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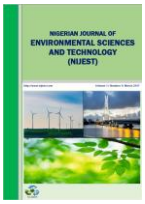

Ameliorative effects of coconut oil on the ovaries of refinery effluent intoxicated Norwegian rats

Ekaye S.[1], Uwagie-Ero E. A.[2,*] and Aghayedo C. O.[3]

[1,3]Department of Animal and Environmental Biology, University of Benin, Benin City, Edo State, Nigeria

[2]Department of Veterinary Surgery, University of Benin, Benin City, Edo State, Nigeria

Corresponding Author: *edwin.uwagie-ero@uniben.edu

ABSTRACT

The study was conducted to determine the possible ameliorative activity of coconut oil on the toxic effects of untreated refinery effluents on the ovaries of Norwegian rats. Three experimental groups of 10 rats each were used for the study; all animals had feed and water ad libitum. Group 1 was untreated and served as the control group, Group 2 was treated with 2 ml of untreated refinery effluent daily PO and group 3 was treated with 2 ml of untreated refinery effluent and 2 ml of coconut oil daily PO for 9 weeks. Every 3 weeks 2 rats in each group were euthanized with chloroform and ovarian tissues were surgically harvested; tissue concentration of heavy metals was assayed and histology was carried out. Treatment was discontinued at nine weeks and rats in group 2 and 3 were designated groups 4 and 5; allowed a 21 days resting period after which they were euthanized, ovaries surgically harvested and assayed as well. Results indicate that changes in ovarian tissue concentration of Chromium and Lead in the treated groups were of statistical significance ($P \leq 0.05$) compared to control. Results also showed that rats treated with coconut oil as abatement had normal histological architecture. Coconut oil had ameliorative effects on the ovary of rats intoxicated with refinery effluent and the ovaries returned to normal activities within 21 days post exposure.

Keywords: Coconot oil, Refinery Effluents, Ovary, Toxicity, Amelioration

1.0. Introduction

Coconut oil, a potent natural yeast fighter, contains three medium chain fatty acids, i.e., lauric acid (50–53%), caprylic acid and capric acid, all of which have antifungal effect against *Candida spp* and other fungi. Coconut oil has been confirmed to possess antimicrobial, antiviral and antiprotozoal activities (Isaacs *et al*., 1995; Thormar, 1996; Enig, 2000).

Increased human and industrial activities have led to increased pollution of man's environment and water bodies. Industrial waste which includes heavy metals and toxic chemicals are increasingly contaminating the environment. Deposits of metals and chemicals from industrial effluents can be found in the food and water consumed by both man and animals most especially when they are not properly treated before disposal.

Crude refinery effluents usually contain a variety of heavy metals such as chromium and lead; decreases in body weight gain have been reported in mice exposed to chromium and lead (Calvero *et al*., 1989; Campbell *et al*., 1989; Kanojia *et al*., 1998; Isselhard and Kushe, 1998; Giridharan, 2000; Ihedioha *et al*., 2004).

The Norwegian rat (*Rattus norvegicus)* is preferably used for toxicity assessment as they are the closest available bridge to the actual assessment in human population (Tawari *et al*., 2002). For a clearer insight into the histopathological effects of exposure to untreated refinery effluents an assessment on the toxicity response of Norwegian rat (*Rattus novergicus)* exposed to untreated refinery effluents with possible amelioration of these effects with the use of coconut oil was carried

out. The specific aim of this research was to assess the effects of oral administration of untreated refinery effluent on the ovaries of the Norwegian rat (*Rattus novergicus)* and evaluate the possible ameliorating effect of the toxicity using coconut oil as abatement.

2.0. Materials and Methods

2.1. Refinery effluent collection and stocking

Refinery Effluent (Untreated wastewater or produce water including both the tank farm drainage water and the spent caustic & MEA (Monoethanolamine)) was collected from a crude oil refinery located in Ekpan, Delta State, Nigeria. This was then transferred to the laboratory in pre-cleaned 1.5-liter plastic containers and stored at room temperature until use. This was considered as the stock effluent (100%).

2.2. Preparation and Phytochemical analysis of Coconut Oil

Fresh coconut (*Cocos nucifera*) was obtained from New Benin Market, Benin City, Edo State, Nigeria. The fresh coconut meat was grated and pressed using a sterilized sieve to produce coconut milk, which was allowed to ferment for 48 h, after which the solids and water content were separated from the oil. The oil was then heated in a water bath slightly to remove retained moisture. The oil was filtered by passing it through a 25 m pore size filter (Millipore, St. Quentin, France) to give an aqueous extract of coconut oil. This was collected in a sterile vial and stored at 4°C until use (Ogbolu *et al*., 2007). Phytochemical analysis was carried out and tests were conducted to determine the presence of flavonoids, tannins, cardiac glycosides, saponin, steroids, terpenoids**,** alkaloids**,** and reducing sugar according to standard methods (Harborne, 1973).

2.3. Animal handling and experimental design

2.3.1. Experimental animals

Thirty (30) adult female Norwegian rats weighing between 20 to 30g were used for the study.

2.3.2. Animal care and handling

The rats were fed on growers' mash obtained from Top-Feeds, Sapele, Delta State, Nigeria and were given clean drinking water *ad libitum*. The animals were kept in plastic cages, under a controlled condition of 12 hr light and 12 hr dark cycle. The animals were maintained in accordance with the guidelines approved by the Animal Ethical Committee, University of Benin, Benin City.

2.3.3. Animal grouping and treatment administration

The thirty (30) animals were grouped into three (n = 10/grp). Rats in group 1 were given feed with drinking water *ad-libitum* all through the experiment. These served as the control group. Group 2 rats were given feed with drinking water *ad-libitum* and also received 2 ml of 100% of the untreated refinery effluent continuously for 9 weeks. These served as the treatment group. Group 3 rats were given feed with drinking water *ad-libitum,* 2 ml of 100% of the untreated refinery effluent, and 2 ml of Coconut oil as abatement continuously for 9 weeks. Group 3 was the abatement group. At 3 weeks intervals, two rats were sacrificed from each group and ovaries were harvested. Morphometric and histologic analyses were carried out on them. Treatment was discontinued and the remaining rats in groups 2 and 3 were designated groups 4 and 5. They were left untreated for a period of 21 days without oral administration of both the untreated refinery effluent and coconut oil for the respective groups. They were given feed and drinking water *ad-libitum*. This was the post-exposure stage of the experiment. At the end of the 21 days, samples from groups (4 and 5) were collected and analyzed.

2.3.4. Physical observations, body, and organ weight determination

Rats in each of the treatment groups were observed twice daily (before and after exposure) for signs of clinical toxicity in the appearances of the skin and fur, eyes and mucous membrane, behavioral pattern, respiratory system, morbidity and mortality. The body weight of each animal in the control and treatment groups was measured at the beginning of the experiment and at the end of exposure period using OHAUS® Scout™ Pro, Model: SPU202 digital weighing balance.

2.3.5. Collection of specimen and analysis from experimental animals
At a three weekly interval, two (2) animals from each group were euthanized under chloroform anaesthesia. The ovaries of the animals were surgically removed and weighed, then fixed in Boiuns' fluid. The absolute organ weight was determined.

2.3.6. Tissue concentration of heavy metals in ovaries
The concentrations of heavy metals specifically lead (Pb) and chromium (Cr), in the ovaries were also determined by atomic absorption spectrophotometry as described by Brzoska *et al*. (2002) and Zhong *et al*. (2016). The model used was the Buck Scientific 210 VGP.

2.4. Histopathology

2.4.1. Histological preparation and examination of harvested ovaries
Ovaries harvested from the rats during the experiment were prepared for histological examination carried out at the Pathology Department, University of Benin Teaching Hospital. The organs were fixed in Bouin's fluid to arrest metabolic activities in the tissues, avoid autolysis and protein precipitation thus preventing enzymatic digestion of dead tissues. The fixed tissues were passed through several concentrations of alcohol, 70% alcohol for 24 hours and 90% alcohol for 12hours and through absolute alcohol. This was done to remove water from the fixed tissues and allow complete infiltration of tissue by paraffin. The tissues were then passed through xylene for 3 hours to prevent shrinkage and tissue brittleness in paraffin. Blocks of paraffin were melted and placed in beakers in the oven with a temperature of 60°C. After melting, the tissues were placed in paraffin wax. Forceps were used to arrange the tissues in the desired plane after which the wax was allowed to cool for 1 hr 30 min in a water bath. Blocks of wax were attached to the block holder of the microtome which trimmed it using a planoconcave knife with the microtome gauge set at 5um. Upon exposure of the whole tissue surface, sections were placed one at a time on a slide and flooded with egg albumin. Sections were exposed to 90 and 70% absolute alcohol for 2 minutes respectively and then in distilled water. Slides were then stained with hematoxylin for 15 minutes at room temperature and the excess stains washed in absolute alcohol. Differentiation was done using 1% acid alcohol and counter-stained with eosin for 3 minutes. Stained sections were cleared with xylene. Canada balsam was carefully placed on the stained section of the slide and a coverslip was carefully placed over the tissue to prevent air bubbles from being trapped in the slide. Slides were viewed under an Olympus Microscope (light microscope) (Nikon Eclipse E400). All alterations from the normal structure were registered. Photomicrographs were obtained at different magnifications to show the differences in tissues for the rats from each experimental group and phase.

2.4.2. Statistical analysis
All data were analyzed using the Statistical software, SigmaPlot for advanced statistics (Systat Inc. USA, 2010), Version 12.0. A significant difference between treatment(s) and control was analyzed with Two-Way and One-way ANOVA (Analysis of Variance) under DMR test (Duncan Multiple Ratio) for pair-wise comparison to detect significant differences at $P \leq 0.05$.

2.5. Phytochemical analysis of coconut oil

Coconut oil was found to be rich in essential constituents that could serve as anti-oxidants and also useful in nutrient enrichment. This included flavonoids, terpenoids, steroids, anthraquinones, saponin, reducing sugar, alkaloids, tannins and cardiac glycosides.

2.6. Physical observation and behavioural changes

During the duration of exposure of rats to effluents, increased water intake was observed in rats across the treatment groups compared to control (*per observation*). After 2 weeks of exposure, there was a continued increase in body sizes across all group (Figure 1). At the end of the sixth week, rats in the group given effluent only and also those given coconut oil as abatement were more active. Other observations which can be termed as clinical symptoms such as diarrhea, loss of fur, regional edema and loss of appetite were also observed in refinery effluent treated rats.

3.0. Results

3.1. Body weight

There was a significant difference ($P < 0.05$) in body weight of rats at 3, 6 and 9 weeks of treatment (Table 1). Body weight of rats increased across all treatment groups (Figure 1). Rats treated with effluent and coconut oil as abatement showed an increase in body weight from week 10 to 11 with body weight decreasing from week 11 to 12 and an increase in body weight observed from 12-13 weeks (Figure 1).

Table 1: Results of repeated measures ANOVA and test of significance of mean body weights between various time points across control, effluent and coconut oil abated groups.

Weight	Time period (weeks)	Time point	Body weight (g) Mean± SE	95% CI		Compared time points	Mean difference	*P*
				From	To			
Body	3	0	107.1±6.26	92.281	121.886	0 - 1	-36.250	<0.0001
		1	143.3±6.03	129.085	157.582	0 - 2	-46.25	<0.0001
		2	153.3±7.91	134.639	172.027	0 - 3	-61.25	<0.0001
		3	168.3±10.47	143.587	193.08	1 - 2	-10.0	0.032
						1 - 3	-25.0	0.007
						2 - 3	-15.0	0.016
	6	0	101.7±9.70	74.729	128.605	0 - 4	-68.889	0.004
		4	170.6±15.54	127.408	213.703	0 - 5	-73.333	0.001
		5	175.0±11.55	142.922	207.078	0 - 6	-81.667	0.001
		6	183.3±9.62	156.617	210.05	4 - 5	-4.444	>0.05
						4 – 6	-12.778	>0.05
						5 - 6	-8.333	>0.05
	9	0	102.5±7.30	71.139	133.861	0 - 7	-85	0.023
		7	187.5±10.0	144.473	230.527	0 - 8	-91.25	0.041
		8	193.8±14.63	130.798	256.702	0 - 9	-88.75	0.094
		9	191.3±9.76	149.244	233.256	7 - 8	-6.25	>0.05
						7 - 9	-3.75	>0.05
						8 - 9	3.75	>0.05
	13	10	182.5					
		11	195					
		12	187.5					
		13	190					

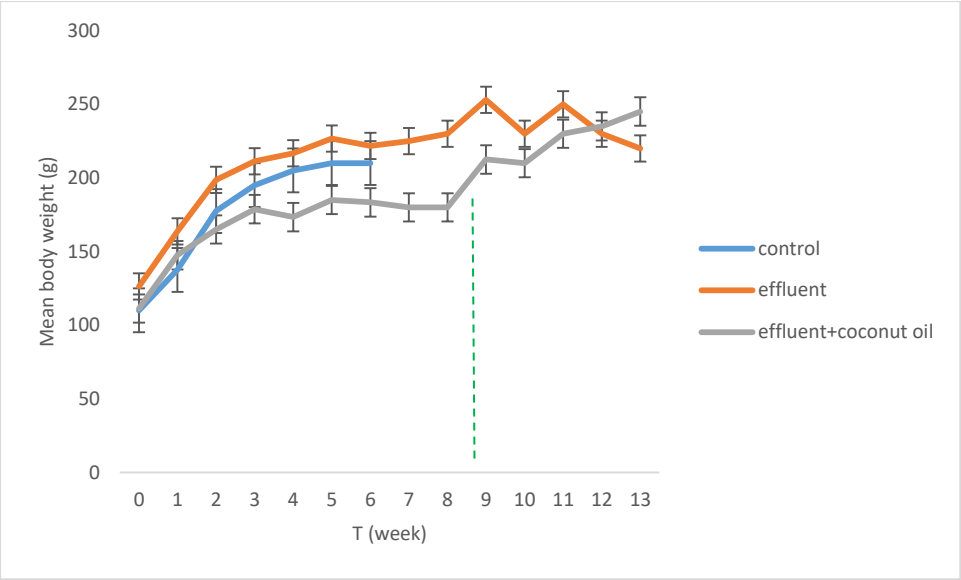

Figure 1: Changes in mean in mean body weight across experimental and control groups respectively during and after amelioration with coconut oil.

3.2. Tissue concentration of heavy metals chromium (Cr) and lead (Pb)

Ovaries were found to contain certain detectable concentrations of chromium (Cr) and lead (Pb) (see Figure 2).

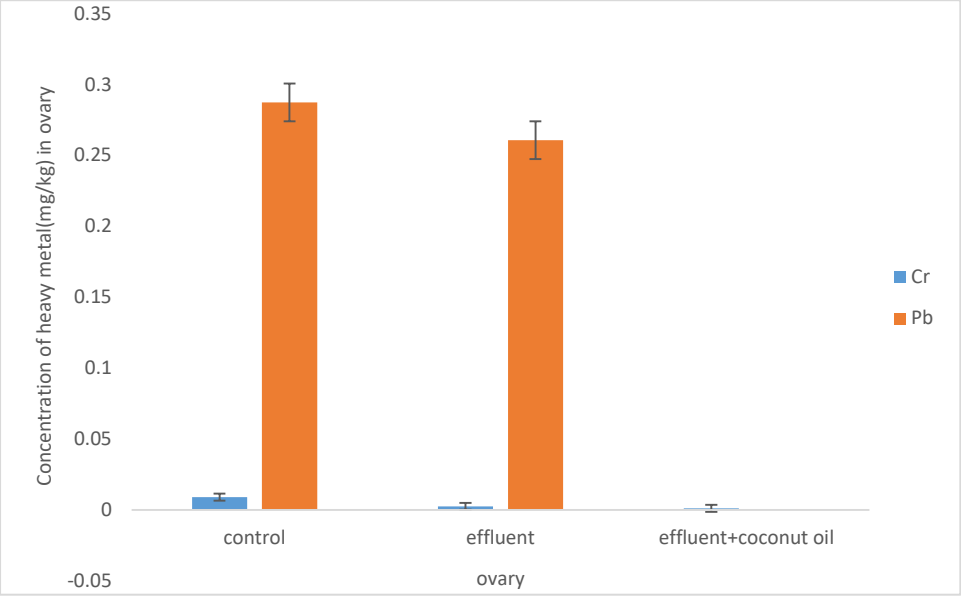

Figure 2: Mean concentration of chromium (Cr) and lead (Pb) respectively in the ovary across experimental and control groups.

3.3. Histopathology

The results of the histologic examination of ovaries of Norwegian rats are presented at 9 weeks of exposure; ovaries of the control group showed normal matured and developing ovarian follicles at different levels of maturation with normal granulosa cells, the basal lamina and the antrial fluid (Figure 3A), the granulosa cells were severely sloughed off in the effluent treated (Figure 3B) while the coconut oil abated group had moderate sloughing off of the granulosa cells with the basal lamina intact (Figure 3C).

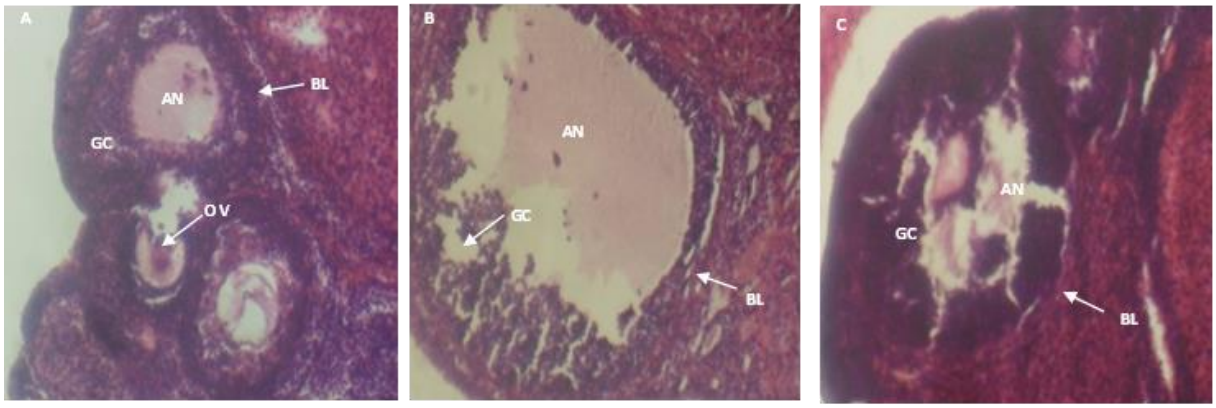

Figure 3: Photomicrograph of Norwegian rats mature ovaries, showing in **A**, the control group, ovulatory follicle (OV). Note the integrity of the granulosa cells (GC) and the basal lamina (BL), and the antrial fluid (AN). In **B**, the granulosa cells are sloughed off as seen in **C,** although the basal lamina are apparently intact.

