sawdust dump 2 (6.84 ± 0.37 mg/kg) and sawdust dump 3 (7.82 ± 0.40 mg/kg). The values of Cu at the three dumps suggest that the sawdust were likely generated from trees harvested from the same sites (i.e. location) or sites with similar edaphic nature. The values of Cu in sawdust dumps range from 6.84 ± 0.37 to 8.24 ± 0.60 mg/kg which is higher than 0.65 ± 0.08 mg/kg in pine wood briquette made from planer shavings and sawdust from high quality pure pine wood (Swietlik *et al*., 2014).

The value for the highest concentration of Cd (4.72 ± 0.071 mg/kg) was recorded at sawdust dump 3 and the value is significantly ($P < 0.05$) higher than values of Cd at sawdust dump 1 (3.715 ± 0.219 mg/kg) and sawdust dump 2 (3.895 ± 0.4313 mg/kg). The high Cd at sawdust dump 3 is attributed to Cd assimilated by the trees (via the roots) while taken up macronutrients from soil solution. The Cd assimilated in such trees were released in form of sawdust particles while been processed at the Ahiaeke timber market and possibly disposed at sawdust dump 3. The values of Cd in sawdust dumps range from 3.715 ± 0.219 to 4.720 ± 0.071 mg/kg which is higher than 0.50 mg/kg reported in sawdust particles in the vicinity of sawmill in Sapele, Nigeria (Nwajei and Iwegbue, 2007).

The value for the highest concentration of Cr (0.170 ± 0.014 mg/kg) was obtained at sawdust dump 2 and the value is significantly ($P < 0.05$) higher than value observed at sawdust dump 1 (0.084 ± 0.0085 mg/kg) but statistically equal ($P > 0.05$) to the value of Cr at sawdust dump 3 (0.125 ± 0.0071 mg/kg).

The main source of Zn, Cu and Cr in sawdust particles of Ahiaeke timber market are the chemicals used in pest and disease control in various man-made forest plantations. Pesticides such as copper sulphate, Boliden salt (BIS-salt) mixed with zinc sulphate and chromate copper arsenate (CCA) have been used for over five decades (Bahattacharya *et al*. 2002). The values of Cr in sawdust dumps range from 0.084 ± 0.0085 to 0.170 ± 0.014 mg/kg which is well below 1.46 to 160.50 mg/kg in sawdust particles in the vicinity of sawmill in Sapele, Nigeria (Nwajei and Iwegbue, 2007). The values of Cr (0.084 ± 0.0085 to 0.170 ± 0.014 mg/kg), Cd (3.715 ± 0.219 to 4.720 ± 0.071 mg/kg) and Cu (6.84 ± 0.37 to 8.24 ± 0.60 mg/kg) in the three sawdust dumps at Ahiaeke timber market are well below the maximum permitted levels of 25 mg/kg (Cr), 50 mg/kg (Cd) and 40 mg/kg (Cu) established by the Waste and Regeneration Action Program and the British Standard Institution (BSI, 2012). Thus, the sawdust is safe for panel board manufacturing. Similarly, the values of the metals are well below the maximum permitted levels of 100 mg/kg (Cr), 200 mg/kg (Cu) and 400 mg/kg (Zn) except for Cd that is higher than 1.5 mg/kg (Cd) for porous surface application (BSI, 2012) of sawdust in soil. Notwithstanding this, persistent application of the sawdust for composting and mulching over time (i.e. years) can trigger the concentrations of the metals (Cr, Cd, Zn and Cu) to and above the maximum permitted levels in agricultural lands. Generally, the concentration of the metals in sawdust particles followed a decreasing order: Zn > Cu > Cd > Cr.

3.2. Metals concentration (mg/kg) in soil

The values of the concentration of metals in different soil depths at the various distances at timber market sawdust dumpsite are presented in Table 2. The results show that the highest and lowest metal concentrations in soil were observed at the dumpsite and control site, respectively. Investigations on some pollution surveys showed that air, soil or plants adjoined to source of pollutants had elevated metal concentrations than the control area (Imperatoa *et al*., 2003; Moreno *et al*., 2003; Birch and Snowdon, 2004; Davila *et al*., 2006). Since there were no other sources of contamination in the area, the high concentrations of metals in soils of the sawdust dumpsite (unlike the control site) may be attributed to leaching of these metals (Cd, Zn, Cu and Cr) from the mountainous sawdust waste. Ncube and Phiri (2015) reported presence of metals in *Eucalyptus* and *Pinus* wood sawdust and smoke in Copperbelt province, Zambia. Nwajei and Iwegbue (2007) also reported some heavy metals in sawdust particles in the vicinity of sawmill in Sapele, Nigeria. Consequently, sawdust can influence the natural concentrations of heavy metals in soil. Copper fungicides and other forms of pesticides used to control disease infection and pest infestation in exotic plantations (e.g. *Gmelina arborea. Pinus caribea, Eucalyptus camadulensis, Tectona grandis* among others) may have contributed to metal load in soil and subsequent accumulation in the trees. Mala *et al*. (2007) in their study of heavy metal uptake in plants reported heavy metals in the anatomical features of stem. From the study, it was observed that the values of metals decreased with soil depth at the timber market sawdust dumpsite.

The magnitude of decline in metals concentration with depth in this study varied amongst sampling distance (20, 40, 60 and 80 m) and control area but the rate of decline were highest at the control area, followed by 80 m, 60 m, 40 m, and lastly 20 m. The high concentration of Zn, Cu, Cd and Cr in 0-10 cm depth at various distances is attributed to organic materials on the surface soil. Metals are bound to topsoil by organic matter (Sukkariyah *et al*., 2005) because they (metals) are complexed, hence reducing the leaching of metals into the lower depths (i.e. 11 – 20 and 21 – 30 cm). It was also observed that the values of metals at the timber market sawdust dumpsite area decreased exponentially with distance. Such non-linear decreasing metal concentrations in soils with increasing distance to the emission source have been reported in a similar study (Escarré *et al*., 2010). This suggests that sawdust is the source of metals leached across the various distances where soil samples were tested in this study. Liang *et al*. (2003) opined that transfer through water runoff is the main vehicle of heavy metals transportation in soil.

Table 2: Metals concentration (mg/kg) in soil samples

Distance (m)	Depth (cm)	Zn	Cu	Cd	Cr
20	0-10 11-20 21-30	119.7 ± 7.02^{a} 89.4 ± 9.01^{b} 67.36 ± 4.06^{c}	75.85 ± 4.8^{a} 53.63 ± 2.3^{b} 36.67 ± 2.96^{d}	22.39 ± 3.3^{a} 13.72 ± 1.52^{c} 7.93 ± 1.66^{e}	0.8 ± 0.07^{a} 0.55 ± 0.47^{abc} 0.27 ± 0.05^{bcd}
40	0-10 11-20 21-30	82.01 ± 7.97^{b} 70.42 ± 6.24^{c} 56.99 ± 9.00^{d}	48.36 ± 3.34^{c} 31.27 ± 1.15^{e} 21.92 ± 1.95^{f}	16.90 ± 1.94^{b} 10.62 ± 1.14^{d} $4.95 \pm 4.0.71^{g}$	0.641 ± 0.03^{ab} 0.35 ± 0.03^{bcd} 0.19 ± 0.03^{bcd}
60	0-10 11-20 21-30	$63.42. \pm 7.82^{cd}$ 56.16 ± 8.61^{cd} 39.1 ± 9.42^{e}	31.18 ± 1.19^{e} 23.74 ± 4.39^{f} 18.36 ± 2.99^{g}	11.55 ± 1.59^{d} 6.27 ± 1.17^{f} 3.15 ± 1.35^{h}	0.39 ± 0.03^{abc} 0.22 ± 0.05^{bcd} 0.12 ± 0.04^{cd}
80	0-10 11-20 21-30	49.56 ± 5.14^{d} 35.48 ± 11.78^{e} 25.49 ± 7.35^{fe}	22.96 ± 1.64^{f} 17.37 ± 1.09^{g} 11.86 ± 0.81^{h}	4.76 ± 0.36^{g} 1.35 ± 0.47^{i} 0.48 ± 0.16^{i}	0.15 ± 0.03^{cd} 0.09 ± 0.03^{d} 0.05 ± 0.03^{d}
Control	0-10 11-20 21-30	31.26 ± 3.23^{e} 19.08 ± 2.94^{f} 10.11 ± 0.97^{gf}	18.18 ± 2.27^{g} 11.06 ± 1.40^{h} 6.80 ± 1.59^{i}	0.29 ± 0.11^{ij} 0.11 ± 0.05^{ij} 0.02 ± 0.02^{j}	0.01 ± 0.01^{d} 0.00 ± 0.00^{d} 0.00 ± 0.00^{d}

Mean in the same column followed by the same letter are not significantly different (p<0.05) according to DMRT
Values are mean ± standard deviation of 3 replications

The concentration of Zn (119.7 ± 7.02 mg/kg), Cu (75.85 ± 4.80 mg/kg) and Cd (22.39 ± 3.30 mg/kg) in 0 – 10 cm at a distance of 20 m to the timber market sawdust dumpsite is significantly ($P < 0.05$) higher than their corresponding values at 40 m (82.01 ± 7.97, 48.36 ± 3.34 and 16.90 ± 1.94 mg/kg), 60 m (63.42 ± 7.82, 31.18 ± 1.19 and 11.55 ± 1.59 mg/kg), 80 m (49.56 ± 5.14, 22.96 ± 1.64 and 4.76 ± 0.36 mg/kg) and control (31.26 ± 3.23, 18.18 ± 2.27 and 0.29 ± 0.11 mg/kg). The metals present in the timber market sawdust dumpsite may have provided a source for continued dispersion down the distance, and have resulted to various degree of contamination in soils. The concentrations of Zn, Cu and Cd in 0 – 10 cm depth at a distance of 20 m were found to be 1.46, 1.57 and 1.32 times higher than their values in 0 – 10 cm at 40 m; 1.89, 2.43 and 1.94 times higher than their values at 60 m; 2.42, 3.30 and 4.70 times higher than their values at 80 m; and 3.83, 4.17 and 77.21 times higher than their values at the control area, respectively for Zn, Cu and Cd. The concentration of these metals at the study area is well above their concentrations at the control area. Logan and Miller (1983) suggested that soil is contaminated when concentrations of metals in soils were two-to-three times higher than the control. In this study, the concentrations of Zn, Cu and Cd were more than three times higher than their concentrations at the control area. Therefore, the soil at the timber market sawdust dumpsite area can be said to be contaminated based on the findings that Zn, Cu and Cd concentrations in the control soil samples were well below their corresponding values at the study area.

The values of the concentration of Zn, Cu and Cd in timber market soils of Ahiaeke, Abia State, Nigeria were 25.49 ± 7.35 to 119.7 ± 7.02, 11.86 ± 0.81 to 75.85 ± 4.80 and 0.48 ± 0.16 to 22.39 ± 3.30 mg/kg, respectively for Zn, Cu and Cd, which are above the maximum permitted levels of 60 mg/kg (Zn) and 0.1 mg/kg (Cd) established by the Codex Alimentarius Commission (FAO/WHO, 2001) (Table 3). Similarly, the concentrations of Cu (11.86 ± 0.81 to 75.85 ± 4.80 mg/kg) and Cd (0.48 ± 0.16 to 22.39 ± 3.30 mg/kg) in soils at the timber market sawdust dumpsite area is above the accepted limits (i.e. target value) of 36 mg/kg (Cu) and 0.8 mg/kg (Cd) as described by Dutch criteria for soil (Wikipedia, 2013).

Table 3: Comparison of results with International Standard (Dutch Criteria and FAO/WHO Codex Alimentarius Commission

	Dutch criteria (target value) mg/kg	FAO/WHO 2001 Codex Alimentarius Commission (mg/kg)	NESREA 2011 Standard (mg/kg)
Zn	140	60	421
Cu	36	100	100
Cd	0.8	0.1	3
Cr	100	100	100

The highest concentration of Cr (0.80 ± 0.07 mg/kg) in 0 – 10 cm depth at 20 m is statistically equal ($P > 0.05$) with the values recorded in 0 – 10 cm depth at 40 m (0.641 ± 0.03 mg/kg) and 60 m (0.39 ± 0.03 mg/kg) but significantly ($P < 0.05$) higher than 0.15 ± 0.03 mg/kg at 80 m and 0.01 ± 0.01 mg/kg

at control area. The values of Cr (0.05 ± 0.03 to 0.80 ± 0.07 mg/kg) is well below the permitted limit of 100 mg/kg (Cr) established by the Codex Alimentarius Commission (FAO/WHO, 2001) (Table 3) and Dutch criteria for soil (Wikipedia, 2013). The values of Zn is 25.49 ± 7.35 to 119.7 ± 7.02 mg/kg at the timber market sawdust dumpsite area, which is well above 3.58 to 9.19 mg/kg for Zn in soils at sawmills in Ekiti State, Nigeria (Ezekiel *et al*., 2013). The values of Cu (11.86 ± 0.81 to 75.85 ± 4.80 mg/kg) in this study are higher than 0.76 to 3.54 mg/kg (Ezekiel *et al*., 2013) in a similar study. Similarly, the value of Cd (0.48 ± 0.16 to 22.39 ± 3.30 mg/kg) is higher than 0.07 to 0.47 mg/kg reported by Ezekiel *et al*. (2013) but the values of Cr (0.05 ± 0.03 to 0.80 ± 0.07 mg/kg) in this study is well below 0.68 to 3.34 mg/kg for Cr in soils at sawmills in Ekiti State (Ezekiel *et al*., 2013). Generally, the values of the concentrations of metals in soil followed an increasing order: Cr < Cd < Cu < Zn.

3.3. Metals concentration (mg/kg) in plants

The values of the concentration of metals tested in plant samples in this study are summarized in Table 4. The result indicates that the highest and lowest values of the concentration of metals were observed at the sawdust dumpsite and control site, respectively. The table shows that the plant species assimilated different levels of concentration of metals at various distances from the emission source (i.e. sawdust dumps). The result clearly indicate that *Centrosema pubescence* assimilated the highest values of Zn (34.70 ± 7.05 mg/kg), Cu (5.34 ± 0.11 mg/kg) and Cd (2.94 ± 0.515 mg/kg) but the values are statistically equal (P > 0.05) to the values of Zn, Cu and Cd in *Eleusine indica* (30.90 ± 7.70, 4.87 ± 1.20 and 2.92 ± 0.60 mg/kg) and 28.50 ± 6.74 mg/kg Zn in *Amaranthus spinosus* but significantly (P < 0.05) higher than values of Zn, Cu and Cd, respectively for *Eleusine indica*, *Sida rhombifolia*, *Amaranthus spinosus* and *Centrosema pubescence* at 40 m (22.07 ± 5.93, 3.106 ± 0.23 and 1.80 ± 0.28 mg/kg; 15.51 ± 7.30, 2.16 ± 0.73 and 1.04 ± 0.575 mg/kg; 16.25 ± 5.46, 1.90 ± 0.20 and 1.06 ± 0.46 mg/kg; and 23.79 ± 4.01, 3.70 ± 0.337 and 1.78 ± 0.44 mg/kg), 60 m (10.11 ± 3.14, 2.183 ± 0.30 and 1.05 ± 0.11 mg/kg; 7.75 ± 6.58, 1.14 ± 0.30 and 0.51 ± 0.11 mg/kg; 7.05 ± 8.032, 1.47 ± 0.13 and 0.82 ± 0.09 mg/kg; and 10.89 ± 2.73, 2.39 ± 0.45 and 1.13 ± 0.072 mg/kg), 80 m (3.49 ± 1.70, 1.10 ± 0.98 and 0.577 ± 0.04 mg/kg; 2.30 ± 1.10, 0.903 ± 0.12 and 0.45 ± 0.19 mg/kg; 2.63 ± 0.16, 0.95 ± 0.63 and 0.413 ± 0.071; and 3.67 ± 2.00, 1.13 ± 0.14 and 0.52 ± 0.01 mg/kg) and the control (1.17 ± 0.54, 0.23 ± 0.095 and 0.010 ± 0.11; 0.61 ± 0.95, 0.096 ± 0.08 and 0.021 ± 0.003 mg/kg; 0.49 ± 0.06, 0.22 ± 0.078 and 0.013 ± 0.0013 mg/kg; and 1.540 ± 0.71, 0.38 ± 0.10 and 0.020 ± 0.005 mg/kg). The high values of Zn, Cu and Cd in *C. pubescence* may be attributed to the inherent ability of the plant (*C. pubescence*) to absorb and translocate more Zn, Cu and Cd to the aerial plant parts (leaves) than other plant species. Its deep root system (Wikipedia, 2018) might have facilitated the absorption of the metals in soil solution from a significant depths and translocation to the aerial part of the plant. Metal accumulation in plants is dependent on type of metal and plant species involved (Juste and Mench, 1992; Ogbonna and Okezie, 2011).

The value of the concentration of Zn increased from 2.30±1.10 mg/kg (*S. rhombifolia*) at 80 m to 34.70 ± 7.05 mg/kg (*C. pubescence*) at 20 m. The level of Zn in this study is below the permissible limit (PL) of 50 mg/kg set by Codex Alimentarius Commission, FAO/WHO (2006) for vegetables and herbs. The value of Zn in *C. pubescence* at 20 m is 22.53 times higher than the highest value of Zn in plant at the control site. The value of the concentration of Cu increased from 0.903 ± 0.12 mg/kg (*S. rhombifolia*) at 80 m to 5.345 ± 0.11 mg/kg (*C. pubescence*) at 20 m. The level of Cu is lower than the permissible limit (PL) of 40 mg/kg set by FAO/WHO (2006) for vegetables and herbs. The value of Cu in *C. pubescence* at 20 m is 14.07 times higher than the highest value of Cu in plant at the control site. The value of the concentration of Cr increased from 0.0037 ± 0.0055 mg/kg (*C. pubescence*) at 80 m to 0.132 ± 0.01 mg/kg (*C. pubescence*) at 40 m. The level of Cr is lower than the permissible limit (PL) of 2.3 mg/kg set by FAO/WHO (2006) for vegetable and herbs. The value of Cr in *C. pubescence* at 40 m is 0.132 times higher than the highest value of Cr in plant at the control site. The value of the concentration of Cd increased from 0.413 ± 0.071 (*S. rhombifolia*) at 80 m to 2.94 ± 0.515 mg/kg (*C. pubescence*) at 20 m. The level of Cd in this study is well above the permissible limit (PL) of 0.3 mg/kg set by FAO/WHO (2006) for vegetables and herbs. Consequently, the use of *C. pubescence* at the timber market for forage and source of protein for grazing animals can be a route of entry of metal (Cd) in herbivores and subsequent bio-magnification of Cd in people that consume such metal contaminated animals. In furtherance to this, collection of planting material for growing as cover crops from such Cd contaminated *C. pubescence* will hamper soil fertility and health of soil

organism such as earthworm. The value of Cd in *C. pubescence* at 20 m is 140 times higher than the highest value of Cd in plant at the control site. According to FAO (1991), sawmill wastes contain significant spectrum of organic substances capable of affecting the physical, chemical and biotic environment. Consequently, consumption of plants, animals or water contaminated with such substances can be deleterious to human health. Generally, the values of the concentration of metals followed an increasing order: Cr < Cd < Cu < Zn.

Table 4: Metals concentration (mg/kg) in plant samples

Distance (m)	Plant species	Zinc	Cu	Cd	Cr
20	*E. indica*	30.9 ± 7.70^{a}	4.87 ± 1.20^{a}	2.92 ± 0.60^{a}	0.05 ± 0.009^{b}
	S. rhombifolla	23.9 ± 6.35^{b}	3.173 ± 0.68^{bc}	1.89 ± 0.42^{c}	0.04 ± 0.007^{b}
	A. Spinosus	28.5 ± 6.74^{ab}	3.57 ± 1.35^{b}	2.3 ± 0.41^{bc}	0.039 ± 0.021^{b}
	C.pubescen	34.7 ± 7.05^{a}	5.345 ± 0.11^{a}	2.94 ± 0.515^{a}	0.037 ± 0.18^{b}
40	*E. indica*	22.07 ± 5.93^{bc}	3.016 ± 0.23^{bc}	1.8 ± 0.28^{c}	0.0243 ± 0.005^{b}
	S. rhombifolla	15.51 ± 7.3^{cd}	2.16 ± 073^{d}	1.04 ± 0.575^{d}	0.0273 ± 0.01^{b}
	A. Spinosus	16.25 ± 5.46^{cd}	1.9 ± 0.20^{d}	1.06 ± 0.46^{d}	0.05 ± 0.04^{b}
	C.pubescen	23.79 ± 4.01^{b}	3.7 ± 0.337^{b}	1.78 ± 0.44^{c}	0.132 ± 0.013^{a}
60	*E. indica*	10.11 ± 3.14^{de}	2.183 ± 0.3^{d}	1.05 ± 0.11^{d}	0.044 ± 0.048^{b}
	S. rhombifolla	7.75 ± 6.58^{ef}	1.14 ± 0.3^{e}	0.51 ± 0.11^{def}	0.054 ± 0.059^{b}
	A. Spinosus	7.05 ± 8.032^{ef}	1.47 ± 0.13^{de}	0.82 ± 0.09^{de}	0.037 ± 0.037^{b}
	C.pubescen	10.89 ± 2.73^{de}	2.39 ± 0.45^{c}	1.13 ± 0.072^{d}	0.043 ± 0.04^{b}
80	*E. indica*	3.49 ± 1.70^{fg}	1.10 ± 0.98^{ef}	0.577 ± 0.04^{def}	0.007 ± 0.05^{b}
	S. rhombifolla	2.3 ± 1.10^{fg}	0.903 ± 0.12^{ef}	0.45 ± 0.19^{ef}	0.004 ± 0.06^{b}
	A. Spinosus	2.63 ± 0.16^{fg}	0.95 ± 0.63^{ef}	0.413 ± 0.071^{ef}	0.0071 ± 0.0051^{b}
	C.pubescen	3.67 ± 2.00^{fg}	1.13 ± 0.14^{e}	0.52 ± 0.01^{def}	0.0037 ± 0.0055^{b}
Control	*E. indica*	1.17 ± 0.54^{fg}	0.23 ± 0.095^{fg}	0.010 ± 0.11^{f}	ND
	S. rhombifolla	0.61 ± 0.95^{g}	0.096 ± 0.085^{g}	0.021 ± 0.003^{f}	ND
	A. Spinosus	0.49 ± 0.06^{g}	0.22 ± 0.078^{fg}	0.013 ± 0.0013^{f}	ND
	C.pubescen	1.540 ± 0.71^{g}	0.38 ± 0.10^{fg}	0.020 ± 0.005^{f}	ND

Mean in the same column followed by the same letter are not significantly different ($p<0.05$) according to DMRT
Values are mean ± standard deviation of 3 replications

4.0 Conclusion

The results of this work showed that sawdust particles at Umuahia timber market contain Zn, Cr, Cu and Cd and their concentration are within the safe limit. It was discovered that the sawdust is safe for mulching and production of wood panels. The highest concentration of metals occurred at the surface soil and the levels of Zn and Cd exceeded the permissible limit set by Codex Alimentarius Commission and Dutch criteria for soil. Similarly, the value of the concentration of Cd in *Centrosema pubescence* exceeded the permissible limit established by the Codex Alimentarius Commission. Thus, the *C. pubescence* can be used for phytoremediation of the metal contaminated site only on the condition that it will not be fed to animals or used for medicinal purposes by man.

Acknowledgement

The authors wish to acknowledge the laboratory staff of National Root Crops Research Institute, Umudike, Abia State toward the success of this work.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 171 - 180

An Investigation of Barriers to Females' Involvement in the Nigeria Construction Industry

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ABSTRACT

The continuous domination of the Nigeria construction industry by men remains an issue of concern to construction stakeholders as females in the Nigerian construction industry continue to be largely underrepresented. The objective of this study was to investigate the barriers to females' involvement in the Nigerian construction industry with a view to suggesting strategies that will assist to bridge this barrier. The survey reviewed literature on the level of female participation, the perceptions about women, the opportunities available to females and strategies of increasing the number of female participation in the industry. The instrument for data collection was obtained by the use of a survey questionnaire as well as the reviews of extant literature. The sampling method employed is stratified random sampling. The questionnaires were administered to built environment practitioners in consulting and contracting establishment in Lagos metropolis, Nigeria. The findings revealed that the barriers which influence female under-representation in the Nigerian construction industry include; the male-dominated structure of the construction industry, family commitments such as marriage and childbirth, masculine nature of the job, long working hours. The strategies recommended to bridge this barrier include the formulation of employment policies which prevent sexism, educating young women about the industry, providing better working conditions and flexible working policies for women, provision of incentives in order to attract more women into the Nigerian construction industry.

Keywords: Barriers, construction industry, discrimination, gender, recruitment

1.0. Introduction

The construction industry contributes immensely to any economy; it is the sector responsible for the provision of physical infrastructure that guarantee improvement in the economic and social needs of the people; it significantly contributes to the fulfillment of national goals (Shittu and Shehu, 2010). The Nigeria construction industry is next to the agriculture sector as regards its contribution to the Gross Domestic Product (GDP) and regarding the number of people it engages as the workforce. However, a significant issue confronting the construction industry is that of gender barriers and discrimination (Sang and Powell, 2012; Kharmalamova, 2013; Powell and Sang, 2013). This according to Adeyemi *et al.* (2006) leads to the substantial under-representation of women in the construction and engineering sectors. This issue of the poor representation of female in the construction industry is a concern among construction stakeholders. Previous studies posit that issues such as bad company policies with respect to recruitment and promotion, inadequate or unsafe working conditions, the tasks, the number and variability of hours worked, the monotony of the job, time pressures, targets, the consequences of mistakes, and family commitment constitutes some of the intrinsic factors that impose barriers to female under-representation in construction industry (Lingard and Francis, 2002; Loosemore and Waters, 2004; Lingard and Lin, 2004; Galea *et al.*, 2015). The masculine nature of the construction industry, which is mostly characterized by its high levels of conflict and confrontational practices as well as its recruitment practices, has been known for some time to be a source of frustration for its female employees (Gale, 1994; Fielden *et al.*, 2000; Fielden *et*

al., 2001). Other factors include interruption of women's careers due to reproduction at certain times of their lives which also leads to gender discrimination (Lusa *et al.,* 2009).

The construction sector according to Jahn (2009) has an extreme case of gender discrimination and lack of equal opportunities. The construction industry is one of the most male-dominated industries. Although researchers have shown that the performance ability of men and women in construction is at par and women can compete favourably when given equal opportunities (Ekesionye and Okolo, 2012). The industry has one of the highest percentages of gender discrimination (Amaratunga *et al.,* 2003). Sang and Powell (2012) opined that women are under-represented in all construction occupations and professions. Fielden *et al.* (2000) reported that over 11 million women are employed in the UK, this account for half of the total workforce of the nation. However, the survey exposed that women constituted for only 13% of the construction industry's workforce. Low female participation in the construction industry has continuously been the trend globally. In Canada, the labour force survey showed that women constituted only 15% of the construction industry and only 10% in South Africa (Darlene *et al.,* 2012; Jahn, 2009). Adeyemi *et al*. (2006) in a study revealed that approximately 16% of the Nigerian construction industry workforce was women; this implies that construction workforce continues to be mostly male-dominated of all the major industrial groups.

The underrepresentation of women in the construction industry results from numerous barriers which exist in the industry. The subsistence of these obstacles affects women at three significant levels; at recruitment, retention and job progress (Sang and Powell, 2012). While the construction industry has had difficulties recruiting women, it refused to retain the women who find themselves in the industry. Issues of career progression are a topical issue as their male counterparts tends to progress faster in the industry than the females (Kaewsri and Tongthong, 2012). Khazenet (1996) opines that employers of labour in the construction sector should try to retain the number of women that enlist the construction industry to reduce their continuous departure from the industry by promoting equality of opportunities.

The number of female enrolments in construction-related courses such as engineering, architecture and other built environment fields in Nigeria tertiary institutions has witnessed a significant increase over the years. Kehinde and Okoli (2004) reported that these enrolments are more concentrated in courses requiring office work rather than fieldwork. However, the industry has not seen an equivalent change in the number of female participants, implying that the increase of female entrants into construction related courses in higher institutions does not automatically represent an increase in the number of women actively involved in their area of acquired expertise. Equal Opportunities Commission (EOC, 2006) published that despite women constituting approximately 50% of the UK population, more than 46% of the labour market and more than 50% of the entrants into higher education; they account for just 10% of the construction workforce.

Numerous questions have arisen as to the reason why female participants are fewer in the construction industry, whereas sectors such as nursing, banking, and even agriculture have seen women perform brilliantly despite rigours which may be involved in these other industries. Dainty *et al.* (2000) suggested that to keep hold of women; the construction sector requires a practical understanding of women's careers and what promotes their career progression in comparison to men's. This fact will allow the industry to formulate policies on how to develop human resources management (HRM) plan for a fair and equitable work environment and thus improve their retention in the future.

Further investigation is however required as to why this situation persists and how to improve female retention in the construction industry. However, this research is centred on investigating the barriers to female involvement in the Nigeria construction industry.

2.0. Literature review

2.1. The construction industry skill shortage and need for women participation

The viable construction sector is required for nation building. The Confederation of International Contractors' Associations (2002) reported that the built environment represents more than half of the

total national capital investment while construction activities represent as much as 10% of GNP in developed and developing countries. The Nigeria Construction Industry is the largest employer of labour with over three million people working in the industry in different functions as practitioners (architects, quantity surveyors, planners, estate surveyors, land surveyors, engineers, and accountants), management staff, operatives, technical and labourers on construction sites. The construction industry contributes about 70% of the country's gross fixed capital and contributes about 3% to the gross domestic product (GDP). Construction output affects the economic activities positively, and other industrial activities revolve around the sector (National Bureau of statistics, 2015; Isa *et al*., 2013).

However, the industry is said to be facing potential skill shortages (Babatunde *et al.*, 2012; Worrall *et al.*, 2006; Campbell, 2006). Moir *et al.* (2011) stated that this skill shortage is due to an aging workforce, spontaneous retirements in the industry and other social reasons and economic factors which result to shortages of skilled labour in the trades. In addition to the skilled labour shortages, the shortage of female professional workers is even more striking, and these skill shortages/gaps need to be controlled on time so that the industry can progress (Bryer, 2010). To overcome the shortages of skilled workforce, there is a need for a stable, skilled, motivated and available workforce to meet up with these skill demands. The Equal Opportunities Commission (EOC, 2006) observes that under-representation of women in the construction sectors is fuelling skill shortages and solving this problem, studies have shown that employing more women will help solve the problem (Darlene *et al.*, 2012). Babatunde *et al.*, (2012) suggest that construction employers need to access a larger pool of talent from a broader range of people and gender for recruitment to develop a higher quality workforce that is optimally motivated and well-skilled to meet increasing construction needs.

For the construction industry to surmount the challenge of skill shortage/gap, solve the problem of an aging workforce and meet the future demands of the industry, more women undoubtedly need to be employed and encouraged to stay in the industry.

2.2. Under-representation of females in the construction industry

The statistics of construction labour force indicate that the construction industry is male-dominated; women are reluctant to join the workforce because they experience discrimination when they apply for a job or when in practice (Chun *et al.*, n.d.). According to Munn (2014), there is continuously high enrolment of women undertaking full-time construction-related training in colleges in Britain and other European countries. This is an indication of the willingness of women to work in the industry, but they decline to progress further. There is, however, the perception that some women do not want to take courses in construction because of how the industry is perceived. The construction sector has always been known as a male-dominated industry. This problem is prevalent with the continued shortage of women within its workforce. The perspectives of the industry have not changed over the years, and the failure to contend with the damaging perception is what discourages some women from seeking for jobs within the construction industry (Arslan and Kivrak, 2004; Post, 2003).

Jahn (2009) found that the number of male workers compared to the female workers in the construction industry still varied in extreme amounts. This is as shown in Figure 1 were female workers only make up 10% of the total number of workers in the South African construction industry as of 2007. In the context of a developing country like Nigeria with a population of approximately 150 million people as of 2006; half of these are females (Fapohunda, 2012). The statistical strength of women demands that they be adequately represented in all facets of the economy of the country with particular emphasis on the construction industry which is one the prime motivators of any country's economic activities (Adeyemi *et al.*, 2006). Tajudeen and Adebayo (2013) opine that Nigeria women have high potentials to improve the social and political landscape and hence transform the society better. Nevertheless, the construction industry has had a difficult time engaging women; in the UK for example, female constitute nearly 50% of the population, over 46% of the labour market, and over half of the total entrants into higher education, women are however responsible just 10% of the construction workforce (EOC 2006).

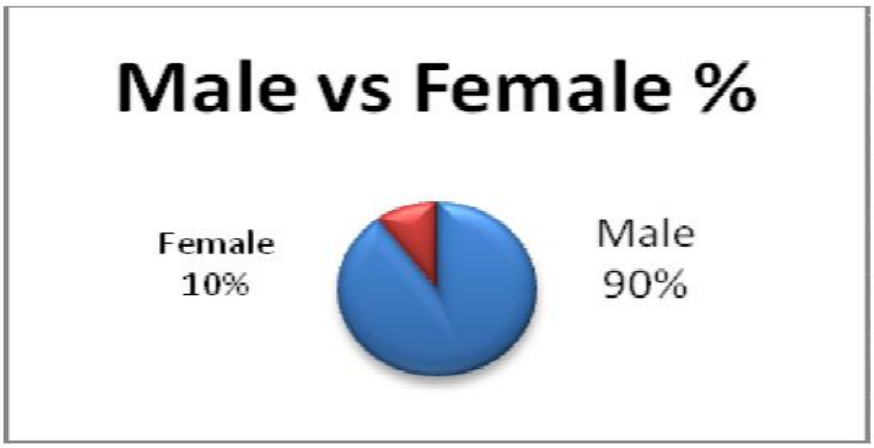

Figure 1: Percent of females to males in the South African Construction industry as at 2007
(Source: Jahn, 2009, p. 17)

Adeyemi *et al.* (2006) revealed that although female labour force represents about 50 percent of Nigeria's human resources, only 16.3% of the industry's workforce is women. Approximately half of these women are employed as labourers, 37.5% as secretarial staff, 10% as office staff and 2.5% as craftsmen. The National Bureau of Statistics (NBS, 2015) revealed that men make up more than 90% of the Nigerian construction workforce even though women constitute more than half the existing total workforce. The distribution of male employees in the sector between 2010-2012 shows that male employees represent 91.38% in 2010, 91.61% in 2011 and 91.52% in 2012 (NBS, 2015).

Table 1 presents the employment by gender of the construction industry in Nigeria. From the table, there was an increase in the number Nigerian male employees for all three years while the number of females employed saw a reduction in their numbers by 0.45% between 2010 and 2011, but an increase by 6.10% for 2012 (National Bureau of statistics, 2015). This is the clear indication of apathy in the involvement of females in the construction sector in Nigeria.

Table 1: Employment size by gender in Nigeria construction industry 2010-2012

Year	Male		Female		Total
	Nigerian	Non-Nigerian	Nigerian	Non-Nigerian	
2010	5,861,845	147,633	398,403	7,202	6,415,082
2011	6,065,033	150,719	396,602	8,488	6,620,842
2012	6,327,377	157,644	420,779	7,716	6,913,536
Total	18,254,255	455,996	1,215,784	23,406	

Source: (National Bureau of statistics, 2015, p. 5)

3.0. Methodology

3.1. Data collection

Questionnaires were administered to respondents to elicit information on the involvement of females in the Nigeria construction industry directly by the researcher. The population for the survey is made up of the professionals in the Nigerian construction industry; the targeted stakeholder groups are the professionals in the building construction industry. Stratified random sampling technique was used in the choice of the sample size of the population to professionals in consulting and contracting organisations of the built environment in Lagos metropolis, Nigeria. Purposive sampling technique was used in administering the questionnaire to the professional as identified from the sample size. The study area was limited to Lagos metropolis in South-western Nigeria because about 65% of corporate head offices of consulting and contracting organisations were in this area and due to the time frame of the research work.

The designed questionnaire was structured into two sections. The first section contained the title of the study and background information of the respondents, such questions as the type of organization, respondents' designation, academic qualifications, and work experience, marital status, and sex of respondents. The second section of the questionnaire related to objectives of this research which was to identify the barriers that lead to female underrepresentation in the Nigerian construction industry and to investigate if women are given equal opportunities in the Nigerian construction industry.

A total of 100 questionnaires were administered to the selected professionals. Out of the 100 respondents that were selected, 55 respondents completed the questionnaire reasonably, however, 14 questionnaires were rejected by the researchers for inadequate responses in the most critical section of the questionnaire; while 45 respondents did not return the questionnaire. Therefore, 41 questionnaires were found suitable and used for the analysis. These questionnaires were analysed with the use of Statistical Packages for Social Sciences (SPSS 16) using the statistical methods of average, percentage, mean score (MS).

4.0. Results and Discussion

This section discussed the findings of the study with respect to the barriers to female representation in the construction industry and the type of opportunities that exist by gender in the Nigerian construction industry.

4.1. *Barriers that lead to female under-representation in the Nigeria construction industry*

Table 2 presents the mean scores of the rankings of male and female respondents concerning barriers that influence female underrepresentation in the Nigerian construction industry. The male respondents agreed that the male dominance of the industry is the highest barrier with a mean score of 4.65 followed by family commitments. Masculine nature of the job both had mean scores of 4.13. The results of the female respondents agree with the response of the males as the male-dominated nature of the industry ranked the highest with a mean score of 4.7. While the female preference for some jobs other than jobs in the construction industry ranked second with a mean score of 4.3; family commitments, long working hours, Social-cultural perceptions and orientation about women not being as strong as men ranked third and fourth with mean scores of 4.2, 4.1 and 4.1 respectively.

The table further shows the mean score of both the males and females' perspective of the barriers in the industry. The male-dominated nature of the construction industry ranked the highest with a mean score of 4.66, followed by family commitments such as marriage and childbirth with a mean score of 4.15. The masculine nature of the job and long working hours ranked third with mean scores of 4.07 and 4.07 respectively; while lack of career progression, the poor image of the construction industry, lower pay than male counterparts for the same level of work ranked the least with mean scores of 2.95, 2.85, 2.78, and 2.51 respectively.

The findings of this research revealed that the male-dominated nature of the industry ranked the highest which is similar to the result obtained by Olusola *et al.* (2012) where the male-dominance of the industry, as well as family commitment, ranked highest. The findings of Olusola *et al.* (2012) further revealed that the nature of the construction industry, gender discrimination, social-cultural perceptions and orientation ranked third, fourth and fifth respectively. On the other hand, the least ranked factors from their research were lack of career progression, reduced image of the construction industry, lack mentoring and recruitment policies and procedures which is similar to the findings of this study as fear of competition with men, lack of career progression, poor image of the construction industry and lower pay than male counterparts for the same level of work were the least barriers

Table 2: Barriers to female participation in the Nigerian construction industry

Identified Factors	Male Mean	Female Mean	Overall Mean	Rank
Male dominance of the construction industry	4.65	4.7	4.66	1st
Family commitments such as marriage and childbirth	4.13	4.2	4.15	2nd
Masculine nature of the job	4.13	3.9	4.07	3rd
Long working hours	4.06	4.1	4.07	3rd
Female preference of some jobs other than jobs in the construction industry	4.00	4.3	4.07	5th
Social-cultural perceptions and orientation about women not being as strong as men	3.84	4.1	3.9	6th
Negative stereotypes toward women mingled with the traditional belief that construction is men's job	3.65	4	3.73	7th
Discriminatory recruitment practices	3.52	3.3	3.46	8th
Discouragement due to male attitude	3.19	3.2	3.2	10th
Salaries and wages when compared to other professions	3.06	3.3	3.12	11th
Sexual harassment	3.00	3.2	3.05	12th
Lack of family-friendly working environments.	2.94	3.2	3	13th
Fear of competition with men	2.87	3.2	2.95	14th
Lack of career progression	2.71	3.3	2.85	15th
Poor image of the construction industry	2.77	2.8	2.78	16th
Lower pay than male for the same level of work	2.52	2.5	2.51	17th

Hence, the agreement in the identified barriers given in this research work with findings in the past research work within Nigeria shows that the identified barriers which influence female under-representation in this research work are valid and are not just methodological manufactured fact.

4.2. *Equality of opportunities amongst male and females in the Nigerian construction industry*

Table 3 shows the responses given by the respondents to the questions asked on the number of employees and females in each respondent's organization. From the table a total number of five (5) respondents representing 12.2% indicated that there are 0-5 number of employees in their organization, 2.4% indicated that there were 6-10 employees and 70.7% of them indicated that the number of employees within their organization was above 20. The numbers of female in the respondents' organization were also revealed: the result shows that 4.9% of the respondents indicated that there are no female professionals in their organization. A large number of the respondents indicated that the number of females in their organization was in the range of 1-3 with a percentage of 63.4%.

Furthermore, Table 3 presents another set of questions which the respondents were asked as shown with the responses given by each respondent. This section was analysed using frequency counts and mode. From the table, 26 respondents said 'Yes' to the question "do women in your organisation have equal chances of executing site related works as men", while a total number of 13 and 2 filled 'No' and 'Unsure' respectively.