3.4. Antimicrobial activities of coconut oil

All bacterial isolates were inhibited at concentration of 100 mg/ml in coconut oil with *Micrococcus spp* having the highest zone of inhibition (19 mm, 14 mm) and *Klebsiella spp* having the lowest (4mm) for coconut oil.

4.0. Discussion

Results showed that lead (Pb) had a higher concentration in the ovary as compared to chromium (Cr) in both intoxicated and intoxicated/ameliorated groups. While lead concentration was 0.27 mg/kg in the intoxicated group, it was 0.25 mg/kg in coconut oil treated group and chromium was 0.02 mg and 0.01 mg in the intoxicated and coconut oil treated group respectively.

At 3 and 6 weeks the majority of the treated rats showed ovarian atrophy. At nine weeks the coconut oil abated group showed matured follicles which are suggestive of active ovarian activity due to the ameliorative effect of coconut oil. Increase in ovary weight has been reported in chinchilla rabbits exposed to Escravos crude oil. This was attributed to enlargement of follicles in the ovary which is probably induced by the crude oil. However, the ovary weight and morphology were not estimated in this study because the ovary of some of the rats was atrophied. However, significant weight changes in the ovary of rats exposed to Lead during pregnancy was not observed by an earlier study (Okoye *et al*., 2014). A 40% reduction in fertility rate had earlier been reported for rats fed with 60 mg/kg of Lead (Wiebe *et al*., 1988). The decrease in fertility was attributed to a possible decrease in acetylcholine concentration which is important for steroidogenesis. Also, an irregular estrus cycling in female albino rats exposed to lead has been reported (Der *et al*., 1985; Dhir and Dhand, 2010).

In this study, rats in the refinery effluent intoxicated groups showed a level of degenerated follicular architecture with follicles not having ovum (enucleated) with varying degrees of atrophy. This agreed with previous reports (Ronis *et al*., 1998). Others had disorganized granulosa cells and stromal inflammation. However, rats in the coconut oil abated group showed follicles in the different stages of development (maturation), showing recovery from the damaged state. This research has shown that the biologically active ingredients which are found in coconut oil have an ameliorative effect on the ovaries of rats exposed to lead and chromium and initiated early regeneration and return to function of the ovarian follicles after intoxication with refinery effluents.

Ovarian sections from group 2 revealed severe congestion and degeneration of follicles. In addition, cystic follicles were seen in large numbers. Ultrastructural changes like alterations in size and shape of basal laminal and granulosa cells were also noticed in group 2 rats. Recovery from histological injury had been observed in α-tocopherol co-administered rats, with mild cloudy swelling in uterus and congestion in ovaries (Ronis *et al*., 1998). In this study, ultra-structurally, no changes were noticed in group 3 rats. Potassium dichromate treatment causes a significant negative change ($P < 0.05$) in uterine and ovarian weights, serum GSH level, percentage of vaginal time opening and diameter of ovarian follicles in categories (101-200) and (> 400), with a significant increase in serum MDA level (Balakrishnan *et al*., 2013).

Banu *et al*., (2008) stated that many environmental toxicants gain access to the ovary via the circulation. The risk of damage to the ovarian follicle cell population from the toxicants depends mainly on the accessibility of toxicants to ovarian follicles. Recent studies found out that there was a decrease in ovarian weight and lipid peroxidation of female mice treated with chromium trichloride, these findings are similar to this study (Elbetieha and Al-hamood, 1997; Banu *et* al., 2008; Jeber and Tawfeek, 2013). Banu *et al*., (2008) also found a decrease in the percentage of vaginal opening time in female rats treated with potassium dichromate as an index of delay onset of puberty in female rats and decreased in a number of primordial, primary and secondary follicles with no observation of antrial follicles. This was also reported in earlier studies (Dosumu *et al*., 2010; Adikwu *et al*., 2013).
Rats in the intoxicated and abated groups had varying degrees of degeneration of the atrophied ovaries within 3 to 6 weeks of treatment. After 9 weeks of exposure, those in the ameliorated group showed levels of regeneration in the ovarian follicular architecture; with follicles tending to varying levels of maturation and showing recovery from the damaged state. After the 21 days, post-exposure period matured ovarian follicles were seen in the coconut oil ameliorated group.

5.0 Conclusion

The study concluded that intoxication from refinery effluents resulted in a high accumulation of heavy metals chromium (Cr) and lead (Pb) in the ovaries of exposed rats. There was ovarian atrophy in Norwegian rats intoxicated with refinery effluents. High deposits of Lead and Chromium could be a leading cause of follicular degeneration in the ovaries of Norwegian rats intoxicated with refinery effluents. Effluents from the refinery and other chemical industries containing heavy metals should be treated and disposed of properly to reduce the level of environmental pollution. Finally, coconut oil ameliorated the toxic effects of refinery effluent in the ovaries of Norwegian rats.

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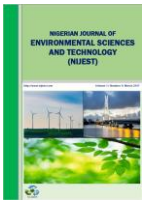

Evaluation of the Feasibility of the Use of Bamboo as Potential Reinforcement in Concrete Beams

Osuji S. O.[1] and Kayode-Ojo N.[2,*]

[1,2]Department of Civil Engineering, University of Benin, Benin City, Edo State, Nigeria

Corresponding Author: *engrngozi@yahoo.com

ABSTRACT

This study presents the evaluation of the feasibility of using bamboo as a potential reinforcement in concrete beams. To achieve this, absorption test, tensile tests on the bamboo; compressive test on concrete cubes were conducted. Three-point bending tests on concrete beams reinforced with bamboo were performed to identify their behaviour compared to steel reinforced concrete members. The result for the absorption test indicated that water absorption of bamboo is quite high. The bamboo absorbed about 25% of water of its saturated weight in just 24 hrs and increased number of nodes brought about increased absorption of water. It also showed that the bamboo from the top part of the culm absorbed more water than those from the bottom of the culm, with an increase of about 9%. For the tensile tests all the bamboo specimens showed brittle failure at node, making the node the most critical section for failure under tensile stresses, which was also verified in the beam tests. The yield stress was 56.80 N/mm^2. In general, the test results indicated that bamboo reinforcement enhanced the load carrying capacity by approximately 200%.

Keywords: Bamboo, Three-point bending tests, Absorption, Tensile tests, Compressive tests

1.0. Introduction

In most countries, concrete is widely used as the foundation for the infrastructure. Concrete is used largely because it is economical, readily available and has suitable building properties such as its ability to support large compressive loads. However, the use of concrete is limited because it has low tensile strength. For this reason, it is reinforced, and one of the more popular reinforcing bars (rebar) is steel (Salau *et al*., 2012). Steel has a relatively high tensile strength, as high as 792 N/mm^2, complementing the strength of concrete. It is available and affordable in most developed countries but unfortunately not in all parts of the world. In many countries, none or very little steel reinforcement is used in construction, which is evident from the crumbling of buildings.

Steel reinforcement at some point may no longer be available. Even today there exists a need for more economical and readily available substitute reinforcements for concrete. In some parts of the world many buildings are constructed only with concrete or mud-bricks. This is dangerous in case of seismic activity. These buildings have little hope of standing in the case of an earthquake. Steel reinforcement would be an ideal solution, but cost is a considerable problem. Scientists and engineers are constantly seeking for new materials for structural systems; the idea of using bamboo as possible reinforcement has gained popularity (Siddhpura *et al*., 2013).

The energy necessary to produce 1 m^3 per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete, has been compared with bamboo. It was found that for steel it is necessary to spend 50 times more energy than for bamboo. The tensile strength of bamboo is very high and can reach 370 N/mm^2 (Bhonde *et al*., 2014). This makes bamboo an alternative to steel in tensile loading applications as the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel.

Recently, in the attention and response to global warming issues and sustainable society, the use of natural materials for manufacturing has become more active. Bamboo's low cost, fast growing, and broad distribution of growth, is expected to contribute significantly to earthquake-resistant construction and seismic retrofit technology in the developing countries (Steinfeld, 2001). In concrete, reinforcement is put in place to provide tensile strength, a property that concrete lacks. Therefore, if bamboo is to be used as concrete reinforcement, it is necessary to understand how bamboo behaves in tension.

The aim of this study is to determine the feasibility of using bamboo as reinforcement in concrete beams and will be providing a preliminary contribution toward the collection of the mechanical properties and behaviours of bamboo and bamboo reinforced beams. The objectives are:

i. To carry out water absorption rate test on bamboo
ii. To carry out tensile tests on bamboo
iii. To compare the elastic modulus and flexural strength of bamboo reinforced beams and steel reinforced beams.

This study will consider the *bambusa vulgaris* specie, seasoned and cut into thin strips and tested without any treatment to determine the absorption and tensile properties of the bamboo. To examine the behaviour of the bamboo in the concrete, three-point load bending test will be conducted on bamboo reinforced beams and the results compared with that of steel reinforced and plain concrete beams.

This study is performed mainly for the rural areas, where bamboo is of ample amount, steel is rare, expensive or transportation cost is high. In coastal areas, the economic condition of people is very poor. In such type of backward area, such study may be essential for their development as well as an assurance for low cost housing. After the study it is seen that samples constructed as aid of bamboo can offer respectable amount of strength that can be safely used for low-cost housing.

The use of bamboo as a structural element may contribute to the reduction of material-based energy use of a structure (Sakaray *et al*., 2012). Even with the rising rate of insurgency around the globe, bamboo can be used to construct low cost but befitting structures for displaced individuals and families. The main obstacle for the application of Bamboo as a reinforcement is the lack of sufficient information about its interaction with concrete, strength and durability, hence the relevance of this work cannot be over emphasized.

2.0. Materials and Methods

The bamboos used for this study were very matured and cut from the undeveloped Site B section of the University of Benin, Benin City, Edo State in Nigeria. They were dried under the sun for thirty days before reducing to thin strips for the tests. The following tests were carried out:

2.1. Absorption test

Bamboo like wood changes its dimension when it loses or gains moisture. Bamboo is a hygroscopic material, tending to absorb moisture from air and surroundings (Wakchaure,and Kute, 2012). Four different bamboo splints were taken from top and bottom portions of bamboo culm for the test as shown in the Figure 1, with their properties listed in Table 1.

Figure 1: Absorption test specimen

Table 1: Description of absorption test specimen

Specimen	Property
$A1_a$	One internode (from top of culm)
$A2_a$	Two internodes (from top of culm)
$B1_a$	One internode (from bottom of culm)
$B2_a$	Two internodes (from bottom of culm)

Using the below mathematical expression the amount of water absorbed by both types of samples was calculated.

$$Water\ absorbed\ (gm) = final\ saturated\ weight(gm) - Dry\ weight(gm) \quad (1)$$

$$\%\ by\ weight\ of\ water\ absorbed\ = \frac{water\ absorbed\ (gm)}{final\ saturated\ weight\ (gm)} \times 100 \quad (2)$$

2.2. Tensile test

Tension test is the most basic type of mechanical test. It is easy to perform and relatively inexpensive compared to other tests. The stress- strain characteristics of bamboo is derived from the results of this tension test.

The Bamboo strips were of various lengths and thicknesses (see Table 2). The ends of the specimen were roughed at both ends to have better grip in Universal Testing Machine. The sample strip of the Bamboo is as shown in Figure 2.

Figure 2: Tensile test specimen

Table 2: Description of tensile test specimen

Sample	Node position	Specimen size		Cross sectional area		
		Length(mm)	Thickness(mm)	End A	End B	Average area(mm^2)
$A1_t$	Centre	540	10	220	230	225
$A2_t$	End	540	10	220	190	205
$B1_t$	Centre	450	15	450	420	435
$B2_t$	End	450	15	420	450	435

The position of the Bamboo strip in UTM is as shown in Figure 3.

Figure 3: Bamboo strip in UTM

A stress vs strain curve was drawn from the results of the tensile test on the strip. The yield stress is also got from the stress vs strain curve.

The equation to calculate the Modulus of Elasticity is as mentioned in Equation 3.

$$E = \frac{\sigma}{\varepsilon} \tag{3}$$

where:

σ	Stress
ε	Strain
E	Modulus of Elasticity

2.3. Beam tests

Since it is the purpose of this research to determine the feasibility of the use of Bamboo as reinforcement in concrete, it is necessary to compare its behaviours to steel, which is the traditional reinforcement. Therefore, beam designs were in accordance with BS 1881-118:1983 codes and specifications.

The dimensions were those that would allow for practicality of testing and construction, therefore a width of 150 mm and a depth of 150 mm was chosen for the test beam.

The next step was to determine the length of the beam. Evaluating the laboratory conditions and desired testing set-up, a beam length of 750 mm was chosen. Figure 4 shows the final dimensions of the test beam.

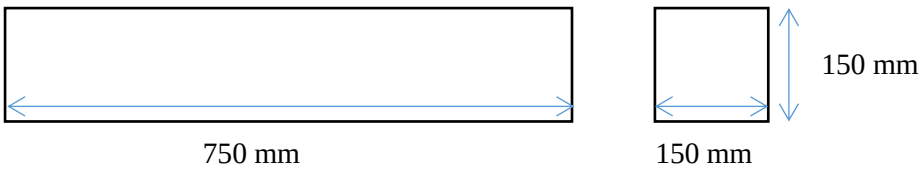

Figure 4: Beam dimension

2.4. Flexural test

The Universal Testing Machine (UTM) was used for this test. The test set-up was done according to BS1881-118 1983.

The flexural strength F_{cf} (in N/mm^2) is given by the equation:

$$F_{cf} = \frac{(F \times L)}{(d_1 \times d_2^2)} \tag{4}$$

where:

F	Breaking load (in N);
d_1 and d_2	Lateral dimensions of the cross-section (in mm);
L	Distance between the supporting rollers (in mm).

From the results got from the test, a load vs deflection graph was plot and the elastic modulus of each kind of beam was calculated from the formula:

$$E = \frac{[23 \times W \times L^3]}{[\,648 \times \delta \times I]} \quad (5)$$

where:

W	Load
L	Length of the beam
δ	Deflection
I	Moment of inertia.

Now,

$$I = \frac{bd^3}{12} \quad (6)$$

where:

b	Width of the beam
d	Depth of the beam

3.0. Results

3.1. Absorption test result

The absorption test result is shown in Table 3 below, while the graph showing the relationship between percentage of water absorbed and number of nodes is shown in Figure 5.

Table 3: Absorption test result

Specimen	No. of nodes	Dry weight (g)	Saturated weight (g)	Water absorbed after 24hrs (g)	% of water absorbed (by sat. wt.)
A1	1	55	72	17	23.61%
A2	2	115	155	40	25.81%
B1	1	115	135	20	14.81%
B2	2	150	180	30	16.67%

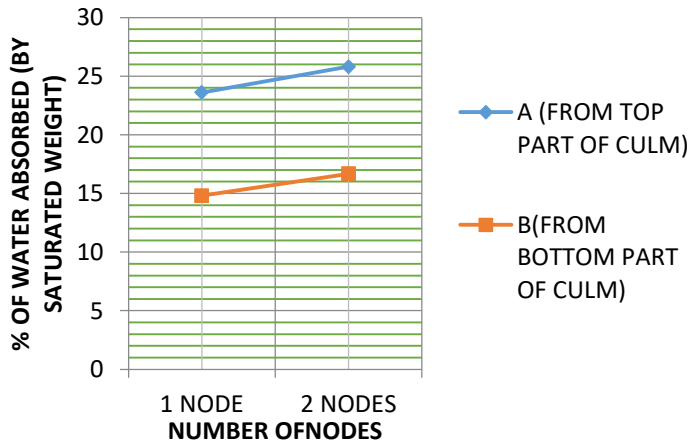

Figure 5: Graph of % of water absorbed vs number of nodes

Figure 5 shows that specimen with higher number of nodes absorbed a larger amount of water. The water absorption capacity of bamboo from the top of the culm is higher than that from the bottom of the culm. We see an additional increase of about 9%.

Generally, from the experiment done, it is seen that the water absorption capacity of bamboo is high ranging to about 25% of saturated weight in just 24 hrs. This shows that there is a high possibility of swelling of the bamboo splints once they absorb water from the surrounding, eventually generating additional stresses in reinforced concrete elements if used as reinforcing material. It could also absorb and reduce a part of the water added in the concrete mix for hydration reactions and when the concrete becomes dry the bamboo splints contracts and creates spaces between the bamboo and concrete and the bamboo-concrete bond strength decreases and member fails in bond.

3.2. Tensile test result

Tensile tests were conducted on bamboo samples from different part of the culm and with different nodal position to find a pattern of behaviour based on the structure of Bamboo as a plant. The result of the tensile test (shown in Table 4) showed a pattern of failure. The samples failed at the node. Figure 6 shows four different test specimens after failure at the nodes.

Figure 6: Failure patterns of bamboo specimens.

It was also observed that the samples with centre nodes held a larger load before reaching failure in contrast to those without a node. Examination of the node structure shows that the fibres in the nodes are much denser than those of the internodal regions. Also, the fibres which are straight elsewhere become chaotic in the node. Tests and study of Bamboo nodes indicate that the node may be very brittle and stiff, suggesting the reason why the specimen fails at the nodes. Test sample suggested the internodal regions of the Bamboo elongated until it reached a limiting value and then the load was transferred to the node.

The test results also showed that samples from the bottom of the culm generally held larger load before failure in contrast to those from the top part of the culm.

Table 4: Tensile test result

Sample	Failure Load (N)	CSA (mm^2)	L (mm)	Δ L (mm)	Stress (N/mm^2)	Strain
$A1_t$	18000	225	540	10	80.00	0.0185
$A2_t$	16000	205	540	9	78.05	0.0167
$B1_t$	37000	435	450	15	85.06	0.0333
$B2_t$	34000	435	450	13	78.16	0.0289

A sample test result is summarized in Figure 7.