The response 'Yes' also ranked the highest for questions such as "do women on the same cadre receive the same rate of salary as their male counterparts" and "are women likely to have a chance to get jobs equal to men on office related works." On the other hand, questions like "are women employed based on their marital status in your organization" and "are their policies in place for flexible working hours for women" had 'No' as their highest response. Hence, it can be concluded that equal opportunities exist for women in the construction industry as the majority of the respondent agreed to the statement on female opportunities. From the findings of the survey, although the percentage of female employers to their male counterparts is approximately 16%, it was concluded that women in the construction industry are being accorded equal opportunities in the Nigerian construction industry. However, this finding is not in agreement with Madikizela and Haupt (2005) where a survey was carried out on the South African construction industry women. In the research, 94.1 percent of women said women do experience discrimination on the job in the construction industry while about 76.5 percent opine that this discrimination is more prevalent on construction sites than in consultancies films.

Table 3: Equal opportunities for females in the construction industry

Description	Range	Frequency	%
Total number of employees in your current organization	0-5	5	12.2
	6-10	1	2.4
	11-15	3	7.3
	16-20	3	7.3
	Above 20	29	70.7
	Total	41	100
	Mean	19	
How many female professionals are employed currently in your organization	None	2	4.9
	1-3	26	63.4
	4-6	10	24.4
	Above 9	3	7.3
	Total	41	100
	Mean	3	

Description	Frequency			Mode
	Yes	No	Unsure	
Do women in your organization have equal chances of executing site related works as men?	26	13	2	Yes
Do women in the same cadre receive the same rate of salary as their male counterparts?	31	3	7	Yes
Are women likely to have a chance to get jobs equal to men on office related works?	32	4	5	Yes
Are there provisions for separate facilities for women employees e.g. toilet, ablution, etc.?	12	28	1	No
Does your company have clear policy on non-discrimination when hiring and training based on gender?	11	13	17	Unsure
Are there policies in place for flexible working hours for women?	8	25	8	No
Are women allowed to take maternity leave in your organization?	34	3	4	Yes
Are women employed based on their marital status in your organization?	7	27	7	No
Does your company have explicit policy on non-discrimination when hiring and training by sex?	11	13	17	Unsure

However, the findings of this research agree with Mohammaden (2013) which revealed that 66% of construction organisations accord women equal chance as men in office work, 48% allow women same chance as men in task work on site, 22% provide separate facilities to women, 48% of organisation do have distinct and clear policy on non-discrimination when hiring, training and gathering information on the basis of sex, 96% of organisations give females opportunities to get promoted within the structure of the company's organisation.

From the outcome of this study, if equal opportunities exist for both male and female, why is the high gap in the percent of female involvement to that of their male counterparts in the construction industry? This was revealed in this research as there is no flexibility in the working hours for female in the construction industry. From the study, women are not employed based on marital status, but the lack of flexibility in working hours for female can be responsible for the dearth in female participation. Women are mothers and homemakers, flexibility should be allowed in certain circumstances such as when pregnant as well as when nursing a new-born baby aside from the usual maternity leave, by so doing women might be encouraged to take up construction jobs.

Lack of clear-cut policies on gender discrimination during hiring is also viewed as an impediment to female representation in construction. The formulation recruitment policies that take away the dichotomy of gender disparity in the construction industry will stem the tide of female underrepresentation.

5.0. Conclusion and recommendation

5.1. Conclusion

Females have continued to be mostly underrepresented in the Nigerian construction industry. This is seen in a typical construction firm; women are always fewer than men. This research sought to identify the barriers which lead to this underlying problem in the industry.

The summary of the findings of this study revealed that the perceived male-dominated nature of the construction industry and family commitments such as marriage and childbirth are responsible for the underrepresentation of female. However, it was established that there exists equal opportunity for both male and female in the industry but the lack of flexibility in working conditions is also an impediment to female entrants into the industry.

Discrimination during hiring does not promote equality because employers are mindful of the fact that women tend to go on maternity leaves during childbearing. They therefore, prefer males to their females' counterpart; nonetheless, if the female is more qualified or can perform as much as the male during recruitment. If employers can see women as of equal value as men, the issue of non-discrimination concerning gender during recruitment will tend to improve female representation in the construction industry.

5.2. Recommendations

Grounded on the findings and the recommendations of respondents the following recommendations are put forward:

1) The government, construction professional bodies, and organizations should give sufficient attention to the challenges women face in the industry and employ adequate strategies to solve these problems.
2) Policies which ensure equal opportunities and prevent discrimination against women at recruitment should be enforced in construction organisations.
3) Women should be allowed flexible working conditions in certain circumstances such as when pregnant and during the nursing of their new baby after completing the standard maternity leave.
4) More women should be employed and encouraged to stay to bridge the skills shortage of the construction industry

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 181 - 185

Haematological Changes Induced by Municipal Solid Waste in Wild Rats (*Rattus rattus*)

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ABSTRACT

The effect of the exposure of landfill pollutants on haematology, body and organ weights of Rattus rattus was investigated. The potential hazards of this landfill on the haematology of the exposed rats were investigated. Weights of rats in the control group (232.6g) were significantly higher ($p<0.05$) than the exposed wild rats (167.6g). The Packed Cell Volume, PCV (%) of rats exposed to landfill pollutants was found to be 32.0 ± 13.9 while that of control rat was 43.4 ± 4.7. Haemoglobin (g/dl) of control rats was observed to be 14.2 ± 1.2 while that of exposed rats was 10.0 ± 4.1. The constituents of the municipal waste especially heavy metals probably aggravated the observed changes in the blood parameters. The experimental results indicated that exposure to landfill pollutants may lead to ill health particularly anaemia. Also, exposure to municipal solid waste landfill may induce haematological alterations in humans as evident in the wild rats studied.

Keywords: Landfill, Solid waste, Haematology, Hazards, Environmental Pollution

1.0. Introduction

A waste is any unwanted material intentionally thrown away for disposal (Oresanya, 1998). According to World Health Organization (WHO, 1984), wastes comprise countless different materials such as dust, food wastes, packaging in the form of paper, metal, plastic, or glass, discarded clothing, garden wastes, pathological and radioactive waste. When these wastes are discharged to the environment, they do not pose any risk to people or the environment (Hogson, 2004). A Municipal Solid Waste (MSW) therefore is any non-hazardous, solid waste from a combination of domestic, commercial and industrial sources. Examples of these wastes include natural materials such as clay, soil and rock, concrete, brick and demolition products. Ogwueleka (2009) defined it to include refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), market waste, yard waste and street sweepings. Landfill is considered as one of the most common methods of waste disposal throughout the world due to its cost effectiveness and it involves dumping of waste in unused/unwanted sites (Bougioukou *et al*., 2005; El-Fadel *et al*., 1995). According to Porta *et al*. (2009) and Rushton (2003), landfill is defined as the dumping of waste in places precisely meant for such.

Bougioukou *et al*. (2005) stated that one of the most common waste disposal methods is landfilling where large volumes of municipal and industrial solid wastes are buried in landfills. In recent years, it has been discovered that the quality of ground water is being affected by a growing number of contaminants (Adeyemi *et al*., 2007). There are a number of environmental concerns associated with the disposal of municipal solid waste in landfills. Hazardous waste may pose an unreasonable risk to health, safety or property, especially those materials that are toxic, corrosive, reactive or ignitable. Disposal sites are capable of releasing large amounts of harmful chemicals to nearby water sources and air via leachate and landfill gas respectively (Alimba, 2006). According to Alimba *et al*. (2009), leachate can have an adverse impact on the environment when released in an uncontrolled manner. As humans we cannot do without generating waste. As a result, managing these generated wastes has been a world-wide challenge (Kadafa *et al*., 2013). Porta *et al*. (2009) reported that waste

management which deals with generation, collection, processing, transport and disposal of solid waste is highly important for both ecological and communal reasons. It is very possible that being exposed to refuse dump would be disastrous on human behaviour and brain. However, it is so unfortunate that the less privileged are found living close to these dump sites. As a result, this present study will therefore assess the effect of landfill pollution on haematology and body weights of wild rats, *Rattus rattus.* The result will then give us an insight into the possible long-term effects of municipal solid waste landfill on humans.

2.0. Methodology

2.1. Study site

The study site is Abule-Egba landfill, located in Lagos, Nigeria (Figure 1 below). This Abule-Egba dump site is located on a 21-hectare habitable area and was open to the public for dumping of refuse in 1982. It has been used for municipal solid waste disposal for public and private waste management operators. The site manager indicated that an average of about 1,400 metric tonnes of waste is dumped at this site per day. The waste is discarded in an area adjacent to the only vehicular entrance to the site. Samples of leachates were collected from the landfill site and analysed for some standard physical and chemical properties and compared with FEPA and USEPA limits for safe disposal to surface water body (Table 1).

Figure 1: Dumping of waste at Abule-Egba landfills

2.2. Experimental animal

Twenty five (25) exposed wild rats (*Rattus rattus*) were collected from the dumpsite, while five (5) animal samples were captured from Iyana-Ipaja (10km) from the neighbouring countries to serve as control.

2.3. Weighing, dissection of rats and collection of blood samples

At the beginning of the experiment, the body weight (BW) of each animal in the test group and control was measured using electronic analytical balance (Acculab USA, Model-vic-303). The liver, kidney, lungs, heart and spleen were removed through a central incision on the abdomen and weighed immediately. Blood samples were taken from the 25 exposed rats and five (5) controls through the ocular puncture using capillary tube. Samples collected were analysed with the Automated Haematological Analyzer, KX-21N (Sysmex) at the Lagos State University College of Medicine, Department of Haematology and Blood Transfusion. The blood parameters analysed were: Haematocrit (HCT/PCV), Haemoglobin (HGB), Red blood cells (RBC), Platelet Counts, Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC) and Differential White blood cell count: Neutrophil, Lymphocytes and Mixed cell ratio (ratio of the summation of Monocytes, Eosinophils and Basophils).

Table 1: Heavy metals, Physical and Chemical characteristics of Leachates Samples from Abule-Egba landfills

Parameters	Abule-Egba Landfill	FEPA	USEPA
BOD+	585	50	-
COD++	440	-	410
pH	7.1	6-9	6.5-8.5
Hardness	350	-	0-75
Total Alkalinity	490	250	20
Iron	1.6	0.05	0.3
Sulphate	60.50	20	250
Nitrate	3.20	-	10
Ammonia	8.4	0.01	0.02
Chloride	480	-	250
Copper	0.58	0.3	1
Total Dissolved Solid	1.20	2000	500
Manganese	1.0	0.5	0.5
Cadmium	0.62	0.5	0.5
Lead	1.1	0.01	0.015

**All values are in mg/L except pH +Biochemical Oxygen Demand ++Chemical Oxygen Demand Federal Environmental Protection Agency (www.epa.gov/safe/mcl.html) *The FEPA/USEPA limits indicates safe disposal to surface water body*

2.4. Statistical analysis

The mean values of data obtained were compared using students' test to determine significant difference between the control and the exposed rats. Statistical significance was accepted at $p < 0.05$. Relative weights and Haematological values are expressed as means ± standard deviation.

3.0. Results and Discussion

3.1. Body weights and organ weights

The mean and standard deviation of the body weights, liver, heart, lung, kidney and spleen of rats are shown in Table 2. The body weights of rats in the control group were significantly higher than the body weights of the exposed rats. The differences in body weights were considered based on the ratio of the organ weight to body weight. The relative weights of liver, hearts, lungs, heart and spleen were significantly higher ($p < 0.05$) in the rats that were exposed to landfill pollutants than the control group.

Table 2: Mean values of body weights and relative organ weights of control and exposed rats

Parameters	Control	Exposed
Body weight	232.6 ± 28.8	167.6 ± 126.8
Liver	4.0 ± 0.1	5.2 ± 2.5
Left Kidney	0.3 ± 0.1	0.6 ± 0.2
Right Kidney	0.3 ± 0.1	0.6 ± 0.2
Lung	0.3 ± 0.1	1.1 ± 0.4
Heart	0.4 ± 0.1	0.6 ± 0.2
Spleen	0.4 ± 0.1	0.5 ± 0.3

**Values are expressed as mean ± sd. Means are found significantly different at P<0.05 with p-value = 0.0335*

3.2. Haematological parameters

The blood haematological parameters are shown in Table 3. The haemoglobin content and haematocrit values showed decline in the animals that were exposed to municipal solid waste when compared with control values. The red blood cell (RBC) counts in the exposed rats showed no significant difference from those of the controls ($p > 0.05$). The total white blood cell (WBC) count showed variable values, but were found not significant. Haematological examination of rats did not reveal any statistically significant variations in the numbers of total WBC, platelets, amounts of Haemoglobin or levels of haematocrit between the control and exposed animals.

Table 3: Mean values of full blood assay of wild rats

Parameters	Control	Exposed
White Blood cell (WBC) ($x10^9$/l)	10.4 ± 0.8	8.9 ± 5.8
Lymphocyte ($x10^9$/l)	7.7 ± 0.7	4.6 ± 3.1
Mixed ($x10^9$/l)	1.1 ± 0.3	2.8 ± 3.0
Neutrophil ($x10^9$/l)	1.6 ± 0.3	1.5 ± 1.4
Red Blood cell (RBC) ($x10^{12}$/l)	7.0 ± 0.5	5.0 ± 2.2
Haemoglobin (HB) (g/dl)	14.2 ±1.2	10.0 ± 4.1
Packed Cell Volume, PCV (%)	43.4 ± 4.7	32.0 ± 13.9
Platelet (PLT) ($x10^9$/l)	391.6 ± 22.4	700.3± 351.2
Mean Corpuscular Volume (MCV) (fL)	54.9 ±2.6	64.1± 5.9
Mean Corpuscular Haemoglobin (MCH) (pg)	21.8 ± 0.8	22.0 ± 6.4
Mean Corpuscular Haemoglobin Concentration (MCHC) (g/dl)	35.7 ± 5.2	33.7 ± 7.4

Values are expressed as mean ± sd. Means are found significantly different at P<0.05 with p-value = 0.1818

The observed low weights in the body weights of animals under study compared with the control may be associated with the high concentrations of pollutants in the leachate-contaminated landfills. The weights of rats exposed to leachate-contaminated landfills reduced significantly compared to control. However, the increase in weights observed by the organ weight of exposed rats compared to control may be due to inflammatory responses of organ tissues. Torres *et al.* (2006) also in their study observed changes in kidney weight which may reflect renal toxicity, tubular hypertrophy or chronic progressive nephropathy. The relatively low haemoglobin, PCV and RBC concentrations of the blood of the exposed rats observed in this study suggest that the pollutants of the leachate-contaminated groundwater can directly or indirectly destroy blood cells and lower the haemoglobin concentrations. Islam *et al*. (2004) gave a report that changes observed in haematological parameters like haemoglobin, packed cell volume and red blood cells usually determines stress associated with environmental, nutritional and pathological factors. They also noted that these changes can be associated with anaemia.

Increased platelets concentration observed in the blood of rats exposed to leachate-contaminated landfills may be attributed to the presence of heavy metals amongst others (Table 1). These rats must have ingested high levels of metals like lead (Kadafa *et al*., 2013). Bioaccumulation of metals like cadmium and lead in the liver and kidneys of small mammals in landfill sites and polluted areas have been reported (Torres *et al., (*2006). Oladele *et al*. (2013) in their study observed that the white blood cells, total proteins and differential counts were significantly high in mice exposed to paint effluents. This was probably due to the heavy metals contained in the paint effluents. Also, Alimba *et al*. (2009) observed significantly high levels of metals such as lead, cadmium, mercury and copper in the two municipal wastes studied when compared with FEPA and USEPA limits. Further in their study, they opined that the leachate constituents including metals are capable of suppressing the activities of lymphoid tissues and haematopoietic cells in the bone marrow of rats. Amin *et al*. (2016), in their haematological studies revealed that the values of TEC (total erythrocyte count), ESR (erythrocyte sedimentation rate), Hb (hemoglobin) and PCV (packed cell volume) were decreased significantly in mice exposed to textile dye wastewater. Also, Bakare and Wale-Adeyemo (2004) stated that the land fill of Aba-Eku led to mortality of domestic animals and destruction of crops as a result of exposing the test organisms to contaminated water by the landfill leachate.

4.0. Conclusion

The findings in this study indicated that landfills from Abule-Egba contained toxic constituents capable of inducing haematological changes in study organism; wild rats (*Rattus rattus*). As a result, leachate generation at the study site is of health concern to humans. There is therefore a need for proper disposal of wastes.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 186 - 195

Farmers' Perceptions about the Effect of Farm Land Management Practices and Soil Depth on the Distribution of Major Soil Physico-Chemical Properties in Eroded Soils of *Aboy Gara* Watershed, Gidan District, North Wollo Zone

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ABSTRACT

The study was conducted at the Abuhoy Gara Catchment, which is located in the Gidan District of North Wello Zone. The aim of the study was to study farmers' perceptions about the effect of farm land management practices and soil depth on the distribution of major soil physico-chemical properties in eroded soils of Aboy Gara watershed. To address this issue, semi-structured interviews were conducted in 64 households to gain insight into soil fertility management practices, local methods were used to assess the fertility status of a field, and perceived trends in soil fertility. Thirty-three farmers were then asked to identify fertile and infertile fields. According to farmers response, farmers' fields were characterized as fertile where it comprise black color, cracks during dry season, good crop performance, vigorous growth of certain plants and presence of plants in a dry environment whereas the infertile is where it shows yellow/white and red colors, compacted soils, stunted plant growth, presence of rocks and stones and wilting or dying of crops in a hot environment. A total of eight indicators (soil color, texture, soil depth, topography, soil drainage, and distance from home, type of weeds grown and cultivation intensity) were found to be used by farmers to evaluate and monitor soil fertility. The results of administered questions showed that the principal indicators mentioned by farmers as very important were soil colour (82.8%), continuous cropping land (72.2%), soil texture (62.8%), distance from home (61%), type of weeds grown (56%), soil depth (55.6%), topography (51.1%), and soil drainage (28.7%) as very important. So, among sixty four interviewed farmers: deep soil (60 farmers), soils near to home (60 farmers), forest soil (59 farmers), smooth fine soil (59 farmers), black color soil (58 farmers) and gentle slope soil (57farmers) are categorized as fertile whereas 59, 57, 56, 55, and 44farmers said that Sandy/coarse soil, shallow soil depth, steep slope soils and yellow/white, red soils and continuously cultivated soils are infertile, respectively. The overall result showed that there was good agreement between farmers' assessment of the soil fertility status of a field and a number of these indicators. The soil laboratory analysis also corresponded well with farmers' assessment of soil fertility. Therefore, to design more appropriate research and to facilitate clear communication with farmers, researchers need to recognize farmers' knowledge, perceptions about assessments of soil fertility. Because, as they included all soil factors affecting plant growth, farmers' perceptions of soil fertility were found to be more long term day-to-day close practical experience finding than those of researchers.

Keywords: Farmers' perceptions, Soil fertility, Physico-chemical properties, Indicators, Eroded soils, Watershed

1.0. Introduction

The Ethiopian economy and the livelihoods of its population depend heavily on agriculture sector; efforts to sustain and improve the sector's productivity are therefore crucial to the country's economic development and to the welfare of its people. Securing food and a livelihood is inextricably linked to the exploitation of the natural resource base (land, water and forest) in Ethiopia, where over 85

percent of the population lives in rural areas and contribute significantly to the total export value (Alemneh, 2003). The pressure of intense human activity and improper farming and management practices pose serious threats to the sustainability and the suitability of soil for crop production which is based on the quality of the soil's physical, chemical and biological properties.

Land degradation, mainly due to soil erosion and nutrient depletion, has become one of the most important environmental and economic problems in the highlands of Ethiopia. And it was estimated that half of the Ethiopian highlands' arable lands are moderately to severely degraded and nutritionally depleted due to over cultivation, over grazing, primitive production techniques, and over dependent on rainfall (Hugo *et al*., 2002). According to World Bank (2008), Ethiopia high lands including the study areas are most seriously affected by land degradation resulting in low and declining agricultural productivity, persistent food insecurity and rural poverty. The complex inter-linkages between environmental degradation, poverty and fast population growth have brought several changes (Dasgupta and Mäler, 1994) like farm holdings becoming smaller and more fragmented, fallow periods becoming shorter, farmers cultivating fragile margins on steep slopes previously held in pasture and woodlot.

In order to give a sustainable solution to all these challenges, collaborative research between researchers and farmers is very crucial. However, until recently, farmers' knowledge of soil fertility has been largely ignored by soil professionally biased researchers. Hence, their adoption of improved techniques has been limited and biased (Shrestha *et al*., 2000). But with increasing use of participatory research approaches, it is becoming clear that farmers have a well- developed ability to perceive differences in the level of fertility between and within fields on their farms. They also see the actual fertility of a soil at any time as a function not only of these longer-term soil properties, but also of the current and past management regime. As such, they assess the fertility of the soil using a range of indicators which they can actually see or feel, including crop yields, soil depth, drainage, moisture, manure requirements, water source, slope, and weed abundance. Therefore the findings of this paper can build cooperative researches with farmers' perceptions about the assessment of soil fertility in a more detail way in line with the criteria of soil fertility used by researchers. Therefore, the objective of the study was to study farmers' perceptions about the effect of farm land management practices and soil depth on the distribution of major soil physico-chemical properties in eroded soils of *Aboy Gara* watershed.

2.0. Methodology

2.1. Description of study area

The study was conducted at *Abuhoy Gara* catchment in Gidan district (Figure 1) which is found in North Wollo Zone of Amhara National Regional State. Gidan is bordered by Tigray Region in the North; Gubalafto district in the North east; Meket district in the south east and Lasta district in the south and south west. Astronomically, it is located between 11°53'-12°16' North and 39°10'-39°35' east 39°10'-39°35' East. Muja is the administrative town of the district and is situated at about 595 km from the capital city, Addis Ababa. According to the district agricultural office report, the population of the study catchment is 580 people of whom 420 are male and 160 are female. The total area of *Abuhoy Gara* catchment is about 615 hectares (250 hectares cultivated and 365 hectares none cultivated lands). According to north-east Amhara meteorological data survives, the annual mean rainfall is 1100 mm with the annual mean maximum and minimum temperature of 21.23°C and 9.57°C, respectively. The topography and land form of the area is dominated by rolling hills dissected streams and valleys. The altitude ranges from 3,089 to 3,559 m.a.s.l (having an average altitude 3,324 m.a.s.l). The topography of the watershed (i.e., at total of 1819 ha) is characterized as 15% gentle slopes, 53.6% steep slope, 31.4% very steep. Rained subsistence farming is the dominant form of agriculture coupled with livestock keeping. Dominant crops include wheat, barley and faba bean cultivated during the main rainy season. Livestock production is an essential part of the farming system. Most farm households keep cattle dominated by oxen and small stock including sheep, poultry, and equines.

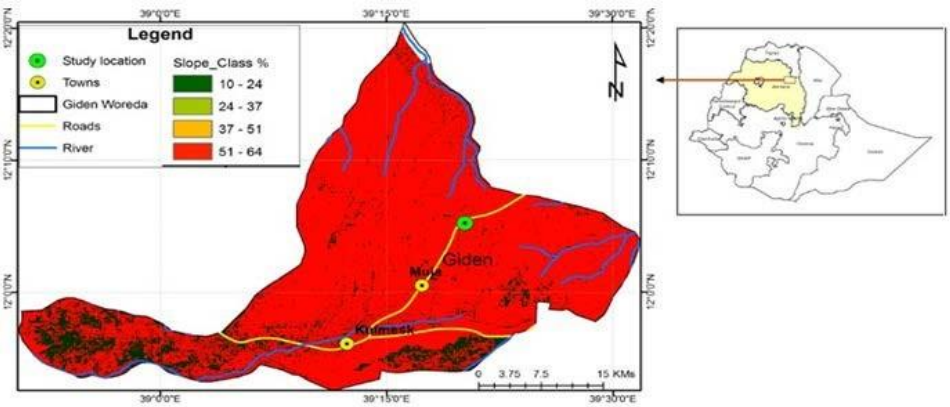

Figure 1: Location map of the study area

2.2. Methods of data collection

2.2.1. Field observation and household interviews

At the beginning, a general visual field survey of the area was carried out to have a general view of the study area. Global Positioning System readings were used to identify the geographical locations and the coordinate system where data could be taken, and clinometers were used to identify slopes of the sampling sites. In order to capture the local indicators and farmers' perception of soil fertility on the study site, participatory rural appraisal tools were conducted using namely direct observation, formal and informal discussion, focus group interviews and key informants. Some limited field work was also undertaken to verify some of the information and data gathered during the discussions and interviews. On the identification of the local indicators of soil fertility through interviews with local people, the soils were broadly categorized into two groups: fertile (*ertib)* soils and infertile (*koda*) soils with respect to crop yields. Indicators were related to management induced changes in the soil which includes only those properties relevant to the soil types, farming system, and land uses of the areas. Therefore, questionnaire survey was administered to 64 sampled households (43 males, 21 female) to capture information on farmers' perceptions about the fertility status of their farm lands. The sampled households who having a minimum of 0.75 hectares of land size with an average experience of 20 year were randomly selected from a list of total households collected from the representatives of each village. Special care was taken to ensure that the most experienced member of the household is being interviewed. Fields that were rented out to other farmers, or fields that were being rented by the interviewee, were excluded from the discussions to minimize errors due to a possible lack of knowledge regarding the management of these fields. To increase the validity and reliability of data, focus group discussions (composed of elders, male and female farmers and community leaders) and informal interviews with developmental agents and district agricultural experts were carried out. Secondary sources of data were gathered from unpublished documents and official reports from relevant government offices.

2.2.2. Soil sampling

Before sampling, forest litter, grass, dead plants and any other materials on the soil surface were removed and during collection of samples, field/terrace edges, furrow, old manures, wet spots, areas near trees, compost pits, fields used as kitchen gardens and fertilizer bands were excluded. From those interviewed, a subset of 33 farmers were selected at random and asked to indicate their most fertile field and their most infertile field. Each of these fields and its surrounding environment was then characterized according to its distance from the household, its size, terrace height, tree shade, stoniness, aspect of crops, and hardness of the soil felt when sampling. Representative soil sampling sites were purposely selected based on cultivation history and indigenous local indicators of soil fertility groups using farmers' perceptions'. In order to determine the impact of management practices and depth on the distribution of soil physic-chemical properties, a total of 42 composite soil samples were collected by flexible gridding system (flexible grid survey method of 1:30,000 scales throughout the field at two depths, surface (0-15 cm) and subsurface (15- 30 cm) soil layers) (Ryan *et al*., 2001). The number and distribution of soil samples were determined using Global Positioning mapping system based on the identified soil fertility groups (fertile and infertile). Soil sampling was based on

the identified soil fertility groups. In each soil group, a composite soil sample of 10 sub-samples was taken from each soil depth (0-15 and 15-30 cm).

2.3. Method of data analyses

2.3.1. Soil laboratory analysis

The collected samples were air-dried, homogenized and sieved to pass a 2 mm mesh sieve for physical and chemical analyses. Particle-size distribution was determined using the pipette methods or hydrometer method (Gee and Bauder, 1986). Soil pH was determined in water (1M potassium chloride in a soil to solution ratio of 1: 2.5 soil water solution (McLean, 1982) using glass electrodes after reciprocal shaking for 1 hour). The exchangeable acidity was extracted with 1M potassium chloride (KCl) and it can be determined by the titration method using 0.01M sodium hydroxide (NaOH) (Sumner and Stewart, 1992). Organic matter and total organic carbon were determined using loss-on-ignition method (Corbeels *et al.*, 2000). Total nitrogen was determined using Kjeldahl method (Okalebo *et al.*, 1993) and total carbon in soil was determined by the wet digestion method of Walkley and Black (Bremner and Mulvaney, 1982; Nelson and Sommers, 1982). Olsen *et al*. (1954) and Bray II method (Kuo, 1996) was used to determine available phosphorous content of the soil. Exchangeable cations (potassium, calcium, magnesium and sodium) were extracted with 1M Ammonium acetate (NH4OAc) buffered at pH 7. The concentrations of potassium, calcium, magnesium and sodium in the solutions were measured by atomic absorption spectrophotometer (Shimadzu AA-6800). The cation exchange capacity of the soil was determined by 0.05M potassium sulphate (K_2SO_4) using the soil used for the basic exchangeable cation determination or by the neutral ammonium acetate (CH3COONH4) saturation method (Ryan *et al*., 2001). The exchangeable bases in the ammonium acetate filtrates collected above were measured by atomic absorption spectrophotometer (Ryan *et al*., 2001).

2.3.2. Data analysis

Analysis of variance (ANOVA) using the general linear model procedure of the statistical analysis system (SAS) was performed to detect soil physicochemical properties differences on the surface soils (0-15 cm) and subsurface soil (15-30 cm) of fertile (*ertib*) and infertile (*koda*) soil groups. The data generated by structured questionnaires were analyzed using descriptive analysis to describe and investigate the characteristics of the farmers' perception.

3.0. Results and Discussion

3.1. Farmers' Perceptions about Soil Fertility

Farmers in the study area have almost common criteria to evaluate and identify their soils. Usually, fields were characterized as fertile (*ertib*) or infertile (*koda*). They used soil color, texture, soil depth, soil drainage, topography and distance from home as criteria to classify the soil into different groups (Table 1). Based on these criteria farmers of the catchment categorized their soils into: fertile (*ertib*) and infertile *(koda)*.

Soil color is an important criterion for farmers, whereas with respect to soil texture, farmers preferred heavy soils (clay soils) to sandy soils because of their high water holding capacity and nutrients of plants. Sandy soils are mostly highly weathered and their physical, chemical and biological attributes of soil fertility are extremely limited (Brady and Weil, 2002). According to farmers response, farmers' fields were characterized as fertile (*ertib*) where it comprise black color, cracks during dry season, good crop performance, vigorous growth of certain plants and presence of plants in a dry environment and as infertile (*koda*) where it shows yellow/white and red colors, compacted soils, stunted plant growth, presence of rocks and stones and wilting or dying of crops in a hot environment. On the other hand, fifty five farmers said that white and red soils were most commonly used to describe infertile (*koda*) soils. The reason was because of its low water holding capacity; making it less productive in low rainfall years and low nutrient retention capacities. So, sixty-four interviewed farmers for each type of soil, 60, 60, 59, 59, 58 and 57 said deep soil, soils near to home, forest soil, smooth fine soil, black color soil and gentle slope soil are fertile, respectively whereas 59, 57, 56, 55, and 44 farmers said that sandy/coarse soil, shallow soil depth, steep slope soils and yellow/white, red soils and continuously cultivated soils are infertile, respectively (Table 1). According to farmers in the area,

these red and light-colored soils have acidic soil reactions and non-productive soils. The occurrence of light and red-colored soils is related to very low organic matter content and significant amounts of iron and aluminum oxides and hydroxides in the soil Pawluk *et al*. (1992).

Table 1: Soil types identified by farmers using possible indicators (n= 64)

Local indicators	Fertile (*ertib*)	Infertile (*koda*)	Undecided
Yellow/white and red	5	57	2
Black (‘*Koticha)*	58	4	2
Light black	39	21	4
Brown *Dalacha’* soil	31	30	3
Steep slope soil	4	55	5
Gentle slope	57	4	3
Deep soil depth	60	3	1
Shallow soil depth	2	57	1
Swampy soil	1	56	3
Well drained soil	57	3	
Sandy/coarse soil	1	59	
Smooth fin soil	59	2	3
Soils around near to home	60	4	
Continuously cultivated soils	8	44	4
Grazing land soils	41	17	6
Forest soils	59	5	

3.2. Farmer Indicators of Soil Fertility

The results of administered questions showed that the principal indicators mentioned by farmers (Table 2) were soil colour (82.8% of the farmers), continuous cropping land (72.2%), soil texture (62.8%), distance from home (61%), type of weeds grown (56%), soil depth (55.6%), topography (51.1%), and soil drainage (28.7%) as very important. Similar to Corbeels *et al*. (2000) farmers were found to classify their soils very importantly according to their colour relatively than texture and others (Table 1 and Table 2).

Table 2: Indicators rank based on their importance

Indicators	Rank based on farmers’ perceptions				
	Very important	Important	Undecided	Least important	Not important
Soil color	149/180=82.8%$^{(1st)}$	15/180=8.3%$^{(8th)}$	16/180=8.9%	-	-
Soil Texture	113/180=62.8%$^{(3rd)}$	36/180=20%$^{(6th)}$	10/180=5.6%	14/180=7.8%	7/180=3.9%
Soil Depth	100/180=55.6%$^{(6th)}$	39/180=21.7%$^{(5th)}$	8/180=4.4%	18/180=10%	15/180=8.3%
Topography	92/180=51.1%$^{(7th)}$	47/180=26%$^{(4th)}$	22/180=12.2%	18/180=10%	1/180=0.6%
Soil Drainage	52/180=28.9%$^{(8th)}$	48/180=26.7% $^{(3rd)}$	51/180=28.3%	21/180=11.7%	8/180=4.4%
Farm distance	112/180=61%$^{(4th)}$	29/180=16.1%$^{(7th)}$	8/180=4.4%	23/180=12.8%	8/180=4.4%
Continuous cropping	131/180=72.7%$^{(2nd)}$	49/180=27.2%$^{(2nd)}$			
Type of weeds	101/180=56%$^{(5th)}$	72/180=40%$^{(1st)}$		7/180=3.9%	

3.3. Farmers Perceptions and Laboratory Results

Soil Texture:

There were no significant differences in sand and clay particle size distribution among /between the two soil groups (fertile and infertile), but the highest mean sand fraction and clay fraction were observed in infertile and fertile soils, respectively (Table 3). The increasing of clay fraction and decreasing of sand fraction indicates that these have positive correlation with soil fertility. This is apparent because the clay particles unlike the sand particles, have substantial exchange surface areas, and therefore adsorb and stabilize organic matter and soil nutrients (Saggar *et al*., 1994; Saggar *et al*., 1996).

Table 3: Selected soil physical characteristics of farmer designated *ertib* (fertile) and *koda* (infertile) soils

Variables	Sand %	Silt %	Clay %
	Farmers' Perception		
Fertile soil	59.17a	16.25a	24.58a
Infertile soil	60.00a	16.25a	23.75a
LSD (0.05)	NS	NS	NS
SEM (+)	29.1667	3.4722	15.9722
CV (%)	9.0640	11.4670	16.5374
Soil Depth			
0-15 cm	57.92a	18.33a	23.75a
15-30 cm	61.25a	14.17b	24.58a
LSD (0.05)	NS	2.633	NS
SEM (+)	29.1667	3.4722	15.9722

**Values with the same letter are not significantly different (P < 0.05); SEM = Standard Error of Mean; LSD = Least Significance Difference; CV = Coefficient of Variation*

Table 4: Interaction effects of farmers' perception and soil depth on selected soil physical properties

	Sand (%)		Silt (%)		Clay (%)	
Variables	Soil Depth (cm)		Soil Depth (cm)		Soil Depth (cm)	
	0-15	15-30	0-15	15-30	0-15	15-30
Fertile soil	58.55a	60.21a	17.29a	15.20ab	24.17a	24.58a
Infertile soil	58.96a	60.63a	17.29c	15.21bc	23.75a	24.16a
LSD (0.05)	NS		3.723		NS	
SEM (±)	29.1667		3.4722		15.9722	
CV (%)	9.0640		11.4670		16.5373	

**Values with the same letter are not significantly different (P < 0.05); LSD = Least Significance Difference; SEM = Standard Error of Mean; CV = Coefficient of Variation*

Soil chemical properties:

According to farmers' perception, fields can be classified as fertile (*ertib*) and infertile (*koda*) based on different local indicators. There was significance difference in soil exchangeable cations (calcium, magnesium, potassium), cation exchange capacity, total nitrogen, organic carbon and available phosphorous between soils classified as fertile (*ertib*) and infertile (*koda*) by farmers, while no significance difference in soil exchangeable sodium and acidity and pH (Table 5). Considering the two soil groups (*ertib* and *koda*), the higher mean values of calcium (7.88cmol(+) kg^{-1}), magnesium (1.97cmol(+) kg^{-1}), potassium (0.78cmol(+) kg^{-1}), sodium (0.29cmol(+) kg^{-1}), cation exchange capacity (15.57cmol(+) kg^{-1}, pH-H_2O (6.01), total nitrogen (0.116%), organic carbon (1.583%) and available phosphorous (8.33 ppm) were observed within the fertile (*ertib*) soils while the highest mean value of exchangeable acidity (0.263 cmol(+) kg^{-1}) was observed on infertile (*koda*) soils (Table 5). This result is in agreement with other studies, for instance, Murage *et al*. (2000) found in Kenya that productive soils (fertile soils), as identified by farmers, had significantly higher soil pH, effective cation exchange capacity, exchangeable cations, extractable phosphorus, and total nitrogen than non-productive soils (infertile soils). According to the classification of soil chemical properties as per the ranges suggested by FAO (2006), Jones (2003), Landon (1991), Tekalign (1991), Barber (1984) and Murphy (1968), the soils of *Abuhoy Gara* Catchment was moderate content in calcium (5-10 cmol(+) kg^{-1}), cation exchange capacity (12 – 25 cmol(+) kg^{-1}), potassium (0.3–0.7 cmol(+) kg^{-1}), magnesium (1–3 cmol(+) kg^{-1}), pH-H_2O (5.6-6.0), whereas low in sodium (0.1–0.3 cmol(+) kg^{-1}), total nitrogen (0.05–0.15%), available phosphorus (1-9 ppm), and organic carbon (1 - 2%). Thus these results showed that there was no significantly difference between both perceptions of researchers and farmers.

Table 5: Selected soil chemical characteristics of farmer designated fertile soil and infertile soil

Variables	Exchangeable (cmol(+) kg^{-1})									
	Ca	Mg	K	Na	Exa.A	CEC	pH-H_2O	TN %	OC%	Av. P(ppm)
Farmers' Perception about soil fertility										
Fertile soil	7.88a	1.97a	0.78a	0.29a	0.215a	15.57a	6.01a	0.116a	1.583a	8.33a
Infertile soil	5.98b	1.75b	0.44 b	0.27a	0.263a	13.90b	5.90a	0.100b	1.228b	6.67b
LSD (0.05)	0.620	0.188	0.120	NS	NS	0.558	NS	0.010	0.074	0.692
CV (%)	6.3358	7.1494	13.9288	20.2556	14.1280	2.6826	1.4578	6.9612	3.7491	6.5295
Soil Depth										
0-15 cm	6.71a	1.76b	0.57a	0.27a	0.251a	14.48a	5.93a	0.112a	1.365b	7.25a
15-30 cm	7.12a	1.96a	0.65a	0.29a	0.227a	14.99a	5.98a	0.104a	1.447a	7.75a
LSD (0.05)	NS	0.188	NS	NS	NS	NS	NS	NS	0.074	NS

**Values with the same letter are not significantly different (P < 0.05); Ca = Calcium; Mg = Magnesium; K = Potassium; Na = Sodium; Ex. acidity = exchangeable acidity; CEC = Cation Exchange Capacity; TN = Total Nitrogen; OC= Organic Carbon; Av.P = Available Phosphorous; NS = not significant; LSD = Least Significance Difference; CV = Coefficient of Variation*

Table 6: Interaction effects of farmers' perception and soil depth on selected soil chemical properties

Variables	Exchangeable (cmol(+)kg^{-1})											
	Ca		Mg		K		Na		Exa.A		CEC	
	Soil depth (cm)											
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Fertile soil	7.47a	8.29a	1.81b	2.13a	0.71a	0.86a	0.27a	0.31a	0.23ab	0.19b	15.37a	15.77a
Infertile soil	5.95b	6.02b	1.72b	1.79b	0.43b	0.44b	0.27a	0.28a	0.27a	0.26ab	13.59b	14.22b
LSD(0.05)	0.877		0.266		0.169		0.113		0.067		0.790	
SEM (±)	0.1928		0.0177		0.0072		0.0032		0.0011		0.1562	
CV (%)	6.3358		7.1494		13.9288		20.2556		14.1280		2.6826	

Table 6 Continued

Variables	Exchangeable (cmol(+)kg^{-1})							
	pH-H_2O		Total Nitrogen (%)		Organic Carbon (%)		Av. Phosphorous(ppm)	
	Soil depth (cm)							
	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Fertile soil	5.99a	6.04a	0.121a	0.111ab	1.562a	1.604a	8.17a	8.50a
Infertile soil	5.88a	5.92a	0.103b	0.097b	1.168c	1.289b	6.34b	7.00b
LSD(0.05)	NS		0.015		0.105		0.978	
SEM (±)	0.0075		0.0001		0.0028		0.2398	
CV (%)	1.4578		6.9612		3.7491		6.5295	

**Values with the same letter are not significantly different (P < 0.05); Av. =Available; LSD = Least Significance Difference; SEM = Standard Error of Mean; CV = Coefficient of Variation*

All these physical and chemical properties of the soils were linked with the farmers' soil fertility management practices of the study sites**.** Farmers used oxen to pull the local plough material '*Maresha*'. Most of the farmers in the study areas cultivate their land 2-3 times before planting cereals. The study area has two cropping seasons short rain season (*'Ganna')* and main rain season (*'Bona')* and only few farmers divided their land into *'Ganna'* and *'Bona'* cropping land. The main reasons raised by farmers for not using the land for double cropping was fear of soil fertility depletion as a result of double cropping.