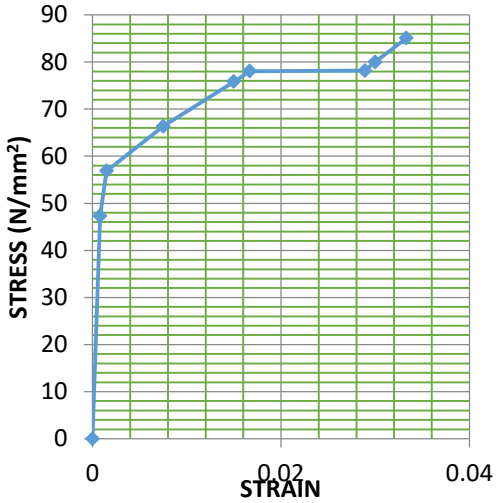

Figure 7: Graph of stress vs strain

It seems that constitutive relationship of the nodes differs from those of internodal regions with nodes having a brittle behaviour while internodal regions exhibit a more ductile behaviour. However, the ultimate strength of the node is anticipated to be higher than other regions.

The yield stress of the Bamboo strip is 56.80 N/mm^2.

The modulus of elasticity is calculated as follows:

$E = \frac{\sigma}{\varepsilon}$

σ = 56.80 N/mm^2, ε = 0.0015.

Thus,

E =56.80 / 0.0015

E = 37,866.667 N/mm^2

The Modulus of Elasticity of the Bamboo strip is 37,866.667 N/mm^2.

3.3. Flexural test result

The beam was carefully placed under the testing machine and supports were placed at the measured location of 150 mm inside from each end. After placing the beam, one point loading at the mid-span of the beam was applied gradually. The deflection of the beam at mid- span was measured at regular interval of loading. From the experimental test the load deflection graph, ultimate carrying capacity and the type of failure were recorded.

3.4. Comparison of modulus of elasticity of singly reinforced and doubly reinforced Bamboo beams

Based on the experimental study the modulus of elasticity of Doubly Reinforced Beam is about 160% that of the Singly Reinforced Beam (see Table 5). The comparison is also shown in Figure 8. Modulus of elasticity for Singly Reinforced Beam is 8,246.04 N/mm^2. Modulus of elasticity for Doubly Reinforced Beam without steel stirrup is 12,422.84 N/mm^2 and with steel stirrup is 13,094.81 N/mm^2.

Table 5: Modulus of elasticity and flexural strength for the different types of beams

	Load, W(KN)	Deflection, δ (mm)	Modulus of elasticity, E (N/mm^2)	Flexural strength, F_{cf} (N/mm^2)
Plain concrete	18	0.87	7,343.6	2.4
Singly reinforced with bamboo	23	0.99	8,246.04	3.1
Singly reinforced with steel	50	1.08	16,432.33	6.7
Doubly reinforced with bamboo without stirrups	35	1.00	12,422.84	4.7
Doubly reinforced with steel without stirrups	59.8	1.12	18,951.17	8.0
Doubly reinforced with bamboo with steel stirrups	38	1.03	13,094.81	5.1
Doubly reinforced with steel with steel stirrups	62	1.15	19,135.80	8.3

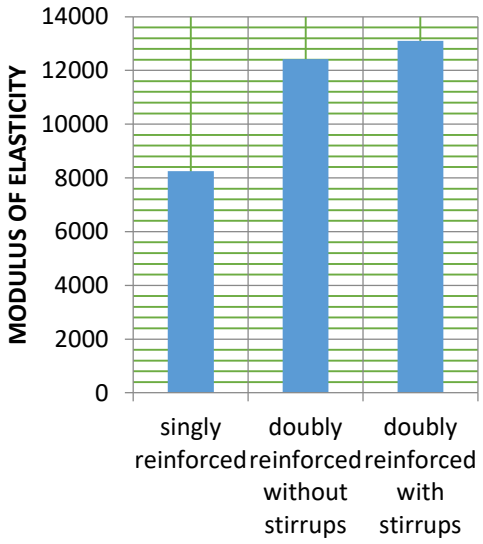

Figure 8: Comparison of modulus of elasticity for Bamboo reinforced beams

4.0 Conclusion

This work provides bamboo as a potential reinforcement in concrete beams. Bamboo has excellent engineering properties and can be utilized for low cost housing project. It can mainly be used as reinforcement to the structure. Drawback of bamboo as construction material is its water absorption and moisture content properties. This mainly affects its strength. To reduce this effect, seasoning and proper coating to bamboo should be done before using it for reinforcement. After the experiment, the following conclusions were made:

1. Water absorption of bamboo is quite high. To reduce this effect, seasoning or other suitable treatment should be given.
2. Tensile strength of bamboo is good and can be used as reinforcement in R.C. structure for low cost housing project. From stress-strain curves of bamboo, it can be seen that bamboo possesses low modulus of elasticity compared to steel. So, it cannot prevent cracking of concrete under ultimate load. But from the flexural test of bamboo reinforced beam, it has been seen that using bamboo as reinforcement in concrete can increase the load carrying capacity of beam having the same dimensions.
3. The stress-vs.-strain curve of bamboo splint in tension shows that bamboo is a visco elastic material having both viscous and elastic properties and exhibits time dependent strain elasticity.
4. Bamboo shows ductile behaviour as in steel. Hence it can be used as compression members in steel as well as R.C. structure.
5. For bamboo reinforced concrete beam, the load carrying capacity increased about 2 times that of plain concrete beam having same dimensions.

6. The flexural strength of bamboo reinforced beam increases as high as nearly doubled compared to the plain concrete beam, so bamboo reinforced beam can be used in low cost buildings.
7. The maximum deflection of bamboo reinforced concrete beam is about 1.5 that of plain concrete.

This study concludes that it is possible to use bamboo as reinforcing for masonry structure.

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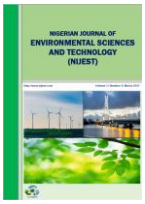

An Assessment of the Reliability of the NIGNET Data

Ayodele E. G.[1], Okolie C. J.[2,*] and Mayaki O. A.[3]

[1,2]Department of Surveying and Geoinformatics, Faculty of Enginering, University of Lagos, Lagos State, Nigeria

[3]Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada

Corresponding Author: *cokolie@unilag.edu.ng

ABSTRACT

The Nigerian Geodetic Reference Frame is defined by a number of Continuously Operating Reference Stations (CORS) that constitute the Nigerian GNSS Network (NIGNET). NIGNET is essential for planning and national development with the main goal of ensuring consistency in the geodetic framework both nationally and internationally. Currently, the strength of the network in terms of data reliability has not been adequately studied due to the fact that research into CORS in Nigeria is just evolving, which constitutes a limitation in its applications. Therefore, the aim of this research is to explore the reliability of the 3-dimensional coordinates of NIGNET to inform usability and adequacy for both scientific and practical applications. In particular, this study examines if the 3-dimensional coordinates of NIGNET are equally reliable in terms of positional accuracy. Accordingly, this study utilised GNSS data collected over a period of six years (2011 – 2016) from the network to compute the daily geocentric coordinates of the stations. Exploratory and statistical data analysis techniques were used to understand the magnitude of the errors and the accuracy level in the 3-dimensional coordinates. For this purpose, accuracy metrics such as standard deviation (σ), standard error (SE) and root mean square error (RMSE) were computed. While One-way ANOVA was conducted to explore the coordinate differences. The results obtained showed that SE and RMSE ranged from $13.00 - 56.50mm$ *and* $14.38 - 73.16mm$ *respectively, which signifies high accuracy. Overall, while 88% of the network showed a high level of positional accuracy, the reliability has been compromised due to excessive gaps in the data archiving. Therefore, due attention must be given to NIGNET to achieve its purpose in the provision of accurate information for various geospatial applications. Also, any efforts directed at understanding the practical implications of NIGNET must be well-embraced for the realization of its set objectives.*

Keywords: Geodetic Infrastructure, Reliability, NIGNET, CORS, Data Analysis

1.0. Introduction

Advancements in positioning have made Global Navigation Satellite Systems (GNSS) a critical component of the modern day geodetic infrastructure and services. In 2008, the Office of the Surveyor General of the Federation started the establishment of the Nigerian GNSS Reference Network (NIGNET). NIGNET consists of a network of Continuously Operating Reference Stations (CORS). Currently, NIGNET is formed by sixteen (16) CORS covering the entire country. CORS are a network of stations using GNSS operating continuously from permanent and stable locations for accurate positioning (Fajemirokun, 2009; Schwieger *et al.*, 2009). CORS provide geodetic controls of comparable accuracy to the classical geodetic network and is a better alternative given the improvements in surveying and mapping technologies. CORS are categorised into different classes according to purpose and the spacing between stations. For example, Burns and Sarib (2010) and the Intergovernmental Committee on Survey and Mapping, ICSM (2014) classified CORS into Tiers 1–3 while LPI (2012) classified CORS into Tiers 1–5. The use of CORS can give an instant position to an accuracy of ±20 mm required by many industries (UNSW, 2017).

For NIGNET, its main goal is to ensure consistency in the local (Nigerian Geodetic Reference Frame) with the International Terrestrial Reference Frame (ITRF). NIGNET serves as the fiducial network that defines the country's spatial reference framework as well as contributing to the African Geodetic Reference Frame (AFREF) using the techniques of modern space geodesy. The establishment of NIGNET is essential given that the national geodetic network of any country is a pivotal infrastructure that provides the foundation for all geo-related activities and services. Such services include land management, urban development, physical planning, construction, mineral exploration, and transportation (land, air and water). NIGNET also provides the base for a coherent multipurpose Land Information System and its subsequent maintenance. This is particularly useful in a country's economic development by delineating and monitoring changes in property, environment, and biodiversity. It is also vital in the smooth implementation of the national land policy (Jatau *et al.*, 2010). In order to ensure consistency, the linking of NIGNET to the ITRF was made by acquiring Global Positioning System (GPS) data from nine International GNSS Service (IGS) stations (OSGOF, 2012). The IGS stations served as the reference points while the data used were acquired at the same time with the data from NIGNET.

Given the critical role played by NIGNET in defining the geocentric datum for Nigeria, it is important to account for any displacement arising from the shift in position of the CORS. Recently, Ayodele *et al.* (2017) analysed data from seven NIGNET stations covering 2011 to 2014 in order to monitor temporal variations and to understand the quality of the three-dimensional coordinates. The results showed an acceptable level in the data quality and accuracy of NIGNET with the highest and lowest variabilities in the initial coordinates occurring in the *x* and *z* directions respectively. The authors also noted some infrastructural problems plaguing NIGNET such as faulty receivers, irregular power supply, and disruptions in internet connectivity. The observations in the network led to the assessment of the accuracy in the three-dimensional coordinates of ten operational NIGNET stations from 2011-2016 using a known IGS station (BJCO) as reference. While the results from the study showed an acceptable level of accuracy, the reliability of the network remains unclear. Consequently, in this study, the reliability of the network was explored using both exploratory and quantitative analysis techniques such as the Mahalanobis distance method of outlier detection and filtering, standard deviation (S.D), standard error (S.E), mean absolute deviation (MAD) and root mean square error (RMSE) for accuracy metrics Also, analysis of variance (ANOVA) was used to test for any significant variation in the 3-dimensional coordinate to understand whether the X, Y, and Z-coordinates are of different levels of reliability-. To conclude the reliability assessment, an evaluation of the sufficiency and adequacy of the NIGNET data was conducted using the data count of the daily observations in line with the IGS and ICSM guidelines for the acquisition of high quality CORS data.

2.0. Materials and Methods

Figure 1 presents the map of Nigeria showing the distribution of the NIGNET COR Stations used in this study. The downloaded files contained data from fourteen (14) NIGNET stations that were available on the online portal and two IGS stations (CGGN and BJCO). Following this, a custom MATLAB script was written to call the offline function of the GNSS Analysis and Positioning Software (GAPS) to read the RINEX files from the folder they were placed. GAPS is a Precise Point Positioning (PPP) application developed at the University of New Brunswick, Canada. Further details about GAPS and how it functions can be found in Leandro *et al.* (2010) and Urquhart *et al.* (2014). During the processing, the geocentric coordinates of the stations were computed and extracted at a sampling interval of 30 seconds and then averaged into daily coordinates. A full description of the methodology for the processing of the station coordinates using GAPS can be found in Ayodele *et al.* (2017). Table 1 presents the summary of BJCO (the reference station) showing the geodetic coordinates and years of observations considered. From the table, the least number of yearly observations recorded was in year 2012 (248) while the highest number of observations was recorded in year 2014 (362). For the 6-year period from 2011–2016 under study, a total number of 1,875 available data files were acquired for BJCO. Four NIGNET stations with excessively large data gaps were excluded leaving a final selection of ten NIGNET stations. The excluded stations include HUKP (Katsina), FPNO (Owerri), FUTA (Akure) and GEMB (Gembu). MDGR had severe service disruptions during this period making it the station with the least number of observations (369 data files) while FUTY had the highest number of observations (1799 data files).

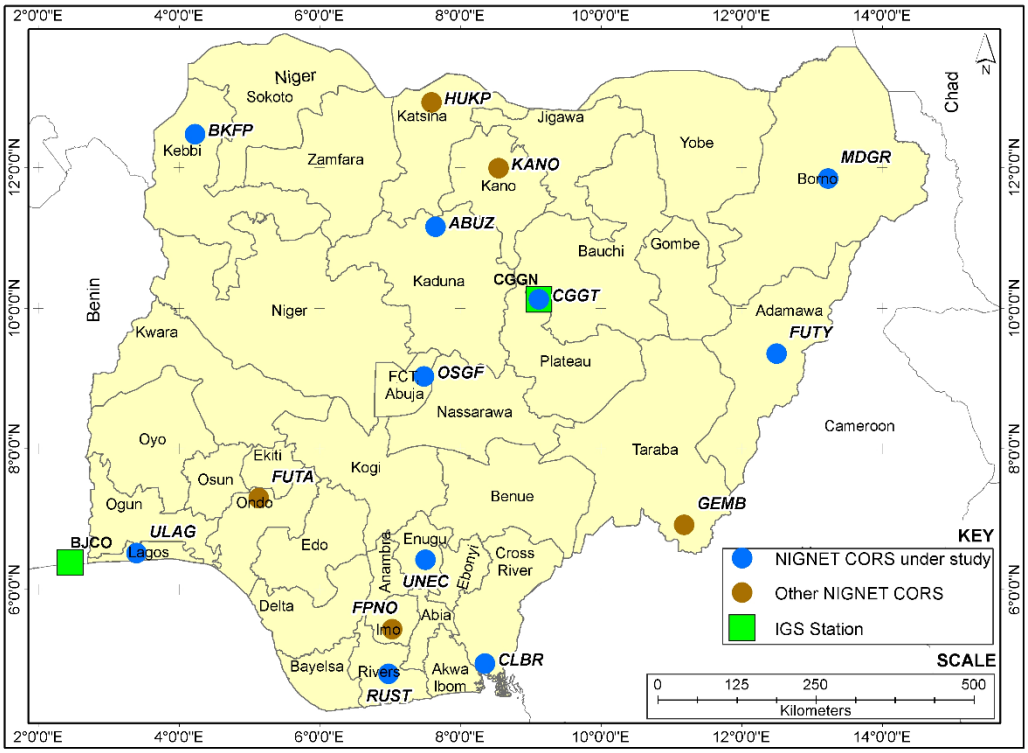

Figure 1: Map of Nigeria showing the distribution of the COR stations

Table 1: The description and the count of the downloaded daily data BJCO IGS station

Station code	Latitude (degree)	Longitude (degree)	Ellipsoidal height (m)	Location	No. of Yearly Downloaded Observations (days)					
					2011	2012	2013	2014	2015	*2016
BJCO	6.38	2.45	30.7	Benin Republic	299	248	332	362	346	288

*1 Jan – 10 Nov, 2016

Following the determination of the coordinates of the stations using GAPS, a final set of daily coordinates for the first months of observation were averaged to derive the initial coordinates for each station. The next stage of the data processing and analysis utilised *R* (a language for computing and statistical analysis) to compute the Mahalanobis Distances. The data points beyond the Mahalanobis distance cut-off value were filtered out as outliers. To obtain a detailed picture of the magnitude of the errors and the accuracy level in the three-dimensional coordinates, the following accuracy metrics were computed: standard deviation – S.D (σ), standard error - S.E ($\sigma/\sqrt{N}$), mean absolute deviation (MAD) and root mean square error (RMSE). Correlation analysis was also performed to check for the correlation between the coordinate differences in the three directions. The MAD and RMSE have been widely used by researchers to measure model performance and are calculated for the data as follows (Chai and Draxler, 2014):

$$MAD = \frac{1}{n}\sum_{i=1}^{n}|e_i| \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2} \quad (2)$$

Next, using the Statistical Package for the Social Sciences (SPSS) version 16.0, an ANOVA test was conducted to explore the differences in the filtered X, Y and Z- coordinate differences. The null hypothesis (H_0) is that there is no significant difference in the means of the X, Y and Z coordinate differences or that the 3-dimensional coordinates are equally reliable. The converse forms the alternative hypothesis (H_1). H_0 is rejected if the *p-value* is less than the significance level of 0.05. If H_0 is rejected, meaning there is a significant difference among the groups, then a Tukey post-hoc analysis will be conducted in order to determine which specific groups differed from each other. Finally, to evaluate the sufficiency and adequacy of the NIGNET data, the data count of daily observations from the NIGNET portal was compared with that of an IGS station (BJCO) which is

believed to comply with the IGS and ICSM guidelines for the acquisition of high quality CORS data. One of the IGS requirements is the need to have long time series of continual stable measurements with as few disruptions and configuration changes as possible (IGS, 2017). For Tiers 1 and 2, less than 8 min/day and 9 hr/year of data outage is recommended, while for Tier 3 CORS, data outage should be less than 15 min/day and 44 hr/year (ICSM, 2014). ICSM (2014) also recommended a survey uncertainty of better than 20mm. These recommendations formed the basis for the assessment of the adequacy of the network data.

3.0. Results

3.1. Exploratory data analysis

Using the Mahalanobis distance method, the variability in the daily coordinates was analysed to screen out the outliers. Figure 2 shows a sample plot of X-coordinate differences against the Mahalanobis distance. All coordinate points beyond the cutoff distance of 2.795 were filtered off as outliers. This manifests in the density plot of the squared Mahalanobis distance shown in Figure 3. The good quality observations are concentrated towards the left portion of the plot. Further right, moving away from the square of the cut-off value, the outliers start to thin out over greater distances. Figure 4 shows a Q-Q plot of the squared Mahalanobis distance against the quantiles of chi-square of 2 degrees of freedom while Figure 5 presents a boxplot of the coordinate differences at all stations in the x-direction.

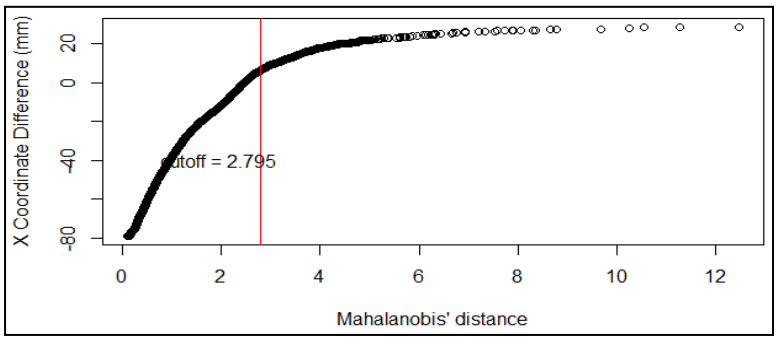

Figure 2: Plot of *x*-coordinate differences against the Mahalanobis distance

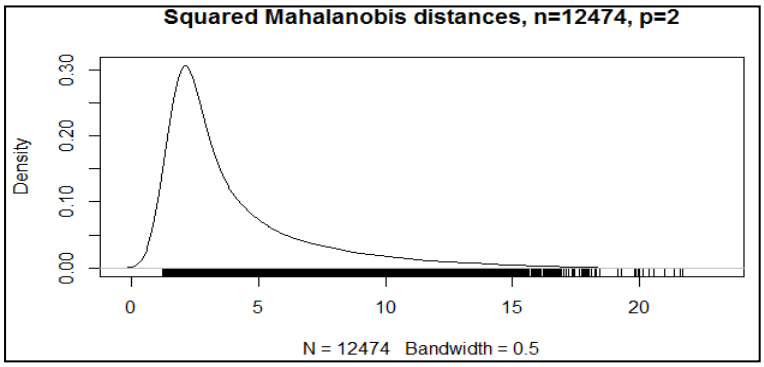

Figure 3: Density plot of squared Mahalanobis distance

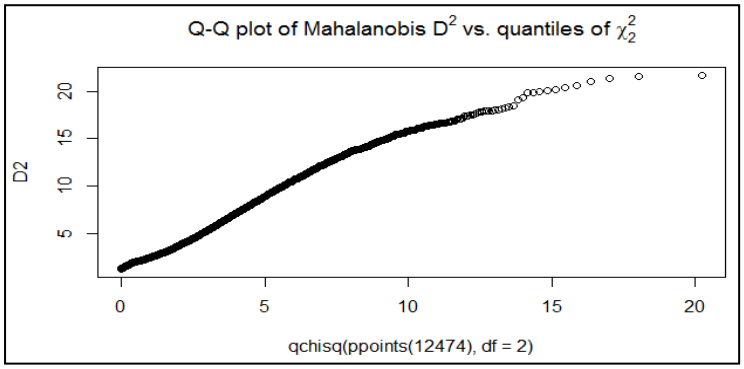

Figure 4: Q-Q plot of the squared Mahalanobis distance against the quantiles of chi-square of 2 degrees of freedom

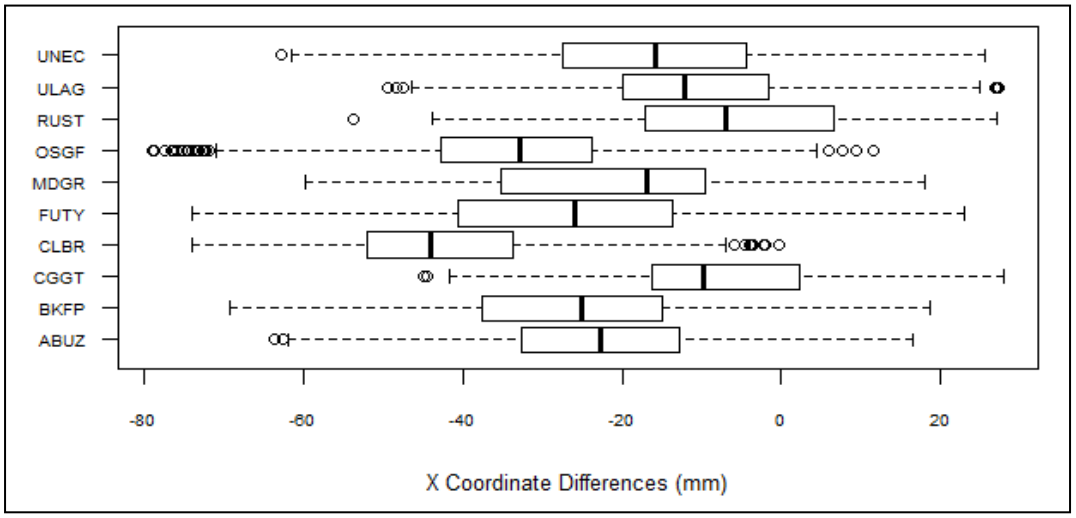

Figure 5: Boxplots of coordinate differences at all stations in the *x*-direction

3.2. Quantitative data analysis

3.2.1. Analysis of the initial station coordinates

Table 2 shows the mean and standard deviations of the initial station coordinates. The SDs in the x, y and z-directions are denoted by SDX_i, SDY_i and SDZ respectively. The results for the IGS station show that BJCO has SDs of 8.9 mm, 9.1 mm and 4.4 mm in the x, y and z directions respectively. In a general assessment of all the eleven IGS and NIGNET stations to understand the level of variability in the initial coordinates, MDGR has the lowest SD (4.9mm) while CLBR has the highest SD (31.6mm) in the x-direction. This signifies the stations with the minimum and maximum variability in the x-coordinates. In the y-direction, ABUZ and BKFP are the least variable stations with an SD of 2.5 mm while OSGF presents the highest variability (SD = 11.2 mm). In the z-direction, CLBR and BJCO are the stations with the minimum and maximum variability in coordinates with SDs of 1.4 mm and 4.4 mm. From the initial assessment, there is no clear indication of whether geographical location is responsible for the variability in coordinates. This is evidenced in the randomness observed in the distribution of the locations of the minimum and maximum values.

Table 2: Mean and standard deviations (SDs) of the computed initial coordinates

Station	$\overline{X}_i(m)$	$\overline{Y}_i(m)$	$\overline{Z}_i(m)$	$SD_{X_i}(m)$	$SD_{Y_i}(m)$	$SD_{Z_i}(m)$	N
ABUZ	6203493.826	833088.697	1225614.635	0.007	0.003	0.002	28
BJCO	6333076.479	270973.572	704552.107	0.009	0.009	0.004	16
BKFP	6211960.353	459365.476	1368115.049	0.006	0.003	0.002	29
CGGT	6201032.284	995277.242	1113815.522	0.007	0.003	0.003	29
CLBR	6287174.239	922979.461	546713.767	0.032	0.006	0.001	3
FUTY	6145058.500	1362078.873	1029389.914	0.008	0.004	0.003	30
MDGR	6080449.306	1418433.497	1299949.426	0.005	0.003	0.002	15
OSGF	6246471.278	820848.736	994267.941	0.010	0.011	0.003	21
RUST	6308859.048	772229.925	530354.458	0.012	0.004	0.004	14
ULAG	6326097.300	375576.105	719131.690	0.008	0.004	0.003	30
UNEC	6284298.307	827900.511	708988.588	0.011	0.003	0.002	28

3.2.2. Analysis of the daily station coordinates

Table 3 presents the mean absolute deviation (MAD) and root mean square error (RMSE) in the daily station coordinates from 2011-2016. In the table, the MAD describes the average distance of each daily coordinate from the mean (initial) station coordinates shown in Table 2. Similarly, the magnitude of the RMSE provides a good measure of the level of spread of the residuals in the data. CGGT has the lowest variability in the three directions ($MAD_X = 12.20mm$, $RMSE_X = 14.38mm$; $MAD_Y = 16.14mm$, $RMSE_Y = 18.44mm$; $MAD_Z = 12.72mm$, $RMSE_Z = 14.42mm$. This observation is as expected and it is not unconnected with the fact that CGGT is located in a solid location compared to the other stations. Similarly, CLBR which is located in the coastal zone has the highest variability in x and z-directions as expected ($MAD_X = 42.77mm$, $RMSE_X = 44.96mm$), and CLBR ($MAD_Z = 62.23mm$, $RMSE_Z = 67.02mm$), while FUTY ($MAD_Y = 64.87mm$, $RMSE_Y = 73.16mm$) has the highest variability y-directions.

Table 3: Summary of MAD and RMSE of the daily station coordinates from 2011-2016

Station	MAD_X (mm)	MAD_Y (mm)	MAD_Z (mm)	$RMSE_X$ (mm)	$RMSE_Y$ (mm)	$RMSE_Z$ (mm)
ABUZ	23.4859	55.1011	44.6664	27.1957	63.6742	53.4848
BKFP	26.8498	61.5280	48.2706	30.9037	70.7931	57.4000
CGGT	12.2014	16.1382	12.7178	14.3844	18.4408	14.4192
CLBR	42.7717	62.0155	62.2251	44.9635	67.9041	67.0195
FUTY	27.7770	64.8650	53.7864	32.3625	73.1647	62.3040
MDGR	21.5268	29.0277	21.9808	26.0540	37.5886	34.0503
OSGF	33.8218	45.8082	31.3158	37.1361	55.1622	41.5294
RUST	13.8697	25.2174	18.8248	16.7598	29.7339	22.6099
ULAG	14.6185	38.3836	28.9511	17.6079	42.5873	32.2187
UNEC	19.1426	57.3797	45.7222	23.0469	67.2318	55.1066

For a quick visualisation of the relationships in the coordinate differences, Figure 6 presents a correlation plots in the 3-dimensions across all the stations. The random spread of the points in the XY and XZ scatter plots shows there is negative correlation between the X and Y coordinate differences. There is also a negative correlation between the X and Z coordinate differences. However, the YZ plot shows a tight grouping of the coordinate differences in the y and z-directions. This shows that there is a high correlation between the Y and Z coordinate differences.

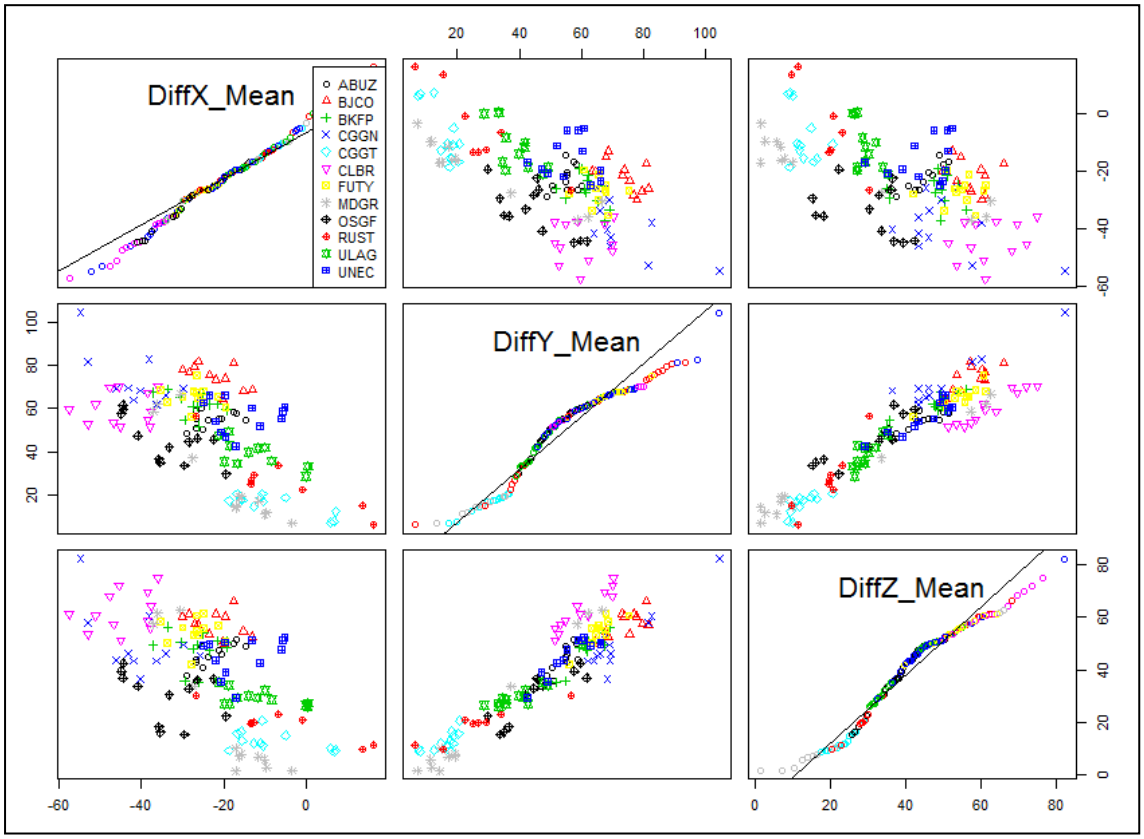

Figure 6: Correlation plot of the mean coordinate differences across all stations

3.2.3. Accuracy analysis of the yearly coordinate differences

After the outlier filtering using the Mahalanobis method, the descriptive statistics of the daily coordinate differences from 2011-2016 were calculated and are presented in Tables 4-6. For the coordinate differences in the x-direction, year 2015 has the least S.D of 12.839 mm while the highest S.D of 14.997 mm occurred in year 2013. For the y-direction, the least S.D was observed in the year 2011 (9.125 mm) while the highest S.D was observed in year 2013 (13.200 mm). The lowest and highest S.Ds in the Z-coordinate differences occurred in years 2016 (5.038 mm) and 2013 (8.629 mm). Figure 7 presents a plot of the mean coordinate differences across all the stations from 2011-2016. From the figure, the result shows a strong relationship between the *Y* and *Z* coordinate differences as the dispersion of their differences from the initial coordinates follows the same trend and direction while the *X* coordinate differences are moving in the opposite direction.

Table 4: Descriptive statistics of the mean X-coordinate differences from 2011-2016

Year	N	Mean (mm)	S.D (mm)	S.E (mm)	95% Confidence Interval for Mean (mm)		Min (mm)	Max (mm)
					Lower Bound	Upper Bound		
2011	2438	-8.585	13.539	27.400	-9.122	-8.047	-55.80	28.00
2012	2258	-20.283	14.487	30.500	-20.881	-19.685	-60.10	20.80
2013	2082	-24.231	14.997	32.900	-24.876	-23.587	-68.90	23.70
2014	1592	-36.332	13.653	34.200	-37.003	-35.661	-74.00	10.10
2015	535	-44.213	12.839	55.500	-45.304	-43.123	-74.00	-3.50
2016	924	-43.818	13.000	42.800	-44.658	-42.979	-78.90	-11.20

Table 5: Descriptive statistics of the mean Y-coordinate differences from 2011-2016

Year	N	Mean (mm)	S.D (mm)	S.E (mm)	95% Confidence Interval for Mean (mm)		Min (mm)	Max (mm)
					Lower Bound	Upper Bound		
2011	2438	16.893	9.125	18.500	16.531	17.256	-26.20	83.30
2012	2258	35.650	10.620	22.300	35.212	36.089	-10.10	79.20
2013	2082	58.548	13.200	28.900	57.981	59.116	9.00	108.80
2014	1592	76.284	12.336	30.900	75.678	76.891	35.80	151.20
2015	535	94.210	13.059	56.500	93.100	95.319	45.60	132.10
2016	924	117.985	10.880	35.800	117.283	118.687	84.00	147.00

Table 6: Descriptive statistics of the mean Z-coordinate differences from 2011-2016

Year	N	Mean (mm)	S.D (mm)	S.E (mm)	95% Confidence Interval for Mean (mm)		Min (mm)	Max (mm)
					Lower Bound	Upper Bound		
2011	2438	9.494	6.421	13.000	9.239	9.749	-10.60	69.50
2012	2258	26.855	7.564	15.900	26.542	27.167	0.50	54.30
2013	2082	46.125	8.629	18.900	45.755	46.496	21.50	90.40
2014	1592	65.750	6.689	16.800	65.421	66.079	43.70	112.40
2015	535	85.972	7.044	30.500	85.374	86.570	65.60	106.30
2016	924	104.269	5.038	16.600	103.943	104.594	88.00	122.30

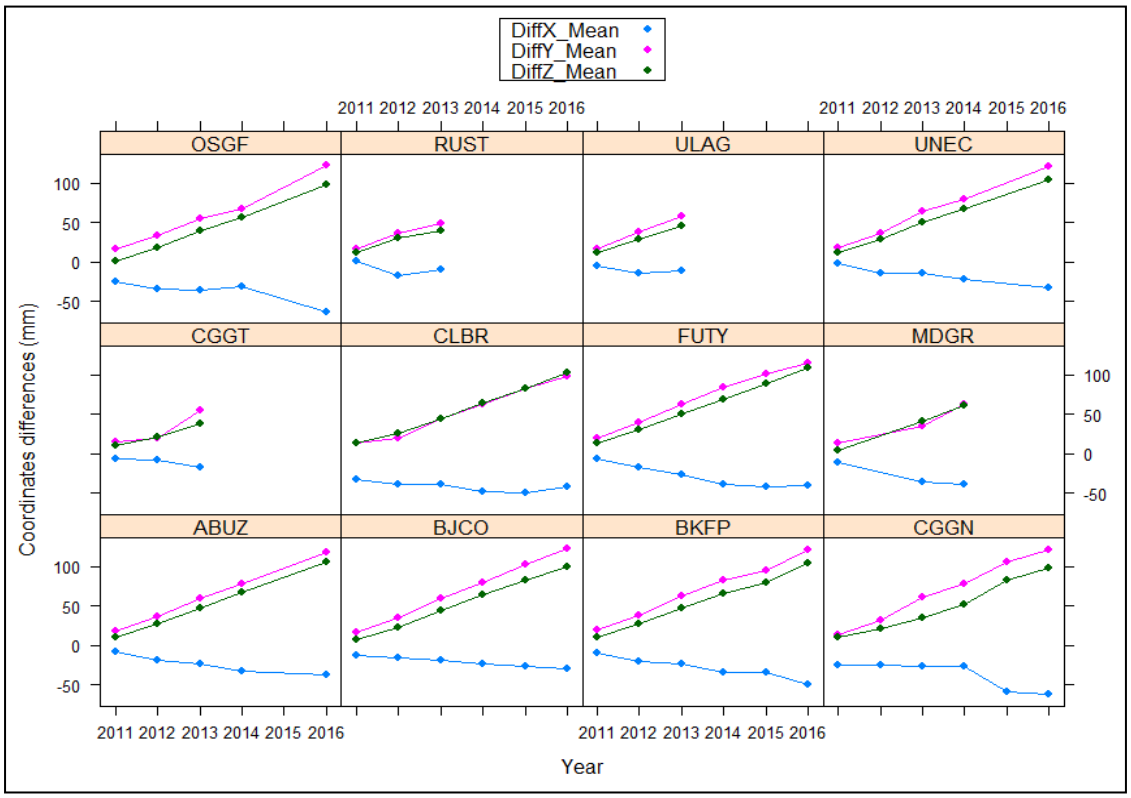

Figure 7: Mean coordinate differences across all stations from 2011 - 2016

In Figure 7, it is evident that the trend of dispersion of the X-coordinate differences is significantly different from the Y and Z coordinate differences. Having established this fact, the next section presents an ANOVA test to analyse the periodic (yearly) variations in the X, Y and Z coordinate differences.