Farmers of the study area are well aware of the advantage of returning crop residues to soil fertility. But, only few farmers around 12% retain most crop residues in their field. This is because crop residues are used as construction material, fuel and source of animal feed. Moreover, farmers used low rate of mineral fertilizers due to the current escalating prices of chemical fertilizers. 75% farmers broadcast/ apply only 50 kg diammonium phosphate /ha for cereals. This rate is by far lower than the blanket recommendation (100 kg diammonium phosphate and 50 kg urea) for the area.

The major practice followed by farmers in this area is to rotate barley and wheat on the same piece of land. However, few farmers in some part of the highland rotated cereals with leguminous crops (e.g. field pea, chick pea, and lentil). Despite the fact that farmers know the benefit of fallowing to restore soil fertility, study also clearly showed that long term fallowing was not practiced in the study area

due to the ever increasing population pressure. Currently, the common practice in the area is seasonal fallowing i.e. leaving the land fallow for one or two seasons.

4.0. Conclusion

The results presented in this paper indicate that there is good agreement between assessment of soil fertility by farmers in *Abuhoy Gara* catchment and scientific indicators of soil fertility such as exchangeable cations, cation exchange capacity, soil organic carbon content, total nitrogen and pH. The names the farmers give to soils do not necessarily correlate to the scientific classification because their classification and indicators rely on soil characteristics that they can practically experience. Nevertheless, both farmers and researchers have common objectives, mainly to ensure that the soil resources are sufficient and sustainable to meet the needs of farmers at present and in the future. In spite of the fact that different soil quality management practices that billions of trees have been planted, and millions of hectares of land treated through the construction of terraces, deep trenches, percolation ponds and others in the study area by the local government, there are still many areas untreated, some of the efforts have not succeeded. According to the response of interviewed farmers, this failure is believed to be due to inadequate capacity to implement relevant technologies at appropriate places which could be innovated by farmer's group research approach. As stated by Pawluk *et al*. (1992), researchers need to understand and use indigenous knowledge systems, which need to be viewed, not as opposing, but rather as complimentary to their own way of thinking**.** Therefore, it is important that both farmers' perception and researchers' scientific methodology of soil fertility assessment are used to give a sustainable solution to land degradation and soil fertility declining problems. And conserving and maintaining the soil quality is not only important for improvement of land productivity but also for climate crises mitigation through storing the world's carbon dioxide emissions and neutralizing or filtering out potential pollutants by well managed soils.

Acknowledgement

This work has been in its present shape with considerable professional, financial, and material inputs from various sources. Therefore, it is an amazing excitement to him to come to this final point and to express his deepest gratitude to all individuals and organizations who contributed directly or indirectly to this study and the production of these research findings. The author would like to express his sincere thanks to his University; Woldia University from the planning stage of the research work and funding to the production of this study output. His heartfelt thanks go to the Amhara National Regional State Sirinka Agriculture Center for offering him all possible helps in all aspects of the laboratory work. Apart from that, he wants to express his appreciation to the *Gidan* District Agriculture office staff members for their unlimited contribution from site selection all the way up to sample collection.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 196 - 207

Seasonal variation in heavy metal accumulation in plants at coal mine sites and possible health risk

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ABSTRACT

Human health challenges in recent times have been attributed to consumption of food contaminated with heavy metals. Coal mining is an anthropogenic activity that releases heavy metals into the environment. This study, therefore, assessed accumulation of heavy metals (lead (Pb), cadmium (Cd), nickel (Ni), arsenic (As) and iron (Fe)) in plant species in the vicinity of Akwuke and Iva coal mine in Coal city, Enugu State. The results indicate that the highest concentration of Ni (9.02 ± 0.03 mg/kg), As (0.005 ± 0.001 mg/kg) and Cd (2.16 ± 0.07 mg/kg) was accumulated in Alchornea cordifolia while the concentration of Pb (10.37 ± 0.52 mg/kg) was highest in Andropogon gayanus and Fe (231.00 ± 1.41 mg/kg) was highest in Irvingia gabonensis. The values of Ni (9.02 ± 0.03 mg/kg), As (0.005 ± 0.00 mg/kg), Pb (10.37 ± 0.32 mg/kg), Cd (2.02 ± 0.03 mg/kg), and Fe (46.00 ± 1.41 mg/kg) accumulated in A. cordifolia, A. gayanus, D. guinense, and M. indica in wet season were significantly ($P < 0.05$) higher than their corresponding values (5.04 ± 0.07, 8.96 ± 0.01 and 0.003 ± 0.001 mg/kg, 1.87 ± 0.07 mg/kg, and 33.45 ± 0.21 mg/kg) in dry season, respectively. Alchornea cordifolia, Andropogon gayanus and Irvingia gabonensis consumed by animals and local inhabitants in the vicinity of the two mined sites could expose them to high levels of Pb, Ni and Cd, thus posing a serious health risk to the local people.

Keywords: Seasonal variation, heavy metal, plants, coal mine, Enugu, Nigeria

1.0. Introduction

Human health challenges in recent times have been attributed to consumption of food contaminated with heavy metals. Food contamination is becoming very alarming due to high rate of exploitation of mineral resources such as coal, petroleum, stones (i.e. quarrying) among others. Coal mining is the process of extracting coal minerals from under the ground (Ogbonna *et al*., 2012) and this anthropogenic activity constitutes environmental problem since mining removes part or all of the standing plant material and litter, as well as the soil organic matter (SOM) in the surface horizons. Mining operations generates tailings that are deposited around mines and part of the tailing dust escape into the atmosphere. Thus, the atmosphere is a pathway for transport of heavy metals and the major input of bio-available metals in the environment, which are potential threats to the health and survival of man (Ogbonna *et al*., 2018b). For instance, the inhalation of cadmium (Cd) causes bronchitis, pneumonitis and inflammation of the liver (Mac Farland, 1979) but the effect becomes fatal and deleterious when up to 8 mg/m^3 of cadmium oxide fume is inhaled for about 5 hours (Ademoroti, 1996). Cadmium is an enzyme inhibitor, having affinity for other ligands in plants and animal cells like carboxyl, crysteinyl and histidyl side chains of protein, porphyrin and purines. The symptoms of Cd toxicity produced by enzymatic inhibition include respiratory disorders, aminoaciduria (urinary excretion of excessive calcium), formation of kidney stones and damage to kidney and liver (Manzur, 1981). Argon (Ar) exert deleterious effect on the skin and this include hyperkeratosis on soles of feet and palms, hyper pigmentation in areas not exposed to the sun and skin cancer after prolonged exposure (Berman, 1980), causes cirrhosis (liver disease) and a rare form of liver cancer called haemogioendothelioma (Hutton, 1986).

Heavy metals are either deposited directly on plant surfaces such as leaves, flowers, branches, and stems or on soils, which are absorbed from the soil solution into plants via the roots (Ogbonna *et al*., 2018b). Since herbivores largely depends on fodder plants for food and man also relied heavily on plants for nutrition and health benefits, heavy metal contamination of plants will constitute serious health risk to both man and animals residing around coal mine sites. A literature search showed that no work has been carried out on heavy metal pollution in seven plant species growing on or near coal mine-contaminated sites in Nigeria. The seven species sampled in this study (*Irvingia gabonensis*, *Dialium guinense*, *Mangifera indica*, *Icacina trichantha*, *Alchornea cordifolia*, *Andropogon gayanus*, and *Manihot esculenta*) are very important source of nutritional fruits (*Mangifera indica*, *Irvingia gabonensis*, *Dialium guinense*), medicine (*Icacina trichantha*), condiment (*Irvingia gabonensis*) and staple food (*Manihot esculenta*) for man while *Andropogon gayanus* and *Alchornea cordifolia* are important fodder plants for herbivores in South east Nigeria. The objective of this study is to investigate the level of concentrations of heavy metals in plants around the coal mine sites and compare the values with the maximum permissible limits of FAO/WHO. The results of this research will provide the background information on the levels of concentrations of heavy metals in the plants and serve as an important document for Enugu State Agricultural Development Programme to carry out extension services to the rural farmers on the possible danger associated with using the lands around the coal mine sites for agricultural purposes or utilizing the plants that are naturally growing there for nutritional and health purposes.

2.0. Methodology

2.1. Study area

The study on the determination of heavy metal accumulation in plants at coal mine sites was carried out at Enugu, Enugu State. The study covered both Akwuke and Iva mines. Enugu is the capital of Enugu State, south east Nigeria and has a population of 722, 000 in 2006 (NPC, 2006) and a large deposit of sub-bituminous coal. It lies within latitude 6° 23' and 6° 26' N and longitude 7° 27' and 7° 30'E (Ogbonna *et al*., 2018a) and the mean monthly temperature lies between 27 and 29°C (Ekere and Ukoha, 2013). The area has tropical climate and experiences two seasons both of which are warm. The wet season begins from April and ends in October while the dry season begins from November and ends in March (Ogbonna *et al*., 2012). The natural vegetation is tropical rain forest type but has significantly changed over time to guinea savannah due to human activities such as farming (Ezeigbo and Ezeanyim, 1993), nomadism and exploitation of fuel wood (Ogbonna *et al*., 2018a), erosion menace and rapid increase in human population. The three largely conformable geologic formations are Enugu shale (Campanian), the Mamu Formation (Lower Maastrichtian) and the Ajali sandstone (Upper Maastrichtian) which constitutes the geology of the Enugu coal mine area. The food and cash crops produced by farmers include yam, maize, ogbono (*Irvingia gabonensis var excelsa*), melon, cassava, local beans, oil palm, rice, groundnut, and cocoa (Ogbonna *et al*., 2018a).

2.2. Sample collections

Prior to the sample collection, a reconnaissance survey was carried out to determine the altitude of the mined sites (251 and 259 m for Akwuke and Iva mines, respectively) and plant species that were common at the two mined sites since mined sites are very slow in vegetation regrowth. The control samples were taken from a 5 year upland bush fallow that is 2 km away from the abandoned mines.

2.2.1. Plant sampling and analysis of heavy metals

In this study, plant sampling for determination of heavy metals content in plants was carried out on individual plant species that had at least 3 frequency of occurrence in each of the mined (Akwuke and Iva) and unmined (control) sites. Fresh leaves were sampled from different shoots/branches and parts of different woody species 7-9 years of age, except for root crops (cassava) and grass (gamba grass) that is less than 2 years. The leaves of *Andropogon gayanus* (gamba grass, family- Poaceae), *Irvingia gabonensis* (wild bush mango, family- Irvingiaceae), *Dialium guinense* (wild black velvet, velvet tamarind, family- Fabaceae), *Mangifera indica* L. (mango, family- Anacardiaceae), *Alchornea cordifolia* (Schum. & Thonn.) *Muell. Arg.* (Christmas bush, family- Euphorbiaceae), *Icacina trichantha* Oliv. (pflamzenfen, family- Icacinaceae), and *Manihot esculenta* (cassava, family- Euphorbiaceae) were randomly collected in February (dry season) and June (wet season) separately

from each individual plant using well-cleaned secateurs at the two mined locations and an unmined plot (a 5 year upland bush fallow that is 2 km from the mined sites where there was no visible source of contamination). Three replicates of each plant species were collected and mixed separately to obtain a composite sample. The plant samples were cleaned sequentially with a phosphate–free detergent (Extran 2%), rinsed once with tap water, once with distilled water and finally twice with deionized water to remove adhering materials such as dust and pollen particles and placed in large clean crucibles where they were oven dried at 60°C for 72 h. Thereafter, the dried plant samples were milled with a Thomas Wiley milling machine (Model ED-5 USA) to fine powder. The procedure according to Awofolu (2005) was used for digestion of plant sample. A 0.5 g of each sieved leaf samples was weighed into 100 ml beaker. A mixture of 5 ml concentrated trioxonitrate (IV) acid and 2 ml perchloric acid was added and digested at 80°C using hot plate until the content was about 2 ml. The sample was allowed to cool, filtered into 50 ml standard flask using 0.45 um Millipore filter kit. The beaker was rinsed with small portions of doubled distilled water and then filtered into the flask.

2.3. Heavy metal content

The concentrations of lead (Pb), cadmium (Cd), arsenic (As), iron (Fe), and nickel (Ni) in the digested samples were determined using flame Atomic Absorption Spectrophotometer (AAS) of UNICAM 919 model. Triplicate digestion of each sample was carried out and blanks were prepared from only reagents without sample to check for background contamination by the reagents. Appropriate quality assurance procedures and precautions were taken to ensure the reliability of the results. Samples were carefully handled to avoid cross-contamination. Glassware was properly cleaned, and reagents used were of analytical grades. Deionized water was used throughout the study. Working standard solutions of Pb, Cd, As, Fe, and Ni were prepared from the stock standard solutions containing 1000 ppm of element in 2N nitric acid. Calibration and measurement of elements were done on flame Atomic Absorption Spectrophotometer (UNICAM 919 model). A blank reading was also taken and necessary correction was made during the calculation of concentration of various elements.

2.4. Experimental design and statistical analysis

A single factor experiment was conducted in a randomized complete block design (RCBD) with three replications. Data collected was subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) v. 15 and means were separated (Steel and Torrie, 1980) at $P < 0.05$ using Duncan New Multiple Range Test (DNMRT).

3.0. Results and Discussion

Heavy metals have maximum permissible level in plants specified by different bodies (Pam *et al*., 2014) such as FAO/WHO. Consequently, the comparison and interpretation of the results of analyzed plant samples in this study is based on the control values, standards set by FAO/WHO and the concentration of the heavy metals in soils from the study sites. The concentrations of heavy metals in plants sampled from the mined and unmined (control) sites of Akwuke and Iva in wet and dry season are presented in Tables 1 and 2, respectively. The results indicate that heavy metal concentrations differed significantly ($P < 0.05$) from one plant species to another and that the highest and the lowest metal concentrations in plants were obtained from the mined and control sites, respectively. The concentrations of Ni, Pb, Cd, Fe and As in plants at the mined sites (Akwuke and Iva) were significantly ($P < 0.05$) higher than their corresponding values at the control site. The highest values of Ni (9.02 ± 0.03 mg/kg), Pb (10.37 ± 0.52 mg/kg), and Fe (231.00 ± 1.41 mg/kg) in *Alchornea cordifolia*, *Andropogon gayanus*, and *Irvingia gabonensis* at the site in Akwuke mine as well as the concentrations of Cd (2.16 ± 0.07 mg/kg) and As (0.005 ± 0.001 mg/kg) in *A. cordifolia* at the site in Iva mine were significantly ($P < 0.05$) higher than the highest corresponding values of Ni (0.02 ± 0.01), Pb (0.01 ± 0.00 mg/kg), Fe (1.31 ± 0.40 mg/kg), Cd (0.01 ± 0.00 mg/kg), and As (0.00 ± 0.00) in plants at the control site. The highest values of Ni, Pb, Fe, Cd, and As in plants obtained from the mined sites exceeded their corresponding values at the control site by 451, 1037, 176, 216, and 0.005 times, respectively. This result corroborates with the findings of Lee *et al*. (2001), Mtui *et al*. (2006) and Jung (2008) who reported that the concentration of heavy metal in plants at the mined site is higher than the concentration of plants at the control site. In the vicinity of a Pb/Zn mine in Shaoxing, eastern China, Pb and Cd concentrations of some plants were 20 and 30 times higher than the

permitted standards (Li *et al*., 2006a) while Chinese cabbage growing in the vicinity of nonferrous metals mining and smelting sites in Baiyin, China contained high concentration of Cd that exceeded the maximum permitted levels (0.05 mg/kg) by 4.5 times (Li *et al*., 2006b).

Table 1: Heavy metal concentration (mg/kg) in plants in wet and dry season at Akwuke mine site

Plants	Ni	Pb	Cd	Fe	As
Irvingia gabonensis (wet)	$4.28^{e} \pm 0.10$	$2.70^{e} \pm 0.07$	$0.97^{c} \pm 0.08$	$2.96^{i} \pm 0.08$	$0.001^{de} \pm 0.000$
Irvingia gabonensis (dry)	$3.06^{g} \pm 0.14$	$1.96^{f} \pm 0.07$	$0.68^{d} \pm 0.03$	$2.16^{j} \pm 0.10$	0.000 ± 0.000
Irvingia gabonensis control (wet)	$0.01^{l} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.27^{lmn} \pm 0.04$	0.000 ± 0.000
Irvingia gabonensis control (dry)	$0.01^{l} \pm 0.01$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.25^{lmn} \pm 0.04$	0.000 ± 0.000
Dialium guinense (wet)	$3.41^{f} \pm 0.16$	$2.96^{d} \pm 0.08$	$2.02^{a} \pm 0.03$	$23.64^{c} \pm 0.91$	$0.004^{b} \pm 0.001$
Dialium guinense (dry)	$1.98^{h} \pm 0.10$	$2.03^{f} \pm 0.06$	$1.87^{b} \pm 0.07$	$17.81^{d} \pm 0.44$	$0.002^{cd} \pm 0.001$
Dialium guinense control (wet)	$0.01^{l} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.01$	$1.31^{k} \pm 0.40$	0.000 ± 0.000
Dialium guinense control (dry)	$0.01^{l} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.00^{i} \pm 0.00$	$1.28^{k} \pm 0.40$	0.000 ± 0.000
Mangifera indica (wet)	$1.62^{i} \pm 0.06$	$0.41^{h} \pm 0.03$	$0.61^{e} \pm 0.01$	$46.00^{a} \pm 1.41$	0.001 ± 0.000
Mangifera indica (dry)	$0.84^{k} \pm 0.04$	$0.33^{h} \pm 0.03$	$0.49^{f} \pm 0.06$	$33.45^{b} \pm 0.21$	0.000 ± 0.000
Mangifera indica control (wet)	$0.02^{l} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.76^{klmn} \pm 0.08$	0.000 ± 0.000
Mangifera indica control (dry)	$0.02^{l} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.00^{i} \pm 0.00$	$0.74^{lmn} \pm 0.08$	0.000 ± 0.000
Icacina trichantha (wet)	$1.27^{j} \pm 0.08$	$0.80^{g} \pm 0.07$	$0.34^{g} \pm 0.06$	$12.10^{f} \pm 0.14$	$0.001^{de} \pm 0.000$
Icacina trichantha (dry)	$1.13^{j} \pm 0.16$	$0.69^{g} \pm 0.06$	$0.27^{g} \pm 0.03$	$10.96^{g} \pm 0.23$	$0.001^{de} \pm 0.000$
Icacina trichantha control (wet)	$0.01^{l} \pm 0.00$	$0.00^{i} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.08^{lmn} \pm 0.02$	0.000 ± 0.000
Icacina trichantha control (dry)	$0.01^{l} \pm 0.00$	$0.00^{i} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.06^{lmn} \pm .03$	0.000 ± 0.000
Alchornea cordifolia (wet)	$9.02^{a} \pm 0.03$	$3.60^{c} \pm 0.14$	$0.27^{g} \pm 0.08$	$18.04^{d} \pm 0.06$	$0.005^{a} \pm 0.001$
Alchornea cordifolia (dry)	$5.04^{c} \pm 0.07$	$2.82^{de} \pm 0.04$	$0.16^{h} \pm 0.03$	$10.02^{h} \pm 0.03$	0.000 ± 0.000
Alchornea cordifolia control (wet)	$0.02^{l} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.01^{i} \pm 0.00$	$0.90^{kl} \pm 0.09$	0.000 ± 0.000
Alchornea cordifolia control (dry)	$0.02^{l} \pm 0.01$	$0.00^{i} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.87^{klm} \pm 0.08$	0.000 ± 0.000
Andropogon gayanus (wet)	$6.42^{b} \pm 0.17$	$10.37^{a} \pm 0.52$	$0.02^{i} \pm 0.01$	$16.06^{e} \pm 0.08$	0.000 ± 0.000
Andropogon gayanus (dry)	$4.81^{d} \pm 0.04$	$8.96^{b} \pm 0.07$	$0.01^{i} \pm 0.00$	$10.03^{h} \pm 0.04$	$0.003^{bc} \pm 0.001$
Andropogon gayanus control (wet)	$0.01^{l} \pm 0.01$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.39^{lmn} \pm 0.11$	0.000 ± 0.000
Andropogon gayanus control (dry)	$0.00^{l} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.00^{i} \pm 0.00$	$0.38^{lmn} \pm 0.12$	0.000 ± 0.000
Manihot esculenta (wet)	$0.01^{l} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.02^{mn} \pm 0.01$	0.000 ± 0.000
Manihot esculenta (dry)	$0.01^{l} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{n} \pm 0.00$	0.000 ± 0.000
Manihot esculenta control (wet)	$0.02^{l} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.14^{lmn} \pm 0.01$	0.000 ± 0.000
Manihot esculenta control (dry)	$0.02^{l} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.13^{lmn} \pm 0.02$	0.000 ± 0.000

a,b,c,d,e,f,g,h,i,j,k,l,m,n means in a column with different superscript are significantly different (P < 0.05), values are mean ± standard deviation of 3 replications

Table 2: Heavy metal concentration (mg/kg) in plants in wet and dry seasons at Iva mine site

Plants	Ni	Pb	Cd	Fe	As
Irvingia gabonensis (wet)	$0.43^{h} \pm 0.03$	$0.92^{i} \pm 0.03$	$0.74^{f} \pm 0.04$	$231.00^{a} \pm 1.41$	0.000 ± 0.000
Irvingia gabonensis (dry)	$0.35^{h} \pm 0.06$	$0.81^{j} \pm 0.06$	$0.62^{g} \pm 0.03$	$217.00^{b} \pm 1.56$	0.000 ± 0.000
Irvingia gabonensis control (wet)	$0.01^{i} \pm 0.00$	$0.01^{k} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.27^{m} \pm 0.04$	0.000 ± 0.000
Irvingia gabonensis control (dry)	$0.01^{i} \pm 0.01$	$0.01^{k} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.25^{m} \pm 0.04$	0.000 ± 0.000
Dialium guinense (wet)	$2.07^{c} \pm 0.04$	$3.30^{b} \pm 0.14$	$0.62^{g} \pm 0.03$	$80.60^{i} \pm 0.85$	$0.001^{bc} \pm 0.000$
Dialium guinense (dry)	$1.69^{d} \pm 0.08$	$3.11^{c} \pm 0.03$	$0.39^{h} \pm 0.04$	$69.80^{j} \pm 1.13$	0.000 ± 0.000
Dialium guinense control (wet)	$0.01^{i} \pm 0.00$	$0.01^{k} \pm 0.00$	$0.01^{i} \pm 0.01$	$1.31^{m} \pm 0.40$	0.000 ± 0.000
Dialium guinense control (dry)	$0.01^{i} \pm 0.00$	$0.01^{k} \pm 0.01$	$0.00^{i} \pm 0.00$	$1.28^{m} \pm 0.40$	0.000 ± 0.000
Mangifera indica (wet)	$1.31^{e} \pm 0.03$	$3.69^{a} \pm 0.06$	$1.06^{e} \pm 0.08$	$153.50^{c} \pm 0.71$	$0.003^{a} \pm 0.001$
Mangifera indica (dry)	$1.01^{g} \pm 0.03$	$2.87^{d} \pm 0.08$	$1.01^{e} \pm 0.04$	$138.20^{d} \pm 0.42$	$0.001^{bc} \pm 0.000$
Mangifera indica control (wet)	$0.02^{i} \pm 0.01$	$0.01^{k} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.76^{m} \pm 0.08$	0.000 ± 0.000
Mangifera indica control (dry)	$0.02^{i} \pm 0.01$	$0.01^{k} \pm 0.01$	$0.00^{i} \pm 0.00$	$0.74^{m} \pm 0.08$	0.000 ± 0.000
Icacina trichantha (wet)	$4.10^{a} \pm 0.14$	$1.46^{g} \pm 0.01$	$1.38^{c} \pm 0.04$	$128.70^{e} \pm 0.99$	$0.002^{b} \pm 0.001$
Icacina trichantha (dry)	$3.48^{b} \pm 0.13$	$1.03^{h} \pm 0.06$	$1.19^{d} \pm 0.13$	$103.10^{g} \pm 0.42$	$0.001^{bc} \pm 0.000$
Icacina trichantha control (wet)	$0.01^{i} \pm 0.00$	$0.00^{k} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.08^{m} \pm 0.02$	0.000 ± 0.000
Icacina trichantha control (dry)	$0.01^{i} \pm 0.00$	$0.00^{k} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.06^{m} \pm .03$	0.000 ± 0.000
Alchornea cordifolia (wet)	$1.37^{e} \pm 0.08$	$2.73^{e} \pm 0.03$	$2.16^{a} \pm 0.07$	$108.20^{f} \pm 0.28$	$0.001^{bc} \pm 0.000$
Alchornea cordifolia (dry)	$1.13^{f} \pm 0.16$	$2.03^{f} \pm 0.04$	$1.90^{b} \pm 0.03$	$83.80^{h} \pm 1.27$	0.000 ± 0.000
Alchornea cordifolia control (wet)	$0.02^{i} \pm 0.00$	$0.01^{k} \pm 0.01$	$0.01^{i} \pm 0.00$	$0.90^{m} \pm 0.09$	0.000 ± 0.000
Alchornea cordifolia control (dry)	$0.02^{i} \pm 0.01$	$0.00^{k} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.87^{m} \pm 0.08$	0.000 ± 0.000
Andropogon gayanus (wet)	$0.10^{i} \pm 0.01$	$0.06^{k} \pm 0.01$	$0.06^{i} \pm 0.01$	$68.00^{k} \pm 0.71$	$0.001^{bc} \pm 0.001$
Andropogon gayanus (dry)	$0.07^{i} \pm 0.03$	$0.05^{k} \pm 0.01$	$0.05^{i} \pm 0.01$	$59.70^{l} \pm 1.27$	$0.001^{bc} \pm 0.000$
Andropogon gayanus control (wet)	$0.01^{i} \pm 0.01$	$0.01^{k} \pm 0.00$	$0.01^{i} \pm 0.01$	$0.39^{m} \pm 0.11$	0.000 ± 0.000
Andropogon gayanus control (dry)	$0.00^{i} \pm 0.00$	$0.01^{k} \pm 0.01$	$0.00^{i} \pm 0.00$	$0.38^{m} \pm 0.12$	0.000 ± 0.000
Manihot esculenta (wet)	$0.01^{i} \pm 0.00$	$0.01^{k} \pm 0.00$	0.01 ± 0.00	$0.02^{m} \pm 0.01$	0.000 ± 0.000
Manihot esculenta (dry)	$0.01^{i} \pm 0.00$	$0.01^{k} \pm 0.00$	$0.01^{i} \pm 0.00$	$0.01^{m} \pm 0.00$	0.000 ± 0.000
Manihot esculenta control (wet)	$0.02^{i} \pm 0.01$	$0.01^{k} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.14^{m} \pm 0.01$	0.000 ± 0.000
Manihot esculenta control (dry)	$0.02^{i} \pm 0.01$	$0.01^{k} \pm 0.01$	$0.01^{i} \pm 0.01$	$0.13^{m} \pm 0.02$	0.000 ± 0.000

a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t, means in a column with different superscript are significantly different (P<0.05), values are mean ± standard deviation of 3 replications

The high concentration of heavy metals in plant species sampled from the mined sites may be attributed to pollutants generated during mining activities. Mining activities such as mineral excavation, ore transportation, smelting and refining, and disposal of tailings and waste waters around mines are important sources of heavy metals build up in plants and phytotoxicity in the environment (Dudka and Adriano, 1997; Pruvot *et al*., 2006; Perez-Sirvent *et al*., 2008; Ogbonna *et al*., 2018a). Since there was no other visible sources of contamination around the study area, the high concentrations of heavy metals in soil (Tables 3 and 4) at the two mined sites are implicated for the higher metal concentrations in plants. Several studies in China, South Korea, and the United States of America have shown that plants are often contaminated by heavy metals dispersed from mining and smelting operations (Chang *et al*., 2005; Yang *et al*., 2006; Zheng *et al*., 2007).

On a comparative basis of plants investigated in this study, the concentration of Ni, As, and Cd was highest in *A. cordifolia*. The high concentration of these metals (Ni, As, and Cd) in *A. cordifolia* may be attributed to inherent ability of the plant (*A. cordifolia*) to absorb and translocate more Ni, As, and Cd to the aerial plant parts (leaves) than other plants. Some plants can tolerate high heavy metals concentration from soil (McGrath *et al*., 2001) by binding metals to cell walls, compartmentalizing them in vacuoles or complexing them to certain organic acids or proteins (Reeves and Baker, 2000). Similarly, heavy metals in soils exist in variable forms, such as exchangeable or absorbed forms, which influence their mobility and bioavailability for uptake by plants and transfer to the aerial parts of plants (Ogbonna *et al*., 2012). Indeed, the concentration of Pb was highest (10.37 ± 0.52 mg/kg) in *A. gayanus* while Fe concentration was highest (231.00 ± 1.41 mg/kg) in *I. gabonensis*. Plant species differ in their ability to take up, accumulate and tolerate heavy metals and this variation occurs not only among plant species but also within a given species (Raskin *et al*., 1997; Angelova *et al*., 2004). Since Pb concentration in soils was higher at Iva mine, the higher concentration of Pb in *A. gayanus* at Akwuke mine may be attributed to inherent ability of the plant to take up Pb from the soil and translocate more to the leaves than other plants at the mined sites. The rate of metal movement in plant tissues varies depending on plant organ, age and element involved (Kabata-Pendias, 2000).

Table 3: Heavy metal concentration (mg/kg) in soil at Iva mine in wet and dry season

Location	Depth	Season	Ni	Pb	As	Fe	Cd
Crest	0-10cm	Wet	$28.01^{g} \pm 0.03$	$55.70^{d} \pm 1.13$	0.00 ± 0.00	$377.30^{j} \pm 3.82$	$5.02^{a} \pm 0.11$
		Dry	$20.05^{i} \pm 0.21$	$48.25^{e} \pm 0.21$	0.00 ± 0.00	$353.00^{k} \pm 1.27$	$0.11^{kl} \pm 0.03$
	10-20cm	Wet	$15.25^{j} \pm 0.42$	$45.30^{f} \pm 0.57$	0.00 ± 0.00	$387.50^{i} \pm 3.54$	$2.87^{c} \pm 0.13$
		Dry	$10.05^{k} \pm 0.78$	$22.05^{m} \pm 0.35$	0.00 ± 0.00	$238.60^{n} \pm 0.28$	$0.07^{kl} \pm 0.03$
	20-30cm	Wet	$10.00^{k} \pm 0.57$	$38.10^{h} \pm 0.28$	0.00 ± 0.00	$402.80^{fg} \pm 2.55$	$1.01^{g} \pm 0.13$
		Dry	$6.10^{l} \pm 0.42$	$29.40^{j} \pm 0.85$	0.00 ± 0.00	$218.00^{o} \pm 2.83$	$0.48^{ij} \pm 0.13$
Middle slope	0-10cm	Wet	$46.45^{d} \pm 0.16$	$37.50^{hi} \pm 0.28$	0.00 ± 0.00	$410.30^{e} \pm 2.40$	$0.49^{ij} \pm 0.08$
		Dry	$21.05^{i} \pm 1.34$	$30.01^{j} \pm 1.40$	0.00 ± 0.00	$238.60^{n} \pm 1.56$	$0.19^{k} \pm 0.01$
	10-20cm	Wet	$64.12^{b} \pm 0.35$	$65.04^{c} \pm 0.34$	0.00 ± 0.00	$467.80^{c} \pm 3.11$	$1.64^{e} \pm 0.07$
		Dry	$40.06^{e} \pm 1.33$	$43.60^{g} \pm 1.56$	0.00 ± 0.00	$392.70^{hi} \pm 3.82$	$0.04^{kl} \pm 0.03$
	20-30cm	Wet	$79.00^{a} \pm 0.57$	$81.60^{a} \pm 0.57$	0.00 ± 0.00	$498.20^{a} \pm 2.55$	$1.86^{d} \pm 0.23$
		Dry	$52.30^{c} \pm 0.57$	$69.70^{b} \pm 2.40$	0.00 ± 0.00	$408.00^{ef} \pm 2.83$	$1.17^{f} \pm 0.04$
Valley	0-10cm	Wet	$15.20^{j} \pm 0.57$	$36.65^{hi} \pm 0.35$	0.00 ± 0.00	$328.50^{l} \pm 2.12$	$3.08^{b} \pm 0.03$
		Dry	$10.06^{k} \pm 0.65$	$23.85^{l} \pm 0.21$	0.00 ± 0.00	$397.70^{gh} \pm 0.42$	$0.01^{kl} \pm 0.01$
	10-20cm	Wet	$23.50^{h} \pm 0.37$	$35.90^{i} \pm 0.85$	0.00 ± 0.00	$454.70^{d} \pm 0.42$	$0.74^{h} \pm 0.07$
		Dry	$10.05^{k} \pm 0.49$	$27.01^{k} \pm 0.01$	0.00 ± 0.00	$273.70^{m} \pm 0.42$	$0.08^{kl} \pm 0.03$
	20-30cm	Wet	$31.07^{f} \pm 0.38$	$26.10^{k} \pm 0.28$	0.00 ± 0.00	$490.00^{b} \pm 5.66$	$0.61^{hi} \pm 0.04$
		Dry	$23.13^{h} \pm 0.33$	$19.60^{n} \pm 0.28$	0.00 ± 0.00	$381.40^{j} \pm 1.98$	$0.41^{j} \pm 0.07$
Control	0-10cm	Wet	$0.02^{m} \pm 0.01$	$1.48^{o} \pm 0.12$	0.00 ± 0.00	$70.60^{r} \pm 0.57$	$0.01^{kl} \pm 0.00$
		Dry	$0.02^{m} \pm 0.01$	$0.72^{o} \pm 0.04$	0.00 ± 0.00	$43.00^{t} \pm 0.57$	$0.00^{l} \pm 0.00$
	10-20cm	Wet	$0.01^{m} \pm 0.00$	$1.01^{o} \pm 0.16$	0.00 ± 0.00	$82.00^{q} \pm 0.71$	$0.00^{l} \pm 0.00$
		Dry	$0.00^{m} \pm 0.00$	$0.40^{o} \pm 0.06$	0.00 ± 0.00	$38.50^{t} \pm 0.85$	$0.00^{l} \pm 0.00$
	20-30cm	Wet	$0.01^{m} \pm 0.01$	$0.26^{o} \pm 0.10$	0.00 ± 0.00	$101.00^{p} \pm 1.41$	$0.00^{l} \pm 0.00$
		Dry	$0.00^{m} \pm 0.00$	$0.22^{o} \pm 0.08$	0.00 ± 0.00	$62.00^{s} \pm 4.24$	$0.00^{l} \pm 0.00$

Source: Ogbonna et al. (2018a)

Table 4: Heavy metal concentration (mg/kg) in soil at Akwuke mine site in wet and dry season

Location	Depth (cm)	Season	Ni	Pb	As	Fe	Cd
Crest	0-10	Rainy	$9.71^{efg} \pm 0.16$	$15.45^{bc} \pm 0.18$	0.00 ± 0.00	$417.00^{f} \pm 1.98$	$1.73^{c} \pm 0.06$
		Dry	$4.15^{k} \pm 0.07$	$12.65^{cd} \pm 0.13$	0.00 ± 0.00	$296.10^{k} \pm 8.63$	$0.68^{de} \pm 0.07$
	10-20	Rainy	$11.72^{d} \pm 0.07$	$15.80^{bc} \pm 0.28$	0.00 ± 0.00	$480.70^{c} \pm 2.40$	$0.72^{d} \pm 0.17$
		Dry	$10.04^{ef} \pm 0.20$	$10.45^{de} \pm 0.07$	0.00 ± 0.00	$290.00^{k} \pm 4.95$	$0.07^{gh} \pm 0.03$
	20-30	Rainy	$14.30^{c} \pm 0.71$	$17.62^{b} \pm 0.08$	0.00 ± 0.00	$522.00^{a} \pm 1.98$	$0.61^{de} \pm 0.13$
		Dry	$8.24^{hi} \pm 0.20$	$13.60^{cd} \pm 0.28$	0.00 ± 0.00	$216.40^{n} \pm 1.27$	$0.38^{f} \pm 0.03$
Middle slope	0-10	Rainy	$10.45^{e} \pm 0.27$	$15.10^{bc} \pm 0.28$	0.00 ± 0.00	$428.10^{e} \pm 0.85$	$2.92^{b} \pm 0.03$
		Dry	$6.04^{j} \pm 0.06$	$10.41^{de} \pm 0.11$	0.00 ± 0.00	$362.20^{i} \pm 4.53$	$0.10^{gh} \pm 0.04$
	10-20	Rainy	$11.65^{d} \pm 0.11$	$12.60^{cd} \pm 0.35$	0.00 ± 0.00	$458.00^{d} \pm 2.12$	$0.17^{g} \pm 0.06$
		Dry	$8.04^{i} \pm 0.20$	$8.21^{ef} \pm 0.44$	0.00 ± 0.00	$267.60^{l} \pm 1.56$	$0.01^{h} \pm 0.01$
	20-30	Rainy	$12.02^{d} \pm 0.48$	$10.30^{de} \pm 0.57$	0.00 ± 0.00	$506.70^{b} \pm 0.42$	$0.08^{gh} \pm 0.01$
		Dry	$9.20^{fgh} \pm 0.42$	$6.11^{f} \pm 0.13$	0.00 ± 0.00	$314.00^{j} \pm 1.56$	$0.02^{h} \pm 0.01$
Valley	0-10	Rainy	$8.85^{ghi} \pm 0.35$	$15.26^{bc} \pm 6.87$	0.00 ± 0.00	$397.80^{g} \pm 11.03$	$3.06^{a} \pm 0.08$
		Dry	$6.07^{j} \pm 0.10$	$17.50^{b} \pm 0.42$	0.00 ± 0.00	$389.80^{h} \pm 0.28$	$0.08^{gh} \pm 0.03$
	10-20	Rainy	$16.03^{b} \pm 0.21$	$21.10^{a} \pm 0.85$	0.00 ± 0.00	$258.70^{m} \pm 0.42$	$0.57^{e} \pm 0.10$
		Dry	$10.04^{ef} \pm 1.47$	$15.65^{bc} \pm 0.35$	0.00 ± 0.00	$207.80^{o} \pm 3.11$	$0.05^{gh} \pm 0.03$
	20-30	Rainy	$19.81^{a} \pm 1.29$	$21.72^{a} \pm 0.69$	0.00 ± 0.00	$203.00^{o} \pm 4.24$	$0.29^{f} \pm 0.01$
		Dry	$12.01^{d} \pm 0.16$	$13.28^{cd} \pm 0.11$	0.00 ± 0.00	$186.00^{p} \pm 2.83$	$0.11^{gh} \pm 0.03$
Control	0-10	Rainy	$0.02^{l} \pm 0.00$	$1.46^{g} \pm 0.23$	0.00 ± 0.00	$70.60^{s} \pm 1.98$	$0.01^{h} \pm 0.00$
		Dry	$0.02^{l} \pm 0.00$	$0.72^{g} \pm 0.04$	0.00 ± 0.00	$43.00^{u} \pm 0.99$	$0.00^{h} \pm 0.00$
	10-20	Rainy	$0.01^{l} \pm 0.00$	$1.01^{g} \pm 0.16$	0.00 ± 0.00	$82.00^{r} \pm 2.83$	$0.00^{h} \pm 0.00$
		Dry	$0.00^{l} \pm 0.00$	$0.40^{g} \pm 0.04$	0.00 ± 0.00	$38.50^{u} \pm 0.99$	$0.00^{h} \pm 0.00$
	20-30	Rainy	$0.01^{l} \pm 0.01$	$0.26^{g} \pm 0.04$	0.00 ± 0.00	$101.00^{q} \pm 4.24$	$0.00^{h} \pm 0.00$
		Dry	$0.00^{l} \pm 0.00$	$0.22^{g} \pm 0.14$	0.00 ± 0.00	$62.20^{t} \pm 1.41$	$0.00^{h} \pm 0.00$

Source: Ogbonna et al. (2018c)

Khan *et al*. (2008) reported that lead causes both acute and chronic poisoning and thus, poses adverse effects on kidney, liver, vascular and immune system. Among the entire metallic element investigated in plants at the two mined sites, Fe (a trace metal) recorded the highest metal concentration in plants in *Irvingia gabonensis* (231.00 ± 1.41 mg/kg) in wet season at Iva mine (Table 2). The high concentration of Fe in soil (522.00 ± 1.98 mg/kg) at Akwuke mine (Table 3) did not culminate to high Fe concentration in plants at Akwuke mine. Consequently, heavy metal uptake via the roots from contaminated soil and direct deposition of metals from tailing dust onto plant surfaces (leaves) may have accounted for the high concentration of Fe in *I. gabonensis* at Iva mine. Iron is essential for the synthesis of chlorophyll and activates a number of respiratory enzymes in plants but its (Fe) deficiency results in severe chlorosis of leaves in plants (Pam *et al*., 2014). High levels of exposure to Fe dust may cause respiratory diseases such as chronic bronchitis and ventilation difficulties. Meanwhile, arsenic had the lowest heavy metal concentration in plant, which can be associated with its (As) level in soil.