3.2.4. Analysis of variance in station coordinates

The results of the ANOVA test in Table 7 shows that there is a significant difference between the X, Y and Z coordinate differences. The results of the ANOVA test suggest a rejection of the null hypothesis. Therefore, a Tukey Post-hoc test was conducted to further explore the differences in the epochs under comparison within the 2011-2016 period. The results of the Tukey Post-Hoc test presented in Tables 8-10 shows that there is a significant difference in the mean X-coordinate differences across all the epochs under study in the 2011-2016 period except for 2015 and 2016. That is, the mean X-coordinate differences for 2015 and 2016 are equally reliable. For the mean Y-coordinate differences and the mean Z-coordinate differences, there is a statistically significant difference between all the epochs under study in the 2011-2016 period.

The mean difference of the yearly comparisons shown in Table 8 yield the same value when viewed in both directions, the only difference being a change of sign from positive to negative or vice versa. For example, the mean difference for 2011-2012 is +11.698; for 2012-2011, it is -11.698. Consequently, the abridged versions of the post-hoc table are presented in Tables 8-10.

Table 7: Results of ANOVA test

		Sum of Squares	df	Mean Square	F	Sig.
DiffX_Mean	Between Groups	1433173.256	5	286634.651	1460.00	.000
	Within Groups	1928973.462	9823	196.373		
	Total	3362146.717	9828			
DiffY_Mean	Between Groups	9594701.173	5	1918940.235	14930.00	.000
	Within Groups	1262478.106	9823	128.523		
	Total	10860000.000	9828			
DiffZ_Mean	Between Groups	8624702.076	5	1724940.415	33510.00	.000
	Within Groups	505669.629	9823	51.478		
	Total	9130371.705	9828			

Table 8: Multiple comparisons of the mean X-coordinate differences with the Tukey Post-Hoc test

(I) Year	(J) Year	Mean Difference, I-J (mm)	S.E (mm)	Sig.	95% Confidence Interval	
					Lower Bound (mm)	Upper Bound (mm)
2011	2012	11.698	0.409	0.000	10.532	12.865
	2013	15.646	0.418	0.000	14.455	16.838
	2014	27.747	0.452	0.000	26.46	29.034
	2015	35.628	0.669	0.000	33.721	37.535
	2016	35.234	0.541	0.000	33.691	36.777
2012	2013	3.948	0.426	0.000	2.734	5.162
	2014	16.049	0.459	0.000	14.742	17.356
	2015	23.93	0.674	0.000	22.009	25.85
	2016	23.535	0.547	0.000	21.975	25.095
2013	2014	12.101	0.467	0.000	10.771	13.431
	2015	19.982	0.679	0.000	18.046	21.918
	2016	19.587	0.554	0.000	18.008	21.166
2014	2015	7.881	0.7	0.000	5.885	9.877
	2016	7.486	0.58	0.000	5.834	9.138
2015	2016	-0.395	0.761	0.995	-2.565	1.775

Dependent Variable - DiffX_Mean

Table 9: Multiple comparisons of the mean Y-coordinate differences with the Tukey Post-Hoc test

(I) Year	(J) Year	Mean Difference, I-J (mm)	S.E (mm)	Sig.	95% Confidence Interval	
					Lower Bound (mm)	Upper Bound (mm)
2011	2012	-18.757	0.331	0.000	-19.701	-17.814
	2013	-41.655	0.338	0.000	-42.619	-40.691
	2014	-59.391	0.365	0.000	-60.432	-58.350
	2015	-77.316	0.541	0.000	-78.859	-75.774
	2016	-101.092	0.438	0.000	-102.340	-99.843
2012	2013	-22.898	0.344	0.000	-23.880	-21.916
	2014	-40.634	0.371	0.000	-41.691	-39.576
	2015	-58.559	0.545	0.000	-60.113	-57.005
	2016	-82.334	0.443	0.000	-83.596	-81.073
2013	2014	-17.736	0.377	0.000	-18.812	-16.660
	2015	-35.661	0.550	0.000	-37.228	-34.095
	2016	-59.437	0.448	0.000	-60.714	-58.159
2014	2015	-17.925	0.567	0.000	-19.540	-16.310
	2016	-41.701	0.469	0.000	-43.037	-40.364
2015	2016	-23.775	0.616	0.000	-25.531	-22.020

Dependent Variable - DiffY_Mean

Table 10: Multiple comparisons of the mean Z-coordinate differences with the Tukey Post-Hoc test

(I) Year	(J) Year	Mean Difference, I-J (mm)	S.E (mm)	Sig.	95% Confidence Interval	
					Lower Bound (mm)	Upper Bound (mm)
2011	2012	-17.361	0.210	0.000	-17.958	-16.764
	2013	-36.632	0.214	0.000	-37.242	-36.022
	2014	-56.256	0.231	0.000	-56.915	-55.597
	2015	-76.479	0.343	0.000	-77.455	-75.502
	2016	-94.775	0.277	0.000	-95.565	-93.985
2012	2013	-19.271	0.218	0.000	-19.892	-18.649
	2014	-38.896	0.235	0.000	-39.565	-38.226
	2015	-59.118	0.345	0.000	-60.101	-58.134
	2016	-77.414	0.280	0.000	-78.213	-76.615
2013	2014	-19.625	0.239	0.000	-20.306	-18.944
	2015	-39.847	0.348	0.000	-40.838	-38.855
	2016	-58.143	0.284	0.000	-58.952	-57.335
2014	2015	-20.222	0.359	0.000	-21.244	-19.200
	2016	-38.519	0.297	0.000	-39.364	-37.673
2015	2016	-18.296	0.390	0.000	-19.407	-17.185

Dependent Variable - DiffZ_Mean

3.3. Sufficiency and adequacy of the station coordinates

Going further on the performance evaluation, the stations are expected to have a long time series of continuous stable measurements with as few disruptions as possible. Table 11 shows the NIGNET stations and the data count of daily observations available on the NIGNET server. In the period under study, the following stations had no data available on the NIGNET server – ABUZ (2015), CGGT (2014-2016), MDGR (2012; 2015-2016), OSGF (2015), RUST (2015-2016) and UNEC (2015-2016). It is observed that the data completeness has degraded overtime since the inception of NIGNET. The most severe cases of incomplete data occur in 2015 and 2016. Apparently, some components of the NIGNET infrastructure have been degrading with time and OSGOF has not been able to meet up with the maintenance demands.

Table 11: The selected NIGNET stations and the data count of daily observations

Station code	Latitude (degree)	Longitude (degree)	Ellipsoidal height (m)	Location	No. of Observations (Days)					
					2011	2012	2013	2014	2015	*2016
ABUZ	11.15	7.65	706.1	Zaria	365	366	355	350	0	180
BKFP	12.47	4.23	251.0	Birnin Kebbi	365	366	339	365	46	221
CGGT	10.12	9.12	917.4	Toro	365	39	116	0	0	0
CLBR	4.95	8.35	61.5	Calabar	36	363	340	355	284	190
FUTY	9.35	12.50	248.4	Yola	361	330	361	289	290	168
MDGR	11.84	13.23	351.8	Maiduguri	262	0	11	96	0	0
OSGF	9.03	7.49	533.6	Abuja	299	363	335	94	0	105
RUST	4.80	6.98	46.6	Port Harcourt	304	132	52	84	0	0
ULAG	6.52	3.40	45.5	Lagos	301	364	364	349	0	0
UNEC	6.42	7.50	255.4	Enugu	362	366	364	365	54	216
Total					3.2	5.8	2.6	23.8	3020	2689

*1 Jan – 10 Nov, 2016

There were also cases of unprocessed observations. These unprocessed observations were due to the fact that some of the RINEX files downloaded from the NIGNET portal contained only single frequency data. The reason for this issue with the RINEX files might be attributed to receiver malfunctions, poor station maintenance or issues with data collection and handling. It is also possible that there were configuration issues in some of the RINEX files created by OSGOF. Within the period under study, the total number of NIGNET data files successfully processed ranged from 76.2% in 2014 to 99.3% in 2016. However, virtually all the data files from BJCO were successfully processed with the least being 97.2% in 2012 as presented in Table 1. The most severe cases of unprocessed data in NIGNET occurred in 2012 and 2014 at RUST – 319 unprocessed files (64.4%) and 366 unprocessed files (100%) respectively; at ULAG in 2014 – 364 unprocessed files (99.7%) and at UNEC in 2015 – 365 unprocessed files (100%). Other significant cases occurred at CLBR – 2012 (19.6%), RUST – 2011 (29.9%), ULAG – 2013 (19.0%) and UNEC – 2014 (34.2%). Despite the observed disruptions in the data from BJCO, the IGS data are still more consistent and well distributed over the period under consideration. At no point was BJCO offline all year round as in the case of some NIGNET stations. This points to the fact that the IGS stations are well monitored and

better maintained than NIGNET. Summarily, the analysis conducted revealed a gross deficiency in data archiving and a consequent inadequacy of the network data to meet with the various geodetic needs. This is particularly evident in 2015 with maximum of 77% and 81% data recording in only two stations (CLBR and FUTY). The condition is worse in 2016 as only one station (BKFP) recorded up to 60% data.

4.0 Conclusion

This study examined the reliability of the GNSS data collected over a period of six years (2011 – 2016) from the Nigerian CORS network (NIGNET). Both exploratory and statistical data analysis techniques were used in the study to arrive at a concrete conclusion. The results obtained showed that while more than 80% of the network data is highly accurate in terms of positional accuracy and stability, the adequacy is highly deficient. This constitutes a serious challenge considering the requirements to meet various geodetic and geospatial needs. The current results revealed a 100% sub-standard in data recording and archiving in 2015 and 2016 when compared with the IGS standard. The trend observed in the data showed a deteriorating state that if nothing is done to address it, then not only is its objectives cannot be realised but also its sustainability is not guaranteed. To avoid this, the relevant stakeholders are enjoined to work together to salvage the network from failure.

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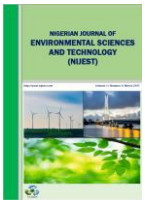

Residents' Awareness and Aspiration for Smart Building Features: The Case of Okota, Lagos, Nigeria

Oyewole M. O.[1,]*, Araloyin F. M.[2] and Oyewole P. T.[3]

[1,2,3] Department of Estate Management, Obafemi Awolowo University, Ile-Ife, Nigeria

Corresponding Author: *wolesike@yahoo.com

ABSTRACT

The study investigated the level of awareness and aspiration of residents for smart building features in Lagos, Nigeria. This is with a view to determining the extent of residents' level of familiarity and desire for smart homes in the country. Questionnaires were administered on 586 residents selected through systematic random sampling technique in the study area. Having identified the major streets in the study area, the first building along the major streets was selected randomly and every fifth building formed the subsequent unit of study. Data were analyzed with the use of frequency distribution, percentages, and measures of residents' aspiration index. The results showed that the awareness of smart building technologies was just fair in the study area as almost half of the respondents (49.21%) were not aware of smart building features. The results also indicated that internet facility ranked highest as the medium of awareness for the residents who were aware of smart building features. It was revealed that the aspiration of the residents for smart features was above average (2.98 on a five-point scale). The results showed that the features mostly aspired were features relating to "security and safety" (CCTV, Intrusion detection system and fire detection and alarm), while those relating to building maintenance (Moisture and humidity sensor and building performance analytic devices) were the least category of smart features desired.

Keywords: Energy efficiency, Facility management, Satisfaction, Security, Smart building, Smart features

1.0. Introduction

The growth in recent years in popular interest in smart building globally has been substantial. The concern has been driven largely by technological advancement and the quest for a safe, energy efficient and sustainable environment (Sinopolis, 2010). The need to incorporate smart features in real estate development is of utmost importance particularly in developing economies that are confronted with severe environmental challenges. Insecurity and energy crisis which are prevalent in most parts of the world could be alleviated by incorporating smart features in buildings.

In order to mitigate the severe environmental problem that has impeded economic growth and development in developing countries, adopting smart technology becomes imperative. The benefits of incorporating smart features in building design are enormous. Smart buildings are designed to guarantee energy conservation; greater systems' functionality; security of lives and properties, and health and productivity of the occupants (Sinopolis, 2010; Buckman *et al*., 2014). However, barriers to development and investment of smart building particularly in Nigeria and other emerging nations are numerous. The most critical constraint to investing in smart is perhaps the knowledge gap. To date, there is dearth of studies outside the developed economies on smart buildings. This makes developers, investors, government and even NGOs hesitant in the agitation and formulation of policies relating to the development of smart buildings.

It is in the context of the foregoing that information on the residents' awareness and inclination for smart homes especially their degree of preference for specific features of smart building is particularly important in overcoming many of the constraints to smart building practices. This study therefore will

begin to fill this gap in literature by investigating residents' inclination for smart homes in an emerging economy with particular reference to Lagos, Nigeria. Such information is expected to assist developers/investors, investment advisers and managers in the planning and managing the supply of smart buildings. It is also expected that the study will provide useful information for foreign investors targeting Nigeria and other emerging economies.

Relevant studies have been carried out on smart building in developed and some emerging economies. However, such studies have received very insignificant attention in Africa countries. In the United Kingdom, Chapman and McCartney (2002) investigated the perception of people with physical disabilities with a view to identifying appropriate technology to generate energy efficient building. Using Portsmouth smart homes as a case study, the authors employed focus group discussion and in-depth interviews to establish how smart technology might boost independence and quality of life of people with disabilities. The result showed that the respondents desired a home that can respond to emergencies and environmental changes and that will not stand out from neighbouring properties. Meanwhile, the survey above was specifically targeted at people with physical disabilities and tailored towards their peculiar needs.

Ma *et al.* (2005) discussed the potential trends and challenges of smart technologies. The study posited that the future world would be highly computerized and transmuted to a smart world. The paper also suggested that challenges exist in translating ubiquitous things to smart world and trustworthy services owing to both technical and real world complexities. Apart from the fact that the study did not consider the aspiration of the users, the paper also lacked in empirical evidence.

Taylor (2006) examined the benefits that integrated systems offer facility managers and owners who sought to security and overall performance of building. The study revealed that there was innovative technology emerging in the security market that offered major improvement for facilities and security managers and end users. Sabha (2006) investigated the impact of embedded smart sensor (ESS) technologies on users' performance. The study discovered that ESS would have wide ranging effects on office users' productivity depending on the utility of space and internal environment. Apart from the fact that the study focused on a developed economy (UK), the study did not investigate the extent of users' aspiration for smart building technologies.

Kim *et al.* (2009) sought to identify security technologies that were essential in making home network systems secure. The research model was designed to support basic functions of smart security technologies. The findings revealed that home network users could access services conveniently and securely. The study also revealed that security policy for home network required specialized rather than general specification. Apart from the fact that only one attribute of smart building was considered, the perception of users was not considered.

Linskell and Hill (2010) illustrated how smart technology can enhance the provision of supported living for people with complex needs and challenging behavior. The authors adopted an informal semi-structured approach to review the effectiveness of technological solutions that had been employed and interview a range of staff from a number of projects. The study concluded that smart home technology had been demonstrated to be effective in providing information that assist in reducing the level of direct supervision of individuals with complex needs and challenging behaviour. Apart from the fact that the study was carried out in a developed economy where implementation framework exists for a smart building, the opinion of residents who are the users was not explored.
Kadaouche and Abdulrasaq (2012) proposed a novel model for inhabitant prediction in smart houses. The model was designed to learn users' habits when they performed their daily activities, and then predicts the user. The findings showed that the users could be recognized with high precision which imply that each user had his own way of performing the activities. Apart from the fact that the study focused on a more matured market, the survey was based on blind user recognition in smart homes to predict users without personal information.

Sidawi and Deakin (2013) evaluated the potential of smart city technologies to promoting healthy lifestyles for diabetic patients in the Kingdom of Saudi Arabia. The authors reviewed the link between diabetes, unhealthy lifestyles and built environments and found that smart technology that was being developed in Saudi Arabia did not highlight the health related benefits of their design and layout.

Foray (2014) focused on the difference between smart specialization and smart specialization policy by constructing a conceptual framework based on historical evidence. The paper highlighted important design principles for the policy process that should help to minimize potential risks of policy failure and policy capture. Flores *et al.* (2015) sought to design and test the effective indoor navigation solutions for visually impaired people utilizing internal measurement units, the compass and barometer of a smart phone. The study discovered the possibility of guiding visually impaired some hundreds of meters using sensors of a smart phones under certain conditions. Aside the fact that the study focused on a developed economy, the aspiration of the users for the technology was not investigated.

Arditi *et al*. (2015) examined the perspectives of constructional professionals of the various features of smart buildings with a view to developing an index of smartness. The findings indicated that the designers and owners were more focused on energy issue than constructors, and those professionals with less years of experience gave greater attention to the subject of energy. Though, the paper sought the opinions of some key stakeholders in the supply of smart products, the perception of users who are the key stakeholders in the demand side was not addressed.

Wong and Leung (2016) sought to identify factors driving senior citizens to adopt smart home technology that support ageing-in-place in Hong Kong. The study employed structural modeling approach and found that strong government support and efficient back up supporting service and the design of user interface devices were the major factors influencing the adoption of smart home technology. Cooper *et al*. (2017) developed a model to harness occupancy sensing in a commercial hot-desking environment. The authors employed data from a commercial office environment in London to feed a discrete event stimulator and showed that sensor data can be used for desk allocation in a hot-desking environment with results that outweighs the cost of occupancy detection. The study also demonstrated that overall productivity of occupants increased as individuals were allocated desk of their preference. However, the focus of the paper is on office environment and not residential property which is the subject of this study.