In comparing the concentration of heavy metals in soil with the concentration in plants, the results indicate that the concentration of metals were higher in soil than in plants. The highest concentration of Ni, Pb, Fe, and Cd in soils (Tables 3 and 4) at the mined sites were significantly ($P < 0.05$) higher than their highest corresponding values in plants (Tables 1 and 2) in this study. Thus, the concentration of Fe (522.00 ± 1.98 mg/kg), Ni (79.00 ± 0.57 mg/kg), Pb (81.60 ± 0.57 mg/kg), and Cd (5.02 ± 0.11 mg/kg) in soil were 2.3, 8.8, 7.9, and 2.3 times higher than their corresponding values in plant species, respectively. In contrast, As had higher concentration in plant than in soil. The highest concentration of As (0.005 mg/kg) in plants was 0.005 times higher than its corresponding value in soil. Consequently, the soil is implicated for the concentration of Ni, Pb, Fe, and Cd in plants while aerial deposition may be responsible for the higher concentration of As in plants.

The concentrations of all metals in the plants were raised to different degrees in wet and dry season at the study sites. In this study, the concentrations of metals in plants were significantly ($P < 0.05$) higher in wet season than in dry season at the 2 mined (Akwuke and Iva) sites. At the site at Akwuke mine, the concentration of Ni (9.02 ± 0.03 mg/kg) and As (0.005 ± 0.00 mg/kg) observed in *A. cordifolia*, Pb (10.37 ± 0.32 mg/kg) in *A. gayanus*, Cd (2.02 ± 0.03 mg/kg) in *D. guinense*, and Fe (46.00 ± 1.41 mg/kg) in *M. indica* in wet season were significantly ($P < 0.05$) higher than their corresponding values (5.04 ± 0.07, 8.96 ± 0.01 and 0.003 ± 0.001 mg/kg, 1.87 ± 0.07 mg/kg, and 33.45 ± 0.21 mg/kg) in dry season and the concentrations of Ni, Pb, Cd, Fe, and As in wet season at the site in Akwuke mine were 1.8, 1.2, 1.1, 1.4, and 1.7 times higher than their corresponding values in dry season, respectively. At the site of Iva mine, the concentration of Ni (4.10 ± 0.14 mg/kg) in *I. trichantha*, Pb (3.69 ± 0.06 mg/kg) in *M. indica*, Cd (2.16 ± 0.07 mg/kg) in *A. cordifolia*, Fe (231 ±

1.41 mg/kg) in *I. gabonensis*, and As (0.003±0.001 mg/kg) in *M. indica* in wet season were significantly ($P < 0.05$) higher than their corresponding values (3.48 ± 0.13, 3.11 ± 0.08, 1.90 ± 0.03, 217.00 ± 1.56, and 0.001 ± 0.000 mg/kg) in dry season and the concentrations of Ni, Pb, Cd, Fe, and As in wet season at the site in Iva mine was 1.2, 1.2, 1.1, 1.1, and 3 times higher than their corresponding values in dry season, respectively.

Different metals and different plant species show different patterns of seasonal growth and metal accumulation (Pokethitiyook *et al*., 2008). For instance, shoots of *Spartina alteriflora* accumulated Mn, Cu, and Zn rapidly in the spring, and then the levels decreased (Gleason *et al*., 1979). The decrease was attributed to a growth-dilution effect due to growth increase, whereby changes in the amount of plant biomass bring about corresponding changes in plant metal content (Deram *et al*., 2006). Nickel in plants ranged from 0.01 ± 0.00-9.02 ± 0.03 mg/kg, which is higher than 0.02-5 mg/kg (Alloway and Ayres, 1997). Classic symptoms of Ni toxicity include interveinal chlorosis and development of perpendicular white strips on the above ground biomass (Hunter and Vergnano, 1952; Singh *et al*., 2010). Lead (Pb) in plants ranged from 0.01 ± 0.00-10.37 ± 0.52 mg/kg, which is lower than 0.3-16.6 mg/kg of Pb observed in soybean leaves, red peppers and rice stalks and leaves at the Daduk Au-Ag-Pb-Zn mine, Korea (Lee *et al*., 2001), 2.90-89.00 mg/kg observed in *Pergularia tomentosa, Calotropis procera, Acacia tortilis, Ochradenus baccatus, Salsola sp., Rhiza strica, Convolvulus sp., Euculeprus sp*., Family graminaea, and *Prosopis juliflora* in Mahad AD'Dahab mine, Saudi Arabia (Al-Farraj and Al-Wabel, 2007), 56.00-160 mg/kg observed in *Salsola kali, Andropogon barbinodis, Aster tanacetifolius, Baphia absinthifolia, Asphodelus sp., Solanum elaeagnifolium*, and *Dyssodia papposa* in Zacatecas mine, Mexico (González and González-Chávez, 2006), 33.00 ± 28.00-8967 ± 6181 mg/kg of Pb observed in *Alchornea conyzoides, Buddleja asiatica, Conyza sumatrensis, Equisetum debile, Imperata cylindica, Mimosa pudica, Neyraudia reynaudiana, Paspalum conjugatum, Phragmites karka, Sonchus arvensis, Thysanolaena maxima and Vigna umbellate* at Bo Ngam lead mine, Thailand (Pokethitiyook *et al*., 2008) and 3.4-920 mg/kg of Pb in different wetland plant species collected from mine tailings (Stoltz and Greger, 2002). Lead is a non-essential element in metabolic processes (Alloway, 1995) and may become toxic to ecological systems, even at trace levels (Borg and Johansson, 1989; Ogbonna and Okeke, 2011). It (Pb) produced a phytotoxic impact resembling necrosis, stunted growth of roots and shoots, chlorosis, and decreased biomass production in *Vetiveria zizanoides* and *Nicotiana tabacum* (Boonyapookana *et al*., 2005). In man, Pb poisoning causes inhibition of synthesis of haemoglobin; cardiovascular system and acute and chronic damage to the central nervous system and peripheral nervous system (Ogwuegbu and Muhanga, 2005), poor development of grey matter in the brain of children, resulting in poor intelligent quotient (Udedi, 2003).

Lead (Pb) and nickel (Ni) concentration in *Andropogon gayanus* (10.37 ± 0.52 mg/kg) and *Alchornea cordifolia* (9.02 ± 0.03 mg/kg) is well above the permissible limit (PL) of 0.30 mg/kg of Pb and 1.63 mg/kg of Ni for plants established by Codex Alimentarius Commission FAO/WHO (2007), shown in Table 5. The leaves of *A. gayanus* and *A. cordifolia* are very important forage material for West African Dwarf (WAD) goats in south-eastern Nigeria (Ogbonna *et al*., 2012). Thus, such Pb and Ni concentrations in plant aerial parts might be detrimental for the local herbivorous fauna, which could be unable to detect the presence of toxic metals in plant tissues as shown for snails (Noret *et al*., 2007). The concentration of Cd in plants ranged from 0.01 ± 0.00-2.16 ± 0.07 mg/kg, which is lower than 0.11-5.85 mg/kg of Cd observed in soybean leaves, red peppers and rice stalks and leaves at the Daduk Au-Ag-Pb-Zn mine, Korea (Lee *et al*., 2001), 8.70-12.70 mg/kg observed in *Pergularia tomentosa, Calotropis procera, Acacia tortilis, Ochradenus baccatus, Salsola sp., Rhiza strica, Convolvulus sp., Euculeprus sp*., Family graminaea, and *Prosopis juliflora* in Mahad AD'Dahab mine, Saudi Arabia (Al-Farraj and Al-Wabel, 2007) and 2.00-10.00 mg/kg observed in *Salsola kali, Andropogon barbinodis, Aster tanacetifolius, Baphia absinthifolia, Asphodelus sp., Solanum elaeagnifolium*, and *Dyssodia papposa* in Zacatecas mine, Mexico (González and González-Chávez, 2006).

Cadmium is a non-essential element for plant metabolism and disturbs symbiosis between microbes and plants, and predisposes plants to fungal invasion (Kabata-Pendias and Pendias, 2001). It (Cd) has no known bio-importance in human biochemistry and physiology and consumption even at very low concentrations can be toxic (Nolan, 2003; Young, 2005) and long term exposure results in renal

dysfunction, characterized by tubular proteinuria (Duruibe *et al*., 2007) in humans. Thus, Cd is highly zootoxic and is a common contaminant in the environment (Pulford and Watson, 2003). The concentration of heavy metals especially Cd in *Alchornea cordifolia* (2.16 ± 0.07 mg/kg) and *Dialium guinense* (2.02 ± 0.03 mg/kg) is well above the permissible limit (PL) of 0.2 mg/kg (Cd) in plants established by Codex Alimentarius Commission FAO/WHO (2007) and this may constitute serious health risk to inhabitants of the mined areas.

Table 5: Comparison of values obtained in this study with permissible limits by FAO/WHO and FEPA

Heavy Metal	Concentration of plants in sample site (mg/kg)	FAO/WHO permissible limits for heavy metals in plants (mg/kg)	FEPA guidelines for heavy metals in plants (mg/kg) (Threshold values)	Concentration of soil in sample site (mg/kg)	FAO/WHO permissible limits for heavy metals in soil (mg/kg)	FEPA guidelines for heavy metals in soils (mg/kg) (Threshold values) FEPA 1991
Pb	0.01±0.00-10.37±0.52	0.3[b]	NA	6.11±0.13-81.60±0.57	50[b]	1.6
Cd	0.01±0.00-2.16±0.07	0.2[a]	NA	0.01±0.00-5.02±0.11	3[b]	0.01
Ni	0.01±0.00-9.02±0.03	1.63[b]	NA	4.15±0.07-79.00±0.57	50[b]	0.1
Fe	0.01±0.00-231.0±1.41	425[b]	NA	186.00±2.83-522.00±1.98	NA	400
As	0.001±0.000-0.005±0.001	0.2[c]	NA	0.000±0.000-0.003±0.000	20[b]	NA

[a]FAO/WHO (Codex Alimentarius Commission, Joint FAO/WHO, 2007), [b]FAO/WHO (Codex Alimentarius Commission, Joint FAO/WHO, 2001), [c]FAO/WHO (Codex Alimentarius Commission, 1991), FEPA 1991, NA = Not available

Therapeutic use of *D. guinense* leaves (from the mined sites) on a regular basis for treatment of malaria and similar ailment in the study area will result to Cd poisoning. The fruit of *D. guinense* is highly consumed in south-eastern Nigeria as a veritable source of vitamin and mineral (Ogbonna *et al*., 2011). Consequently, households or individuals that have been consuming fruit of *D. guinense* from the study area may have predisposed themselves to serious health hazard. Heavy metals contamination has great significance due to their tendency to accumulate in human organs over a period of time and its presence beyond the allowed upper and lower limits can cause metabolic disturbance. The environmental impact of heavy metals, as well as their health effects has been the source of major concern (Hussain and Khan, 2010). Iron concentration in plants ranged from 0.01 ± 0.00-231.0 ± 1.41 mg/kg, which is higher than 153.2-170 mg/kg (Ebong *et al*., 2008) in a related study while the concentration of As in plants ranged from 0.001 ± 0.000-0.005 ± 0.001 mg/kg. The concentrations of As in plants was low and this may be attributed to its concentrations in soil at Akwuke mine (Table 3) and Iva mine (Table 4) sites. This suggests that As in soil was not in the forms (soil solution) that are readily available and absorbable by plants via the roots (Ogbonna *et al*., 2011). Notwithstanding this, in order to resist the damaging effect of heavy metal in soil, plants adopt different strategies which vary according to the plant genotype (Foy *et al*., 1978; Di Salvatore *et al*., 2009). Some of the most effective regulation mechanisms are exclusive, reduce transfer to the shoot of metals adsorbed at the cell walls of the root, chelation and compartmentation of the metals in the vacuole through the production of organic acids and formation of metal binding polypeptides known as phytochelatins (Hall, 2002).

Generally, the highest concentration of heavy metals accumulated in wet season were significantly ($P < 0.05$) higher than their corresponding values in dry season. Indeed, while several studies showed seasonal changes in heavy metal content in plants, others found no seasonal changes in metals (Gleason *et al*., 1979; Larsen and Schierup, 1981; Cacador *et al*., 2000; Weis *et al*., 2003). Consequently, it is very difficult to generalize about seasonal changes in heavy metal levels, since they appear to vary greatly with the heavy metal and species of plants studied (Weis and Weis, 2004).

4.0 Conclusion

This study indicated that the levels of heavy metals accumulated in the plant species were higher in wet season than in dry season. Plant samples from the coal mine sites recorded significant levels of heavy metals but the concentration of Ni, Pb and Cd accumulated in *A. cordifolia* and *A. gayanus* was

higher than the permissible limits established by the Codex Alimentarius Commission FAO/WHO safe limit. Further studies should be carried out to ascertain other heavy metals present at the mined sites.

Acknowledgement

We thank Mrs. I.L. Princewill-Ogbonna for the encouragement and support she provided during the field visit and sample collection at the Akwuke and Iva coal mine sites.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 208 - 218

The Potentials of Iron and Steel Slags as Supplementary Cementitious Materials in the Nigerian Construction Industry: A Review

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ABSTRACT

Ground Granulated Blast Furnace Slag (GGBS) is a type of Supplementary Cementitious Material (SCM) that is currently being used extensively in the global construction industry. SCMs are cheaper than Portland cement, help to improve certain properties of concrete and also help to reduce the environmental footprint associated with the production of Portland cement. GGBS is readily available in most parts of the world as a waste product from iron and steel production. However, its use as a SCM in some countries has not been fully maximized. This is primarily because of lack of documented studies on the properties of GGBS that influences its suitability as a SCM, especially in tropical environments. This paper reviewed the use of GGBS as a SCM for the partial replacement of Portland cement, with particular emphasis on its potential use in tropical warm environments such as Nigeria and other similar countries.

Keywords: GGBS, Tropical environment, SCM, Slag hydraulicity, Slag blends

1.0. Introduction

Slag is the by-product obtained from the production of iron and steel. In the production of iron, the iron oxide ore is reduced to metallic iron by means of a flux (limestone or dolomite) at temperatures of about 1400 to 1500°C. During the heating process, the impurities in the iron ore comprising mainly of silica and alumina, combine with lime and magnesia to form a molten slag which is collected separately from the molten iron via the bottom of the blast furnace (Siddique and Bennacer, 2012).
Currently, there is no reliable data regarding the global production of slag. However, in a report by Van Oss (2016), the global iron slag output in 2015 was estimated to be in the range of 300 to 360 million metric tons, while that of steel slag was about 170 to 250 million tons. These figures were obtained based on typical ratios of slag to crude iron and steel output. According to Van Oss (2002), a steel furnace will generate about 0.2 metric ton of steel slag per ton of crude steel. However, about half of this steel slag will be comprised of entrained metal, which is usually removed and put back in the steel furnace, thus reducing the amount of steel slag produced to about 0.1 metric ton per ton of crude steel.

Ohimain (2013) reported that the Nigerian steel sector was being upheld by the recycling of scrap steel obtained from municipal solid wastes and that this resulted in the production of 7 – 15% slag for low and high carbon steel respectively. In another report by Akinwumi (2012), it was estimated that about 3.5 to 4.5 million metric tonnes of steel was being produced per annum by the steel plants in Ajaokuta, Delta, Jos, Katsina and Osogbo. This implies that approximately 0.35 to 0.45 million metric tons of steel slag is produced per annum in Nigeria.

Currently, the rate of utilization of slags in Nigeria is very low and as a result, there is increase in the volume of slag piles at dump sites and landfills (Ohimain, 2013). Despite the numerous range of

applications for which slags can be used, only very few studies have reported the use of slags in Nigeria and in most of these studies slag was not used as a partial replacement material for Portland cement, but as a stabilization agent for problematic soils as seen in the study by Akinwumi (2012). Similar low utilization had been reported in the past on a global scale, as shown in Figure 1. However, some developed countries seem to be experiencing shortage of slag supply, given recent evidence in the literature (Miller, 2018). Akinwumi (2012) observed that steel slag can be utilized in the stabilization of lateritic soils at proportions up to 8%, while Olonade *et al.* (2015) reported that up to 50% replacement of fine aggregates by steel slag resulted in an increase in the compressive strength of concrete. This is below the range of GGBS replacement levels reported by (Oner and Akyuz, 2007) for achieving optimal compressive strengths.

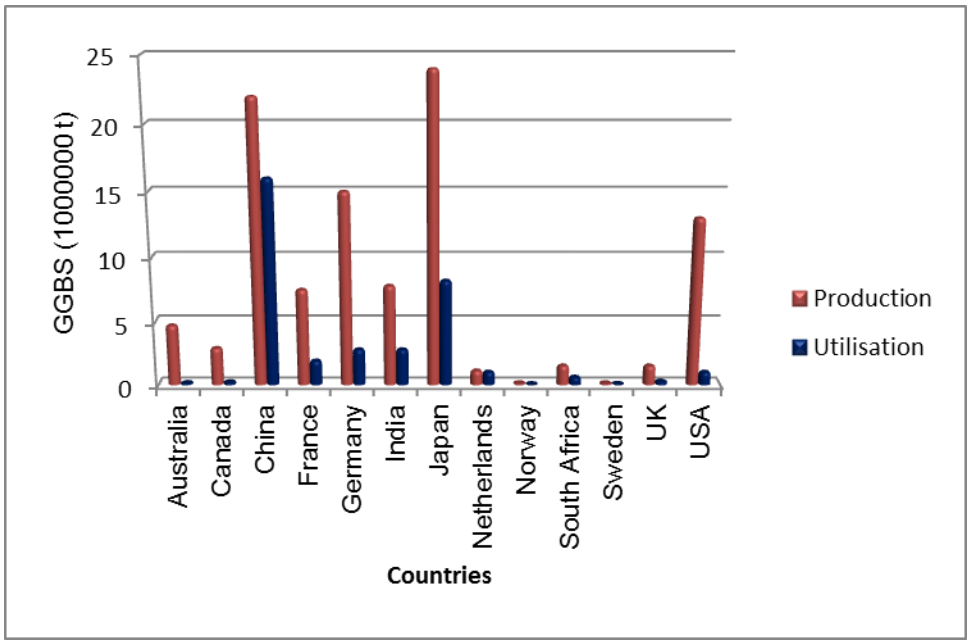

Figure 1: Production and utilization of GGBS by different countries [Adapted from (Moranville-Regourd, 2003)]

Slags ground to finer particle sizes, otherwise known as Ground Granulated Blast Furnace Slag (GGBS), has been shown to possess cementitious properties and can be used as a Supplementary Cementitious Material (SCM) in combination with Portland cement (PC) at various proportions ranging from as low as 6% to as high as 95% (EN197-1: 2011). GGBS is latently hydraulic (Shi *et al.*, 2012) and reacts with water at a much slower rate as compared to PC (ACI-233R-03: 2003). Amongst the common SCMs, only GGBS has the hydraulic cementing nature similar to Portland cement (Hossain, 2006). The ease with which GGBS reacts with water, otherwise known as hydraulicity, has been found to be dependent on various factors. This paper takes a critical look at some of these factors and how they influence the performance of slag blended cements, relating it to suitability of application in tropical environments like Nigeria.

2.0. Properties of GGBS that influences its performance as a SCM

2.1. Physical properties of GGBS

2.1.1. Particle fineness

The fineness of GGBS is a very important parameter that influences its hydraulicity, and often times, recommendations are given in Standards as to what should be the minimum value. For example, EN15167-1: 2006 recommends that the specific surface area of GGBS should not be less than 275 m^2/kg. According to Swamy (1998), an increase in fineness of GGBS to two or three times that of PC, will lead to enormous improvement in a variety of engineering properties such as bleeding, setting time, heat evolution, strength and durability. In the study by Gao *et al.* (2005), the hydration characteristics of two slag blends with the same chemical composition but different degrees of fineness, were investigated using XRD and SEM. The slags had specific surface areas of 425 and 600

m^2/kg respectively and were used to replace PC at 40%. They observed a higher degree of slag hydration for the finer slag, and concluded that slag hydration was a function of the specific surface area of the slag.

Moranville-Regourd (2003) reported that for PC - slag blends containing between 50 – 60% of slag, the early strength was influenced mainly by the clinker fineness and the later age strength by the slag fineness; whereas for blends containing higher slag proportion, the fineness of the slag had major influence on strength at all ages. Table 1 shows a typical example of how concrete's strength can be influenced by slag's fineness for a 30:70 PC:GGBS blend. From the table, it can be clearly seen that the higher the specific surface area of the slag, the more reactive it will be.

Table 1: Influence of slag fineness on strength of concrete (Moranville-Regourd, 2003)

Blaine fineness (cm^2/g)	Compressive strength (MPa)				
	1 day	3 days	7 days	28 days	90 days
3095	0.72	2.48	5.90	16.96	27.23
3930	0.88	2.88	8.41	21.79	32.34
4850	1.05	3.60	10.58	24.82	36.34
6140	1.19	4.87	12.48	27.06	39.09

PC:GGBS = 30:70, Gravel concrete (1:2:4 by vol), w/b = 0.55, water cured

2.1.2. Particle size distribution

Properties such as fluidity and compressive strength can be influenced by the particle size distribution of GGBS. In a study by Wan *et al.* (2004), a particular type of GGBS was ground to the same degree of fineness using three different techniques – ball mill (with steel balls as the grinding medium), laboratory vibromill, and an industrial airflow mill. They observed that the samples ground by the ball mill had the widest particle size distribution, followed by those ground by the laboratory vibromill. Fluidity was greater for samples having narrow particle size distribution. In terms of strength properties, mixes made from GGBS samples containing more particles of size < 3 microns, had higher early strengths; while those containing more particles in the size range of 3 to 20 microns had higher later strengths.

2.1.3. Glass content

The glass content of GGBS also has considerable effect on its reactivity, and it is influenced by the rate of quenching of the molten slag. Slags that are cooled rapidly will contain a high amorphous glassy phase and low crystalline phases. The glass fraction is generally considered to be very reactive while the crystalline part is considered to be inert (Mehta, 1989). In a typical XRD pattern of a slag, the glassy part of the slag will appear as a large hump peaking at *d*-values of about 0.3 nm (or 2θ values of about 30° as shown in Figure 2); while the crystalline fraction comprising mainly of melilite, merwinite, calcite and quartz, will appear as little peaks around the large hump (Smolczyk, 1980; Regourd, 1986). Typical glass content of GGBS vary between 85 and 99% (Siddique and Bennacer, 2012). EN197-1: 2011 specifies that at least two-third of the mass of the slag must be glassy, although research data show that slag samples with as little as 30 – 65% glass contents are still suitable (Pal *et al*., 2003).

The structure of the amorphous glass phase comprise mainly of isolated or polymerized silica tetrahedral with bridging oxygen atoms. These silicates are mostly present as monomers and dimers (Mehta, 1989). Cations such as Ca^{2+} or Mg^{2+}, referred to as network modifiers, are often coordinated in the cavities of the network to neutralize the negative charges resulting from the Si-O-Si covalent bonds. The coordination of calcium atoms are considered as octahedral while that of magnesium atoms as either octahedral or both octahedral and tetrahedral (Regourd, 1986). Aluminium can also be coordinated as a network modifier, in the forms of Al^{3+}, AlO^{+} or AlO_4^{5-} (Smolczyk, 1980; Regourd, 1986). The tetrahedral atoms are the network formers while the octahedral atoms are the network modifiers (Satarin, 1974). Higher number of network modifiers present in the structure will result in a smaller polymerization degree, and higher reactivity of the slag (Smolczyk, 1980).

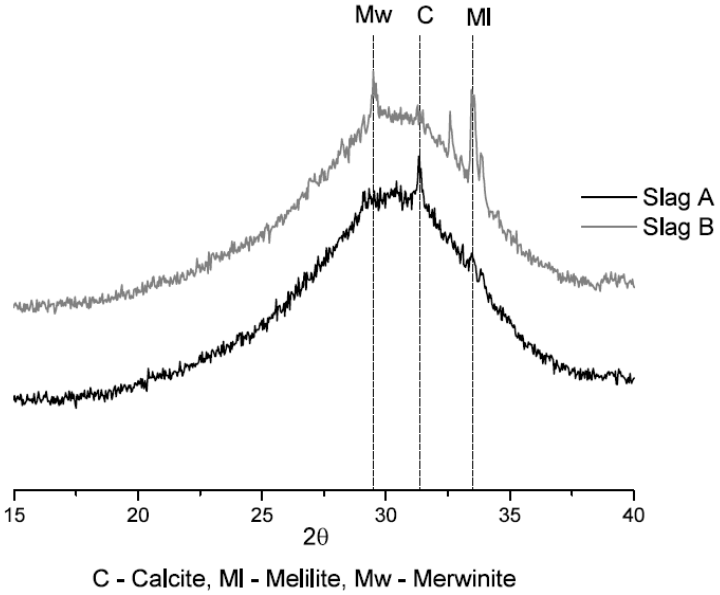

Figure 2: XRD patterns of two slags showing the crystalline phases (Ogirigbo and Black, 2016)

2.2. Chemical properties of GGBS

The chemical composition of slag can vary over a wide range depending on the nature of the ore, the composition of the limestone flux, coke consumption and the type of iron being made. It can also change over the years with alterations in the sources and types of ore being smelted. In general, the lime content may be in the range 30 – 50%, silica 28 – 38%, alumina 8 – 24%, magnesia 1 – 18%, sulphur 1 – 2.5% and ferrous and manganese oxides 1 – 3%. Other minor components are TiO_2, which is usually less than 4%, and $Na_2O + K_2O$, which is less than 2% (Moranville-Regourd, 2003).
The oxides of calcium, magnesium and aluminium are known to increase the hydraulicity of GGBS, while those of silicon and manganese decrease it (Haha *et al.*, 2012). Ratios of some of these oxides have been used by various standards to assess the hydraulicity of a slag. For example, EN197-1: 2011 prescribes that for GGBS, the $(CaO + MgO)/SiO_2$ ratio by mass must exceed 1. Several workers (Smolczyk, 1979; Pal *et al*., 2003), have also suggested other oxide ratios, some of which are shown in Table 2. However, some studies (Mantel, 1994; Bougara *et al*., 2010) have shown that these ratios do not necessarily give accurate prediction of a slag's performance.

Table 2: Formulas proposed for assessment of hydraulicity of GGBS (Ogirigbo, 2016)

	Basicity/hydraulic index	Requirement for good performance	Remarks
P1	CaO/SiO_2	1.3 – 1.4	Mantel (1994) proposed for medium-fine slags of 350 kg/m^2, P1 or P2 must be greater than 1.0
P2	$(CaO + MgO)/SiO_2$	> 1.0	
P3	$(CaO + MgO)/(SiO_2 + Al_2O_3)$	1.0 – 1.3	Here Al_2O_3 is assumed to have a negative influence
P4	$(CaO + MgO + Al_2O_3)/SiO_2$	≥ 1.0	In Japan, must be ≥ 1.4 (Moranville-Regourd, 2003); while in S. Korea, must be ≥ 1.6 (Jeong *et al.*, 2016)
P5	$(CaO + 0.56Al_2O_3 + 1.4MgO)/SiO_2$	≥ 1.65	
P6	Al_2O_3/SiO_2	0.53 – 0.55	

MgO has the same influence as CaO up to about 11% by weight (Moranville-Regourd, 2003). The influence of P_2O_5 depends on the clinker type and test age, but generally has a positive influence beyond 28 days of curing. Oxides of tin and iron, as well as sulphur, seem not to have any effect.
Increasing the Al_2O_3 content to 13% and above will result in an increase in early strength and a decrease in the later strength (Satarin, 1974). Wang *et al.* (2004) observed a positive correlation between the Al_2O_3 content and the reactivity of the slags, for slags having a CaO content greater than 37%. In the studies by (Haha *et al.*, 2011, 2012), it was observed that the reactivity of the slags increased with the magnesia content. As they increased the alumina content, the reactivity of the slags were reduced at early ages, but became similar at later ages beyond 28 days. Perhaps, the reason for

the reduced reactivity observed in the study by (Haha *et al.*, 2012), may be due to the CaO content of the high alumina slags, which in their case was less than 37%.

Several studies (Dhir *et al*., 1996; Luo *et al.*, 2003; Cheng *et al.*, 2005; Thomas *et al.*, 2012) have also reported that the alumina content of GGBS contributes significantly to chloride binding, due to the increased possibility of forming Friedel's salt and also the formation of C-A-S-H phases that is responsible for the binding of about two-thirds of the chloride (Florea and Brouwers, 2012). This is the main reason why slag blends are more resistant to the ingress of chloride ions than plain cements, as has been reported in various studies (Ramezanianpour and Malhotra, 1995; Sengul and Tasdemir, 2009; Shi *et al.*, 2011; Bouteiller *et al.*, 2012).

2.3. Other properties that influence the reactivity of GGBS

2.3.1. Type of activator used

Slag activators can either be alkaline in nature, such as sodium hydroxide, lime, sodium carbonate and sodium silicate; or sulphate-based, like calcium sulphates or phosphogypsum. The type of the activator influences the nature and type of the hydrates formed (Moranville-Regourd, 2003; Siddique and Bennacer, 2012). Table 3 gives a summary of the hydration products obtained when different activators were used.

Table 3: Slag hydration products in the presence of different activators (Glasser, 1991)

Nature of activator	Crystalline phases	Comments
NaOH, Na_2CO_3, sodium silicate	C-S-H, C_4AH_{13}, C_2AH_8, $Mg(OH)_2$	Some Si in C_3AH_{13}, C/S in C-S-H less than in OPC
$Ca(OH)_2$	C-S-H, C_4AH_{13}	C_2AH_8 absent
Sulphate e.g. gypsum, hemihydrates, phosphogypsum	C-S-H, AFt, $Al(OH)_3$	Sulphate in slag acts to some extent as an auto-activator
Portland cement	C-S-H, AFm, AFt, hydrogarnet, hydrotalcite-like phase	Not all phases are likely to be seen in the same paste

In the study by Ben Haha *et al.* (2011), slags were activated by two different alkalis – NaOH and waterglass (sodium silicate). They observed that the NaOH activated slags were more reactive than the waterglass activated slags at the early stages. However, at ages beyond 7 days the trend was reversed. In terms of the impact on the microstructure, the initial fast reaction of the NaOH activated slags resulted in a more porous microstructure; whereas the slow hydration of the waterglass activated slag led to a more refined microstructure. Similar findings were reported by Jeong *et al.* (2016), where they investigated the influence of four supplementary activators on $Ca(OH)_2$ activated slag system. They observed that the Na-based additives were less desirable, producing lower 28 day strengths.
In PC slag blends, the hydration of slag in the presence of the cement depends on the breakdown and dissolution of the glass slag structure by hydroxyl ions released during the hydration of the PC and also on the alkali content of the PC (Güneyesi and Gesoğlu, 2008). The later (alkali content of the PC) cannot be said to be very important as there are no specifications on the minimum alkali content a Portland cement should have before it can be blended with a slag. Also, in contrast to alkali activated systems, using different types of PC as activator for slags does not seem to have any significant effect on the hydration of the slags (Lumley *et al.*, 1996; Scrivener and Nonat, 2011).

2.3.2. Proportion of slag used

Whittaker *et al.* (2014) studied the hydration kinetics of PC slag blends. The two slags they studied had the same fineness but different chemical composition and glass content. They observed that after 1 year of hydration of 60–40 PC slag blends, about 57% and 68% of the slags had reacted. The more reactive slag had higher alumina and glass contents. When they increased the slag loading from 40 to 70%, the degree of slag hydration dropped from 68% to 60%. In another study, (Luke and Glasser, 1988) observed that for 70–30 PC slag blends, about 41% and 65% of the slag had reacted after 1 month and 1 year of hydration respectively. This generally implies that the higher the slag proportion in a mix, the lower the degree of slag hydration (Escalante *et al.*, 2001). Studies have shown that for maximum strength, the optimum amount of slag replacement in PC ranges between 55% and 59%

(Oner and Akyuz, 2007), while up to 65% has been reported for improved chloride resistance (Arya and Xu, 1995).

On the other hand, at a given water/binder ratio, increasing the slag proportion will result in a decrease in the chloride diffusion coefficient of concretes prepared from slag blends (Yeau and Kim, 2005; Olsson *et al.*, 2013). Yeau and Kim (2005) conducted rapid chloride permeability tests (RCPT) and accelerated chloride ion diffusion tests on concrete samples made from GGBS and plain cements. They used concrete mixes containing 0, 25, 40 and 55% of GGBS by weight of PC at a constant w/b ratio of 0.42. Irrespective of the curing duration before exposure, they observed that the chloride penetrability decreased as the proportion of the slag in the concrete mixes was increased, with the 55% GGBS having the lowest chloride penetrability.

2.3.3. Curing conditions

1. Curing medium:
In the study by (Ramezanianpour and Malhotra, 1995), slag concrete specimens prepared with a w/b ratio of 0.5 were subjected to four different curing regimes – continuous moist curing, 2 days moist curing followed by air curing, continuous air curing and curing at 38°C and 65% RH. The samples were cured for various lengths of 7, 28 and 180 days before testing for chloride diffusion using RCPT. They observed that the slag concretes were more sensitive to poor curing than the plain concretes, with this effect increasing with greater slag replacements.

2. Length of curing:
Yeau and Kim (2005) observed that, for slag concretes, the chloride penetrability decreased as the initial curing before exposure to chloride solution was increased from 28 to 56 days. This was attributed to the effect of prolonged curing on the microstructure, which resulted in a more refined pore structure that had better resistance to the ingress of chloride ions. Similar observation was also reported by (Ogirigbo and Black, 2018), although in their case, they observed that the effect of prolonged curing was more pronounced on slags of lower reactivity. Recent study on the expansion of 30 wt.% slag-blended mortars exposed to combined sodium chloride and sulphate solution at 20°C have shown significant effect of slag reactivity and alumina content on curing duration. Expansion was found to be lower in slag blended mortar bars cured for only 7 days before exposure compared with those cured for 28 days. This was associated with advanced slag hydration leading to more formation of monosulfoaluminate which formed ettringite crystals on reacting with in-coming sulphate ions (Ukpata *et al.*, 2018).

3. Curing temperature:
Several studies (Richardson *et al*., 1989; Ma *et al.*, 1994; Escalante-Garcia and Sharp, 2000) have shown that GGBS contributes more to the total heat of hydration at higher temperatures than at lower temperatures. This has been largely attributed to the accelerating effect of temperature on slag hydration and has been cited as the main reason for the increase in early strength observed for slag blends cured at elevated temperatures (Hogan and Meusel, 1981; Barnett *et al.*, 2006; Çakır and Aköz, 2008). For example, Richardson et al. (1989) hydrated slag blends at elevated temperatures, and observed that the reactions of the silicates and aluminates were accelerated at elevated temperatures. Slags are richer in silica and alumina than PC. Hence, the accelerating effect of temperature on hydration would be more pronounced on slags than plain cements. Ogirigbo and Black (2016), in their study on the combined influence of slag composition and temperature on the hydration of slag blends, observed that the chemical composition of the slags also played an important role. In their study, two slag blends prepared from two slags of different chemical compositions, at a replacement of 30%, were hydrated at temperatures of 20 and 38°C. The slags had alumina contents of 12.23% and 7.77% respectively. They observed that the higher alumina slag (slag 1 as seen in Figure 3) reacted more at both temperatures, and that the difference between the degrees of hydration of the slags was much greater at the higher temperature of 38°C. They attributed the increased reactivity of the slag 1 blend at the higher temperature to its higher alumina content.

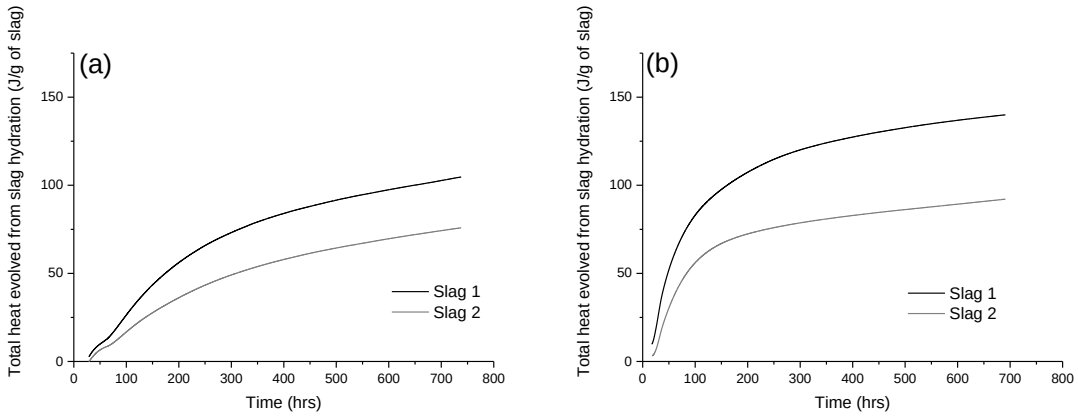

Figure 3: Total heat evolved from slag hydration normalised to the slag content at (a) 20°C and (b) 38°C (Ogirigbo and Black, 2016)

Some studies (e.g. (Angulski da Luz and Hooton, 2015)) have also shown that curing slag blends at elevated temperatures can result in lower porosity at early ages. Angulski da Luz and Hooton (2015) observed that paste samples made from super sulphated cements and cured for 7 days at higher temperatures had lower porosities than the ones cured at lower temperatures. Similar findings were also reported in the study by (Ogirigbo and Black, 2016). They observed that the porosity of 7 day old paste samples prepared from slag blends were lower for samples cured at 38°C as compared to those cured at 20°C. However, when they increased the curing age from 7 days to 28 days (as shown in Table 4), the trend reversed. They attributed the lower porosity of the 7 day samples cured at 38°C to the increased reactivity of the slags at 38°C, and the higher porosity of the 28 day samples cured at 38°C to the coarsening effect of high temperature curing on the microstructure. This seems to suggest that the impact of the accelerating effect of temperature on the hydration of the slags is more pronounced at early ages than at later ages. However, more studies would have to be carried out in this area to fully understand the interplay between curing temperature and slag hydration.

Table 4: Degree of porosity (%) of PC:slag blends (70:30) at 7 and 28 days measured by SEM image analysis (Ogirigbo and Black, 2016)

Mix	Temperature	7 days	Error	28 days	Error
Slag 1	20°C	11.75	0.10	6.54	0.11
	38°C	9.21	0.14	8.87	0.08
Slag 2	20°C	12.27	0.12	7.03	0.07
	38°c	9.88	0.11	9.48	0.09

3.0. Factors to consider for effective utilization of slag in Nigeria

A number of factors affecting the reactivity of slags have been reviewed to encourage proper and increased use of slags to reduce environmental footprints of concretes. The factors ranged from physical to chemical properties, as well as, the influence of exposure environments - curing conditions and temperature. In summary, the following points are highlighted:

- Slags having fineness greater than 275 m^2/kg and glass contents within the range of 85% and 99% are adequate for use as a supplementary cementitious material.
- The chemical composition of slag depends mainly on the nature of the ore, the composition of the limestone flux, coke consumption and the type of iron being made.
- The main compounds that influence the hydraulicity of slags are the oxides of calcium, magnesium, aluminium and silicon. The first three oxides increase the hydraulicity of slag, while that of silicon decreases it.
- Slags can be activated by alkaline compounds such as sodium hydroxide, lime, sodium carbonate and sodium silicate; or sulphate-based, like calcium sulphates or phosphogypsum; or the hydration products of Portland cement.
- Slags can be used to replace Portland cement in proportions ranging from 6 – 99%. The higher the proportion of slag, the lower the chloride penetrability and degree of hydration of the slag, and vice versa.

- Concretes made from cements containing slags are more sensitive to poor curing techniques than those made from plain cements, and they often require longer curing durations for adequate performance.

Higher curing temperatures, typically in the range experienced in Nigeria, enhance the early age performance of cements containing slag due to the accelerating effect of temperature on the reaction of the aluminates and silicates.

4.0 Conclusion

A number of countries such as Nigeria are yet to fully utilize their potentials of slags to reduce the cost of concrete binders, as well as reduce the carbon footprints of concrete materials, despite their natural advantage in climates that support improved slag performance. While this review has shown that there is huge potential for incorporating slags into concrete binders in Nigeria, further studies would still need to be carried out to characterize the range of chemical compositions of the slags; as chemical composition is an essential factor influencing the hydraulicity and/or performance of slags, especially in high temperature environments. Except this characterization is carried out, the potential application of GGBS and other types of slags from the abundant steel and iron ore deposits in Nigeria might not be fully realized.

Acknowledgement

The authors would like to acknowledge the input of Prof. Leon Black of the Center for Infrastructure Materials, School of Civil Engineering, University of Leeds, for his support and contributions towards this work.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 219 - 232

Geostatistical Modelling and Mapping of the Concentration of Gaseous Pollutants

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ABSTRACT

In this study, the prediction of the concentration of gaseous pollutants around Ughelli West gas flow station in Delta State of Nigeria was carried out using Geostatistical technique in GIS environment. Since air pollutants negatively affect quality of air, lives and the environment, there is therefore the need to frequently monitor air quality, have thorough understanding of the pollutants' concentration and their spatial distribution in an environment. The gaseous pollutants data of volatile organic compounds (VOCs), methane (CH_4), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and ozone (O_3), were obtained using Multi-parameter gas monitor while that of fine particulate matter ($PM_{2.5}$) was obtained with SPM meter for a period of three months. Thermo Anemometer was used to obtain the values of wind speed, ambient temperature, atmospheric pressure and relative humidity. Artificial Neural Network designer software (Pythia) was used to validate the acquired field data; predict the concentration of the gaseous pollutants at selected distances from the flow station. The geospatial coordinates of the flow station were obtained using Global Navigation Satellite System (GNSS) receivers; the geospatial modelling and analysis were performed with ArcGIS software and ordinary kriging method of Geostatistical techniques. The results of the maximum concentration for the gaseous pollutants in the study area were 28.17 $\mu g/m^3$, 19.44 $\mu g/m^3$, 0.37 $\mu g/m^3$, 49.81 $\mu g/m^3$, 0.061 $\mu g/m^3$ and 0.047$\mu g/m^3$ for VOCs, CH_4, NO_2, $PM_{2.5}$, O_3 and SO_2 respectively. The root mean square error for the concentration of the gaseous pollutants, ozone and sulphur (IV) oxide in the study area were 0.01618 and 0.008417 indicating a good interpolation model, while their root mean square standard errors, which show the reliability of the predicted values, were 0.70513551 and 0.8459251 respectively. These results conform with the report of other researchers that a better kriging method yields a smaller root mean square and a standard root mean square closer to one. The developed prediction maps for the gaseous pollutants in this study revealed that the study area will experience lower concentration of gaseous pollutants at a distance of 400 m and above.

Keywords: Gaseous pollutants, Spatial interpolation, Geostatistical mapping, Kriging, Modelling

1.0. Introduction

Air pollution is the contamination of the atmosphere by gaseous, liquid or solid wastes or their by-products, including noise present in the atmosphere in concentrations that can endanger human health and the health and welfare of plants and animals, or can attack materials, reduce visibility, or produce undesirable odour (Khitoliya, 2007). Air pollution is a major problem with strong impact on the environment (Clark *et al*., 2016), economy (Carleton and Hsiang, 2016) and human health (Lelieveld *et al*., 2015).

Gaseous pollutants from burning of fossil fuels such as gas, oil, coal and wood affect the earth, buildings, water and air, resulting in fog, smog and global warming, which deteriorate vegetation, forests, and even human health (Obahiagbon, 2002; Khitoliya, 2007; Rai *et al*., 2011). Gas flaring is one of the most challenging energy and environmental problems facing the world today, a local environmental catastrophe and a global energy and environmental problem which have persisted for decades (Ismail and Umukoro, 2012). Gas flaring in the study area of the Niger Delta Area of Nigeria

degrades soil, makes it poor and infertile for crop production; excessive heat from the flare kills or scares away most of the micro- and macro-organisms that would have helped to improve the soil fertility through further breaking down of the soil particles, further decaying and decomposition of the organic matters of the soil (Odjugo and Osemwenkhae, 2009). Gas flaring contributes to the emission of toxic gases such as carbon monoxide, nitrogen dioxide, sulphur dioxide and methane (Orubu, 2002; Ite and Udo, 2013). Gas flares damage vegetation, economic crops and the environment; contaminate surface and ground water, corrode roofing sheets, monuments and structures through acidification of rain water (Olabaniyi and Efe, 2007; Akpoborie *et al*., 2000; Oghifo, 2011).

Nigeria flares 17.2 billion m^3 of natural gas per year from crude oil exploration in the Niger Delta area which is approximately one quarter of the current power consumption of the African continent. This contributes to climate change which has serious implications for both Nigeria and the rest of the world (Ajugwo, 2013). There is therefore a need to predict the level of gaseous pollutants concentration and the spread of gaseous pollutants from the activities of Ughelli West flow station so as to know at what distance from the flare point the pollution effect will be minimal.

Dispersion modelling is undertaken in order to predict the concentration and spread of pollutants (Anjaneyuhu *et al*., 2011). Yannawar *et al*. (2014) opined that dispersion models are used to predict the fate of pollutants after they are released into the atmosphere. The goal of air quality dispersion modelling is to estimate a pollutant's concentration at a point downwind of one or more emission sources (Narayanan, 2009).

The aim of this study is to carry out the geostatistical dispersion modelling and mapping of the gaseous pollutants emitted from Ughelli West Gas flow station and determine their level of concentration in the environment of the study area. The objectives of the study therefore are to: determine the gaseous pollutants with their concentrations which are emitted from Ughelli West flow station; develop a geo-statistical dispersion model, using kriging method, a geostatistical technique for spatial interpolation with ArcGIS software and produce a prediction map of the un-sampled location showing the spread of monitored gaseous pollutants as well as determine the distance where the effect of the gaseous pollutants was minimal.

1.1. Spatial interpolation, Geostatistical techniques and modelling

a) Spatial interpolation

The earth's surface is one type of surface that most professionals in the Construction industry inter alia are familiar with. Nowadays, due to technological advancement, there is another type of surface used in GIS environment, which cannot be seen physically but can be visualized in the same way as the land surface. It is the statistical surface and some of its examples are precipitation, population density, water table and snow accumulation. Constructing a statistical surface is similar to that of the land surface except that the input data are typically limited to a sample of point data. A process of filling in data between the sample points is therefore required (Chang, 2014). Spatial interpolation refers to the process of using points with known values to estimate values at other unknown points. Through spatial interpolation, the precipitation value at a location with no recorded data can be predicted by using known readings at nearby weather stations. Spatial interpolation is therefore a means of creating surface data from sample points so that the surface data can be displayed as a three dimensional (3-D) surface and also used for modelling and analysis. The two basic inputs required in spatial interpolation are the known points, also called the control points, sample points or observation points (which are actual points such as weather stations or survey sites) and an interpolation method. The control points provide the necessary data for developing an interpolator (e.g. a mathematical equation) for spatial interpolation. The number and distribution of control points can greatly influence the accuracy of spatial interpolation.

The first spatial interpolation methods can be grouped into global and local interpolation methods. The second spatial interpolation methods can be classified into exact and inexact interpolation while the third spatial interpolation methods can also be grouped as deterministic and stochastic interpolation. The global interpolation method uses every available known points to estimate an unknown value; it's designed to capture the general trends of the surface, include trend surface

models and regression models while the local interpolation method uses a sample of known points to estimate an unknown value; it's designed for the local or short-ranged variation and required much less computation than a global interpolation method. The exact interpolation predicts a value at the point location that is the same as its known value. It generates a surface that passes through the control points. The inexact interpolation or approximate interpolation predicts a value at the point location that differs from its known value. The deterministic interpolation provides no assessment error with predicted values, while the stochastic interpolation considers the presence of some randomness in its variables and offers assessment of prediction errors with estimated variances (Chang, 2014).

Davis (1986) together with Bailey and Gatrell (1995) reported that for an inexact interpolation method, the trend surface analysis approximates points with known values using a polynomial equation (interpolator). This polynomial equation can then be used to estimate values at the other points. A linear or first-order trend surface model, which can be used to approximate inclined plane surfaces and has three coefficients, uses the following equation (Chang, 2014):

$$Z_{xy=}b_{0+}\, b_{1x+}\, b_{2y} \tag{1}$$

where,

x and y	known coordinates of the points.
z	function of x and y coordinates
b_0, b_1, b_2	coefficients estimated from the known coordinates.

The "goodness of fit" of trend surface model in Equation 1 can be measured and tested since it is computed by least square method. Besides, the deviation or residual between the observed and the estimated values can be computed for each known point.

Complex surfaces require higher-order trend surface models and more computation than a lower-order trend surface model. A cubic or third-order trend surface model such as hills and valleys, etc. which requires estimation of 10 coefficients is based on the following equation (Chang, 2014):

$$Z_{xy=}b_{0+}\, b_{1x+}\, b_{2y} + b_{3x^2+}\, b_{4xy+}\, b_{5y^5+}\, b_{6x^3+}\, b_{7x^2y+}\, b_{8xy^2+}\, b_{9y^3} \tag{2}$$

where,

x and y	known coordinates of the points
$b_0, b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9$	coefficients estimated from the known coordinates.

A GIS package offer up to 12th-order trend surface models. Coordinates are the most used method for describing the horizontal positions of points and features on the earth's surface. A GIS software has many options of coordinate systems. A coordinate system is a method for identifying the location of a point on the earth's surface. Decimal degrees system is a measuring system for geographical coordinates (longitudes and latitudes) expressed in degrees. Universal Transverse Mercator (UTM) system is a coordinate system that divides the earth's surface between 84°N and 80°S into 60 zones, with each further divided into the Northern hemisphere and the Southern hemisphere (McCormac, 2004; Chang, 2014).

b) Geostatistical Techniques and modelling

Geostatistics is a class of statistics used to analyze and predict the values associated with spatial or spatiotemporal phenomena. It incorporates the spatial (and in some cases temporal) coordinates of the data within the analyses. Many geostatistical tools were originally developed as a practical means to describe spatial patterns and interpolate values for locations where samples were not taken. Those tools and methods have since evolved not only to provide interpolated values, but also measures the uncertainty for those values. The measurement of uncertainty is critical to informed decision making, as it provides information on the possible values (outcomes) for each location rather than just one interpolated value (ESRI-ArcGIS manual). Geostatistics is then used to produce predictions (and related measures of uncertainty of the predictions) for the unsampled locations. Geostatistics is widely used in many areas of science and engineering, for example: In the environmental sciences,

geostatistics is used to estimate pollutant levels in order to decide if they pose a threat to environmental or human health and warrant remediation (ESRI-ArcGIS manual). Geostatistical analysis has also evolved from uni-to multivariate and offers mechanisms to incorporate secondary datasets that complement a (possibly sparse) primary variable of interest, thus allowing the construction of more accurate interpolation and uncertainty models. These models can be applied to a wide variety of scenarios and are typically used to generate predictions for unsampled locations, as well as measures of uncertainty for those predictions.

Geostatistical techniques assume that at least some of the spatial variation observed in natural phenomena can be modelled by random processes with spatial autocorrelation and require that the spatial autocorrelation be explicitly modelled. Geostatistical techniques can be used to describe and model spatial patterns (variography), predict values at unmeasured locations (kriging), and assess the uncertainty associated with a predicted value at the unmeasured locations (kriging). The Geostatistical Wizard offers several types of kriging, which are suitable for different types of data and have different underlying assumptions: ordinary, simple, universal, indicator, probability, disjunctive, areal interpolation and empirical Bayesian.

Kriging, a geostatistical method for spatial interpolation, differs from other local interpolation methods because it can assess the quality of prediction with estimated prediction errors. Kriging has since been adopted in a wide variety of disciplines. In GIS environment, kriging has also become a popular method for converting light detection and ranging (LIDAR) point data into DEM_S (Zhang *et al*., 2003). The digital representation of topography (the shape, configuration, relief, roughness, three- dimensional quality of the earth's surface) is referred to as digital elevation model (DEM) (McCormac, 2004).

Kriging assumes that the spatial variation of an attribute is neither totally random (stochastic) nor deterministic. Instead the spatial variation may consist of three components, namely: a spatially correlated component (representing the variation of the regional variable; a drift or structure (representing a trend) and a random error term. The interpretation of these components has led to the development of different kriging methods for spatial interpolation. Kriging uses semi-variance to measure spatially correlated component (also called *spatial dependence or spatial autocorrelation*). The semi-variance is expressed mathematically as (Chang, 2014):

$$\gamma(\mathrm{h})=\frac{1}{2}\,[\mathrm{z}(x_i)\mathrm{z}(x_j)]^2 \tag{3}$$

where
$\gamma(h)$ semi-variance between known points, x_i and x_j
h distance between the points
z attribute

If spatial dependence does not exist in a data set, known points that are close to each other are expected to have small semi-variances, and known points that are farther apart are expected to have larger semi-variances. In other words, the semi-variance is expected to increase as the distance increases in the presence of spatial dependence.

A semi-variogram is used as measure of spatial autocorrelation in the data set. When it's used as an interpolator in kriging, it must be fitted with a mathematical function or model. The fitted semi-variogram can then be used for estimating the semi-variance at any given distance. Webster and Oliver (2001) opined that fitting a model to a semi-variogram is a difficult task in geostatistics because of the number of models to choose from. When the kriging method is ordinary, the available models are spherical, circular, exponential, Gaussian, and linear, whereas in universal Kriging, the available models are linear with linear drift and linear with quadratic drift. Kriging attempts to minimize the error variance and set the mean of the prediction errors to zero so that there is no over- or under-estimates. Geostatistical Analyst extension to ArcGIS offers eleven (11) models.

As regards the procedure for comparing the models, Webster and Oliver (2001) recommend a procedure that combines visual inspection and cross-validation. Cross-validation is a method for comparing interpolation methods. Jarvis *et al*. (2003) propose the use of artificially intelligent system for selecting an appropriate interpolator based on task-related knowledge and data characteristics. Two common models for fitting semi-variograms are the spherical and exponential. A spherical model shows a progressive decrease of spatial dependence until some distance, beyond which the spatial dependence levels off.

An exponential model exhibits a less gradual pattern than a spherical model. The spatial dependence decreases exponentially with increasing distance and disappear completely at an infinite distance. A fitted semi-variogram has three elements, viz: nugget, range and sill. The nugget is the semi-variance at the distance of zero (0), representing measurement error, or microscale variation or both. The range is the distance at which the semi-variance starts to level off. In other words, the range corresponds to the spatially correlated portion of the semi-variogram. Beyond the range, the semi-variance becomes a relatively constant value. The semi-variance at which the levelling takes place is called sill. Assuming the absence of a drift, ordinary kriging focuses on the spatially correlated component and uses the fitted semi-variogram directly for interpolation. The general equation for estimating the Z value at a point for ordinary kriging is:

$$Z_0 = \sum_{i=1}^{s} Z_x W_x \tag{4}$$

where,

Z_0 estimated value,

Z_x known value at point x,

W_x weight associated with point x,

S number of sample points used in the estimation.

The weights can be derived from solving a set of simultaneous equations.

2.0. Methodology

2.1. Study area

The study area is located at Ughelli West oil and gas plant flow station of Delta State of Nigeria. Ughelli West facility is very strategic and supplies more than 80percent of gas used in Nigeria. It is the number one gas processing plant in the whole of West Africa (SPDC, 2000). Ughelli West oil field, which is situated at the Oil Mining Lease (OML) 34 in Delta State of the Niger Delta Region, is about 20 km South East of Warri and 7km to the South of Ughelli West field. The facility is bounded by three communities namely Otu -Jeremi, Otor – Udu and Iwhreka communities. It produces an average of 205 mmscf of gas daily (an equivalent of 786MW of electricity). The map of Delta State showing the position of OML34 and the map of OML34 showing the location of Ughelli West Gas Plant are shown in Figures 1 and 2 respectively.

2.2. Data acquisition, processing and Geostatistical analysis

The study involved prediction of the level of concentration of gaseous pollutants from Ughelli West flow station, and it was carried out using the following steps: data acquisition and processing; determination of the gaseous pollutants as well as their level of concentration which were emitted from the study area; Geo-statistical analysis of the data.

Figure 1: Map of Delta State showing the position of OML34 (Source: SPDC, 2000)

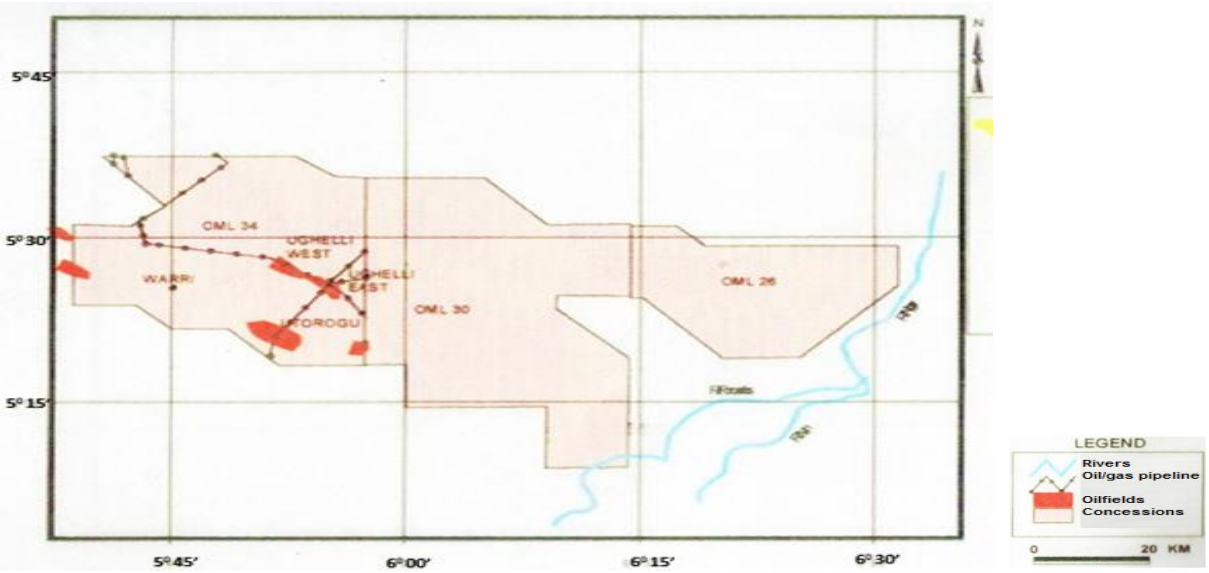

Figure 2: Map of OML 34 showing location of Ughelli West Gas Plant (Source: SPDC, 2000)

2.2.1. Data acquisition and processing

In this study, the gaseous pollutants in the study area are volatile organic compounds (VOCs), methane (CH_4), nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$), ozone (O_3) and sulphur dioxide (SO_2). They were monitored on daily basis for a period three months, from September to November. The data were transformed into weekly maximum concentration in accordance with Directorate of Petroleum Resources (DPR) standards (EGASPIN, 2002). The monitoring points were established in line with Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) and the range of measurement was 60m to 500m, using spacing distances of 60m, 80m, 100m, 150m, 200m, 250m, 300m, 350m, 400m, 450m and 500m from the flare point (EGASPIN, 2002). The standard gaseous pollutants monitoring equipment, namely: Gas monitor, SPM meter, Anemometer and GNSS receivers were calibrated, tested and confirmed to be in good working conditions and were therefore used for this study. Aeroqual multi-parameter environmental monitor (series 500) was employed to monitor the concentrations of volatile organic compounds (VOCs), oxides of nitrogen (NO_2), oxides of sulphur (SO_2), ozone (O_3) and methane (CH_4). Aerocet-531 SPM meter was used to monitor the concentration of particulate matter ($PM_{2.5}$), while Sky master thermo anemometer (SM-28) was used to obtain the important climatic variables such as wind speed,

atmospheric pressure, ambient temperature and relative humidity, which affect the dispersion of gaseous pollutants.

The maximum concentration of the pollutants at each sampling point within the entire period of experimentation was selected for the modelling; extreme value statistics was carried out using the data analysis tool pack of Microsoft Excel software. The Global Navigational Satellite System (GNSS) receivers were used to obtain the geographical coordinates at each monitoring point in the study area. The coordinates were converted to decimal degrees format and the results presented in grid UTM coordinates. The field data were validated using artificial neural network (ANN) designer software (Pythia) in order to evaluate the adequacy of the field data for use in the modelling of the gaseous pollutants. Using the training data, Pythia employed the evolutionary optimizer to search the neural network topology that best understands the input and output data presented for training. During the training phase, the actual output of the network was compared with the experimental output and the error propagated back towards the input of the network. The condition for the best performance, evolutionary optimization for selecting best network topology and the optimum neural network of the architecture for Ughelli West flow station were determined. Using the optimum neural network, the repro pattern set function of the pythia program was activated to predict the pollutant concentration based on the input and field output of the Ughelli West gas flow station.

2.2.2. Geo-statistical analysis of the data

One of the unique features of spatial analysis is the development of a prediction map which allows for the determination of the concentration of gaseous pollutants in unsampled location. In order to understand the dispersion and spatial variation of the pollutants with sampling points around the study area, a geospatial modelling using ArcGIS software and ordinary kriging technique was used to interpolate the gaseous pollutants values at the unknown locations. The objectives of this study, the understanding of the phenomenon (gaseous pollutants) and the required output of the interpolation model were the factors that determine the choice of the geostatistical tehnnique (ordinary kriging) used for this study.

Detailed geo-statistical analysis of the data acquired from Ughelli West flow station was carried out. The input parameters for the geostatistical modelling are the rectangular coordinates of each sampling point which include: Northings, Eastings and the Elevations in addition to the concentrations of the gaseous pollutants investigated, which are the attribute data. To perform the geospatial analysis of the toxic gaseous pollutants, ordinary kriging method of geostatistical interpolation techniques was employed in this study because of its abilities of modelling and producing maps of kriging: predicted values, standard errors associated with the predicted values. The kriging weights were obtained from fitting of semi-variogram models developed by viewing the spatial structure of the data.

The basic steps involved in the application of kriging interpolation method include:- generation of coordinates and the attribute data; fitting of semi-variogram/covariance model; generation of cross validation statistics for assessing model performance and production of prediction map(the output of the variables being modelled) which shows the spatial distribution of each specific pollutant.

3.0. Results and Discussion

3.1. Predicted pollutant concentration for Ughelli West Flow Station using Pythia software

The input parameters (acquired field data) and the output parameters used for the network training with Pythia Neural net software for the study area (Ughelli West Flow Station) are presented in Table 1. The input parameters in Table 1 were selected in this study since they form the bedrock of the critical climatic variables that affect the geostatistical dispersion of gaseous pollutants in the study area. The results of Pythia predicted (net) gaseous pollutants concentrations at Ughelli West gas flow station, shown in Table 1 , are in close agreement with the obtained field output values indicating that the field data were accurate and reliable.

Table 1: Predicted pollutant concentration for Ughelli West Flow Station using Pythia software

File Pattern Net Edit Help

Pattern Set:

UGHELLI WEST FLOW STATION.PAT

	INPUT VARIABLES					FIELD (PRIMARY) OUTPUT DATA						PYTHIA GENERATED OUPUT DATA						
	I1	I2	I3	I4	I5	O1	O2	O3	O4	O5	O6	O1(NET)	O2(NET)	O3(NET)	O4(NET)	O5(NET)	O6(NET)	SQ DV
1	60.000000	4.100000	1010.00000	29.700000	88.700000	28.170000	19.440000	0.370000	49.810000	0.061000	0.047000	28.061731	19.316308	0.364099	49.747651	0.059769	0.046758	0.000297
2	80.000000	3.200000	1010.00000	29.400000	91.200000	26.930000	18.770000	0.330000	48.880000	0.052000	0.043000	26.632219	18.186065	0.330024	48.150295	0.051761	0.044149	0.001101
3	100.00000	3.400000	1010.00000	28.500000	78.900000	26.040000	17.390000	0.310000	47.330000	0.046000	0.043000	25.519898	17.374240	0.305963	46.520481	0.046500	0.041783	0.000715
4	150.00000	3.700000	1010.00000	29.100000	88.300000	25.330000	16.880000	0.280000	45.780000	0.041000	0.041000	24.950177	16.634882	0.275518	44.851697	0.038469	0.039097	0.001788
5	200.00000	3.900000	1010.00000	29.500000	88.600000	24.780000	16.240000	0.270000	43.290000	0.038000	0.038000	24.511573	16.179522	0.259801	43.813433	0.034840	0.037443	0.001317
6	250.00000	4.200000	1010.00000	27.400000	75.800000	23.130000	15.780000	0.240000	42.410000	0.033000	0.034000	23.644410	15.529605	0.238572	42.619596	0.032005	0.033550	0.000419
7	300.00000	3.700000	1010.00000	28.800000	79.200000	21.490000	14.090000	0.220000	36.760000	0.024000	0.031000	21.129698	14.237638	0.224611	36.156759	0.026917	0.031734	0.001033
8	350.00000	3.100000	1010.00000	26.700000	88.100000	18.370000	13.370000	0.220000	23.410000	0.021000	0.029000	18.672789	13.487167	0.221790	23.705978	0.020713	0.029081	0.000116
9	400.00000	2.800000	1010.00000	27.800000	79.900000	16.210000	12.330000	0.210000	20.770000	0.019000	0.026000	14.760252	11.470403	0.191503	20.297501	0.017985	0.024747	0.004463
10	450.00000	2.800000	1010.00000	28.600000	82.500000	13.320000	10.370000	0.180000	19.030000	0.016000	0.023000	13.602913	10.756314	0.179479	18.894624	0.016117	0.023214	0.000343
11	500.00000	2.500000	1010.00000	27.400000	78.900000	11.740000	9.970000	0.160000	17.120000	0.014000	0.021000	12.430384	10.265161	0.170623	17.361511	0.014545	0.021826	0.001083

I1, I2, I3, I5 are the input variables; I1 = sampling distance in m, I2 = wind speed in m/s, I3 = atmospheric pressure in mmHg, I4 = ambient temperature in °C, I5 = relative humidity in %. O1, O2, O3, O4, O5, O6 are the field output data; O1 = VOC in µg/m^3, O2 = CH_4 in µg/m^3, O3 = NO_2 in µg/m^3, O4 = $PM_{2.5}$ in µg/m^3, O5 = O_3 in µg/m^3, O6 = SO_2 in µg/m^3. O1(NET), O2(NET), O3(NET), O4(NET), O5(NET), O6(NET) are the data generated by the Pythia neural network. SQDV = squared deviation.

3.2. Results and discussion on some vital geostatistical modelling for the spatial distribution of the maximum concentration of ozone(O_3)and sulphur (iv) oxide (SO_2) around Ughelli West Flow Station

The different stages of kriging modelling required for building geostatistical model for the spatial distribution of maximum concentration of ozone and sulphur (iv) oxide around Ughelli West flow station are presented in Figures 3 to 8. Figures 3 and 4 show the first modelling step which describes the modelling technique (kriging) employed to perform the geospatial modelling of maximum concentration of Ozone and sulphur (iv) oxide around the flow station respectively. They contain the choice of the method , which is ordinary kriging /cokriging method and the input data, which is the maximum concentration of the gaseous pollutants: ozone and sulphur (iv) oxide, in Ughelli West flow station.

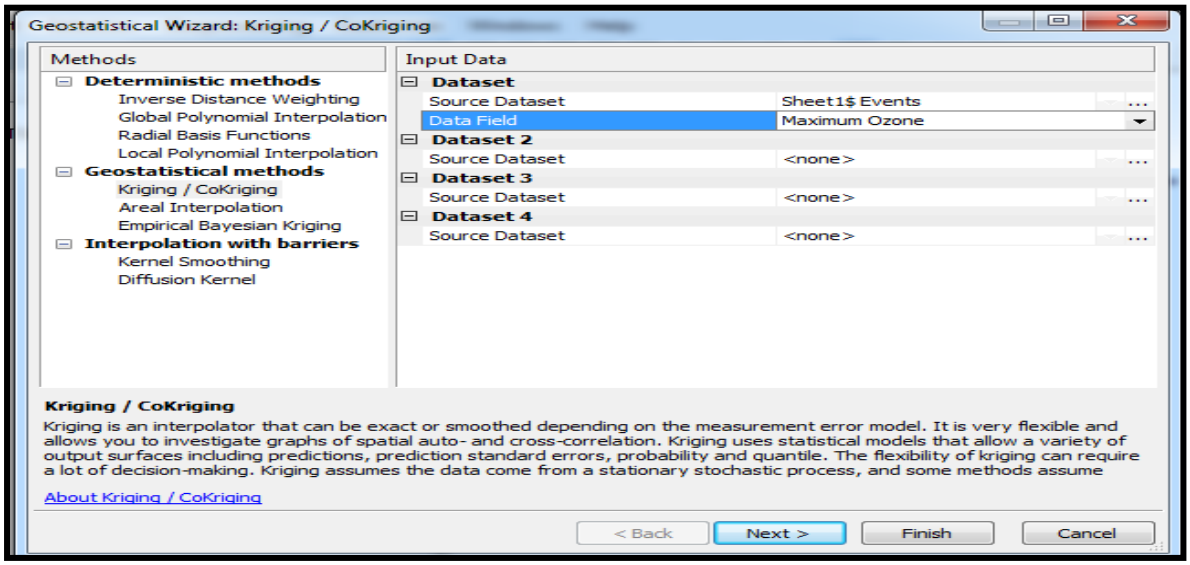

Figure 3: Kriging modelling of ozone around Ughelli West flow station

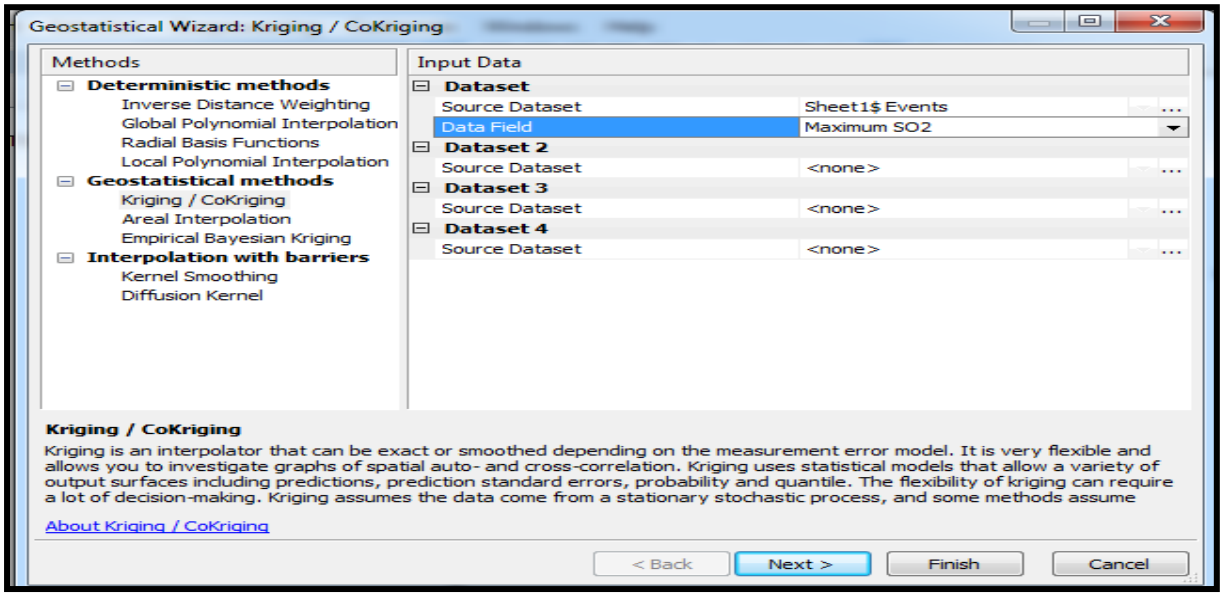

Figure 4: Kriging modelling of sulphur (iv) oxide around Ughelli West flow station

Ordinary kriging method, which is the default interpolation method in the ArcGIS environment and the most flexible method of interpolation, provides better correlation between the input variables and the corresponding output variables. It also considered both the distance and the degree of variation between known data points when estimating values in unknown areas. It is a robust interpolation tool which derives weights from surrounding measured values to predict values at unmeasured locations.

The Semi-variogram/Covariance models for spatial distribution of ozone and sulphur (iv) oxide around Ughelli West flow station are presented in Figures 5 and 6 respectively. The semi-variogram/covariance model in Figures 5 and 6 enabled the spatial relationships between measured points in the study area to be examined and to explore the assumption that points that are closer together are more alike than those that are farther apart. The process of fitting a semi-variogram model to capture the spatial relationships in the data is often known as variography. The cross hairs show the locations that have no measured values. The values at the measured locations were used to predict the values at the crosshairs. The red points have more influence on the values of the unknown locations since they are closer to the location to be predicted.

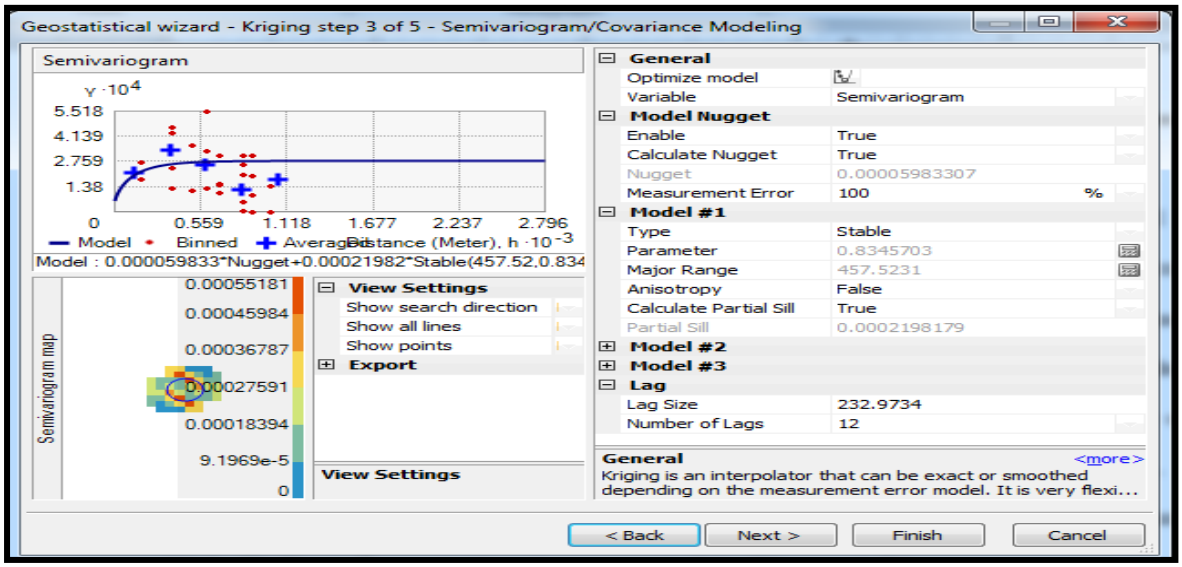

Figure 5: Semi-variogram model for the spatial distribution of ozone around the study area

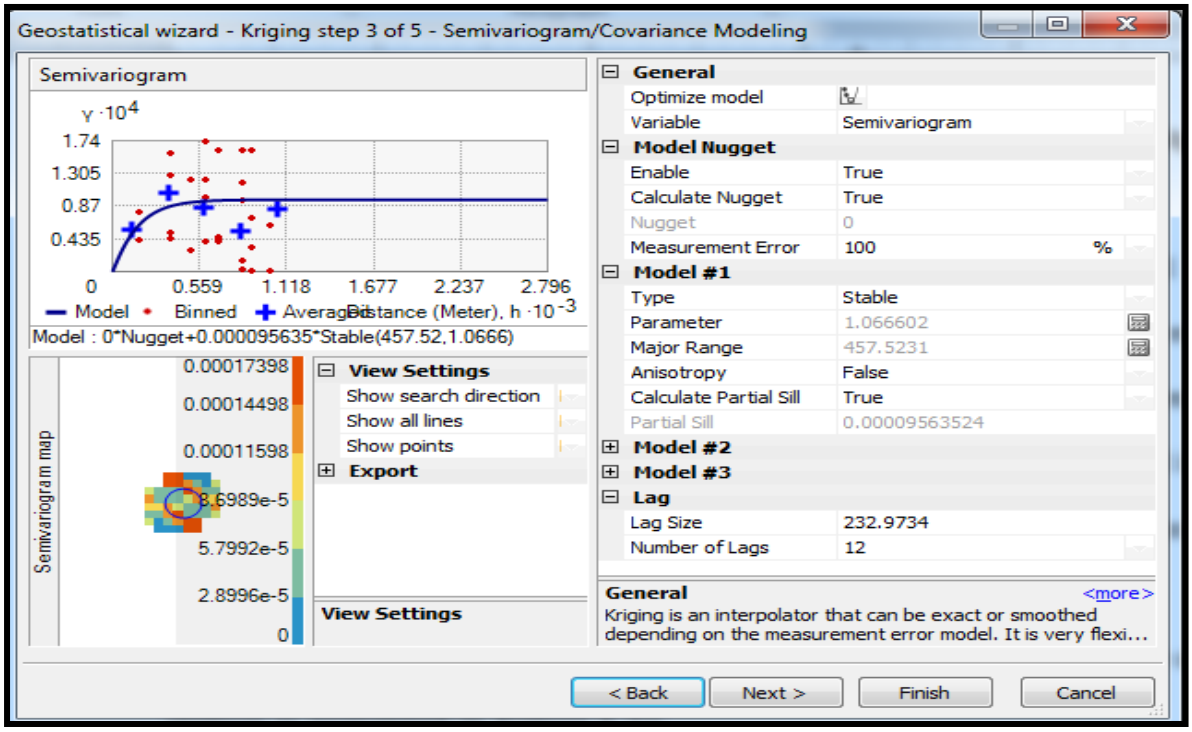

Figure 6: Semi-variogram model for the spatial distribution of sulphur (iv) oxide

The cross validation statistics of the gaseous pollutants, Ozone and sulphur (iv) oxide, and their spatial distribution around Ughelli West flow station are shown in Figures 7 and 8 respectively. Both figures give an idea of how well the models predict the concentration of ozone and sulphur (iv) oxide at the unknown locations in the study area. In Figure 7, the root mean square standard error was 0.8459251 while the average standard error value(the root mean square) which represents the absolute difference between the measured concentration of ozone and the predicted concentration of ozone gave a value of 0.01618 as observed in Figure 7, indicating a good interpolation model prediction for the prediction of the concentration of ozone around Ughelli West flow station. The root mean square, a common measure of accuracy, quantifies the differences betweeen the known and the predicted values at the unknown sample points. In Figure 8, the root mean square standard error was 0.70513551. The average standard error value which represents the absolute difference between the measured concentration of sulphur (iv) oxide and the predicted concentration of sulphur (iv) oxide gave a value of 0.008417 indicating a good interpolation model for the prediction of the concentration of sulphur (iv) oxide around Ughelli West flow station. These root mean square standard errors for the ozone and sulphur (iv) oxide around Ughelli West flow station are measures of uncertainty for these predictions and show the reliability of the predicted values. These results, which are the diagnostic statistics(root mean square error and the standard root mean square error) for ozone and sulphur (iv) oxide conform with the report of Chang (2014) that a better kriging method yields a smaller root mean square, and a standard root mean square closer to one(1).