Some more recent works include Yang *et al*. (2017) proposed and validated a new theoretical model that extended the theory of planned behavior. The study identified mobility, security/privacy, risk, and trust in the service provider as the major factors affecting the adoption of smart home services. The study was carried out in South Korea, a country in Asia continent, where socio-cultural background is different from what obtained in Africa. Hence, the result from this study is not completely adaptable to regions of different socio-cultural background as Nigeria.

Rana *et al.* (2018) examined the barriers to the development of smart cities in India. The authors employed Analytic Hierarch Process technique and discovered that 'Governance' was the most dominant category of barriers affecting smart city development in India. Aside the fact that the study focused smart city and not specifically on smart building, the opinion of the users was not sought. The same argument can be said of Leung (2018) who investigated the hotel stakeholders' perspectives of smart technology with a view to identify gaps between academia and hotel industry in Taiwan. With a focus on definition, expectation and barriers to implementation of smart technology, the authors conducted interviews on investors, managers, owners, technology suppliers and IT consultants. The result of the analysis suggested that the definition of smart hotel was never the same among all stakeholders.

Relative to emerging economy, Gonel and Akinci (2018) explored the potential of ICT use on finding solution to environmental problems in Turkey. The study found that Turkey had an ability to monitor and control data and that smart building was becoming popular with the use of ICT. Although, the study was carried out in an emerging economy, the aspiration of the residents to employ smart technology was not investigated.

Bullie *et al.* (2018) investigated the correlation between the efforts of an employ to comply with security policy and vulnerability. The authors conducted a penetration test involving security locks in the context of building security and found that installing additional key activators was not conducive to reducing vulnerability of handing over of keys to strangers.

Dritsa and Biloria (2018) considered the role of emerging technologies in the promotion of health and wellbeing by examining various technologies associated with smart health care. Specifically focusing on smart cities, physical sensing systems and geospatial data, the result showed that though the technologies had been explored, there was little consideration on the transition from the domestic to urban level. Wilson *et al*. (2017) evaluated the risks and benefits of smart home in the United Kingdom. The authors conducted a national survey of 1025 home owners a field trial of 42 smart home technologies' (SHTs) users and 62 SHT marketing materials. The results showed that the respondents had a positive perception of SHTs while identifying certain risks in the area of 'ceding autonomy and independence in the home for increased technological control'. The analysis also showed that SHT industry was insufficiently emphasizing measures to boost users' confidence on data security and privacy. The study was carried out in a developed economy where structure for smart technology exists. Hence the result from the study may not be completely adaptable to a developing nation as Nigeria. The same can be said of Hargreaves *et al*. (2018) which explored the use of smart home technologies in Loughborough, England. The researchers conducted experiment on 10 households and found that the technologies were both technically and socially disruptive; requires both adaptation and familiarization and demanding and time consuming to learn. The study also showed that there was little evidence that smart technologies would generate substantial energy saving.

In summary, there is the dearth of studies on the users' perspectives on smart building in emerging economy as Nigeria. The study is therefore important, more so, the world has become a global village, and with the incursion of foreign investors in Nigerian real estate market, there is the need to probe into users' awareness and aspiration for smart building.

2.0. Materials and Methods

In investigating the residents' inclination for smart building, the paper focused on both renters and owner-occupiers of residential properties in Okota, Lagos state of Nigeria. The study area was restricted to Okota, Lagos owing to researchers' familiarity with the area purposely to enhance easy data collection and high level of response.

Owing to the absence of the list of houses and with the decision to sample 20% of the buildings in the study area, the systematic random sampling technique was adopted. Having identified the major streets in the area, the first building along the streets was chosen randomly and every fifth buildings formed the subsequent unit of study. Questionnaires were targeted at the household heads. However, where this was not possible, any other person who was not below the age of 18 was targeted. All households in the selected buildings were sampled. Thus, a total of 586 residents in the area were selected. Data on respondents' social economic characteristics, awareness and aspiration for smart building were elicited through structured questionnaire.

In order to develop the questionnaire (research instrument), the authors first carried out extensive literature review to identify twenty five features of smart building as listed in Table 1. The validation of these twenty five items was subsequently carried out considering the perception of experts who are operating in the country. In determining the suitability and appropriateness of the instrument, the questionnaire was given to academicians and practitioners for review. Once this was done, the questionnaire went through refinement process in line with the suggestions of the experts. Furthermore, personal interviews were conducted with some residents (potential respondents) in form of pilot survey to identify the suitability of the instrument and likely difficulties and issues which could affect respondent's ability to provide accurate answers. All experts and potential respondents agreed that all questionnaire items are relevant and offered constructive suggestions for improvement. As a result, minor revisions were made before the final data collection was undertaken.

The residents were asked to rate each of the features using Likert's scale of *highly inclined*, *inclined*, *somewhat inclined*, *not inclined*, or *not at all inclined.* During the analysis, these ratings were assigned weight values of 5, 4, 3, 2 and 1 respectively. The residents' aspiration index (RAI) for each of the variables was arrived at by dividing the summation of weight values ((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; Oyewole and Komolafe, 2018). The residents' aspiration index (RAI) thus ranged between values of 5 to 1.

Table 1: List of smart building features identified from the literature

Smart Building Features	References
Video Surveillance (CCTV)	Wong *et al*. (2008), Sinopolis (2016), Wong and Leung (2016), Fabi *et al*. (2016), Fabi *et al*. (2016), Bhati *et al*. (2017)
Intrusion detection system	Sinopolis (2016), Fabi *et al*. (2016)
Fire detection and alarm	Wong et al.(2008), Wong and Leung (2016), Fabi *et al*. (2016)
Smart thermostat	Sinopolis (2016), Kirkpatrick (2016), SMUD (2017)
Wi-Fi	Sinopolis (2016), Kirkpatrick (2016), SMUD (2017)
Water reclamation device	Sinopolis (2016)
Automatic lighting system	Wong et al.(2008), Kirkpatrick (2016), SMUD (2017), Bhati *et al*. (2017), Fabi *et al*. (2016)
Sensor operator water fixtures	Batov (2015)
Access control	Buckman *et al.* (2014)
Smart meter for monitoring and measuring power to the building	Batov (2015)
In-building cell phone	Sinopolis (2016), Fabi *et al*. (2016)
Devices that maintain building system	Sinopolis (2016), Fabi *et al*. (2016)
Rain water harvesting appliance	Sinopolis (2016)
Water meter	Batov (2015)
Audio-visual	Sinopolis (2016), Wong and Leung (2016), Bhati *et al*. (2017)
Devices that monitor building system	Buckman *et al.* (2014)
Telecom and data system for communication network	Sinopolis (2016), Wong and Leung (2016)
Smart trackers for house keys	Sinopolis (2016)
Meter for measuring usage, specific spaces, tenants or electrical circuits	Sinopolis (2016)
Asset location devices	Sinopolis (2016)
Smart locks	Sinopolis (2016)
Digital signage (LCD or plasma display)	Sinopolis (2016), Fabi *et al*. (2016)
Moisture and humidity sensor	Sinopolis (2016)
Building performance analytic devices	Sinopolis (2016), Fabi *et al*. (2016)
Fault detection and diagnosis for HVAC	Wong *et al*. (2008), Cole and Brown (2009), Fabi *et al*. (2016)

This is expressed mathematically as:

$$TWV = \sum_{i=1}^{5} P_i V_i \quad (1)$$

where:
TWV Total weight value
P_i Number of respondents rating a feature
V_i Weight assigned to each feature i.

The RII to each feature is arrived at by dividing TWV by the summation of the respondents to each of the five ratings of a feature.

This is expressed mathematically as:

$$RAI = \frac{TWV}{\sum_{i=1}^{5} P_i} \quad (2)$$

where:
RII Residents' inclination index

P_i and TWV as defined previously.

The closer the RAI of a feature to 5, the higher the assumed residents' inclination for the feature.
The mean of the RAI distribution was also computed. Furthermore the deviation about the mean of each feature was also calculated to measure the scatter about the mean.

The total response rate was 254 residents out of 586 (43.34%). Though the response rate was not too impressive, it seems adequate particularly in exploratory research in built environment (Arditi *et al*. 2015), also in developing countries such as Nigeria where people's apathy to field research is noticeable (Olaleye and Adegoke, 2009). The 254 responses constitute a large enough sample that allows statistical inference and leads to logical conclusion, particularly because people from all works of life (public servants, private sectors employees, traders, owner-occupiers and tenants) were properly represented.

3.0. Results

In presenting the results of the survey, the paper first examined the socio-economic attributes of respondents and their level of awareness since housing need and requirement is a function of one's social economic status and level of awareness.

3.1. Residents' socio-economic characteristics

The result of the analysis on residents' socio-economic characteristics such as gender, age, educational qualification, accommodation status and types of accommodation, religion, occupational profile among others are presented below.

3.1.1. Gender distribution of the respondents

The result of the analysis shows that 170 (66.93%) of the respondents were males while 84 (33.07%) were females. The finding indicates that more males were household heads. This result however is not unexpected since the culture and the tradition of the people in this part of the world confers headship on males as the head of their respective families.

3.1.2. Age distribution of residents

The response on the question pertaining to the age distribution of the residents showed that 1.57, 1.57, 11.81, 15.75, 57.49 and 11.81 percent were aged between 18 and 19, 20 and 29, 30 and 39, 40 and 49, 50 and 59, and 60 and above respectively. The analysis indicated that majority of the residents who were household heads aged between 50 and 59 years of age.

3.1.3. Educational qualification and occupational profile of the residents

In order to ascertain the educational qualification of the respondents, questions were asked that require the respondents to indicate their highest educational qualification. The result showed that 0.79, 35.43 and 63.78 percent had primary, secondary and tertiary education, respectively. Given this outcome, one may conclude that the majority of the respondents were highly educated. The response on occupational profile showed that 33.86, 21.26, 24.41, 14.96, and 5.51 per cent of the respondents were public servants, private sector employees, traders, consultants, and artisans respectively. The result indicated that the residents of the study area cut across all occupations and professional affiliations.

3.1.4. Accommodation status and types of accommodation of residents

The study enquired into the accommodation status of the residents in order to know those who were owner-occupiers and those who were tenants. The result showed that 80 (31.5%) were owner-occupiers while 174 (68.5%) were tenants. This results suggests that majority of the respondents were tenants. The finding is not unexpected since majority of residents in Nigerian major cities could not afford to own their own house owing to the inaccessibility of institutional sources of housing finance to most Nigerian households (Onibokun, 1985; Oyewole, 2010). The finding revealed that 35.43, 26.77, 15.75, 12.60, 1.57, and 7.87 per cent of the respondents lived in Block of flats, Bungalow, Detached House, Duplex, Mansion, and Semi-detached House, respectively. Given this outcome, one may conclude that the study area houses low, middle and high income members of the society.

3.2. Level and medium of awareness of smart building

In order to ascertain the residents' level of understanding of smart building, questions were asked that required the respondents to indicate their level of awareness of smart building technology.

The findings as indicated in Table 2 revealed that 42 (16.49%) of respondents are very much aware of smart building; 87(34.25%) slightly aware and 125 (49.21%) not aware of smart building. This result showed that the level of awareness of smart building features was just fair as almost half of the respondents (49.21%) were not aware of smart building.

Table 2: Tenants' level of Awareness of Smart Building

Level of Awareness	Frequency	Percentage
Very much aware	42	16.49
Slightly aware	87	34.25
Not aware	125	49.21
Total	254	100.00

On the medium of awareness, the result as revealed in Table 3 shows that greater percentage of the respondents were aware of the smart technologies through internet. Specifically, the finding revealed that 37.11% were aware through internet, 28.56% through television, 8.56% through friends and relations, 10.31% through estate agents, 10.31 through journals, and 5.15% through radio. From this finding, it is established that residents who were aware of smart building technology knew mainly through the medium of internet. The result is not unexpected owing to the scarcity of smart buildings in the country, and the global connectivity of internet technology which is popularly embraced by the Nigerian populace.

Table 3: Residents' medium of awareness of smart building

Medium	Frequency	Percentage
Estate Agent	13	10.31
Internet Website	48	37.11
Friend/Family members	24	18.56
Television	24	18.56
Radio	7	5.15
Brochure	13	10.31
Total	129	100.00

3.3. Residents' aspiration for smart building features

The degree of importance placed on each of the features, denoted by Residents Aspiration Index (RAI), is presented in Table 4. Also shown in the Table is the average RAI denoted by $\overline{\text{RAI}}$. This is obtained by summing up the RAI for each feature and dividing it by the number of identified features (n = 25). Thus the average RAI for all smart features was 2.98. Smart building features with RAI higher than $\overline{RAI}$ were *video surveillance*; *intrusion detection system; fire detection and alarm; smart thermostat; WiFi; water reclamation devices; automatic lighting system; and sensor operator water fixtures*. The implication is that the degree of aspiration for each of these features was higher than the aspiration derived from the aggregate aspiration for the smart building features. The deviations about the $\overline{RAI}$ for each of the features were 1.65, 1.41, 1.35, 1.15, 1.15, 0.92, 0.77 and 0.45 respectively.

Features with lower RAI than $\overline{RAI}$ were *access control; smart meter for monitoring and measuring power to the building; in-building cell phone; devices that maintain building; rain water harvesting appliances; water meter; audio visual; devices that monitor building systems; telecom and data system for communication network; smart trackers for house keys; smart locks; meter for measuring usage specific spaces, tenants or electric circuits; asset location devices; digital signage (LCD or Plasma); moisture and humidity sensor; building performance analytic devices; and fault detection and diagnosis for HVAC.* The feature with the highest RAI was *video surveillance (CCTV)* with an RAI of 4.63, while *building performance analytic devices,* and *fault detection and diagnosis for HVAC* ranked least with an RAI of 2.24.

Further analysis indicated that thirteen out of the twenty five smart features attracted RAIs above average (2.50 out of 5.00). The features are *video surveillance, intrusion detection system, fire detection and alarm, smart thermostat, WiFi, water reclamation devices, automatic lighting system, sensor operator water fixtures, access control, smart meter for monitoring and measuring power to the building, in-building cell phone, devices that maintain building and rain water harvesting appliances.* The implication of this is that the degree of aspiration of residents for the aforementioned features was above average.

The feature of smart building with the highest RAI was *video surveillance (CCTV)* with a RAI of 4.63, and seconded by *intrusion detection system* with a RAI of 4.39. The degree of aspiration expressed by residents for "video surveillance" and "intrusion detection" could be attributed to the ability of the devices to enable residents to monitor and control their security system (Kirkpatrick, 2016). With the spates of security lapses in the country, the concerns of the residents and the degree of their aspiration for features relating to security of lives and property is not unexpected.

It is also interesting to note that the level of residents' aspiration for some other features such as *smart thermostat* (RAI = 4.13), *WiFi* (RAI = 4.13), *water reclamation* (RAI =3.90) *and automatic lighting system* (RAI = 3.75) ranked high. The degree of aspiration associated to these features could be explained by a number of reasons. The level of aspiration associated *with smart thermostat* and *automatic lighting system* for instance could be explained by residents' concern to conserve energy owing to the energy crisis bedeviling the study area. The degree of aspiration of residents for *WiFi* could be ascribed to residents' craves for internet. The rate at which the citizens were embracing the use of internet has resulted to the astronomical growth in the number of internet users in the country which according to Olowole (2018) has been ranked among the top ten in the world.

Table 4: Residents' aspiration for smart building features

Smart building features	TWV	RAI	RAI-$\overline{RAI}$	(RAI-$\overline{RAI}$)^2	Ranking
Video Surveillance (CCTV)	588	4.63	1.65	2.72	1
Intrusion detection system	558	4.39	1.41	1.99	2
Fire detection and alarm	550	4.33	1.35	1.82	3
Smart thermostat	525	4.13	1.15	1.32	4
Wi-Fi	525	4.13	1.15	1.32	4
Water reclamation device	495	3.90	0.92	0.85	6
Automatic lighting system	476	3.75	0.77	0.59	7
Sensor operator water fixtures	435	3.43	0.45	0.20	8
Access control	374	2.94	-0.04	0.16	9
Smart meter for monitoring and measuring power to the building	333	2.62	-0.36	0.13	10
In-building cell phone	331	2.61	-0.37	0.14	11
Devices that maintain building system	329	2.59	-0.39	0.15	12
Rain water harvesting appliance	321	2.53	-0.45	0.20	13
Water meter	316	2.49	-0.49	0.24	14
Audio-visual	316	2.49	-0.49	0.24	15
Devices that monitor building system	312	2.46	-0.52	0.27	16
Telecom and data system for communication network	306	2.41	-0.57	0.32	17
Smart trackers for house keys	303	2.39	-0.59	0.35	18
Meter for measuring usage, specific spaces, tenants or electrical circuits	301	2.37	-.0.61	0.37	19
Asset location devices	301	2.37	-0.61	0.37	20
Smart locks	301	2.37	-0.61	0.37	21
Digital signage (LCD or plasma display)	296	2.33	-0.65	0.42	22
Moisture and humidity sensor	286	2.25	-0.73	0.53	23
Building performance analytic devices	285	2.24	-0.74	0.55	24
Fault detection and diagnosis for HVAC	284	2.24	-0.74	0.55	25

$\overline{RAI} = 2.98$

Also worthy of note are the smart building features that ranked low in the degree of residents' aspiration index. The two least smart features in order of their RAIs (based on ranking) are *building performance and analytic devices* and *fault detection and diagnosis for HVAC.* The low level of aspiration for these features might be as a result of what Tijani *et al*. (2016) termed "lack of maintenance culture" in the country. The result shows that the residents were not really cherish these features as the level of aspiration for these features was very low.

4.0 Conclusion

The study presented an assessment of the awareness and aspiration of the residents for features of smart homes in Lagos. The results revealed that majority of residents were slightly aware, while some were not even aware of smart features.

To promote the awareness and understanding of the smart features in Nigeria, sensitizing government agencies, developers and property users in particular is imperative. There is the need for widespread campaign by all agencies concerned with the advancement of smart buildings. Developers, investors and property managers and occupiers should be educated on the various elements of smart buildings to avoid what Allameh *et al*. (2012) termed "a mismatch between end users demands and smart home possibilities".