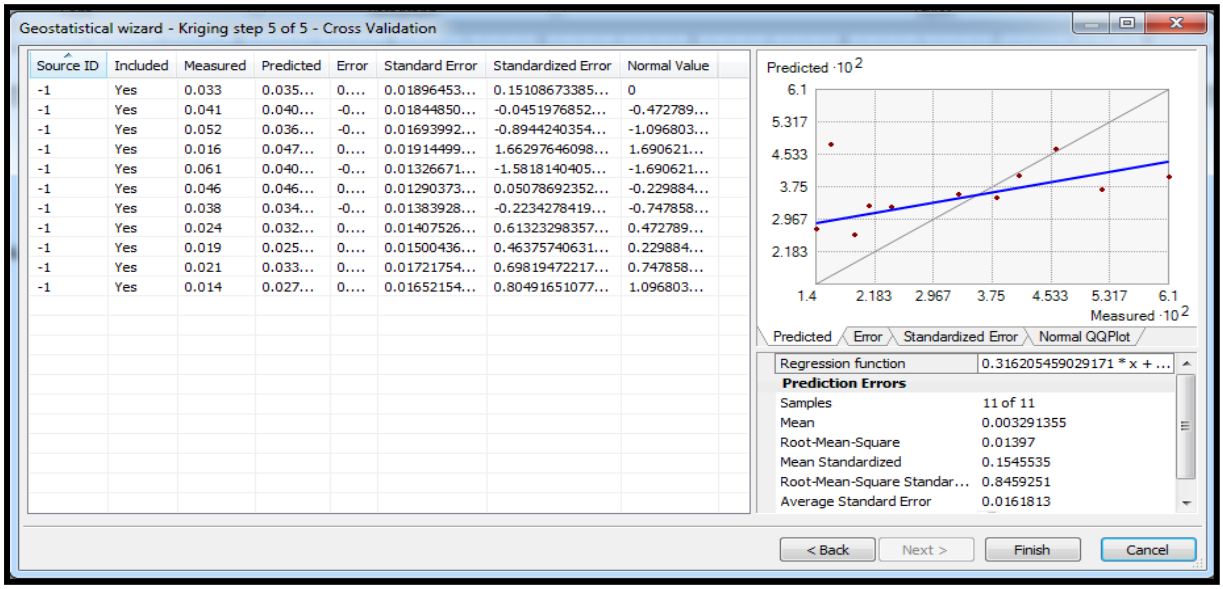

Figure 7: Cross validation statistics of gaseous pollutant(ozone) distribution in Ughelli West Flow Station

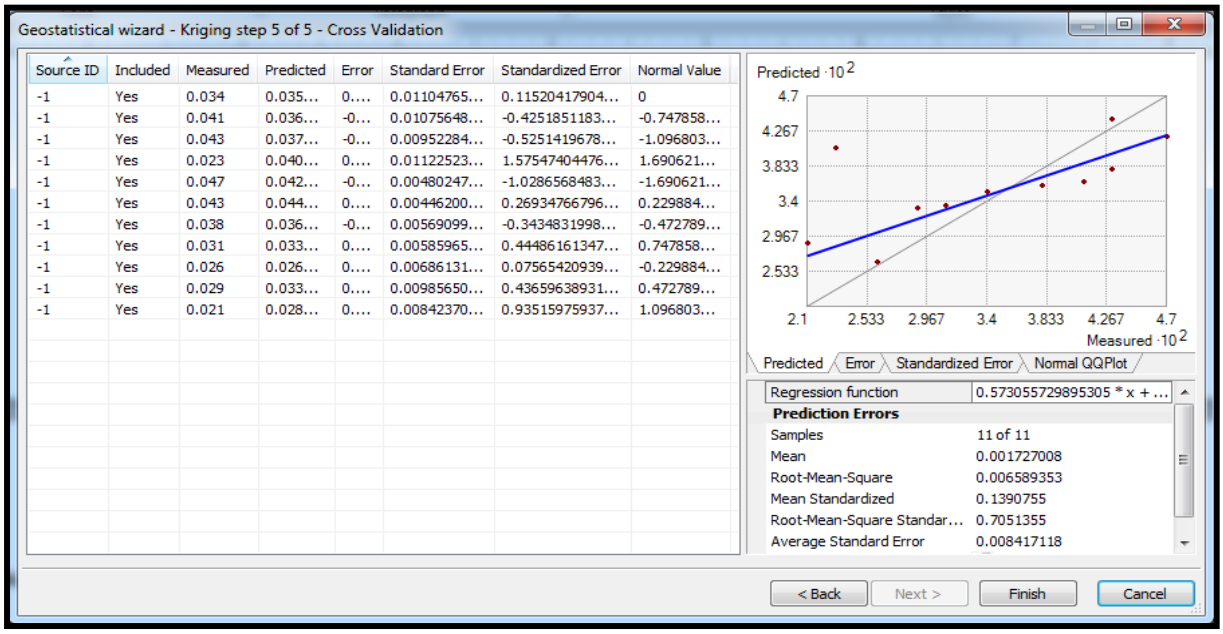

Figure 8: Cross validation statistics of sulphur (iv) oxide distribution in Ughelli West Flow Station

3.3. Prediction maps for spatial distribution of ozone and sulphur (iv) oxide around Ughelli West flow station

The prediction maps which show the spatial distribution of ozone and sulphur (iv) oxide around Ughelli West flow station are presented in Figures 9 and 10 respectively. It is seen from the prediction map of Figure 9 that areas with light brown and lemon colour will experience lower concentration of ozone while areas with purple and red colour will experience higher concentration of ozone. It is seen from the prediction map of Figure 10 that areas with light brown and grey colour will experience lower concentration of sulphur (iv) oxide while areas with purple and red colour will experience higher concentration of sulphur (iv) oxide. Besides, The prediction maps showed that from 400m and above the gaseous pollutants concentrations experience reduction.

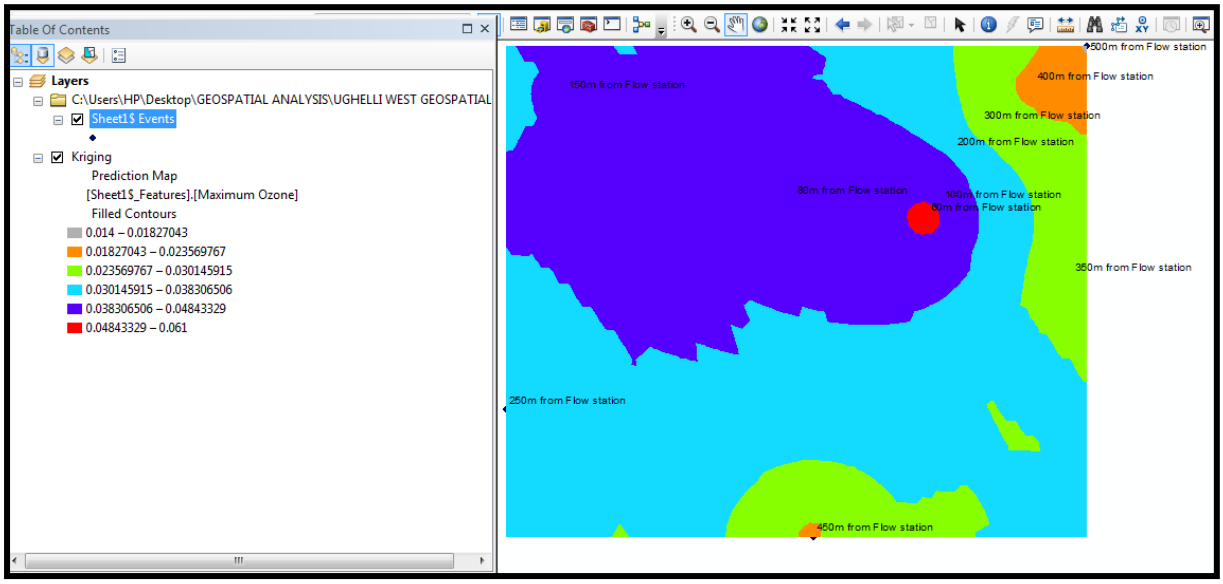

Figure 9: Prediction map for spatial distribution of ozone around Ughelli West flow station

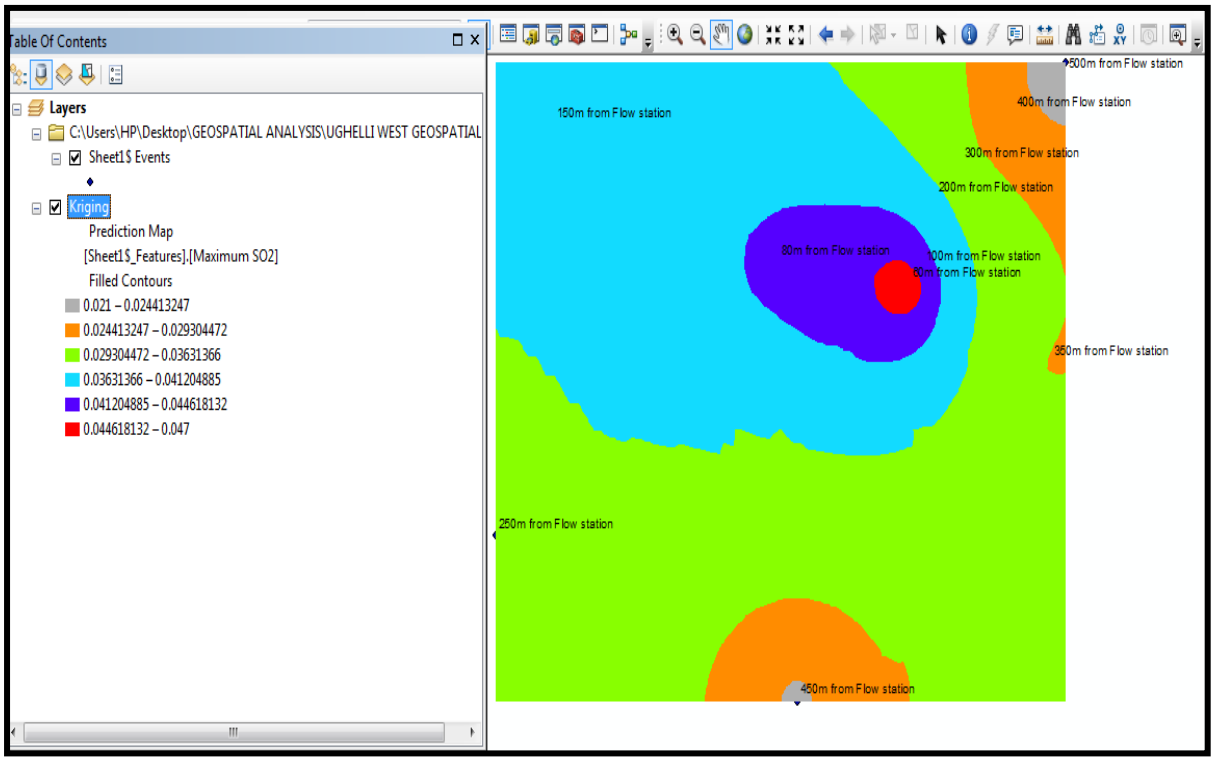

Figure 10: Prediction map for spatial distribution of sulphur (iv) oxide around Ughelli West Flow station

4.0 Conclusion

The geostatistical modelling and mapping of the level of concentration of gaseous pollutants around Ughelli West gas plant and flow station located at OML 34 of Delta State of Nigeria was carried out. Five gaseous pollutants, which were examined in the study area and their concentration determined, include VOCs, CH_4, NO_2, SO_2 and O_3. The results obatined from the diagnostic statistics for the ozone and around sulphur (iv) oxide around Ughelli West flow station show the reliability of the predicted values, since a smaller root mean square, and a standard root mean square closer to one(1) were obtained. The prediction maps do not only showed areas with lower pollutants concentrations which can be utilized for urban/town planning but also showed that from a distance of 400m and above the pollutants concentrations will experience reduction. The prediction maps are useful in the planning of residential areas since they provide relevant information about the spatial concentrations of gaseous pollutants in the study area.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 233 - 242

Tenants' Willingness to Pay for Green Features in Office Properties

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ABSTRACT

The study investigates tenants' willingness to pay for green features in office properties in Lagos, Nigeria. This is with a view to determining the inclinations of users to green buildings. Data for the study were collected through the use of structured questionnaire administered using purposive sampling. Tenants' Willingness To Pay Index (TWTPI) was used to measure the tenants' willingness to pay for green building features. The features considered were 'Water, Rain Water and Sewage', Site Selection, Site Design and Land Scape Ecology', 'Building Ecology, 'Waste and Recycling', 'Indoor Air Climate', Material use and Conservation', and Owner and Occupant Education'. The willingness of tenants to pay for features such as 'Energy Conservation', 'Water, Rain Water and Sewage' and 'Site Selection, Site Design and Land Scape Ecology' ranked first, second and third with TWTPI of 3.12, 2.72 and 2.71respectively. This finding shows that the majority of the features had a TWTPI of less than 3(out of 6) indicating that the level of willingness of tenants to pay for the majority of green features was below average. The paper advocates for relevant agencies to embark on aggressive awareness campaign which emphasizes the direct benefits of green building.

Keywords: Environment, Green features, Office properties, Sustainability, Willingness-To-Pay

1.0. Introduction

The turn of the century has witnessed an increasing concern for sustainability in real estate industry, with major stakeholders: investors, developers, and users trying to embrace sustainability agenda (Royal Institute of Chartered Surveyors, 2010). While the concern may be partly attributed to global focus and advocacy for sustainable investment, the additional benefits and costs that may be incurred by investing or occupying sustainable or green building have combined to produce a formidable force for driving sustainability agenda in the real estate industry. While it will take extra costs to integrate green features in building construction, the benefits of incorporating the features include reduction or elimination of negative impacts on the environment, energy efficiency, water efficiency, improved health and wellbeing of occupiers, higher rental rate, and lower vacancy rate (World Green Building Council, 2013; McGraw Hill Construction, 2014).

Investment in green buildings has been encouraged through government legislation in most developed economies. However, evidence in literature suggests that the response by the private sector has been slow owing to lack of evidential proof of economic viability of green building investment (Myers *et al*., 2007). Meanwhile, the willingness of tenants (space consumers) to pay and the extent to which they are willing to pay for green features are major concerns of the developers and investors particularly in emerging economies at present. Whether the tenants are willing to pay additional costs for green features or not has been a main subject of sustainable investment literature of recent (see for instance, Banfi *et al.*, 2008; Wiencke, 2013; Simons *et al.*, 2014). Such information is demonstrably

valuable in providing an improved understanding for the potential and viability of green building investment.

Sustainability in property investment, particularly the willingness to pay for green features has to date been dominated by developed economies such as the United States of America, the United Kingdom and Australia. Evidence from literature shows that majority of the studies were carried out in developed economies where strong advocacy for sustainable development exist. While a few studies (e.g. Oladokun *et al*., 2010; Nwokoro and Onukwube, 2011; Oyewole *et al*., 2012; Komolafe *et al*., 2016; Oyewole and Komolafe, 2018), have been carried out on sustainable or green building in developing and emerging countries like Nigeria, studies on tenants' willingness to pay for green features are lacking. Meanwhile, sustainability as reasoned by Krosinsky and Robins (2008) has more urgent priorities among world's growing countries. It is imperative for Nigeria and other emerging economies of the world to adopt sustainable property investment owing to the fact that the countries are confronted by unprecedented population growth, environmental degradation, and poor living and working environment. This study therefore bridges the observed omission in literature by investigating the tenants' willingness to pay for green features in office properties in Lagos, Nigeria.

Studies relating to willingness to pay for green features abound. Grosskopf (2003) examined the extent to which "capital construction costs and life-cycle return on investment influenced tenants' willingness to pay for green building alternatives" in Florida. The author complemented the performance of more than 100 high efficiency buildings simulated in the three major climatic regions to a consumer willingness-to-pay survey of more than 400 new home buyers. The result showed that willingness to pay for social and ecological benefits excluding economic returns vary widely from 33.8% to 61.1%. It was also revealed that willingness to pay decisions of respondents vary mainly by age and income. Yau (2012) examined residents' willingness to pay and preferences for green housing features in Hong Kong. The author employed structured questionnaire survey and found that apart from moral or altruistic reasons, residents' willingness to pay was largely influenced by monetary incentives. The study also revealed that residents were more willing to pay for features directly linked with reduction in utilities bill. However, it should be noted that the investigation was carried out on residential property investments and not office properties.

Kotchen *et al*. (2013) estimated the willingness to pay in support of a national climate-change policy that was akin to the costs of actual legislative efforts in the U.S congress. The authors carried a survey of 2034 American adults and found that households were willing to pay between 79 and 89 dollars per year in support of reducing domestic greenhouse gas emission. Apart from the fact that the study was carried out in a developed economy, the study did not specifically targeted office property users.
Wiencke (2013) investigated the firms' willingness to pay for green features in Switzerland. The author employed data from corporate real estate and sustainability survey and found that Swiss corporations were willing to pay a premium price of 3.0% for leasing, 4.75% for purchasing and 5.0% for retrofitting. The result also showed that firms from building and financial service industries as well as public corporations and authorities indicated the highest willingness to pay.

Simons *et al*. (2014) examined office tenants' willingness to pay for green features in the United States of America. The study considered eighteen (18) green building features and discovered that tenants were willing to pay a premium of 9.3% on office buildings. The result also indicated that the tenants' level of willingness to pay ranked highest for improved indoor air quality and access to natural light. Apart from the fact that the study was carried out in a developed economy, the study covered a fewer number of green features to the exclusion of other features such as "availability of tenants' sub-metering (on energy, water etc.) and "availability of waste reduction work plan" among others.

Park *et al*. (2013) investigated consumers' willingness to pay for certain green features of residential buildings in Seoul. The authors employed conjoint analysis and ranking method found that the marginal willingness to pay for 1% reduction of carbon dioxide emission was estimated about 377 USD, two times higher than that for reduction of volatile organic compound VOC emissions and almost the same as that for the reduction of energy bills. The result also indicated that energy bill was most preferred while IT facilities were the least preferred by the residents. Although the study was

carried out in an emerging economy, the study did not consider office property users. Zalejska-Jonsson (2014) measured the stated and rational willingness to pay for green apartment in Sweden. The study considered the responses of residents of green and conventional multi-family buildings to investigate the existence of willingness to pay and to test the difference in the perception of those living in green and those living in conventional building. The result showed that respondents were willing to pay for green building but not as willing to pay for buildings *with environmental certificate.*

In the Nigerian context, Oladokun *et al*. (2010), explored the perception of property developers and tenants on the prospects and difficulties associated with the adoption of green buildings. The analysis revealed that the respondents were not willing to adopt green building but were of the opinion that green building would be desirable in the future. Oyewole *et al*. (2012) investigated the degree of involvement of Nigerian real estate investors in sustainable (green) property investment practice. The authors carried out a survey of eighteen property companies in Lagos and found that insignificant attention was given to social and environmental issues in their investment activities. Although, the study focused in the Lagos property market, the perception of the tenants who are the occupiers of the investment properties was not examined.

Komolafe and Oyewole (2015) examined the estate surveyors and valuers' perception of users' preference for green features in office properties in Lagos. The study employed relative preference index and revealed that users preferred most of the green features to conventional building features. However, the study only considered the opinions of real estate practitioners and not the views of the users who were the object of the study.

In an attempt to bridge the gap in the previous study (Komolafe and Oyewole, 2015), Oyewole and Komolafe (2018) examined users' preference of office properties. The study focused on the users of office buildings in Lagos and found that users' preference for green features in office properties was above average. The analysis also revealed that features relating to 'building ecology, waste and recycling' were the most preferred, while those relating to 'owner and occupant education' were the least preferred. Though, the study focused on the preference of the users, the extent of their willingness to pay for the respective feature was not investigated.

Olaleye *et al*. (2015) examined the perception of industrial and commercial property users on green buildings. The study employed mean and relative importance index, and found that 'reduced resource utilization' and 'improved quality of work life' were the two top tanked advantages that could prompt industrial and commercial property users to pay for green features.

This paper is germane for two reasons. First, the study covers more features of green buildings unlike the previous studies (Park *et al*., 2013; Simons *et al*., 2014) that focused on some specific elements. Second, existing studies on sustainability, especially in Nigeria literature (Oyewole *et al*., 2012; Olaleye *et al.*, 2015; Oyewole and Komolafe, 2018) focused less on tenants' willingness to pay for green features. Office property tenants are viable target for investment in green building and are very important to sustainable development agenda particularly in the area of built environment.

2.0. Methodology

In order to investigate the tenants' willingness to pay for green features in office properties, the study employed data collected through questionnaire from the tenants of office properties in the management portfolio of estate surveying and valuation firms in Lagos in Lagos, Nigeria. In total 88 (representing 20% of 440 estate surveying and valuation firms in the study area) were sampled for ease of coverage. In the administration of questionnaire, 2 office properties were sampled purposively from the portfolio of each sampled firms. The selection was purposively done to cover different location, age of the property, use intensity and tenant type. In each selected property, two tenants were selected purposively from each sampled property. Thus, a total of 352 tenants in 176 properties were selected for sampling.

In earlier works by the authors (Komolafe and Oyewole, 2015; Komolafe *et al*., 2016), building attributes with energy conservation; indoor air climate; material use and conservation; water, waste

and waste recycling; site selection, site design and landscape ecology and owner and occupant education features were identified as green features. These features constitute variables used in this study.

The respondents were asked about their socio-economic characteristics; their perception as to whether they were willing to pay; their level of willingness and the amount they were willing to pay for the respective green features. The tenants were further asked to rate each of the features using Likert's scale of *not at all willing, willing to pay a cost premium 1-5%, willing to pay a cost premium of 6-10%, willing to pay a cost premium 11-20%, willing to pay a cost premium 21-30% and willing to pay a cost premium of above 30%*.During analysis, these ratings were assigned weight values of 1, 2, 3, 4, 5 and 6 respectively. The tenants' willingness to pay index (TWTPI) for each of the variables was arrived at by dividing the summation of weight value (Total weight value - TWV) by the total number of respondents. The TWV is the addition of product of the number of responses to each of the variables and the weight values attached to each rating (see Afon, 2007; Oyewole, 2010). The TWTPIs thus ranged between the values of 6 and 1. This is expressed mathematically as:

$$TWV = \sum_{i=1}^{6} P_i V_i \tag{1}$$

where:
TWV is the total weight value,
P_i is the number of respondents rating an attribute *i*, and
V_i is the weight assigned to each attribute *i*.

The TWTPI to each attribute is arrived by dividing TWV by the summation of the respondents to each of the six ratings of an attribute. This is expressed mathematically as:

$$TWTPI = \frac{TWV}{\sum_{i=1}^{6} P_i} \tag{2}$$

where:
TWTPI is the relative willingness index and P_i is as defined previously.

The closer the TWTPI of an attribute is to six, the higher the assumed relative willingness. The mean of the TWTPI distribution was computed. The deviation about the mean of each variable was also computed to measure the scatter in the data relative the mean

3.0. Results and Discussion

In presenting the results of the study, the paper first examined the characteristics of tenants and subsequently on their level of willingness to pay for green features.

3.1. Characteristics of tenants

The characteristics of office properties' tenants are as shown in Table 1 below. The result shows that majority of responding tenants are males (59.8%), whose ages range between 31 and 40 years (35.3%) with first (HND/B.Sc) degree (41.1%). The result also reveals that majority of the respondents were senor staff (29.0) with between 6 and 10 years of experience.

The analysis of the occupation of the respondents indicates that they were engaged in various activities such as professional services, financial services, recruitment and training, business services and manufacturing. The result further reveals that majority of the respondents (44.8) were engaged in business services, while 27.4%, 12.9%, 7.5%, and 7.5% were engaged in professional services, financial services, recruitment and training and manufacturing activities respectively.

Table 1: General characteristics of tenants

Characteristics	Frequency	Percentage
Gender		
Male	144	59.8
Female	97	40.2
Total	241	100.0
Age		
20-25	30	12.4
26-30	67	27.8
31-40	85	35.3
41-50	33	13.7
51 and above	8	3.3
No response	18	7.5
Total	241	100.0
Highest Educational Qualification		
O' level certificate	19	7.9
ND	90	37.3
HND/BSc	99	41.1
Masters	18	7.5
PhD	0	0.0
No response	15	6.2
Total	241	100.0
Occupation		
Professional services	66	27.4
Financial services	31	12.9
Recruitment and training	18	7.5
Business services	108	44.8
Manufacturing	18	7.5
Total	241	100.0
Official Designation		
Business Owner	28	11.6
General Manager/Assistant	31	12.9
Sectional Head/assistant	46	19.1
Senior Staff	70	29.0
Junior Staff	48	19.9
No response	18	7.5
Total	241	100.0

3.2. Tenants' willingness to pay for green features

This section examines the willingness of users to pay for green building features. The willingness of the responding tenants to pay is examined across the categories of green features examined earlier. The result on the cost premium willing to be paid on each category by the users is as presented in Table 2. The tenants' level of willingness to pay for green features was assessed. This is through tenants' willingness to pay index (TWTPI), computed for each of the green features.

The result in Table 2 showed that majority of the features had a TWTPI of less than 3 (out of 6). This indicates that the level of willingness of tenants to pay for majority of green features in the study area was below average. The study also revealed that the features that ranked first and second in terms of TWTPI are 'energy conservation' with TWTPI of 3.12 and 'water, rain water and sewage' with TWTPI of 2.72 respectively. This finding is in line with Oyewole and Komolafe (2018) that property users in the study area were confronted with severe difficulty in the area of power and water supply. Office property users in the study area depend mainly on public power supply which is erratic in supply necessitating the provision of additional source of power. The tenants might also be willing to pay for water saving facilities to ration the use of water which is considered essential for their daily usage.

The analysis on green features relating to energy conservation shows that 'Availability of contingency plans for power supply' attracts the highest TWTPI of 4.87 while 'Growing of natural vegetation in the surrounding environment attracts the lowest TWTPI of 1.97. The average TWTPI for this group of features is 3.12. Other features with TWTPI higher than average are 'Installation of low-basic energy lighting' (4.01),'Design for low energy intensive in-house and public transportation' (3.45), 'Energy recovery ventilation systems' (3.35) and 'Use of natural cooling systems' (3.15). Each of the features

in this category thus had a positive deviation about the mean. The implication of this is that the degree of willingness to pay for these features is higher than average level of willingness the tenants had to pay for green features relating to energy conservation. Further analysis indicates that six of these features had the negative deviation about the mean of TWTPI. These features are 'Use of natural cooling systems', 'Use of solar cells, winds or photovoltaic means for power supply', 'Use of natural lighting systems', Maximizing the contribution of passive solar energy without reducing the comfort in periods with high solar exposure', 'Energy optimized windows', Design for energy efficient deconstruction and recycling' and Growth of natural vegetation in the surrounding environment'. The deviations about the mean of TWTPI for features relating to energy conservation for the above listed features are -0.11, -0.28, -0.37, -0.38, -0.94 and -1.15 respectively.

The result of the study on features relating to 'Water, rain water and sewage' reveals that' Water saving toilet and bath facilities' shows that the highest WTPI is 4.55 while the least is 1.94. The feature with the highest WTPI was 'Water saving toilet and bath facilities' while design for dual plumbing had the lowest. The average TWTPI for features in this category is 2.72. Other feature with TWTPI higher than the average for this group of features is 'Water efficient plumbing features' with TWTPI of 3.84. Features such as 'Collection of rain water for Utilization to lessen pressure on potable water', 'Waste water reutilization', Pressure reducing mechanisms on the plumbing features' and 'design for dual plumbing features' had a negative deviations about the mean of group of features in this category. A glance at the result also shows that the aforementioned features with negative deviations also attracted TWTPI of less than average (less than 3 out of maximum 6) implying that the level of tenants' willingness to pay for the features was low.

Regarding features relating to 'Site selection, site design and landscape ecology', 'Access to public transport within reasonable time' attracted the highest TWTPI (4.25), followed by 'Good lighting controls' (3.55), while 'A green common area is included in the main plot attracted the least TWTPI (1.98). The average TWTPI for this category of green features is 2.71. Other features with TWTPI higher than the average of all features in the group are 'Space sufficiency' (3.50) and 'Design is flexible to allow for easy conversion' (3.45). The finding as revealed in the table shows that the willingness of tenants to pay for most (eight) of features in this category of green features is below average (3 out of 6).

Among features relating building ecology, waste and recycling, 'Control of site pollution' attracted the highest TWTPI (4.15) among features as most tenants were willing to invest in properties with features that would enable them to safeguard pollution with a view to ensure that their offices are located in an area 'free from contamination' which ranked next with TWTPI of 4.12. The average TWTPI for the green features relating to 'building ecology, waste and recycling' was 2.64. Other features with TWTPI higher than the average included 'Right channelization of water drain' (3.95) and 'Availability of storm water management measures' (2.95). Features with TWTPI lower than the average of this category of features included 'Noise from installations is kept moderate and under control' (2.45), 'Waste water is treated from sinks and showers' (2.12),' Means of waste diversion from living areas where it could be toxic' (2.08),' Facilities for Storing and Handling Recyclable Materials' (2.01),' Measures to ensure that food or food waste is well contained' (1.95),' Collection points for sorting wastes into paper, glass, metal and plastic for treatment' (1.90) and 'Construction, renovation and demolition waste management policy' (1.36). Each of the features in this category thus had a negative deviation about the mean of TWTPI of features relating to 'Building ecology, waste and recycling'. The implication of this is that the degree of willingness of tenants to pay for these features is lower than the average of their willingness to pay for green features relating to building ecology, waste and recycling.

The result of analysis on green features relating 'Indoor air climate' shows that TWTPI of most of the features was below average (3.00) and also attracted negative deviations about the mean of TWTPI (2.38) of the group. Location of air intakes far from sources of pollution' attracted the highest TWTPI (4.39) followed by 'Building design to utilize natural and cross ventilation' (3.43). Other features such as 'In-door materials that are less air-toxic', 'Mechanical ventilation of enclosed parking areas', 'Building effective local exhaust into heavy equipment rooms', and 'A building design which avoids the need for air condition/cooling systems' (1.15) had TWTPI lower than the average and negative

deviations of -0.37, -0.50, -0.95 and -1.23 respectively. The results show that features not directly associated with occupants comfort had TWTPI lower than the average suggesting that tenants had low priority for the features.

Among features relating to 'Materials use and Conservation', 'Availability of equipment on-site to deal with environmental emergencies' ranked highest in terms of TWTPI (3.51) followed by 'use of durable materials' (TWTPI = 3.15) while 'Avoidance of Foam materials using CFC and HCFC' ranked least with a TWTPI of 1.44. The average TWTPI for this category of green features is 2.21. Further analysis indicates that five of these features have negative deviations about TWTPI of green features relating to 'Materials use and Conservation'. These features are 'Use of materials that protect against the local weather conditions', 'Water installations, cable works and related installations without toxic PVC', 'Use of recyclable/recycled materials in construction', 'Use of natural and local materials in construction' and 'Avoidance of Foam materials using Chlorofluorocarbon (CFC) and Hydrochlorofluorocarbon (HCFC)'. The implication of this is that the level of willingness of tenants to pay for these features is lesser than the average level of willingness to pay for 'Materials use and Conservation'. The deviations about the TWTPI for that category of features are -0.06, -0.15, -0.56, -0.70 and -0.77. The level of willingness to pay expressed by respondents on 'Availability of equipments on-site to deal with environmental emergencies' is not unexpected as the tenants who were involved in various business activities, would always be willing to make provision for the protection of their lives and properties.

The aggregate (mean) of tenants' level of willingness to pay for features relating to 'Owner and Occupant Education' is 1.84. Further analysis indicates that two features have positive deviation about the mean of TWTPI of features relating to 'Owner and Occupant Education'. These features are 'Availability of regular procedure for checking and fixing leaks' (2.41), 'Availability of checklist of items connected to Indoor Air Quality that must be discussed with architects, engineers, contractors, and other professionals prior to renovations and repairs' (1.97), 'Availability of regular maintenance schedule' (1.87) and 'Availability of Emergency response Manuals' (1.85). The result reveals that all features in this category of green features attracted TWTPIs that are lesser than the average (3.0 out of 6.0). The implication of this is that the level of willingness of the respondents to pay for these features was low.

In summary, the finding of this study showed that tenants were more favourably disposed and willing to pay for green features that confer comforts to occupants rather than those that confer benefits to the environment. This finding is not unexpected and in line with the outcomes of the earlier studies (Komolafe and Oyewole, 2015; Oyewole and Komolafe, 2018) on the preference of users for green features. The implication of this is that the tenants were more inclined to pay for features that confer occupants comforts such as 'Availability of contingency plans for power failure', 'Water saving toilet and baths facilities', 'Access to public transport within reasonable time', and 'Location of air intakes far from sources of pollution', it is recommended that tenants should be educated on the importance of features that are eco-friendly in order to enhance the sustainability of built environment.

Table 2: Tenants' willingness to pay for green features

Green features	TWTPI	TWTPI – $\overline{TWTPI}$	Ranking
Energy Conservation			**1**
Availability of contingency plans for power failure (eg…power inverter, solar products and kits……)	4.87	1.75	1
Installation of low-basic energy lighting	4.01	0.89	2
Design for low energy intensive in-house and public transportation	3.45	0.33	3
Energy recovery ventilation systems	3.35	0.23	4
Use of natural cooling systems	3.15	0.03	5
Use of solar cells, winds or photovoltaic means for power supply	3.01	-0.11	6
Use of natural lighting systems	2.84	-0.28	7
Maximizing the contribution of passive solar energy without reducing the comfort in periods with high solar exposure	2.75	-0.37	8
Energy optimized windows	2.74	-0.38	9
Design for energy efficient deconstruction and recycling	2.18	-0.94	10
Growth of natural vegetation in the surrounding environment	1.97	-1.15	11
	3.12		
Water, Rainwater and Sewage			**2**

Green features	TWTPI	TWTPI – $\overline{TWTPI}$	Ranking
Water saving toilet and baths facilities	4.55	1.83	1
Water efficient plumbing features	3.84	1.12	2
Collection of rain water for Utilization to lessen pressure on portable water	2.03	-0.69	3
Waste water reutilization	2.01	-0.71	4
Pressure reducing mechanisms on the plumbing features	1.95	-0.77	5
Design for dual plumbing	1.94	-0.78	6
	2.72		7
Site Selection, site design and land scape ecology			**3**
Access to public transport within reasonable time	4.25	1.54	1
Good lighting controls	3.55	0.84	2
Space sufficiency	3.50	0.79	3
Design is flexible to allow for easy conversion	3.45	0.74	4
Availability of controllable internal or external blinds and light fixtures that prevent glare at Visual Display Terminals	2.45	-0.26	5
Shading of glazing (windows) is achieved when necessary	2.43	-0.28	6
Building design allows for non-destructive inspection	2.42	-0.29	7
Sufficient acoustic privacy	2.30	-0.41	8
Ease, in open office areas, to engage in a conversation using a normal voice, understand a phone conversation, and have a private conversation using lowered voices	2.16	-0.55	9
The design is planned for an easy access to technical installations	2.08	-0.63	10
Sustainable landscaping	2.00	-0.71	11
A green common area is included in each main plot of land	1.98	-0.73	12
	2.71		
Building Ecology, Waste and Recycling			**4**
Control of environmental Pollution	4.15	1.51	1
Freedom of building area from contamination	4.12	1.48	2
Right channelization of water drains	3.95	1.31	3
Availability of storm water management measures	2.95	0.31	4
Noise from installations is kept moderate and under control	2.45	-0.19	5
Waste water is treated from sinks and showers	2.12	-0.52	6
Means of waste diversion from living areas where it could be toxic	2.08	-0.56	7
Facilities for Storing and Handling Recyclable Materials	2.01	-0.63	8
Measures to ensure that food or food waste is well contained	1.95	-0.69	9
Collection points for sorting wastes into paper, glass, metal and plastic for treatment	1.90	-0.74	10
Construction, renovation and demolition waste management policy	1.36	-1.28	11
	2.64		
Indoor Air Climate			**5**
Location of air intakes far from sources of pollution	4.39	2.01	1
Building design to utilize natural and cross ventilation	3.43	1.05	2
In-door materials that are less air-toxic	2.01	-0.37	3
Mechanical ventilation of enclosed parking areas	1.88	-0.50	4
Building effective local exhaust into heavy equipment rooms	1.43	-0.95	5
A building design which avoids the need for air condition/cooling systems	1.15	-1.23	6
	2.38		
Materials use and Conservation			**6**
Availability of equipment on-site to deal with environmental emergencies	3.51	1.3	1
Use of durable materials	3.15	0.94	2
Use of materials that protect against the local weather conditions	2.15	-0.06	3
Water installations, cable works and related installations without toxic PVC	2.06	-0.15	4
Use of recyclable/recycled materials in construction	1.65	-0.56	5
Use of natural and local materials in construction	1.51	-0.70	6
4Avoidance of Foam materials using CFC and HCFC	1.44	-0.77	7
	2.21		
Owner and Occupant Education			**7**
Availability of regular procedure for checking and fixing leaks	2.41	0.57	1
Availability of checklist of items connected to Indoor Air Quality that must be discussed with architects, engineers, contractors, and other professionals prior to renovations and repairs	1.97	0.13	2
Availability of regular maintenance schedule	1.87	0.03	3
Availability of Emergency response Manuals	1.85	0.01	4
Availability of readily available operating manual covering standard control settings and operating instructions for all services equipment that may affect the energy consumption	1.84	0.00	5
Availability of documented measures to control pollutants at source in areas	1.82	-0.02	6

Green features	TWTPI	TWTPI – $\overline{TWTPI}$	Ranking
such as washrooms, kitchens, printing areas, chemical storage and general storage areas			
Availability of communications to tenants on the environmental measures that they can implement in the building	1.80	-0.04	7
Availability of Waste Reduction Work plan	1.78	-0.06	8
Regular check of outdoor air intakes to ensure that the openings are protected and free from obstruction.	1.75	-0.09	9
Availability of tenants' sub-metering (On energy, water, etc.)	1.72	-0.12	10
Availability of carbon dioxide monitoring or sensors to maintain pre-set levels of carbon dioxide.	1.65	-0.19	11
Availability of "Use & Maintenance" manual	1.62	-0.22	12
	1.84		

4.0. Conclusion

The study has provided information on the willingness of office property tenants to pay for various categories of green features. The aim is to evaluate the desire and readiness of tenants (office space users) to invest in green buildings. The degree of willingness of tenants to pay for various categories of green features was assessed through tenants' willingness to pay index (TWTPI). Moreover, the objective was to gain insight into the preparedness of office space users to embrace green buildings in the country.

The study also established that the willingness of tenants to pay for most of the groups of green features was low. Most of the features such as 'Water, Rainwater and Sewage' (2.72),' Site Selection, site design and land scape ecology' (2.71), 'Building Ecology, Waste and Recycling' (2.64), 'Indoor Air Climate' (2.38), 'Materials use and Conservation' (2.21) and 'Owner and Occupants' Education' (1.84) attracted TWTPI of less than the average (3.0 0ut of 6.0). Efforts should therefore be intensified to educate the tenants on the benefits of the features. It was also discovered that some green features such as 'Design for dual plumbing', Construction, renovation and demolition waste management policy', and 'Availability of use and Maintenance manual' ranked low in terms of tenants' willingness to pay. This might not be unconnected with what Oyewole and Komolafe (2018) ascribed as the level of importance of such features to management rather than tenants who might not have property management responsibilities. There is therefore the need to educate the users on the importance of such features to achieving full sustainability of built environment.

It is essential to point out some of the limitations of this study. First, features considered in this study were extracted from the various rating systems for green buildings in the developed economies and adapted as in Komolafe and Oyewole (2015) and Komolafe *et al.* (2016) owing to the absence of green building rating system in Nigeria. Second, some of the respondents (19.9%) were junior staff who might not be in position to take decision on the payment of rent. The researcher resulted to obtain information from this group of people owing to the absence of their superiors. Third, because the purpose of the study was to examine tenants' willingness to pay for green features, the study did not investigate the factors responsible for their willingness.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 243 - 247

An Evaluation of the Trends in Land Values around Institutions of Higher Learning in North Central Nigeria

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ABSTRACT

The need to study trends in land values around institutions of higher learning cannot be over-emphasized. Numerous studies in Nigeria have investigated the economic and social influence of the siting of institutions of higher learning at the micro, meso and macro levels. However, very few studies have evaluated the extent at which such institution influences local land values. Institutions, to a large extent, exert an element of control on the physical and environmental aspects of their immediate vicinity. Therefore, attention must be in place to evaluate the influence of such control on land values. This study examined the trend in land values using the Mann-Kendall analysis in order to determine monotonic increase, decrease or stability in the land values across six institutions of higher learning for the period between 2004 and 2014. Specifically, the results of this study revealed that land values have either been increasing or remained stable in all institutions. The study finally recommends measures that can be put in place as counter measures for land values across institutions of higher learning.

Keywords: Land, Value, Trends, Institutions, Physical Environment

1.0. Introduction

Land occupies a unique place in the development process of any society. The supply of usable land is, however, limited (Shaba *et al.*, 2013). The importance of land to man on earth through all ages can hardly be over emphasized. Land provides a platform on which man's activities are predicated (Wildcat *et al.*, 2014). The location of institutions of higher learning has the potential of affecting the price and value of land. Similarly, competitions in the land market (as a determinant for price) are likely to be affected by locational factors. Such trends to a large extent, determines and controls the price of the land in such locations (Ayala *et al.*, 2018). Land is a valuable asset, and is controlled mainly by the level of social economic development, level of competitions, and crime rates (McLaren and Hawe, 2005). The growing demand for land has led to increase in land price; this became heightened with the increase in institution of higher learning in all parts of the nation. Consequently, over the past two to three decades, the land pricing market in Nigeria has experienced an upward trend due to growth and increase in number of Institution of Higher Learning across all parts of the nation.

Considering the current challenges of rapid growth in educational institutions in North Central Nigeria, consistent economic depression and high level of poverty, a study that seeks to improve understanding in the current state price determination system is probably most desirable. Aribigbola (2008) emphasizes that there is an urgent need to create conditions in which all sections of society understand the land market mechanism.

Most institutions in North Central Nigeria has grown consistently in academic programmes and student numbers since the 1990s when the government at the time was committed to the expansion of higher education as one of the development strategies to enhance education for the necessary economic and social development in Northern Nigeria (Fadare, 2013). From that time, student population, social and developmental amenities have increased in North Central Nigeria by over 33% (Ladan, 2004). There is no gain saying that the demand for higher education in North Central Nigeria is expanding (considering the contribution of successive administrations in Nigeria) and pushing the student population growth upwards which is factored by the transformation (social and facilities provisions inclusive) of educational institutions. As an example, some Polytechnics were "upgraded", while new universities were also established.

Institutions of higher learning can greatly influence both the physical and environmental aspects of their immediate vicinity; attention must be taken to understand the influence of such changes on land values driven by locational factors (Akbari *et al.*, 2004). By understanding the trends in land values over time, effective retrospective and prospective flux in land values can be better mitigated using policies and counter measures (Cernea and Christopher, 2000). The aim of this paper is to evaluate the trend of land values and in relation to the siting of institution of higher learning from selected institutions in North Central Nigeria.

2.0. Methodology

The study area is North Central Nigeria. It consists of the seven states situated geographically in the middle belt region of the country, spanning from the West, around the confluence of the River Niger and the River Benue. The region itself is rich in natural land features, and boasts some of Nigeria's most exciting scenery. The study focused on three states, which are, Niger, Nasarawa and Kogi State (Figure 1).