The study found that residents aspired more for smart features directly linked to security. The implication of this is that residents were more interested in features associated with security of lives and properties such as "video surveillance", "intrusion detection system" and "fire detection and alarm". It is advocated that residents should be educated on the benefits of features that are related to health such as "devices that prevent occupant from chemical, biological, and radiological attacks" and "carbon monoxide alarm". Educating the residents on the importance of health promoting features is fundamental to ensuring a sustainable future.

The study also established that the level of aspiration for features relating to property management was low. Most of the elements in this category of smart features such as "devices that monitor building systems", "fault detection and diagnosis for HVAC" and "building performance analytic device" attracted RAIs of less than average. Raising the level of awareness of the importance of property management smart features is central to ensure sustainable building performance.

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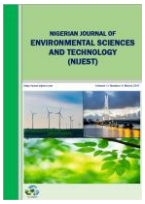

Application of Remote Sensing, GIS and Hydrogeophysics to Groundwater Exploration in parts of Lagos Metropolis: A case study of Oshodi/Isolo LGA

Epuh, E.E.[1], Sanni, K.A.[2,]* and Orji, M.J.[3]

[1,2&3]Department of Surveying and Geoinformatics, University of Lagos, Nigeria

Corresponding Author: *sannikhafilah@gmail.com

ABSTRACT

Productivity through groundwater is quite high as compared to surface water, but groundwater resources have not yet been properly exploited. The present study is used to delineate various groundwater potential zones for the assessment of groundwater availability in Lagos metropolis using remote sensing and GIS and hydrogeophysics techniques. Landsat 8, SRTM, geological, soil, and rainfall data were used in the study to prepare various thematic maps, viz., geomorphological, slope, soil, lineament density, rainfall and land use maps. On the basis of relative contribution of each of these maps towards groundwater potential, the weight of each thematic map have been selected and assigned to each map. Hydrogeophysics investigation using Vertical Electric Sounding (VES) was applied to validate the remote sensing and GIS results. All the thematic maps have been registered with one another through ground control points and integrated using the weighted overlay method in GIS for computing groundwater potential index. Based on the methological approach, the ground water potential zones were delineated. The results showed that there are five categories of groundwater potential zones within the study area in which percentage values were contained in each of the categories thereby making major portion of the study area "high" and "moderate" prospect while a few scattered areas have "low" prospect. The very high potential areas are mainly concentrated along the River Alluvium while the "very low" prospect are majorly where there is sand and clay. The best groundwater potential zone is in the southern part due to the presence of fractures, swamp soils which have high infiltration ability and the presence of waterbody which is chiefly accountable for the groundwater recharge in any area. The VES data showed the depth of the aquifer for good water and the polluted aquifer within the study area.

Keywords: Remote Sensing, GIS, Hydrogeophysics, Groundwater, Aquifer

1.0. Introduction

Water, composed of both surface and groundwater is one of the most significant natural resources which support both human needs and economic development (Ogunba, 2016). As a result of the increasing population and the demand for good quality water to meet the growing needs; such as the agricultural, industrial and domestic uses, quite a lot of attention has been placed on surface water being a component of the hydrological cycle for water supply, particularly in urban areas, while groundwater was considered only as a means of rural water supply. However, the situation is changing even on a global scale (Soladoye and Ajibade, 2014). According to Gronwall *et al.*, (2010), an estimated 269 million urban dwellers depend on well water as their principal source of drinking water. In urban Nigeria, it is estimated that almost 60 percent of the population rely on local water wells. This rapid development of groundwater resources seems to be partly due to large-scale pollution of surface water. The people's need for self-supply of water is due to lack of alternate water sources and the generality with the wide availability of groundwater leading to its low capital development, cost and excellent natural quality (Foster and Chilton, 1993). However, these speedy

and uncontrollable uses poses many problems as it can lead to over-exploitation if not properly sited and managed.

Groundwater often referred to as a hidden resource, is usually stored between pores in the rock, or in fractures, known as aquifers. Its occurrence, movement and availability in any terrain is largely controlled by the prevalence and orientation of primary and secondary porosity (Solomon, 2003) and permeability of the surface and underlying lithology (Shahid *et al.*, 2000). Though, to determine the location of aquifer, quality of groundwater, physical characteristics of aquifers, etc., in any basin, test drilling and stratigraphy analysis are the most reliable and standard methods. However, such an approach for groundwater investigations is very expensive, time-consuming and requires skilled manpower (Sander *et al.*, 1996). Hence, the application of indirect Remote Sensing method with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within a short time, has emerged as a very useful tool for the assessment, monitoring and management of groundwater resources. Jha *et al.* (2007); Saraf and Chowdhary (1998); Khan and Moharana (2002) and Sankar (2002) have demonstrated the technique of integration of remote sensing data and GIS tool to be extremely useful for groundwater studies. Consequently, various attempts have been made in the generation of different thematic maps for the delineation of groundwater potential zones in different parts of the country (ObiReddy *et al*., 2000). The analysis of remotely sensed data along with soil, rainfall, slope, geological map as well as other collateral information with necessary ground checks, helps in generating the base-line information for ground water prospecting. In the present study, a part of Lagos state metropolis has been selected for qualitative evaluation and assessment of ground water potential zones using remotely sensed data, hydrogeophysics and GIS.

2.0. Methodology

2.1. Hydrogeology of the study area

Lagos state is basically a sedimentary area located within the western part of Nigeria, a zone of coastal creek and lagoon (Figure 1). The area is also developed by barrier beaches associated with sand deposition (Hill and Webb, 1987). The sub-surface geology reveals two basic lithologies; clay and sand deposits. These deposits may be interbedded in places with vegetable remains and peak. The water bearing strata of Lagos state consists of sand, gravel or admixtures from fine through medium to coarse sand and gravel (Longe *et al.*, 1987). Basically, there are four major aquiferous units that are being tapped for the purpose of water supply in the Lagos metropolis. The first aquifer extends from ground level to roughly 12 m below ground. It consists of alternation layers of clay and sand. This upper aquifer is prone to contamination because of its limited depth.

The second aquifer is encountered between 20 and 100m below sea level and it can be found around Ikeja and Ojota axis. This aquifer is of greater importance for water supply purposes throughout Lagos metropolis (Jones and Hockey, 1964). The third aquifer in the central part of Lagos has a depth ranging from 130-160 m below the sea level and the fourth aquifer is located at an elevation of approximately 450 m below sea level. It is separated from the third aquifer by a rather thick layer of shale of the Ewekoro formation (Jones and Hockey, 1964).

2.2. Generation of thematic maps

This basically entails the process of image classification. Table 1 shows the datasets and their sources. On the basis of relative contribution of each of these maps towards groundwater potential, the weight of each thematic map has been selected and assigned to each map as shown in Table 2. In this research, the following steps were put into consideration:

i. Processing of digital images using the various processing techniques, viz; enhancement, filtering, classification and other GIS processes. The image processing was carried out in the spatial reference system of the data source.
ii. Analysis and interpretation of the downloaded satellite data, in order to produce thematic maps, such as lineament density, land-use maps etc
iii. Satellite images which had been geometrically corrected and rectified to the WGS 84 ellipsoid and Universal Transverse Mercator (UTM) projection system were

downloaded in the GeoTiff image format with its image parameters described in Table 3.

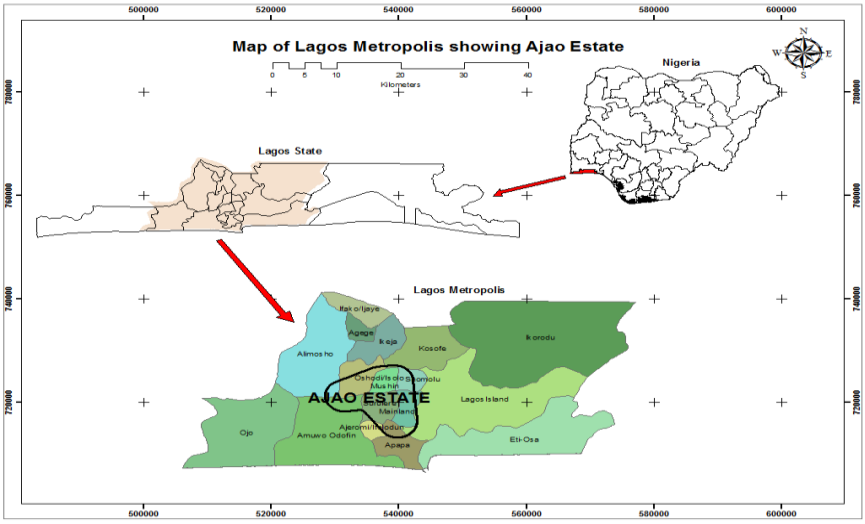

Figure 1: Lagos Metropolis Map

Table 1: Datasets used

Date	Publisher/source	Year
Lithology	Primary field data acquired using VES Method	2018
Landsat Imageries (path191/ row 55)	Downloaded from USGS https://earthexplorer.usgs.gov/	2016
Rainfall data	Nigerian Meteorological Agency (NIMET) Annual Report	2016
SRTM(DEM) (191/55)	Downloaded from https://earthexplorer.usgs.gov/	2018
Geological map	Published by Nigeria Geological Survey Agency (NGSA)	2004
Soil map	Published by Soil Survey Division, Fed. Dept. of Agric. Land Resources (FDALR)	1990

Table 2: The assigned weights and scores to different themes and features respectively

S/N	Themes	Weightage Influence (%)	Each Class Of Themes (Features)	Score
1	Geomorphology	30	River Alluvium	10
			Amphibole, schist	8
			Sand and clay	6
2	Rainfall	22	1387-1554	10
			1554-1661	20
			1661-1715	30
			1715-1742	40
			1742-1780	50
3	Soil Map	18	Swamp soils	40
			Reddish Friable Porous Sand	24
4	Lineament Density map	15	0-1	9
			2-4	18
			5-7	24
5	Slope	10	0-2	40
			2-5	32
			5-10	24
			10-17	16
			17-67	8
6	Land use	5	WaterBody	10
			Built-up	8
			Wetlands	6
			Vegetation	4
			Barelands	2

Table 3: The coordinate system

Parameters	Quantity Value
Projection	UTM Zone 31N
False easting	500000.0
False northing	0.0
Central meridian	3.0
Scale factor	0.9996
Latitude of origin	0.0
Linear Unit	Meter
Datum	WGS 1984

2.3. Methods

The Landsat satellite image, path and row 191/55 was used. Figure 2 shows the flow chart for the project execution.

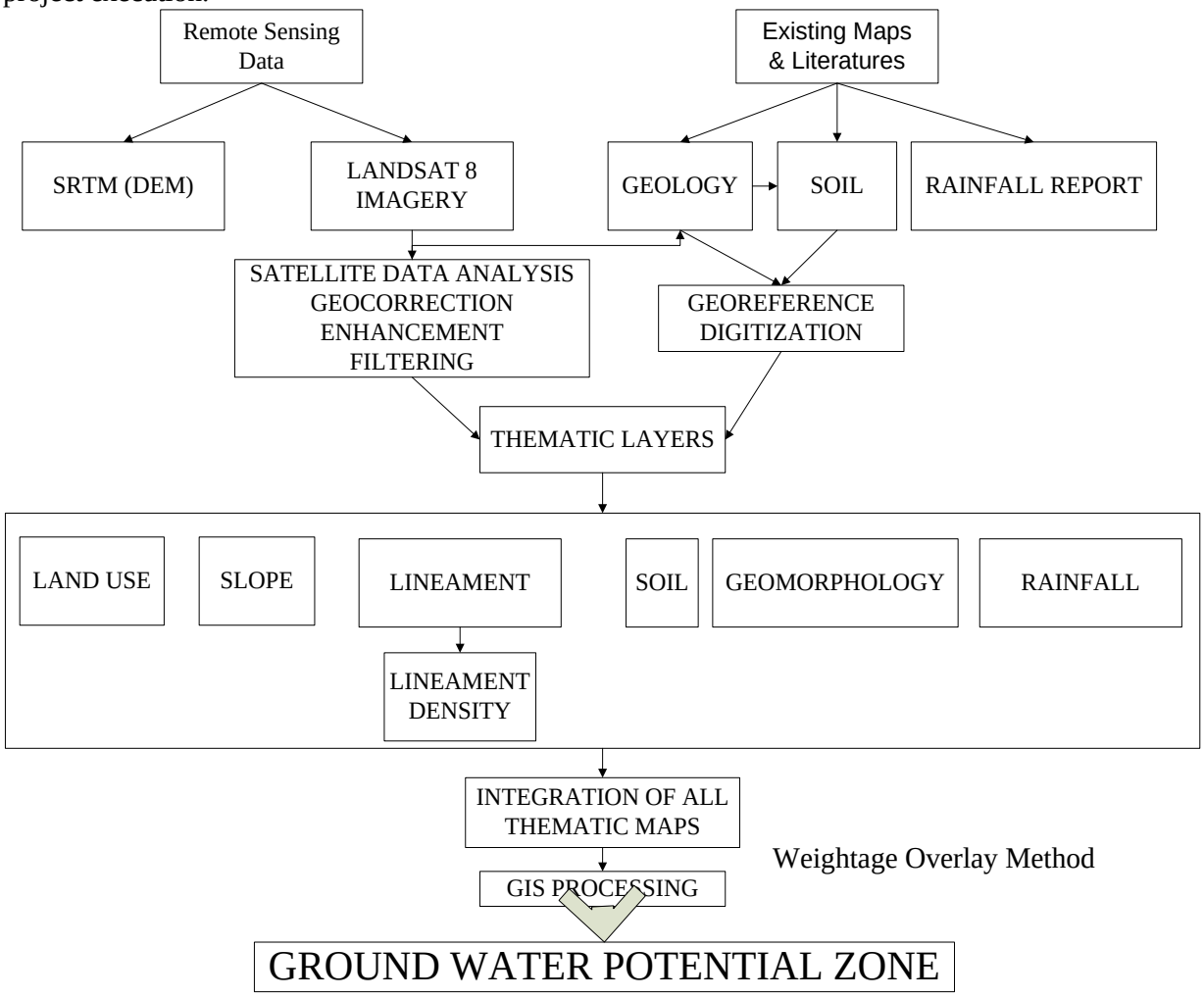

Figure 2: Flowchart for execution

3.0. Results and Discussion

3.1. Results

This presents the result and analysis of the different thematic maps produced namely: slope, land use/ land cover, geomorphology, lineament density, rainfall and soil map.

3.1.1. Geomorphology map

The thematic layer reveals three types of geomorphology units namely; sand and clay, River Alluvium and Amphibole, schist. Larger part of the study area was covered by River alluvium with an area of 2650.25 km^2, Amphibole and schist with an area of 1003 km^2. The least area was covered under sand and clay which covers an area of 232 km^2. Suitable weightage and score has been assigned based on

the rock influence on groundwater. Thus, for this study, River alluvium is the predominant and most assigned geomorphology unit due to its greater influence on groundwater. Figure 3 shows the Geomorphology map of Lagos metropolis.

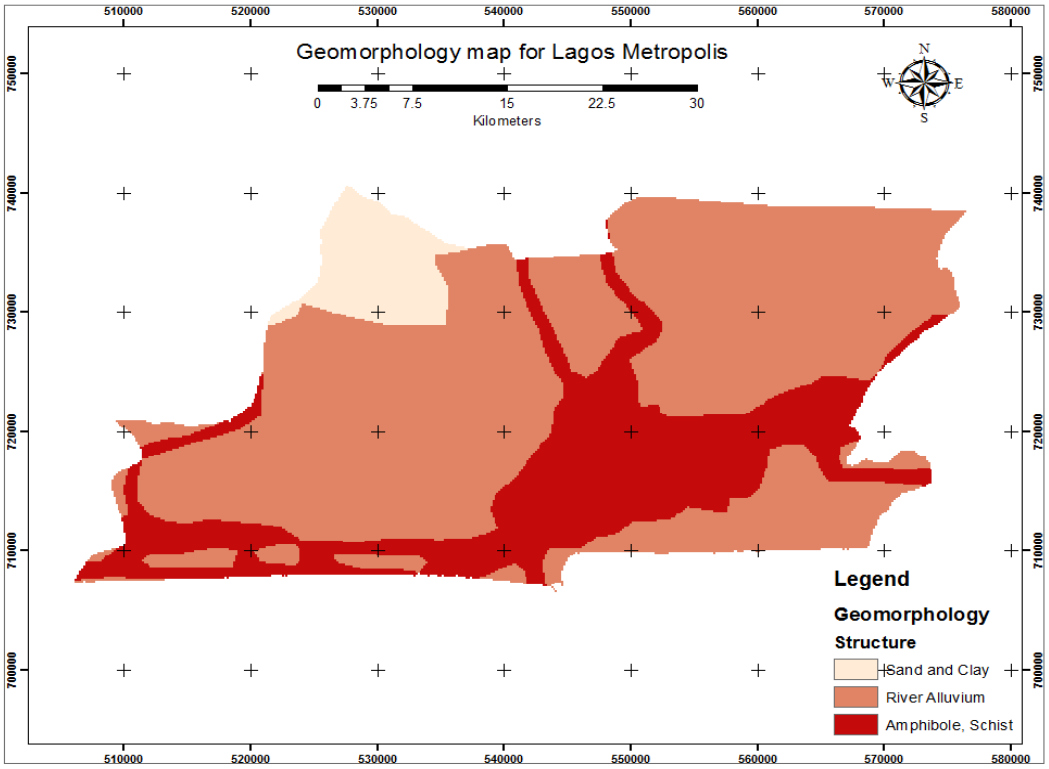

Figure 3: The geomorphology map of Lagos metropolis

3.1.2. Rainfall map

Once the spatial distribution of rainfall has been found; the study area were classified into five zones based on the equal interval and suitable weightage which has been assigned for each classes. Figure 4 shows Lagos metropolis rainfall map.