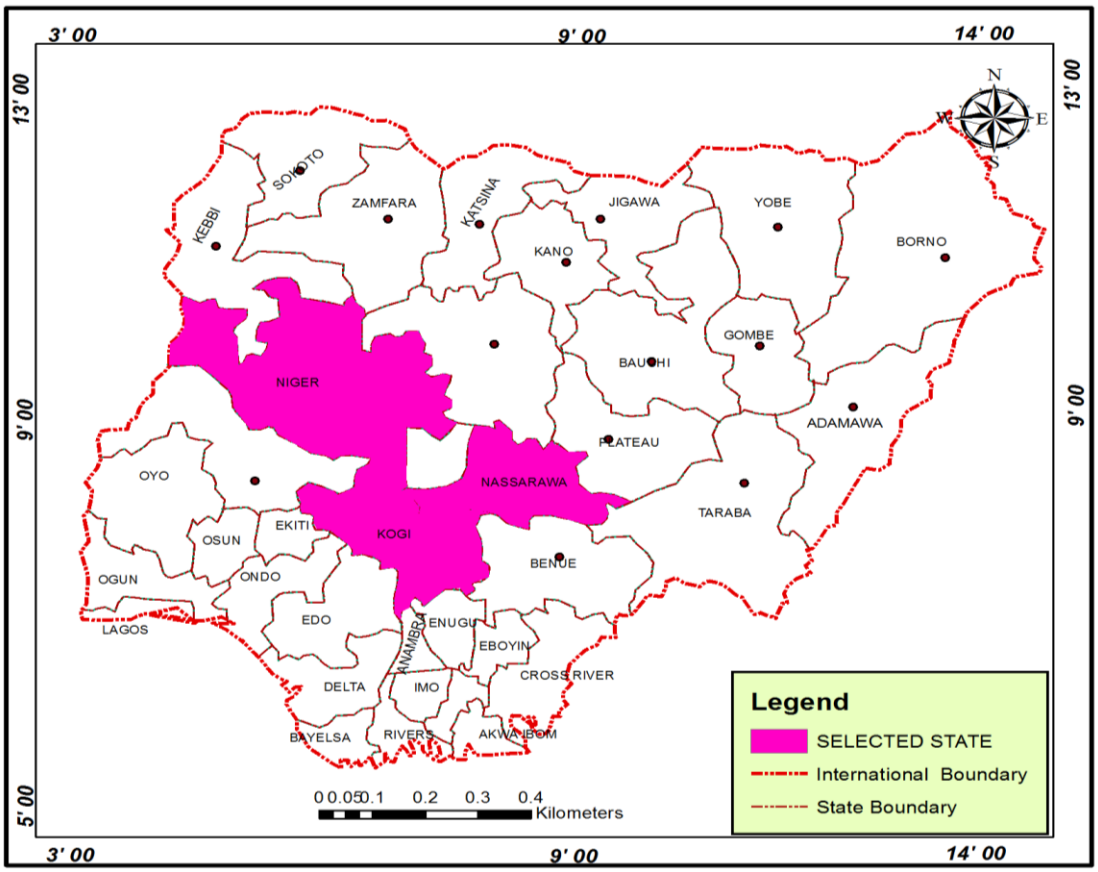

Figure 1: Location of selected states in North Central Nigeria
(Source: National Space Research Development Agency, Abuja)

This paper focuses on the trend of land values across six institutions of higher learning in North Central Nigeria. The six institutions selected are: Nasarawa State University Keffi (NSUK), College of Education Akwanga (COEA), Federal University of Technology Minna (FUTM), Federal College of Education Kontagora (FCOEK), Kogi State University Anyigba (KSUA), and Federal College of Education Okene (FCOEO).The geographical scope of this work covered an area of 6km radius around the selected institutions. Further to the 6km grid, it should be noted that each of the sample institution were selected based on the premise that the adjoining geographical landscape for land development around the institution were not hindered by any natural geographical factor which could affect plots of land available. The analysis also involved collection of data on the values of land across the sampled institutions. In order to estimate the land values across the sampled institutions, Mann Kendall analysis was used to determine monotonic increase, decrease or stability in land values around the higher educational institutions. The Mann-Kendall trend statistic (S) is dependent on the Confidence Factor (CF) and the Coefficient of Variation (COV).

The trend is said to be decreasing if Z is negative and the computed probability is greater than zero. If Z is positive and the probability value is greater than the level of significance, the trend is said to be increasing. The trend is said to be stable or 'no trend' if the computed probability is less than the level of significance.

The test statistic Kendall S is calculated as:

$$S = \sum_{j=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \tag{1}$$

where:
x data values at times j and k
n length of the dataset

$$(x_j - x_k) = \begin{Bmatrix} +1 \; if \; (x_j - x_k) > 0 \\ 0 \; if \; (x_j - x_k) = 0 \\ -1 \; if \; (x_j - x_k) < 0 \end{Bmatrix} \tag{2}$$

$$Var = \frac{|n(n-1)(2n+5) - \sum t(t-1)(2t+5)|}{18} \tag{3}$$

The Mann-Kendall test has two parameters that are of importance for trend detection. These parameters are the significance level that indicates the test strength and the slope which indicate the direction as well as the magnitude of the trend. The notation t is the extent of any given tie and Σt denotes the summation over all ties. In cases where the size $n > 10$, the standard normal value Z is computed by using Equation 4.

$$Z = \begin{Bmatrix} \frac{s-1}{\sqrt{Var(s)}} \; if \; s > 0 \\ 0 \; if \; s = 0 \\ \frac{s+1}{\sqrt{Var(s)}} \; if \; s < 0 \end{Bmatrix} \tag{4}$$

In order to evaluate the trends in land values around each of the Institution, the following operations were carried out before applying the Mann-Kendall Model using Macro Files in SPSS:

a) Raw data on land values were assembled from secondary data records and government archives for the period between 2004 and 2015. A summary of the aggregated data used in this study (2004 - 2014) is presented in Table 1.
b) The raw data on land prices were divided into two groups (see Table 1). The first group contained data on prices of land already sold; the second, contained current prices of available

land. For the plots that were already sold, the total area of the plot size were aggregated with the cost of the land, thereby producing an average value for a plot size with the buffer zone around each institution for the first and second groups.

c) Finally the Mann-Kendall Model Macro file was applied to determine the trends in land values across the sampled institutions.

Table 1: Summary of Aggregated Data for Land Values Matrices of the Institutions.

Year/Inst. 2004-2014	Cost of Land Sold N/Plot	Cost of Land Available N/plot	Aggregation matrix	Average Land Value	Number of Data Points
KSUA	176,131	161,073	0.9785	218,627	131
FCOEO	98,323	81,757	0.8007	129,129	189
NSUK	234,116	293,895	0.8129	239,630	114
COEA	127,114	106,032	0.9464	150,132	123
FUTM	323,567	318,170	0.9915	360,633	145
FCOEK	116,865	130,307	0.9974	171,135	109

3.0. Results and Discussion

3.1. Trend in land values

Tables 2 and 3 are the Mann-Kendall Trend for land value between 2004 and 2014 around each of the Institution. The analysis was applied to the time series of the price (or value) of the land to understand if between 2004 and 2014 their trends are increasing, decreasing or undefined (no trend).

At Kogi State University, a negative *Z* value coupled with a high *P* value for upward trend of 0.65 ($P < 0.05$) indicates that price of land around Kogi State University has been increasing.

Table 2: Mann-Kendall Matrices for Land Values

Year/Inst. 2004 - 2014	P-values for Upward trends in Land Value	P-values for Downward Trends in Land Value	Z values
KSUA	0.41	0.43	1.65
FCOEO	0.13	0.17	0.61
NSUK	0.41	0.61	-1.44
COEA	0.41	0.37	1.21
FUTM	-0.15	-0.09	2.57
FCOEK	-0.43	-0.35	2.16

FCOE Okene also recorded a high *P* value 0.61 ($P < 0.05$) showing an upward trend thus having the same result as Kogi State University. At NSUK, a negative *Z* value coupled with low *P* value for upwards and downwards trends shows that land prices have not been increased or reduced. At the College of Education Akwanga, the prices of land has been increasing due to the relatively high *P* value for upwards trend. The Federal University of Technology Minna also recorded an increasing trend in land price for the period between 2004 and 2014. This is as a result of the higher (0.57, $P < 0.05$).

Table 3: Summary of Mann-Kendall Trend for Land Values

Year 2004-2014	Land Value
KSUA	Increasing
FCOEO	Increasing
NSUK	No Trend
COEA	Increasing
FUTM	Increasing
FCOEK	Increasing

Decreasing = Negative trend in the Value of the land-Kendall trend ($p \leq 0.05$), Increasing = Positive trend in the value of the land Mann-Kendall trend ($p \leq 0.05$), No trend = relatively stable trend at ($p \leq 0.05$)
(Source: Results of Analysis)

Table 2 is a summary of the Mann Kendall analysis generated using changes in the price of the land with data generated from land agents and campus data services in each of the institution. In Kogi

State, between 2004 and 2014 the values of land were increasing at Kogi State University, and Federal College of Education, Okene. For the two institutions sampled in Nasarawa State, land values around NSUK showed no trend for the period between 2004 and 2014, but for the Federal College of Education Akwanga, the value of land was increasing. In Niger state land values around the Federal University of Technology, Minna showed an increasing trend while around the Federal College of Education Kotangora, land values also showed an increasing trend.

4.0 Conclusion

This study revealed that there is a significant relationship between land values and location-based factors around Institution of Higher Learning. By implication, the major determinants of land values around higher education institutions may be driven by the siting of such institution. It is also possible that changes in land price were possibly influenced by various factors such as demand for land from buyers, location, surrounding development and situation of the economy. This study finally recommends that before siting or administering land for any growth pole project (e.g. higher educational institution) attention should focus on the need to assign priority thresholds to other environmental factors that could cushion the distance-effects of such projects on land values.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 248 - 256

Collapsed Buildings: Whose Fault - Clients, Engineers, Architects, Quantity Surveyors, Town Planners or Contractors?

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ABSTRACT

Buildings collapses in the Nigerian major urban cites continues to engender an excessive number of fatalities, injuries and property damage. This study investigates whose fault, the clients, engineers, architects, quantity surveyors, town planner or contractors in the cause of incessant collapse of building in Lagos State. Two research approaches were employed - quantitative and interview protocol. The findings revealed that greed and engagement of quacks by building clients, lack of commitment by top management of contracting firms, bribery and corruption among town planning officers ranked highest. Thus, achieving sustainable environment, liveable, viable, quality buildings, and better performance deserves collective responsibilities of key participants in building construction delivery chain, particularly during the early planning and design stage. The study therefore, recommends that the key stakeholders should have a rethink and attitudinal change towards their roles and responsibilities in all matters concerning building construction process and save the country from wanton destruction of precious life and property resulting from incessant buildings collapses in our major urban cities.

Keywords: Building collapse, Collective responsibilities, Stakeholders, Nigeria

1.0. Introduction

The construction industry remains a high risk business, accounting for one of the major causes of fatalities in Lagos State. Research conducted by Dimuna (2010) to investigate the death rate resulting from building collapses in the Nigeria major urban cities between 2000 and 2010 indicated that Lagos had the highest behind Port Harcourt and Abuja. Thus, the roles of key participants and government agencies involved in building construction should be effectively investigated to avert incessant building collapses.

Over the years, residents of Lagos State have witnessed consistent building collapse leading to fatalities, litigation, regulatory actions, pains, injuries, delayed schedules, tarnished image of contractors, high costs of medical cares and loss of property, etc. On September 12, 2014, six-storey building guest-house belonging to the Synagogue Church of all Nations' at Ikotu in Lagos State collapsed and killed over 117 people mainly of other nationals who came to seek the face of God, and the report also had it that over 350 people were injured (Guardian, 2016). The death of 117 other nationals made headline news in both international and local newspapers. Again, on March 8, 2016, a five-storey building still under construction at Horizon 1, Lekki Gardens, Ikate in Lagos State collapsed killing 35 people and over 20 injured (Guardian,2016). This reckless destruction of precious lives is highly unacceptable.

Statistics show that in every one month 3-5 buildings collapse in the Metropolitan City of Lagos alone. This is translated to 35-60 buildings in a year. Thus, one may be prompted to ask the following questions. Who designed the buildings? Did the buildings receive approval plan from the appropriate authority? What are the competencies of the contractors employed to carry out the construction work

and supervision? Answers to these pertinent questions and more will reveal whose fault for buildings collapses in Nigeria major urban cities.

Natural occurrences outside the control of man such as earthquakes and tremors, landslide, flooding, high wind velocities like hurricane, etc. have contributed to building failures or total collapses in many parts of the World. For instance, Germany, USA, Chain, Russia, Spain etc. have suffered from these natural phenomena. However, in Nigeria the case is different as there are no records yet indicating that these natural phenomena have resulted in building collapses.

Building collapses could probably be attributed largely to design or construction related factors and the roles of clients and their appointed agents in not ensuring quality (Iyagba, 2009). It has been noted that absence of planning approval and improper soil investigation contribute to unsafe structure or failure (Iyagba, 2002). However, a critical review of the causes of building collapse points to failure of responsibilities and unethical behaviours of the key project stakeholders. Iyagba (2009) stated that reducing the spate of buildings collapse in Nigeria major urban cities requires transparent, commitment and ethical behaviour among the key project participants. For instance, the clients as the building owner and financier have responsibilities and duties under the common law and regulations to ensure that their buildings are constructed in a safe manner. However, instances have shown that clients, particularly private clients engage the services of quacks and sometimes abandon the original approved plan due to greed.

The endemic collapse of buildings in Nigeria major urban Cities, particularly Lagos State is worrisome to stakeholders, government and individuals. The colossal economic losses associated with these ugly events in terms of loss in human lives, property damage is highly unacceptable. Thus, there is a need for collective responsibilities of the key stakeholders in all stages of building delivering chain in order to reduce the spates of buildings collapses in Nigeria.

Previous research work focused on causes of buildings collapse in Nigeria such as: the menace of sick buildings (Iyagba, 2009), building disaster and failure (Fadamiro, 2002); incessant incident of building collapse in Nigeria (Dimuna, 2010), and building collapse and safety concern in Lagos (Guardian Newspaper, 2016). Set against these previous studies, this study seeks to fill in the gap by investigating whose fault among the clients, engineers, architects, quantity surveyors, town planner, or contractors to buildings collapses in Nigeria major urban cities. Examining duties and responsibilities of these key building participants at the early stage of building conception and designing will help in distributing liability for occurrence.

1.1. Literature review

1.1.1 Responsibilities and ethical behaviours of key stakeholders

Globally, causes of building collapses have been attributed to either natural disaster or failure of responsibilities and unethical behaviours of the key stakeholders. Nevertheless, in Nigeria studies have shown that the 99% of buildings collapses in the major urban cities are man-made that is failure of responsibilities and unethical behaviours of clients, engineers, architects, quantity surveyors, town planner and contractors. However, building failure or collapse can occur during construction and during use (Dimuna, 2010)). Thus, any type of failure or collapse in building that is not resulting from natural phenomena is traceable to failure of responsibilities and unethical behaviours of key stakeholders.

Arguably, achieving sustainable environment, liveable, viable, quality buildings, and better performance in the Nigerian building industry could be achieved through commitment and behavioural change of the key participants in the industry (Iyagba, 2009; Dimuna, 2010).

1.1.2 Clients' duties and responsibilities

Client commitment in the appointment of competent professionals is the first step for realisation of the quality building and performance (McAleenan, 2010). Client is required under the law to appoint competent professionals: architects, engineers, quantity surveyors, and project managers that will bring in their technical experts into use that will lead to the appointment of competent contractors to

carry out the intended building project in a safe manner. Client is also required to get approval from the town planning authority that conformed to all buildings standards in terms of designs criteria and Town Planning laws.

Investigations into many building failures or collapses have been linked to clients' lack of commitment both at the planning and construction phases. According to Akindoyeni (2002) the desirability of client commitment and involvement stems from the incessant of buildings collapse in our major urban cities that are associated with loss of lives, property damage and protracted litigation. Clients' roles and responsibilities to all stages of building delivering chain are of utmost important. Emphasizing the importance of clients' roles and responsibilities in terms of buildings quality and performance, Iyagba (2002) maintains that clients should demonstrate visible commitment through appointment of competent professionals, robust procurement methods, and prequalification of contractors. Failure by clients to discharge these onuses responsibilities at the early project planning could result in building failure or total collapse.

1.1.3 Duties and responsibilities of the appointed consultants

The quality of the building will be judged by the stability and durability of its structure (Oloke, 2010). It is the responsibility of an engineer to ensure stability and durability through design criteria. According to the British Standard (BS) 8110, the aim of any design is to achieve a probability that the structure being designed will perform an acceptable standard during their intended life span. According to John (2009), the goal of engineers in building design is to ensure that the buildings are designed and constructed in a safe manner so that the loads are sustained and transmitted safely.
Health and Safety Executive (HSE, 2010) maintains that designers should recognise their important roles concerning human lives as demanded by their professional codes of conduct by exercising diligent and due care when designing. The ILO (2010) emphasises that those involved with the design and planning of building should demonstrate visible commitment and ethical behaviour in discharging their professional responsibilities particularly during the early projects planning stages. Research conducted in both developed and developing countries show that design-related aspects have both direct and indirect impact on building stability or failure (Iyagba, 2009).

However, stability of buildings could be a function of strength of materials. Thus, Quantity surveyors' position as cost expert can alleviate most of the materials quality related problems by advising clients, architects and engineers on the alternative uses of construction materials in terms of quality, costs and its performance. Quantity surveyor being one of the key project stakeholders in construction project delivering chain, and more importantly as a cost expert to clients and contractors can influence building materials quality and its performance.

Paucity of funds is one of the major factors contributing to contractors' poor quality of work on site. Inadequate allocation of financial resources to building project during the early project planning or at the tendering stage could contribute to use of sub-standard materials by contractors on site (Brauer, 2006). Arguably, when contractors compromise standards due to lack of funds, the resultant effect will be building failure or total collapse.

1.1.4 The roles and responsibilities of Government towards building collapse in Nigeria

The Town and Country Planning Laws of each state of the Federation set out a development and planning control in place. The precept of these laws is aimed at controlling development to safeguard the public health and safety with particular reference to buildings and other developments. Legislation according to Bassey (1994) is always necessary to ensure that certain national, social and health needs are maintained. The non-compliance of the regulations by the officers of Town Planning Authority in some states of the Federation is worrisome. There are instances where the officers collude with the client or his agent to commence work on the site without the development permit as prescribed by the law.

The contraventions of these regulations have continued unabated as reported in many parts of the country thereby resulting in building failures and disasters (Fadamiro, 2002).The Guardian

Newspaper (2016) reported that greed and corruption are becoming increasingly more of Nigerian culture. The vices of corruptions affect our daily life.

Study conducted by Dimuna (2010) on incessant incident of building collapse in Nigeria identified the use of substandard materials, particularly by private clients as one of the major causes. There is a link between the quality of materials used on construction site and buildings collapses. Dimuna (2010) further contends that the use of substandard or inferior materials on construction site is attributed to high incidence of buildings collapses in our urban cities.

Unethical behaviour of building manufacturers and suppliers in Nigeria market has much to be desired. For instance, it has been discovered in Nigeria that manufacturer of steel rod, which is one of the common materials used in building construction, reduced the sizes of the steel rods from 12mm diameter to 11mm diameter in order to make profit (Guardian, 2016). This love of money over love of life is unethical and should be stopped. When materials are manufactured in accordance to acceptable standards, there is probability for reduction of buildings failure or collapse.

1.1.5 Duties and responsibilities of contracting firms

Contractors have duties and responsibilities under the common law to carry out building construction without causing harm to workers and the general public. This can be achieved through planning, organising, controlling and monitoring of the construction phases and coordinating activities of other contractors on site (Howarth and Watson, 2009). It is the commitment shown by the management of contracting company at all levels that determines how building process will be planned, organised, controlled, and monitored to ensure that quality is achieved. Hopkins (2008) and Markewichz (2009) maintain that achieving desired quality in building requires commitment and management skills. Similarly, Oloke (2010) argues that implementation of high quality building during construction is largely dependent upon commitment at all levels of management in an organisation.

The top management of contracting organisation has responsibility to develop standards and quality assurance of each element of the building process and share it among the departments. For instance, quality required for foundation, concrete mix, formwork, and standards of materials to be incorporated into work are determined by top management and shared as a core value in the organisation. It has been noted that positive behaviour of top leaders send messages to workers on value management places on quality.

Howarth and Watson (2009) stated that managers play a crucial role in promoting building quality on site. Studies comparing low and high failure incidence on structure have shown that on sites where managers show commitment in materials quality control and supervision, such buildings have better performance in terms of structural stability and durability (Dimuna, 2010). Hinze (2006) states that on a building site characterised with poor quality work are those with poor material quality control and absence of site supervision. Howarth and Watson (2009) assert that site managers, team leaders or supervisors play an important role in shaping workers understanding by communicating to them the company's work ethics. Management commitment and leadership skills demonstrated both at the top level and at the shop floor by any contracting organisation has impact on building quality and performance.

2.0. Methodology

To achieve the aim and objectives of this study, a mixed research method approach was adopted. The assumption underlying a mixed method to research represents the two extremes of data continuum (Flick, 2014). Research problems are better understood by employing both quantitative and qualitative methods in a complementary manner (Leedy and Ormrod, 2014). Supporting the adoption of mixed methods in research, Flick (2014) argues that the fundamental objective of a mixed method is to "attack a research problem with a compendium of methods that have no overlapping weakness, in addition to their complementary strengths". The current research involves human behaviour and therefore the mixed method was considered to be appropriate.

The qualitative method entailed conducting interviews. Interviewees were chosen from among Engineers, Architects, Contractors, Town planning Officers in Lagos State Ministry of Environment, Building Materials Merchants. The criterion for interviewee selection included knowledge of the field - should have been in practice for over ten years. Fifty professionals within Lagos State were contacted to participate in the study. However, twenty participated in the study. The decision to proceed with the twenty participants for the interview was made based on the fact that they have expert opinions on the subject matter.

Qualitative data collection does not rely on the statistical strength of the sample but rather on the quality of information. A phenomenological study can be conducted with less than twenty participants (Flick, 2014). Questions for the interviews were prepared beforehand in order to guide the discussions. An interview is an interaction between two or more people meant to gain insight relative to the identified problems (Leedy & Ormrod, 2014; Flick, 2014). The primary sources of the interview questions included literature review on causes of building failure or collapse (Fadamiro, 2002; Iyagba, 2009; Dimuna, 2010). In addition, the questions allowed participating professionals to discuss their expertise and competencies relative to building designs, supervisions and monitoring.
The discussions with each interviewee were audio recorded with the prior permission of the interviewee and transcribed. The researchers listened several times to the recorded opinions and suggestions and thereafter transcribed them. To enhance validity of the findings, the transcribed versions were sent to the participants/interviewees who indeed vouched that accurate versions of the discussions were obtained. The interview method of data collection assisted the researchers to have a well-represented sample devoid of bias and also to increase the validity and reliability of the collected data.

The quantitative data collection involved a distribution of questionnaires to engineers, architects, quantity surveyors, town planners, building merchants operating within Lagos State, Nigeria. The questionnaire consisted three sections. The first section dealt with demographic information. The "yes" and "no" type of responses were solicited in the first section. The other sections consisted of questions partnering to factors contributing to building collapses in Nigeria urban cities. Respondents were required to rate their responses on a five point Likert scale.

A total of 150 questionnaires were distributed to the targeted respondents. However, only 70 questionnaires were correctly completed, translating to a response rate of 47%. The face-to-face method was chosen for questionnaire distribution in order to overcome problems of low response rate as most targeted participants were ever busy professionals.

3.0. Results and Discussion

Analysis of demographic data of the respondents from the quantitative data collection method showed that, 43.3% of the respondents were between the age of 23 and 34 years, 56.7% were above the age of 35. Findings also showed that 25.2% of the respondents had worked in the construction industry for more than five years while 74.8% had worked in the industry for more than ten years. In terms of qualifications, 45% of the respondents indicated that they possessed Master Degree in their chosen professions and 82.2% indicated that they are registered members of their various institutes. The respondents' profile gave confidence to the researchers to conclude that the respondents were mature and their responses could be relied on.

3.1. Greed and engagement of quacks by building clients

In Table 1 presents answers pertaining to extend the respondents perceived greed and engagement of quacks by building client as a contributing factor to building collapse. The findings show that 67.7% of the respondents agreed to the statement, 23.7% did not agree, while 9.2% were not sure.

T**able 1:** Do you agree that greed and engagement of quacks by building client contribute to building collapse?

	Frequency	Percent
Yes	57	81.4
No	21	15.7
Not sure	2	2.9
Total	70	100

Greed and engagement of quacks by building owners have been identified as one of the contributing factors to building collapses in our major urban cities. Greed may exist in form of converting a bungalow designed building into two-storey building without regard to structural stability of the building (Akindoyeni, 2002). In addition to save cost some private clients become the purchasing officers of all the building materials and thereby end up buying inferior and substandard materials (Iyagba, 2009).

In the interview sessions, a question was posed to participants to elicit their perceptions on the extent greed and engagement of quacks by building clients could contribute to building collapse.

Q1- As a stakeholder in the building industry with years of experience, do you agree that clients' greed and engagement of quacks can contribute to building collapse? Almost all the interviewees answered "yes". One of the interviewees went further and stated that:

"Some private clients are the architect, the builder, the surveyor, the procurement officer, and the supervising engineer"

The involvement of competent professionals in planning and designing of building is very critical to its structural stability, functionality and performance. The desirability of clients' involvement and commitment to building stability, quality and performance was noted by Iyagba (2009), when he stated that clients should demonstrate visible commitment through appointment of competent professionals, robust procurement methods and prequalification of contractors.

3.2. Regular site visit/inspection by appointed consultants

The issue of regular site visit/inspection was investigated. Table 2 indicated responses from the respondents on the issue of regular site visit/inspections. The findings show that 35.7% of the respondents agreed that they regularly visit building construction site under their supervision. On the other hand, 55.7% indicated that they do not regularly visit site and 8.6% said that they were not sure.

Table 2: As appointed consultants do you visit building construction site regularly?

	Frequency	Percent
Yes	25	35.7
No	39	55.7
Not sure	6	8.6
Total	70	100

The need for stringent quality control in materials and workmanships on building construction site is very important. Regular site visits and inspections by appointed consultants is one of the factors that ensure or promote quality control in materials and standard of workmanship on sites. The neglect of quality control due to irregular site visits by consultant engineers have resulted in incorporation of low quality materials and poor workmanship on sites. In relation to the abovementioned topic, questions pertaining to how regular do you as appointed consultants visit site to ensure that your designs are being carried out.

Q2- As appointed consultants how regular do you visit building construction project under your supervision?

In response to these questions, one of the interviewees said:

"Construction clients, particularly the private owners do not employ the services of professionals where they do, they do not pay the charged fees, as a result I do not visit site regularly".

These comments supported the questionnaire survey finding of Akindoyeni (2002) study that 95% of building collapses in Nigeria major urban cities were owned by private individuals, as a result of their negligence in employing competent and professional engineers.

3.3. Factors contributing to unethical behaviour of key stakeholder toward building collapse

Table 3 indicates the respondents' rating of the extent to which each of the identified factors contributes to building collapses in Nigeria major urban cities. Table 3 shows in terms of percentage, the responses for each rating on a scale of 1 (minor) to 5 (major). It is notable that all the eight identified factors had the mean scores above the midpoint of 3.00, which, with an average MS of 3.44, indicated that the respondents viewed the identified statements as being contributing factors to building collapses in Nigeria major urban cities.

The findings indicate that the respondents perceived greed and engagement of quacks by building clients, lack of commitment by top management of contracting firms, bribery and corruption among Town planning officers, engagement of incompetent site supervisors, and greed and profiteering among building materials merchants. These factors were ranked highest on the list.

Table 3: Factors contributing to unethical behaviour of key stakeholder toward building collapse

Factor	Unsure	Response (%)					MS	Rank
		Minor…….Major						
		1	2	3	4	5		
Greed and engagement of quacks by building clients	4.2	6.3	11.9	25.2	29.4	23.1	3.51	1
Lack of commitment by top management of contracting firms	9.1	4.9	9.8	27.9	27.9	20.3	3.49	2
Bribery and corruption among Town planning officers	7.7	5.6	14.7	23.1	28.7	20.3	3.47	3
Engagement of incompetent site supervisors	8.4	7.7	10.5	27.9	31.5	13.9	3.46	4
Greed and profiteering among building materials merchants	6.3	5.6	11.9	40.6	12.7	13.9	3.44	5
Absence of quality control on building materials	5.6	9.1	12.6	29.4	32.2	11.2	3.43	6
Use of inferior building materials	7.0	9.9	16.9	26.1	24.7	15.5	3.42	7
Shortage of trained Town planning officer	7.7	6.9	18.2	30.8	27.3	14.1	3.41	8

Interviews conducted with the participants also corroborated the questionnaire survey results and literature.

One of the interviewees made the following comments:
"Greed and engagement of quacks by client, particularly the private clients in Nigerian construction environment is a major cause of building collapse in our urban cities"

Iyagba (2009) pointed out that instances have shown that clients, particularly private clients engaged the services of quacks and sometimes abandon the original approved plan due to greed. As state before, client is required under the law to appoint competent professionals that will bring in their technical expertise into use that will lead to the appointment of competent contractors to carry out the intended building project in a safe manner. In addition, the use of substandard building materials by private clients is another source of concern governments and individuals (Dimuna, 2010).

Q3- Do we have Construction Materials Regulation and Control Board in place that is equivalent to National Agency for Food Drug Administration and Control (NAFDAC) in Nigeria?

In response to this question, one of the interviewees answered with affirmative "*we have*".

He went further to comment that*: "The Construction Materials Regulation and Control Board of Nigeria (CMRCBN), is ineffective and bedevilled with lack of incompetent professional to carry out its aims and objectives". "That in the developed countries construction materials cannot be placed on the market without carrying out performance certification and warranty test". "The materials must undergo series of tests to determine its structural properties before it can be placed in the market"*

Unethical behaviour in form of bribery and corruption prevalent in Nigerian society according to Guardian (2016) impose serious challenges to all facets of our social lives and economic development. For instance, when Government officers compromise with importers of building materials or Town planner officers compromise with clients, the resultant effect will be increases in numbers of buildings disasters in Nigeria urban cities. Bribery and corruption has become a part of our social life and it should be rooted out in order to reduce its vices in our society. This value for money as against value for human lives is highly unethical and unacceptable.

4.0 Conclusion

Buildings collapses in the Nigerian major urban cites continues to engender an excessive number of fatalities, injuries and property damage. It deserves collective responsibilities of key participants in building construction delivery chain, particularly during the early planning and design stage. The clients as the owner and financier should demonstrate commitment through the appointment of professionals who bring in their technical know-how in selecting and appointing competent contractors to carry out the intended building project in most efficient and safe manner. Findings from the survey and interviews protocol indicated that client, engineers, architects, quantity surveyors, town planner, building materials merchant and contractors have pivotal roles and responsibilities in achieving livable, quality and functional buildings.

The study therefore, recommends the followings:

- That the existing Construction Materials Regulation and Control Board of Nigeria (CMRCBN), should be made to be more effective and live up to its aims and objectives.
- There is also a need to license contractors and specialist contractors for easy identification and investigation in a case of collapsed buildings, it is through this that apportionment of liability to persons or entity can be attained.
- The staffs of CMRCBN should be empowered through training and retraining to discharge their responsibilities more effectively.
- At the Federal and State levels both senior, middle and site managers of Town Planner Officers should undergo leadership and interpersonal skills development training.
- The key stakeholders should demonstrate commitment and ethical behaviour in carrying out their professional duties.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 257 - 265

Farmers' Participation in Agroforestry System in Northwestern Nigeria

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ABSTRACT

The aim of this study is to assess agroforestry practices in Northwestern Nigeria with a view to bringing to light some salient features of the system for maximising benefits and improving livelihoods of smallholder farmers in the study area. A total of one hundred and sixty six smallholder farmers were sampled using random technique from five hundred and fifty farmers' listed by the contact forum in the study area. Questionnaire was administered to the one hundred and sixty six smallholder farmers with a view to examining the level of farmers' participation in agroforestry in six villages namely Kabobi and Garki in Katsina State, Bulangu and Abonabo in Jigawa State, Bobo in Zamfara State and Gulma in Kebbi State. Interview was also conducted with ten farmers in Bulangu, Kabobi and Gulma to provide explanations on the limitation to acceptance of agroforestry innovations in the study area. Data collected with the questionnaire was analysed using simple percentage and frequency in order to measure dispersion among sampled farmers. Data collected from the interview was coded, transcribed and presented in textual form in the paper. Result of the study revealed that seven agroforestry systems (alley cropping, boarder line planting, scattered planting, woodlot, apiculture, orchard and home garden) were practiced in the area. Orchard and home garden were not practiced in Kabobi, the northern most of the villages. It also indicated farmers' level of participation for the seven identified technologies as follows: Alley cropping (25.63%), boarder line planting (16.25%), scattered trees on farmland (36.25%), woodlot (1.25%), orchard (1.88%), apiculture (8.75%) and home gardens (10.00%). The key factors limiting acceptance of innovations include: l) lack of tree seedling (25.00%), land tenure issues (17.50%), long tree gestation period of indigenous species (50.63%) and insect attack (06.88%). This study recommended that farmers should be educated more on agroforestry technologies through mass media programmes and ICT.

Keywords: Land management, Alley cropping, Livelihood, Smallholder

1.0. Introduction

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (Lundgren and Raintree, 1982). According to Leakey (1996) agroforestry is a dynamic, ecologically based natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land-users at all levels. This definition is employed in this study.

Agroforestry is not new system. It has been practiced for millennia by many cultures and societies in traditional farming systems throughout the world (Cook and Grut, 1989; Garrity, 2006). The World Bank estimates that 1.2 billion people practice some form of agroforestry on their farms and in their communities (World Bank, 2004). The system provides a range of goods and services such as food, fodder, fuelwood, and timber to farmers (ICRAF, 2009). It also offers one of the most promising

technological options for reversing soil degradation, restoring tree cover, and improving agricultural productivity in Africa (Mbow *et al*., 2014).

Being a feature of agriculture landscapes throughout the world, agroforestry was brought into the limelight due to concerns about the sustainability of agricultural development and the apparent rapid depletion of the natural resources (FAO, 2004). The system has drawn the attention of researchers due to its capacity to reduce the poverty and land degradation, improve food security and mitigate the climate change (Ahmad *et al*., 2017). In the last three decades, agroforestry has been widely promoted in the tropics as a natural resource management strategy that attempts to balance the goals of agricultural development with the conservation of soils, water, local and regional climate, and more recently, biodiversity (Izac and Sanchez, 2001). In the West African savanna, it is common for farmers to retain useful trees (which may also be difficult to fell and resistant to fire) when preparing a plot for cropping, thereby creating park-like landscapes of scattered trees between crop fields and rangelands that are typical of this region (Boffa, 1999). It is particularly significant in Nigeria, but the extent to which it is practised varies from region to region. The taungya system was first introduced to Nigeria in 1928 from Burma in a silvicultural experiment at Sapoba (Edo State) is widely adopted agroforestry practice in the rainforest and derived zones of Nigeria. In the Sahel region, however, scattered trees on cultivated or recently fallowed land form a characteristic land-use system commonly referred to as 'Parklands'. The most important and dominant tree species in used in this system include *Faidherbia albida*, *Butyrespermum parkii*, *Parkia biglobosa*, *Adansonia digitata*, *Tamarindus indica*, *Acacia tortilis* and *Prosopis africana* (Ado, 2012).

The degradation of forest resources poses serious challenges to the rural people who depend on forest resources for livelihoods. This has widened the gap between the demand and supply of forest products in Nigeria. The fundamental concern is however, finding alternative options to support rural livelihoods as well as reducing resource depleting due to shifting cultivation. After all the primary reason for forest destruction is man's ever-increasing demand for more land for producing food (Nair, 1982) and agroforestry offers possibilities for controlling that.

Nao (1978) described Nigeria as one of the countries with the most successful examples of agroforestry experiments particularly the agrosilvicultural types. Recently, other agroforestry practices have evolved in Nigeria. The most popular which Nair (1993) termed agrisilviculture and agrihorticulture are most accepted systems. Similarly, many of these agroforestry technologies have been trialled at research stations since 1980 and also on farms since 1984 in collaboration with farmers (Franzel *et al*., 2002). This indicated that a lot of studies were conducted on agroforestry in Nigeria. Some works that have covered the northern Nigeria or section include Chup, 2004; Adewusi, 2006 and Chukujekwu, 2010. Others are Kabir, 2011 and Ado, 2012. The aforementioned works showed that agroforestry is widely practiced in the northern Nigeria because of its potential on improving livelihood of rural farmers. Arguably, no work has studied agroforestry at regional scale in Northwestern Nigeria in recent time. Because of lack of readily usable and comprehensive information to guide farmers in the study area, this study assessed agroforestry practices in Northwestern Nigeria with a view to bringing to light some salient features of the system for maximising benefits and improving livelihoods in the area.

1.1. Study area

Northwestern Nigeria encompasses three distinct geographic entities namely the Sokoto-Rima Basin, the Kano Region and the North Central Highlands (Udo, 1970). Of Nigeria's total area of 923,768 km^2 (Federal Government of Nigeria, 2012), Northwestern region occupies 226,662 km^2 which encompasses seven states namely Kaduna, Kano, Jigawa, Katsina, Zamfara, Sokoto and Kebbi (Figure 1).

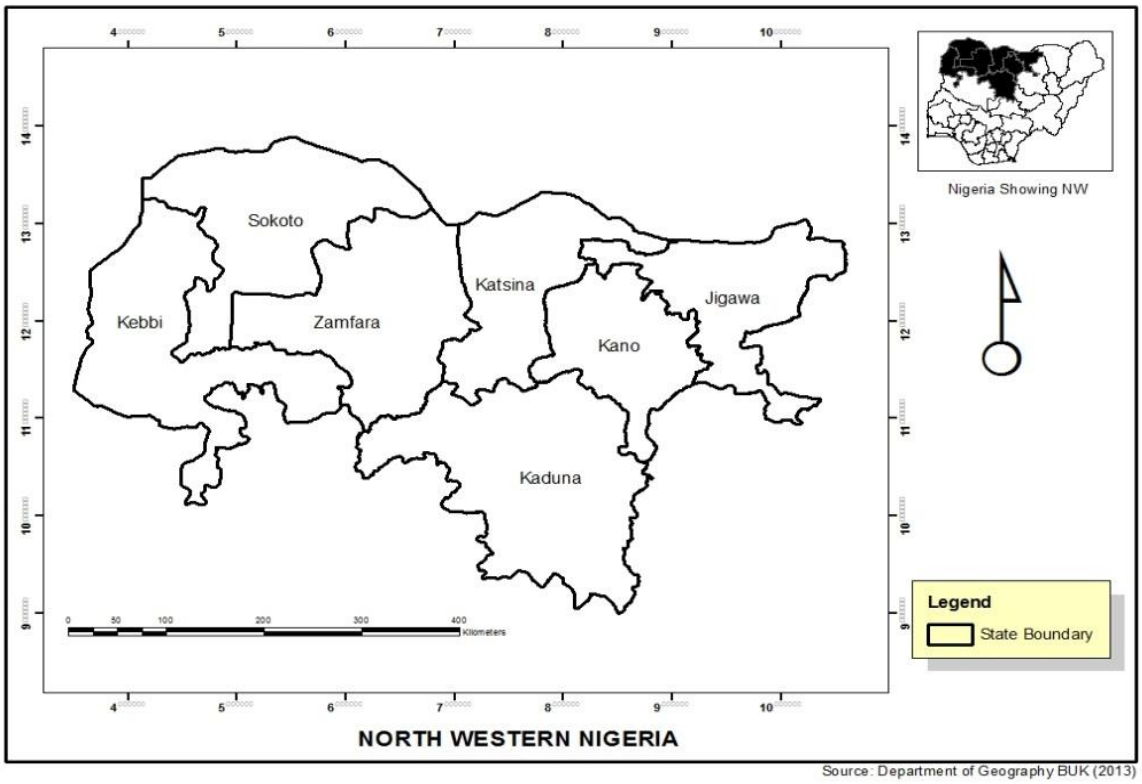

Figure 1: Northwestern Nigeria

Four states which this study covered namely Jigawa, Katsina, Zamfara, and Sokoto share common international border with the Niger Republic to the north, a major part of West African dryland. Total population for the study area was 17,144,135 (National Population Commission, 2006).

Climate of Northwestern Nigeria is the tropical wet and dry type. It is coded as 'Aw' by Koppen in which distinctive wet and dry seasons are caused by the fluctuations of the Inter-tropical convergence zone (ITCZ) or the Inter-tropical Discontinuity (ITD) south to north to bring rainy season and north to south to bring dry season. Climatic elements vary greatly from the southern tip through the central and extreme northern parts of the region (Iloeje, 1981). Average annual rainfall in dryland of Nigeria varies from 500 mm in the north-eastern part to 1000mm in the southern sub-area, but it is unreliable in many parts (Hess *et al*., 1996). A major climatic influence in the region is the periodic drought associated with periodic rainfall deficiencies (Swindell, 1982) which affect the vegetation growth especially of annuals.

Vegetation varies dramatically at both the national and local level in relation to climate, soil, elevation, and human impact on the environment in Nigeria. Northern Nigeria falls within the Sudan Savanna zone of the country which is distinguished by large expanse of grasslands with widely spaced trees of varying heights and diversity (Danjuma, 2017). This Savanna belt is found dominating the Sokoto Plains across to the Chad Basin, covering over a quarter of the country's land area. As a result of low rainfall and poor soil fertility, the natural vegetation of the northwestern Nigeria is made up of mainly thorn shrubs and trees dominated by grasses (Breman and de wit, 1983). Some of the most frequent species in this environment are: *Hyphaene thebaica, Parkia biglobosa, Adansonia digitata, Faidherbia albida, Tamarindus indica, Borassus aethiopum, Prosopis africana, Balanite aegyptiaca* and *Acacia nilotica.* Exotic species include *Acacia senegalensis, Azadirachta indica, Cassia siammea, Dolonix regia,* and *Eucalyptus camaldulensis* (Danjuma, 2017). Northwestern Nigeria is home of farming and livestock breeding (Ileoje, 1981). These two livelihood activities are the major economic activities in northwestern Nigeria, especially in rural areas. The dominant crops grown are staple ones including guinea corn, millet, maize and tubers (Swindell, 1982). The existence of these ecological patterns in Nigeria: the high forest in the south and the savanna region in the north resulted to the adoption of various types of agroforestry in the country.

2.0. Methodology

This study covered six villages in the dryland of Northwestern Nigeria namely: Bulangu and Abonabo in Jigawa State, Kabobi and Garki in Katsina State, Bobo in Zamfara State and Gulma in Kebbi State (Figure 2).

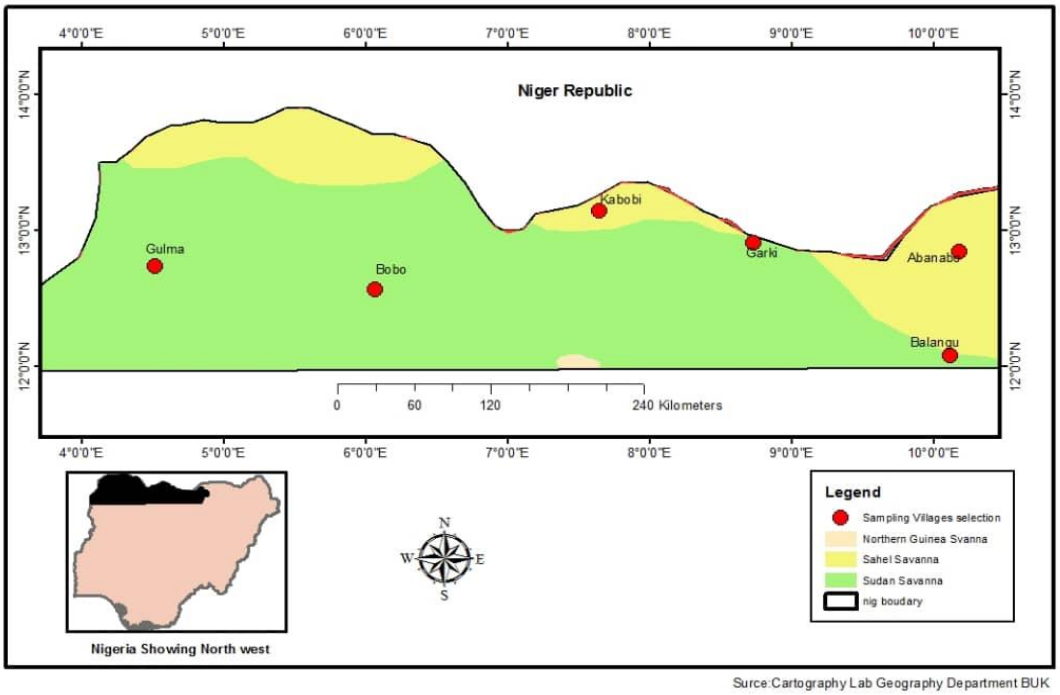

Figure 2: Dryland of Northwestern Nigeria showing study locations

A total of one hundred and sixty six respondents were sampled using random sampling procedure from the sampling frame of five hundred and fifty farmers listed by the contact forum in the study area. The sample is male dominated because out of the six villages studied, five have high male respondents of between 60-90% as follows: Bulangu (90%), Abonabo (60%), Kabobi (50%), Garki (80%), and Bobo (70%) (Table 1).

A total of ten farmers were also drawn using snowball sampling technique three each in Gulma and Kabobi and four in Bulangu for interview based on the understanding that Bulangu has the highest number of contact farmers; Gulma has the only female dominated sample and Kabobi has equal ratio of female to male.

Table 1: Number and Composition of the Sampled Farmers

SN	Study Village	State	No. of Respondents	No. of Male	No. of female
1	Bulangu	Jigawa	43	39	04
2	Abonabo	Jigawa	23	14	09
3	Kabobi	Katsina	17	09	08
4	Garki	Katsina	35	28	07
5	Bobo	Zamfara	30	21	09
6	Gulma	Kebbi	18	08	10
Total			166	119	47

Questionnaire was administered to collect information on the level of farmers' participation in agroforestry in the study area. All the questionnaires except six were retrieved two weeks after administration. Interview was also conducted in Bulangu, Garki, and Gulma to provide explanation on the limitation to acceptance of innovations in the study area.

Data collected with the questionnaire was analysed using simple percentage and frequency in order to measure dispersion among sampled farmers. Data collected from the interview was coded, transcribed and presented in textual form in relevant section of the paper

3.0. Results and Discussion

3.1. Farmers' participation in agroforestry practices in the study area

Agroforestry practices are numerous. According to Young (1989) there are hundreds, possibly thousands of agroforestry systems in the world but only 20 distinct practices. Result of this study showed that the area comprises seven agroforestry practices (Table 2). As in Table 2, variability existed among the study locations in terms of participation and adoption of the different agroforestry practices.

Of the agroforestry systems depicted in table 2, scattered trees on farmland (36.25%) and alley cropping (25.63%) were most extensively practiced in the study area. The system of scattered trees on farmland is widely practiced above all because it requires low investment and labour. Findings on alley cropping supported Adekoya (1997) and Ado (2012) who reported that because of the benefits of leguminous trees and shrubs on improving soil attributes (such as recycling nutrients and controlling erosion on sloping land), alley cropping is widely practiced in Nigeria. This study found that pearl millet and sorghum are cropped in the area between *Faidherbia albida* and *Acacia nilotica* for both ecological and socioeconomic benefits. However, many studies including Kang and Wilson (1987) have reported the growing emphasis on the system even in drier areas such as the northern Nigeria because the provision of nutrients through decomposing mulch is possible in these areas despite low rainfall.

Table 2: Level of farmers' participation in agroforestry practices

SN	Types of Agroforestry	Study Villages						Total	Percentage
		Bulangu	Abonabo	Kabobi	Garki	Bobo	Gulma		
		Freq.	Freq.	Freq.	Freq.	Freq.	Freq.		
1	Alley cropping	12	5	3	10	9	2	41	25.63
2	Boarder line planting	8	2	4	3	5	4	26	16.25
3	Scattered trees on farmland	12	7	7	18	7	7	58	36.25
4	Woodlot	-	-	1	-	1	-	2	1.25
5	Orchard	2	-	-	1	-	-	3	1.88
6	Apiculture	4	2	-	1	4	3	14	8.75
7	Home gardens	5	4	-	2	3	2	16	10.00
	Total	43	20	15	35	29	18	160	100.00

Woodlot (1.25%), orchard (1.88%) and home gardens (8.75%) are least practiced. These are very complex systems with a very sophisticated structure and a large number of components. Often woodlot and orchard requires a little more than what nature provides to start and thus farmers would neglect it.

3.2. Adoption of agroforestry practices in the study area

There is plethora of information on adoption of agroforestry systems globally. However, it is useful to learn why the farmers continue to practice such indigenous systems because the knowledge of factors influencing adoption helps in establishment of site-adapted system for productive and protective purposes. Result of this study indicated the main factor influencing the adoption of agroforestry in the study area is adequate market and linkages (Table 3).

Table 3: Factors influencing the adoption of agroforestry practices in the study area

SN	Types of Agroforestry	Study Villages						(nT)	%
		Bulangu (n)	Abonabo (n)	Kabobi (n)	Garki (n)	Bobo (n)	Gulma (n)		
1	Adequate market and linkages	33	12	11	27	17	6	106	66.25
2	Land holding size	10	8	4	8	12	12	54	33.75
3	(nT)	43	20	15	35	29	18		

(n) = number of respondents (nT) = total number of respondents

Except in Gulma, the farthest village with reported cases of land tenure abuse, respondents in the study area overwhelmingly indicated that market poses a major threat to the promotion of agroforestry in the study area. This finding corroborates Nikiema (2005) who reported that investment in parkland trees will require a set of criteria that give value to each of the potential plant products. One set of criteria that justifies the investment is the market potential of the plant resources. Olumide (2015) also reported that the important criteria for farmers to grow any new tree species depend among others on assured demand for the produce and ready market outlets, minimum support price, at which tree growing is profitable; and generation of cash surplus as the most powerful incentive for most farmers.

3.3. Constraints to wider participation of agroforestry practices in the study area

Despite widespread of potentials of agroforestry, many challenges hinders the scaling up of system in the study area. This work has shown that four factors limit wider participation of farmers in agroforestry in the study area. Long gestation period (50.63%) and lack of tree seed (25.00%) are the main factors limiting the expansion of agroforestry in the study area (Table 4). Finding of this study confirms Ado (2012) who reported that t he fear of delay in returns from long gestation period of trees was a limiting factor for wider participation in agroforestry in the Kano. It is also in line with Kofi *et al*. (2003) the major constraints to agroforestry in forest fringe communities in Ghana are inadequate education on tree tenureship, lack of seedlings, seasonal occurrence of plant and animal diseases and inadequate knowledge on logging procedures as well as poor marketing system are also major setbacks to the conscious introduction of agroforestry in the study area.

Table 4: Factors limiting participation of innovations

SN	Constraints	Number of Farmers	Percentage
1	Lack of viable seedlings	40	25.00
2	Land tenure issues	28	17.50
3	Long tree gestation period of indigenous species	81	50.63
4	Insect attack	11	06.88
Total		160	100.00

Furthermore, this study suggest that reliable seed supply and distribution system is required for up scaling agroforestry and this is largely missing in Nigeria without which farmers may be discouraged from practice and further investing in it. This finding is in line with Kindt *et al*. (2006) who reported that some tree species require many years before they produce seeds delaying investment returns and locking producers into selected products.

Result in Table 4 about other factors limiting farmers' participation on agroforestry is in line with findings of several authors such as Adekanye (2002) who hypothesized that land characteristics such as land and tree tenure, as well as tenure rights; social economic and demographic characteristics; and cultural norms affect farmers' willingness to cultivate agroforestry trees. Aturamu (2008) also indicated that under private user rights, farmers are expected to be more willing to invest in the cultivation of fruit trees because they retain exclusive rights to the benefits of such investments. A major hindrance to agroforestry in the Federal Capital Territory has been the existing land tenure system; which has largely restricted accessibility to land and its resources. It has also hindered individual investment in agroforestry in the study area (Chup, 2004). Land tenure and usufruct rights constraints impose some limitation on agroforestry participants in the drylands of eastern Africa (Jama and Zeila, 2005).

4.0 Conclusion

This study indicated that agroforestry is becoming a recognized land use system which is capable of overtaking other conventional methods of land management because of its potentials in improving farmers' livelihood in the study area. Agroforestry is perfectly the most adopted and accepted land use system in Northwestern Nigeria because about 160 farmers engaged in one or other form of the system in the area despite so many limitations. Evidently, this study concluded that alley cropping; boarder line planting and scattered trees on farms are widely practiced while orchard and apiculture are the least. Based on the findings from this study, the following recommendations are made:

1. Farmers should be encouraged to use new agroforestry technologies. As widely expected, many technologies are not popular hence there should be scaling up of campaigns through mass media programmes and ICT else the system will remain traditional despite innovations with win-win promises.
2. Women constitute a very large work force, yet only few participate in agroforestry practices in the study area. This study recommended that there is need to expand the level of participation of women in agroforestry which will improve livelihood and food security of teaming smallholders in the area.

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Nigerian Journal of Environmental Sciences and Technology (NIJEST)
www.nijest.com
ISSN (Print): 2616-051X | ISSN (electronic): 2616-0501
Vol 2, No. 2 October 2018, pp 266 - 274

Rainwater Harvesting System for Water Supply in a Rural Community in Edo State, Nigeria

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ABSTRACT

Water scarcity is still a major problem in many rural communities in Nigeria. In this study, a rain water harvesting system was designed for Ogbekpen, a rural community in Edo state, Nigeria. A conceptual model for rainwater harvesting was developed using the storm water management model (SWMM), Arcmap 10.1 software and daily rainfall data (2000-2016) obtained from the Nigerian Meteorological Agency (NIMET). Runoff, rainfall intensity and change in elevation of three designated catchment zones were taken into consideration. The results revealed that the total amount of rainwater that could be harvested annually (water supply) was 14,314,351.70 L (14,314 m^3) from an overall effective rooftop area of 6025.9 m^2. This was three times the annual water demand (4,317,965.60 L (4318 m^3)), thus demonstrating the capability of the system to meet annual water demand. The required tank capacities for zones 1, 2 and 3 were 870,412.76 L (870 m^3), 955,319.4 5L (955 m^3) and 788,629.88 L (789 m^3) respectively. Comparative physicochemical and microbial analysis of water from rooftops in the three zones and an existing storage well showed that the latter did not comply with drinking water quality guidelines, thus highlighting the importance of a proper conveyance and storage system to improve water quality and availability in the area.

Keywords: Rainwater harvesting, Water supply, Water demand, Storm Water Management Model (SWMM), Rural community

1.0. Introduction

Rainwater harvesting (RWH) primarily involves the collection, storage and subsequent use of captured rainwater. This is usually known to serve as the principal or supplementary source of water and is applicable for both potable and non-potable uses (Fewkes, 2006). Notably, RWH in developed countries mainly serves to compliment conventional non-potable uses such as clothes washing, toilet flushing, irrigation, and outdoor washings (Hermann and Schmida, 1999; De Gouvello *et al*., 2005; Schets *et al*., 2010; Golay, 2011). In most developing countries however, it provides means to cope with water shortages for both potable and non-potable use (Meera and Ahammed, 2006). In Nigeria, many rural communities still suffer the burden of having to trek long distances in search of water for daily domestic use, thereby wasting time meant for other productive ventures. However, where some form of water sources are available; its quality remains questionable with potential health risks. The quality of rainwater is directly related to the atmosphere as well as quality of materials used for catchment surfaces, gutters and storage tanks (Ariyananda, 1999). Conversely, in areas where the roof top is clean, impervious and made from nontoxic materials, rainwater is usually of good quality and does not require much treatment before consumption (Lekwot *et al*., 2012).

There have been some published studies on rainwater harvesting in Nigeria (Tobin *et al.*, 2013; Lade and Oloke, 2015; Shittu *et al.*, 2015; Abenu *et al.*, 2017). In a study assessing rain water harvesting systems in a rural community in Edo State, it was observed that rainwater harvesting, though widely practiced, was done using poorly designed and maintained systems, resulting in unacceptable levels of microbial contamination (Tobin *et al*., 2013). Abenu *et al.* (2017) investigated rainwater harvesting

as a strategy adopted by the inhabitants of Lokoja town, to meet domestic water needs, and reported that rainwater harvesting was adopted by more households in unplanned neighborhoods than planned neighborhoods.

The aim of this study was to design a rainwater harvesting system for Ogbekpen community, Nigeria using the storm water management model (SWMM) for efficient collection and storage of potable water to meet annual demand.

2.0. Methodology

2.1. Description of study area

Ogbekpen, a rural community in Ikpoba-Okha Local Government Area, Edo State, is located at 6° 8'52.52"N Latitude and 5°33'47.03"E Longitude and is 21 m above mean sea level. It has a tropical climate and receives high rainfall during the raining season, with severe water scarcity in the dry season (Ogwu *et al.*, 2014). Inhabitants of the growing Agrarian community are low income earners and have a major need to access water for domestic use. However, water collection in the community has remained burdensome. A Satellite image of the study area is presented in Figure 1.

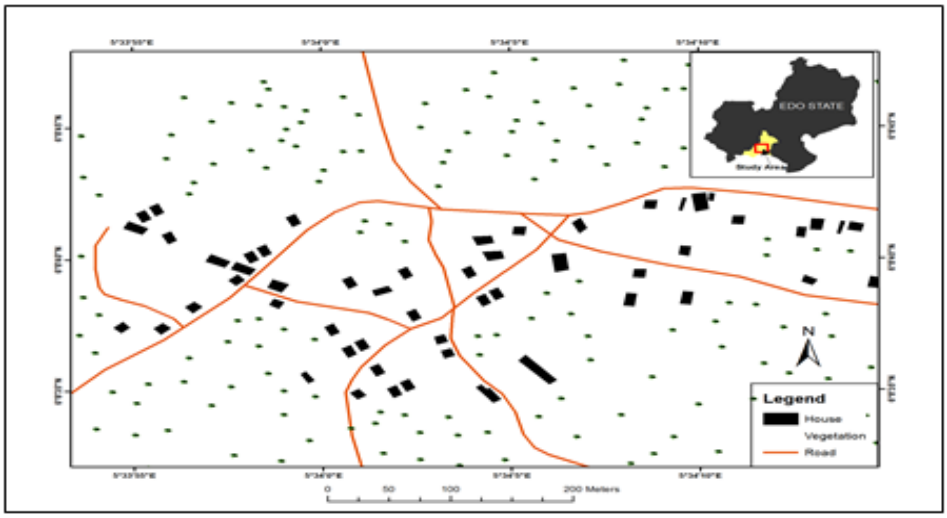

Figure 1: Satellite image of study area
(Source: Google Earth)

2.2. Meteorological data and rainfall analysis

Daily rainfall data for the period of 2000 to 2016 was obtained from the Nigerian Meteorological Agency (NIMET). The daily data was used to calculate the mean monthly and annual rainfall for the study area.

2.3. Delineation of catchment area

To determine the catchment zones that will contribute to rainwater harvesting in the study area, three zones were delineated, taking into cognizance their elevations. Storage units for harvested rainfall water were located at lower elevation zones for easy collection. Slopes were developed using Arcmap 10.1 contour tool. A Digital Elevation Model (DEM) of 30 m resolution was processed to generate a Triangulated Irregular Network (TIN) of the study area.

2.4. Routing of rainwater

This was carried out using kinematic wave method which is a hydrological modeling method. The kinematic wave model equation is developed from the continuity equation for unsteady channel flow with lateral inflow and Manning's equation (Eagleson, 1970).

2.4.1. Area contributing to runoff

The rooftop areas were digitized using Arcmap 10.1 to establish the area of contributing rooftop. Rooftops were considered based on clustering, to allow for ease of networking. Using the geometric calculation tool in Arcmap 10.1 the area of digitized rooftops was calculated.

2.4.2. Demand and supply of harvested rainwater

The monthly water consumption for the study area was computed using a per capita demand of 40 litres per person per day, given the population estimate of 215 (Federal Republic of Nigeria, 1991).

2.4.3. Estimation of storage tank capacity, sizing gutters and downspouts

Three storage tank locations were selected in the entire study area. To calculate the size of storage tank for each zone, the largest harvest of rainwater for each month was considered. As a safety factor, the tank was proposed with an increase of 20% of the required size (UN-HABITAT, 2005). The size of the rooftop gutters and conveyance pipes was then calculated. The gutter was designed using a minimum slope of ≤ 6.25% to allow easy flow of water along the gutter (Despins, 2010). The burial depth of conveyance pipe was then determined using the following equation:

$$D_i = D_f - L_p S_p + L_g S_g \quad (1)$$

where:

D_i Initial pipe burial depth in m
D_f Final pipe burial depth in m
L_p Length of pipe in m
L_g Length of pipe for which there is grade change in m
S_p Pipe slope factor (0.01 recommended)
S_g Grade slope factor (assumes downward slope)

2.4.4. Modeling and design of rainwater harvest system

The Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) software was used to model and design the rainwater harvesting system. This was done by considering the runoff, rainfall intensity and change in elevation in various catchment zones. The model was used to establish the length and size of pipes and location of storage points based on some hydrological parameters. In carrying out the actual rainwater modeling, rainfall intensity for 5 mins interval was sourced from the National Center for Energy and Environment, University of Benin. The rainfall event selected was for the month of September and was recorded for 1 hr 45 mins. The rainfall intensity data and the design hyetograph were then obtained, respectively. Simulation was carried out using the model parameters.

2.5. Storage of harvested rainwater

The storage tank size was considered using a Supply Side Approach (SSA). This method takes into consideration the uneven distribution pattern of rainfall. As in the case of the study area, where there is high rainfall in the months of April-October.

The size of the storage tanks was calculated using the following formula:

$$\text{Size of storage tank} = R_a \times A_r \times R_c \quad (2)$$

where:

R_a Catchment area in m^2
A_r Average annual rainfall in mm
R_c Runoff coefficient

2.6. Water quality analysis

Rainwater samples were collected in pre-rinsed plastic bottles from rooftops in each delineated zone and an existing storage well. Samples were analyzed in accordance with standard methods (APHA, 2001). Heavy metals were analyzed using a Perkin Elmer model 302 atomic adsorption spectrophotometer (AAS). The “HiSelective” *Escherichia coli* (*E.coli*) test kit was used to test for total and fecal coliforms.

3.0. Results and Discussion

3.1. Reconnaissance survey of RWH in Ogbekpen

A survey of current rainwater harvesting practices in the study area was conducted. It was observed that there is no organized system for rainwater collection. The existing conveyance structures were poorly constructed and the collected rainwater was exposed to pollutants, as the storage facilities were barely covered. Figure 2 shows a typical rainwater harvesting system in the area. However, this unconventional practice of rainwater harvesting, though a palliative of some sort, is not affordable for a number of households in the area.

Figure 2: Existing household rainwater harvesting practices in Ogbekpen community

3.2. Meteorological data and rainfall analysis

The chart of normal rainfall and monthly rainfall average presented in Figure 3 shows the month of March-October to be with consistent rainfall, with the highest monthly rainfall in April. The distribution of rainfall shows high potentials for rainwater harvesting in Ogbekpen as 8 months of the year are seen to have abundant rainfall.

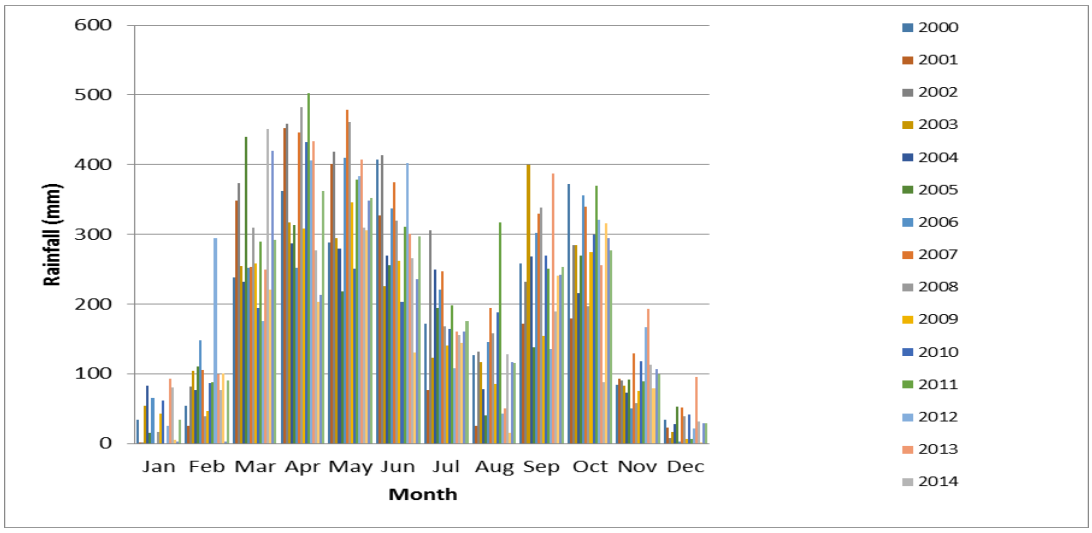

Figure 3: Normal and monthly rainfall average of Benin City from 2000- 2014

3.3. Delineation of catchment area

A Digital elevation model of 30m resolution was processed to generate a Triangulated Irregular Network (TIN) of the study area as shown in Figure 4. The map was used to delineate the study area into three zones based on elevation characteristics. The contour map of the study area shows that the highest elevation is 36m and lowest elevation is 11m, with a gentle sloping terrain (5-8°). Storage units for harvested rainwater were located at lower elevation regions of each zone. The elevation and

slope angles contribute to the hydrological parameters required for modelling and are important in the selection of flow direction in each water distribution pipe, as relevant gradient is required for the free flow of harvested rainwater to storage points.

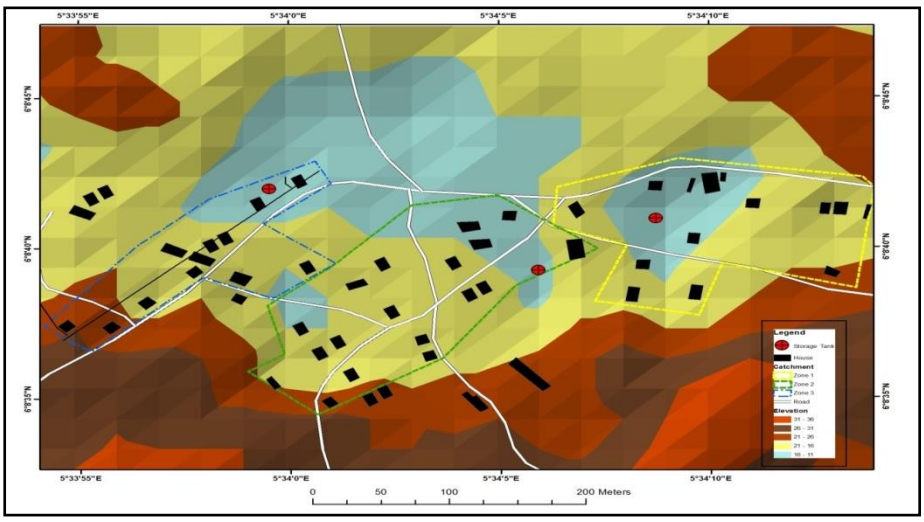

Figure 4: Elevation map using a triangulated irregular network (TIN)

3.4. Demand and supply of harvested rainwater

The water demand and supply for each zone was calculated using the catchment area of each zone and the average monthly rainfall. The rooftop areas were digitized using Arcmap 10.1 and calculated using the geometric calculation tool. Zone 2 had the highest catchment area with an area size of 2,201.9 m^2; zone 1 has an area size of 2006.2 m^2, while the least size is zone 3 with an area of 1817.7 m^2, giving a total effective rooftop area of 6025.9 m^2. Table 1 shows a breakdown of water demand and supply for each catchment zone. The highest amount of harvested rainwater was recorded in the month of April, with a mean value of 2,178,635.08 L (2179 m^3).

The monthly rainwater supply, demand and balance are presented in Table 2. It can be observed that for the month of January and December there was a deficit in water supply due to decreased rainfall. However, the total annual rainwater supply, 14,314,351.70 L (14,314 m^3) is more than three times the amount of water required annually 788,629.88 L (789 m^3), resulting in a water balance of 11,166,751.70 L (11,167 m^3). This indicates that the RWH system will meet and even exceed annual demand with an efficient harvesting and storage system.

Table 1: Harvested rainfall for each zone

Month	Average Rainfall (2000 - 2016) (mm)	Rainfall harvested in Zone 1(L)	Rainfall harvested in Zone 2 (L)	Rainfall harvested in Zone 3 (L)	Total Supply (L)
Jan	34.04	68,287.51	74,948.79	61,871.30	205,107.60
Feb	90.39	181,330.98	199,019.38	164,293.35	544,643.71
Mar	291.65	585,104.69	642,180.25	530,129.00	1,757,413.94
Apr	361.55	725,343.97	796,099.54	657,191.57	2,178,635.08
May	351.66	705,495.57	774,314.97	639,208.11	2,119,018.65
Jun	296.39	594,622.34	652,626.32	538,752.38	1,786,001.04
Jul	175.73	352,548.35	386,938.59	319,423.35	1,058,910.29
Aug	115.15	231,006.85	253,541.01	209,301.74	693,849.60
Sep	253.47	508,506.79	558,110.41	460,728.14	1,527,345.35
Oct	277.29	556,294.48	610,559.67	504,025.76	1,670,879.90
Nov	99.5	199,611.00	219,082.57	180,855.80	599,549.38
Dec	28.71	57,596.82	63,215.25	52,185.10	172,997.17
Total	2,375.51	*4,765,749.34*	*5,230,636.76*	*4,317,965.60*	14,314,351.70

** Runoff coefficient = 0.9*

Table 2: Harvested rainwater supply and demand balance

Months	Number of Days	Monthly Supply (L)	*Monthly Demand (L)	Monthly Balance (L)
January	31	205,107.60	266,600.00	-61,492.40
February	29	544,643.71	249,400.00	295,243.71
March	31	1,757,413.94	266,600.00	1,490,813.94
April	30	2,178,635.08	258,000.00	1,920,635.08
May	31	2,119,018.65	266,600.00	1,852,418.65
June	30	1,786,001.04	258,000.00	1,528,001.04
July	31	1,058,910.29	266,600.00	792,310.29
August	31	693,849.60	266,600.00	427,249.60
September	30	1,527,345.35	258,000.00	1,269,345.35
October	31	1,670,879.90	266,600.00	1,404,279.90
November	30	599,549.38	258,000.00	341,549.38
December	31	172,997.17	266,600.00	-93,602.83
Total		14,314,351.70	3,147,600.00	11,166,751.70

**40 liters per person, for 215 persons*

3.6. Estimation of storage tank capacity

The tank capacity for each zone was calculated as presented in Table 3. The required tank capacities for zones 1, 2 and 3 were 870,412.76 L (870 m^3), 955,319.45 L (955 m^3) and 788,629.88 L (789 m^3) respectively. This invariably means the largest tank would be allocated to zone 2.

Table 3: Maximum harvested rainwater and storage tank sizing

	Zone 1	Zone 2	Zone 3
Maximum Harvested Rainfall (L)	725,343.97	796,099.54	657,191.57
Storage Tank Size (with 20% safety factor) (L)	870,412.76	955,319.45	788,629.88

3.7. Modeling and design of rainwater harvest system

A layout of the conveyance model for each catchment zone is presented in Figure 5. S_1, S_2 and S_3 are the projected storage tank locations for zone 1, 2 and 3 respectively. The water elevation profile (Figure 6) shows the gradient of each conduit considering the slope angles. The steepness of the profile is important to allow for flow of water to storage location.

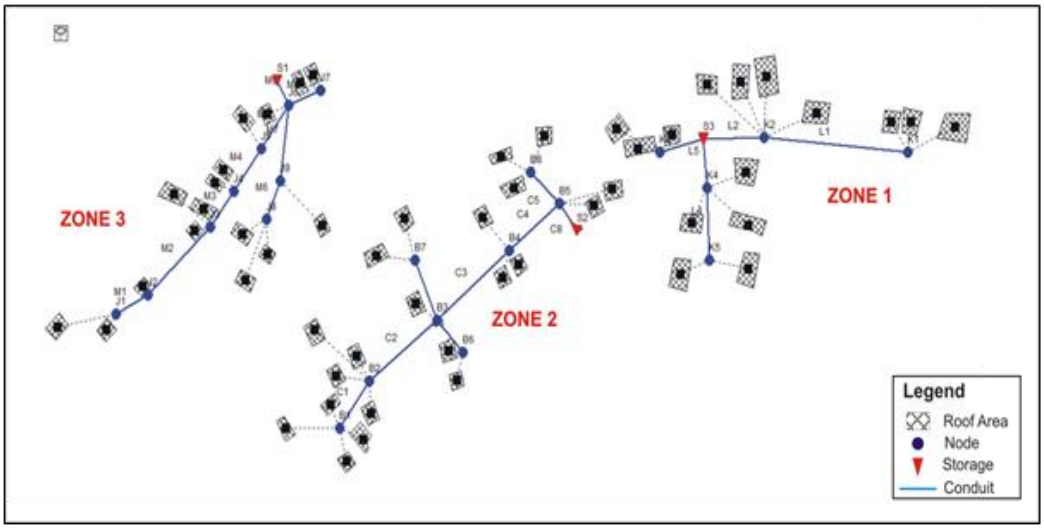

Figure 5: Conveyance system for rainwater harvesting

Data obtained after simulation and proper pipe sizing showed that the average pipe size required was 0.3 m and pipe lengths ranged from 16 to 79 m.

The outlet hydrographs obtained for each of the catchment zones is presented in Figure 7. From the graph the peak inflows were 0.089, 0.12 and 0.15 m^3/s in zones 1, 2 and 3 respectively. The time duration peak inflow coincides with the peak precipitation time in the graph. This shows a direct

relationship between precipitation and inflow. The total infiltration was 2.9% of the total precipitation, as the catchment area had a runoff coefficient of 0.95.

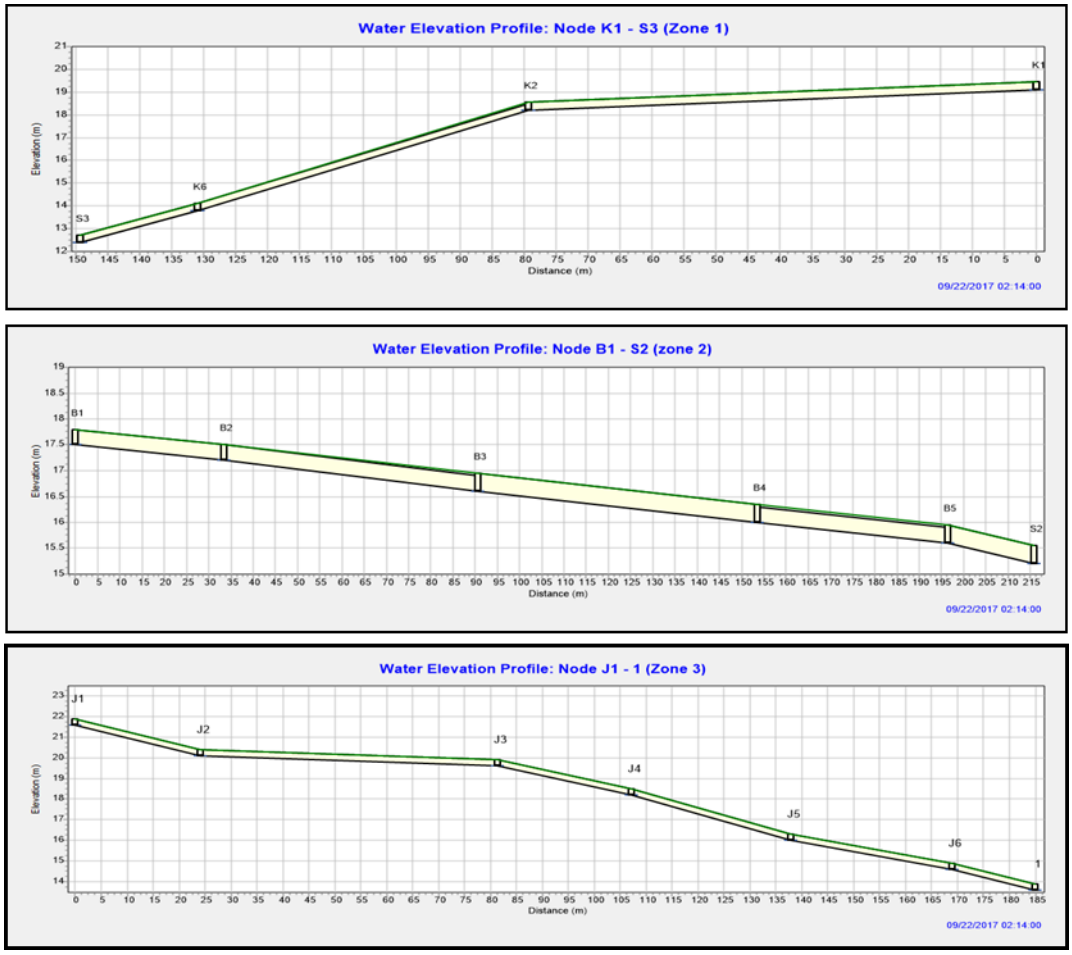

Figure 6: Water elevation and conduit profiles

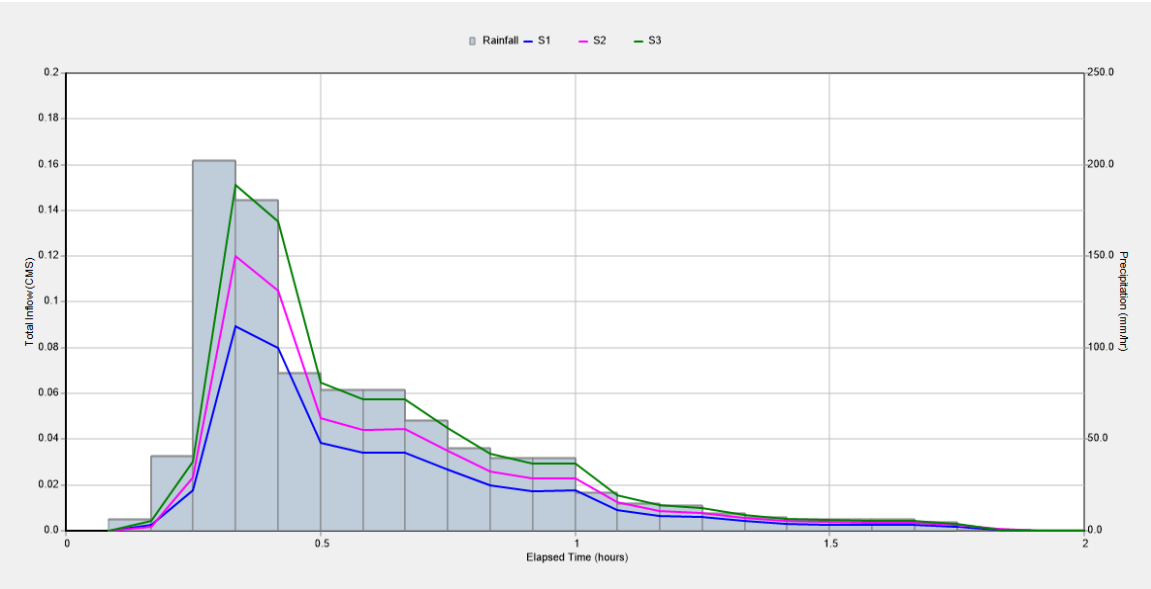

Figure 7: Inflow hydrograph

3.8. Water quality analysis

Physicochemical and microbial analysis of water samples showed that water from the rooftops (zones 1-3) met World Health Organization (WHO) standards for drinking water (Table 4), except for the Total Suspended Solids (TSS). However, the pH, Total Suspended Solids (TSS) and fecal coliform

count in water from the existing well did not comply with the WHO standards. This can be attributed to the poor conveyance structure and maintenance of the existing wells and highlights the need for disinfection (chlorination) to make the water safe for human consumption.

Table 4: Physicochemical and microbial characteristics of rainwater samples

Parameters	Zone 1	Zone 2	Zone 3	Existing Well	WHO (2011)
pH	6.6	6.7	6.5	5.9	7.5
TSS (in mg/L)	1.5	2.8	1.6	20.6	0
TDS (in mg/L)	37.1	35.7	36.2	103.1	500
Na (in mg/L)	0.5	0.61	0.57	2.45	200
K (in mg/L)	0.12	0.19	0.17	1.2	500
Ca (in mg/L)	1.56	1.8	1.66	12.8	200
Mg (in mg/L)	0.77	0.79	0.76	2.3	50
Cl (in mg/L)	16.87	17.7	17.5	32.3	250
Fe (in mg/L)	0.06	0.13	0.15	0.18	0.2
Mn (in mg/L)	0.012	0.008	0.013	0.018	0.05
Zn (in mg/L)	0.06	0.1	0.13	0.16	3
Fecal Coliforms (/100ml)	ND	ND	ND	5	0

4.0. Conclusion

In this study, a rain water harvesting system was designed for Ogbekpen, a rural community in Edo state, Nigeria. The storm water management model (SWMM) and Arcmap 10.1 software were used to develop a conceptual model for rainwater harvesting with daily rainfall data (2000-2016) obtained from the national meteorological agency (NIMET). The results revealed that the total annual amount of rainwater (water supply) was 14,314,351.70 L (m3) from an overall effective rooftop area of 6025.9 m^2. This was three times the annual water demand (4,317,965.60 L), thus demonstrating the capability of the system to meet annual water demand. The required tank capacities for zones 1, 2 and 3 were 870,412.76 L (870 m^3), 955,319.45 L (955 m^3) and 788,629.88 L (789 m^3) respectively and the average pipe size was 0.3 m. Physicochemical and microbial analysis of water samples showed that water from the rooftops (zones 1-3) met WHO standards for drinking water, except for the TSS, while the pH and fecal coliform count in water from the existing well did not comply with WHO standards. The findings of this study have demonstrated the potential capability of a well-designed rainwater harvesting system to meet annual water demand in a rural community, thus improving the quality of life.

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