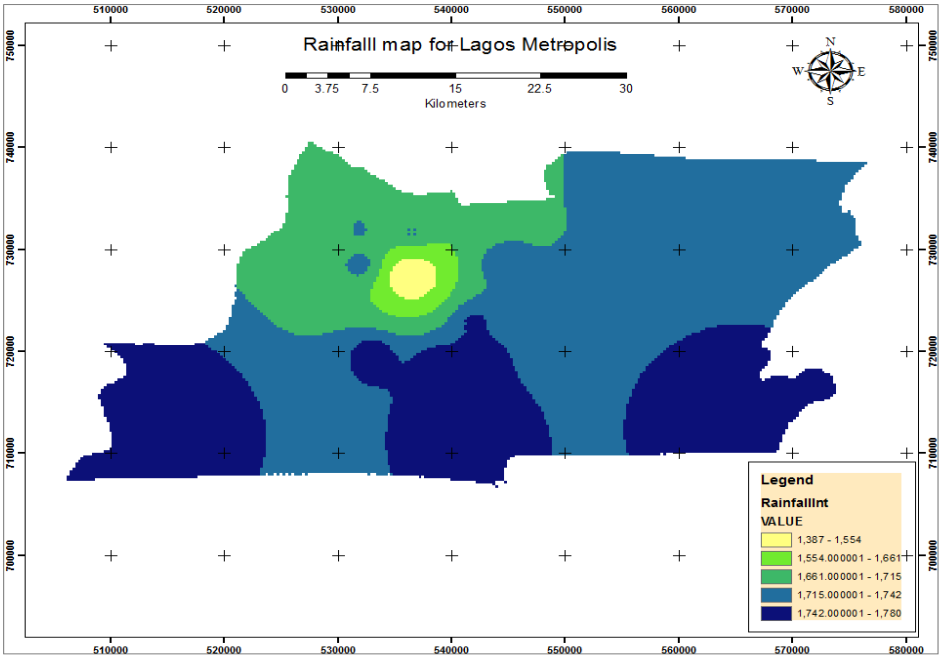

Figure 4: Thematic rainfall map of Lagos metropolis

3.1.3. Soil map

The soil map result (Figure 5), shows that there are two types of soil in our study area which are swamp soils; that covers the southern part of the study area and reddish friable porous sandy clay; covers northern part of the study area. The movement and infiltration of water in these types of soils is not the same. Therefore, based on this property; the score value assigned to swamp soils is greater as they are forested wetlands that may contain water for the whole year.

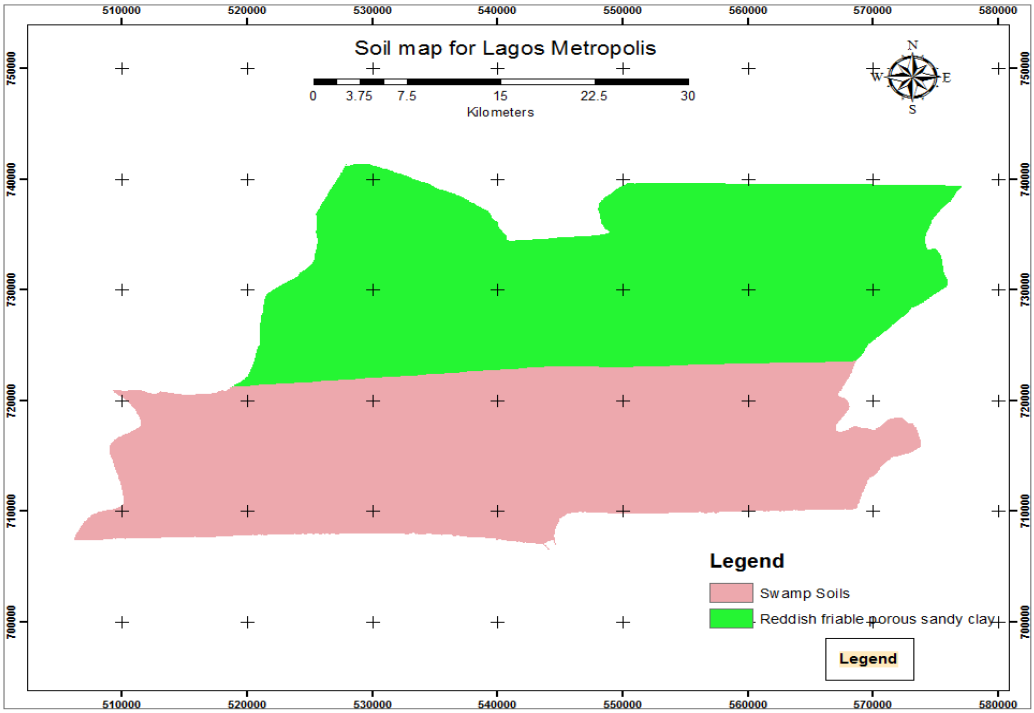

Figure 5: Thematic soil map of Lagos metropolis

3.1.4. Lineament density map

The lineament map was prepared from the band 8 pan shapen enhanced imagery. This was done using automated extraction techniques with the aid of PCI Geomatica 2017 Software, It involves transforming each of the shape points into a straight line in parameter space. Arc GIS v. 10.4 was also used for result analysis. Lineament act as a conduit for groundwater flow and hence, are hydrogeologically significant. The values given for lineaments were based primarily on the relation of well yields to proximity of lineaments. Figure 6 show the lineament density result generated after lineament process. Four (4) classes were defined based on distance from the lineament. From the result, values assigned to the various classes in the lineament decreases as the distance of the buffer zones around the lineament increases. This implies that, the closer the buffer zones are to the lineament. The better are the chances of ground water targeting.

3.1.5. Slope map

The slope of the study area has been calculated in percentage (%) based on the Digital Elevation Model (DEM) which was based on the SRTM data. The slope have been classified into five categories varying from 0-67% as shown in Figure 7.

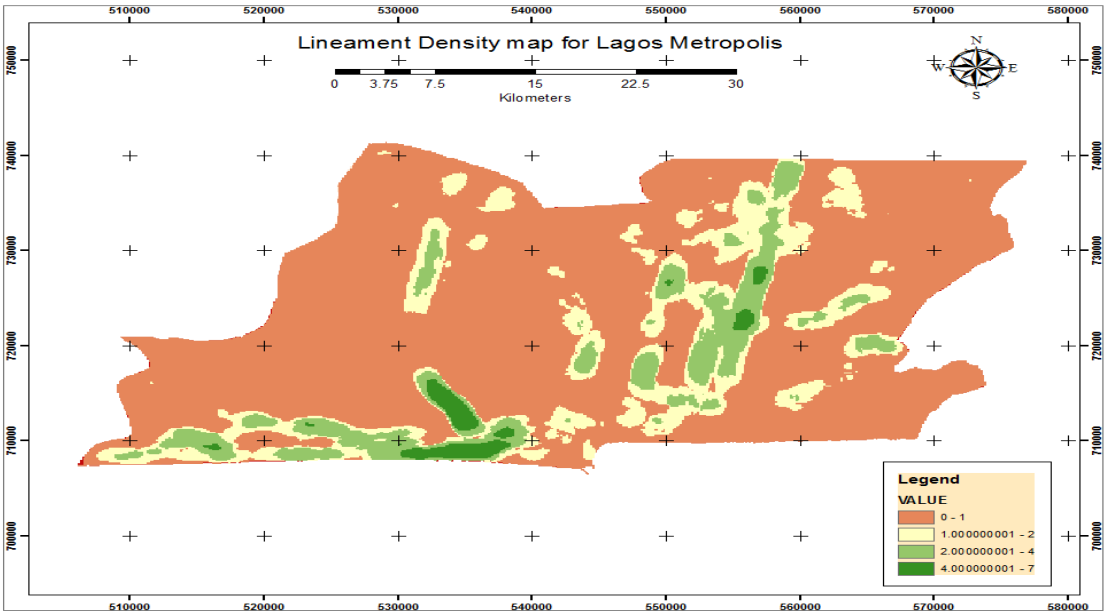

Figure 6: Lineament density map of Lagos metropolis

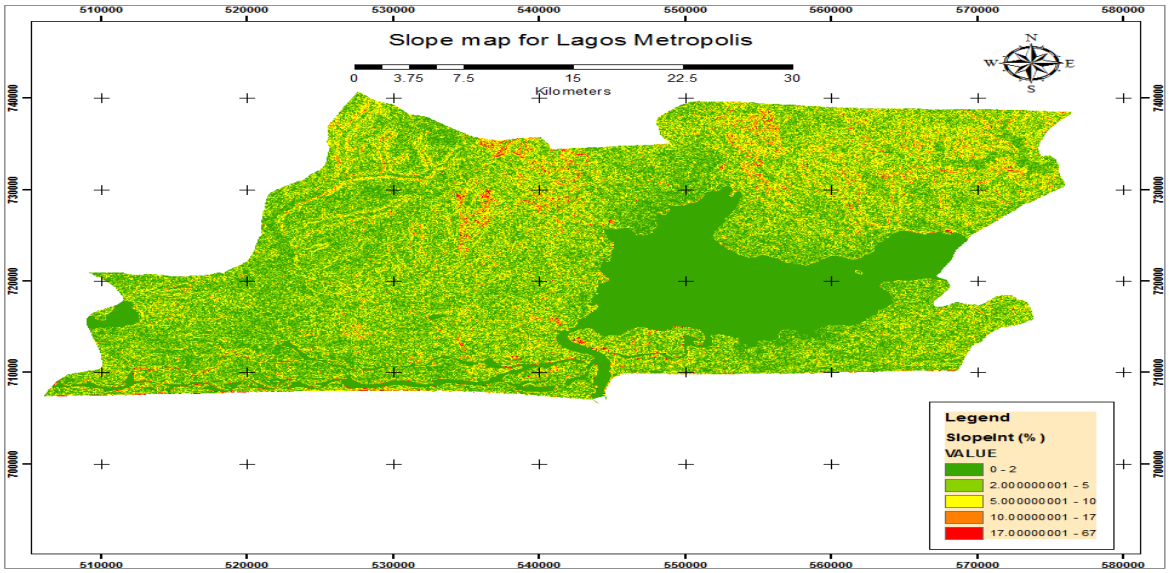

Figure 7: Thematic slope map of Lagos metropolis

3.1.6. Land use / Land cover (LULC) map

The LULC study is useful in assessing impacts of different land uses on water infiltration capacity. From this research, the land use/land cover classification result show that the study area, Lagos metropolis is covered by five classes namely; built-up, bareland, vegetation, wetland and waterbody as shown in Figure 8. It also shows that barely do we have bareland, the entire area is dominated mostly by built-up and waterbody. This dominance help stabilize the surface temperature of the environment, provide clean water and act as shoreline and storm protection.

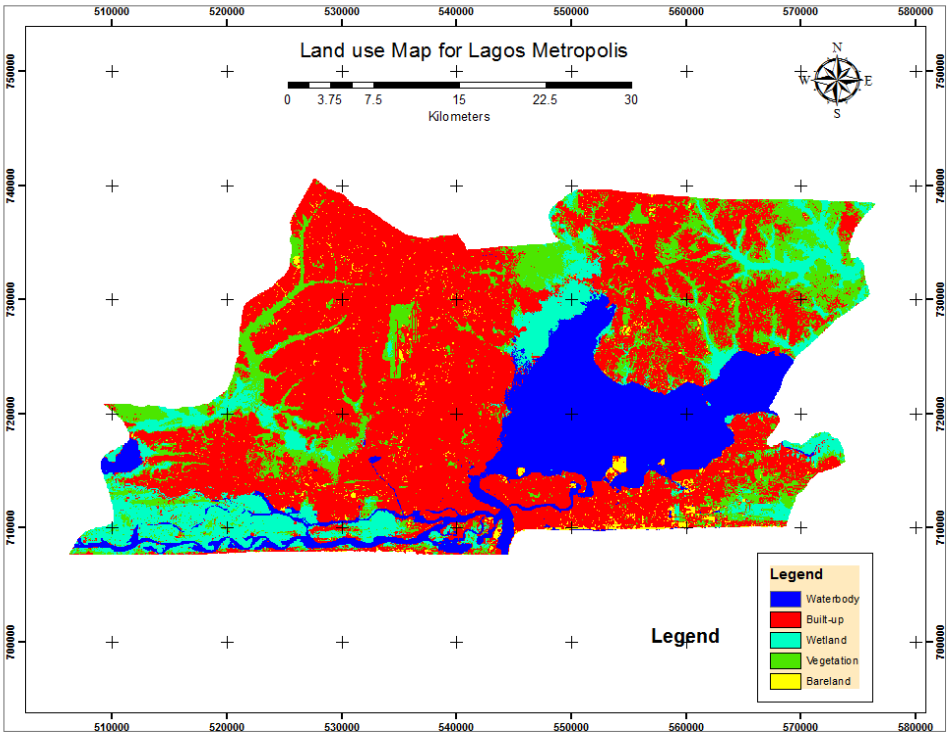

Figure 8: Land use map of Lagos metropolis

3.1.7. Integration of thematic layers using ArcGIS (weightage overlay method)

The ground water potential zones were obtained by overlaying all the six thematic maps in terms of weighted overlay method using the spatial analysis tool in Arc GIS 10.4. Table 2 shows the scores that have been given for each individual parameter of the thematic maps and the weight assigned according to each individual parameter influence on ground water. The weights and rank have been taken, considering the works carried out by researchers such as (Krishnamurthy *et al*., 1996; Saraf and Chowdhary, 1998). All the thematic maps were converted into raster format and superimposed by weighted overlay method (rank and weight wise thematic maps were integrated with one another through GIS ArcInfo grid environment). For assigning the weight, the geomorphology and rainfall map were assigned higher weight due to their high water infiltration, whereas the slope and land use/land cover were assigned lower weight. After assigning weights to different parameters, as shown in Table 2, individual ranks are given for sub-variable. Then, each of the individual themes were overlaid one at a time to get the final composite map such that each polygon in the final composite map is associated with a particular set of information of all thematic layers. Also, the evaluation of ground water prospect for each polygon in the output is based on the added values of scores of various themes as described in Equation 1.

$$GWPI = GsGw + RsRw + SsSw + LsLw + SLsSLw + LUsLUw \quad (1)$$

where:

GWPI	Ground Water Potential Index,
SL	Slope,
G	Geomorphology,
L	Lineament density,
LU	Landuse/landcover,
S	Soil,
R	Rainfall,
s	Score of the feature in the theme and
w	Weight of the theme.

The range of GWPI values (score value) were divided into five classes (called zones) and the GWPI of different polygons falling under different range were grouped into one class. Thus, the entire study

area was qualitatively divided into five ground water potential zones namely; very high potential, high potential, moderate, low potential and very low potential for groundwater as shown in the Figure 9.

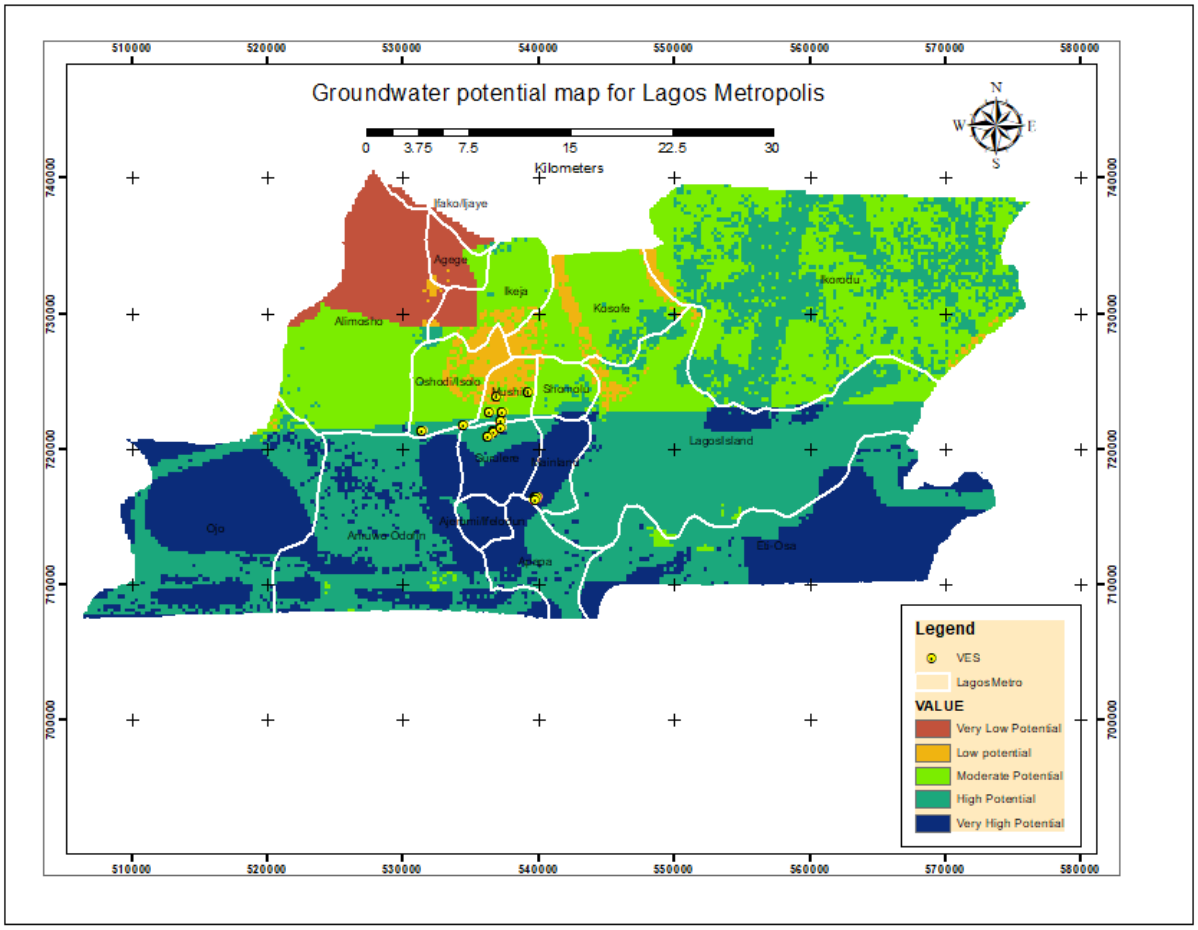

Figure 9: Groundwater potential map for Lagos metropolis

3.2. Discussion

The ground water potential zones map given in Figure 9 shows that 22.8% of the total study area that is Lagos metropolis is under very high zone, 40.4% of the area falls under high, 28% of moderate, and 3% low and 6% very low potential zone as shown in Table 4 with Figure 10 showing the chart of the distribution. Major portions of the study area has “high” prospect while a few scattered areas have “low” prospect as shown in Figure 10. The very high potential areas are mainly concentrated along the River Alluvium while the “very low” prospect is majorly where there is sand and clay.

Table 4: Area distribution of ground water potential zone

S/N	Groundwater potentialzone	Area (Sq.Km)	Area (Percent)
1	Very Low	88.9375	5.672486646
2	Low	49.4375	3.153153153
3	Moderate	440	28.06346169
4	High	632.75	40.35717133
5	Very High	356.75	22.75372718
	Total	1567.875	100

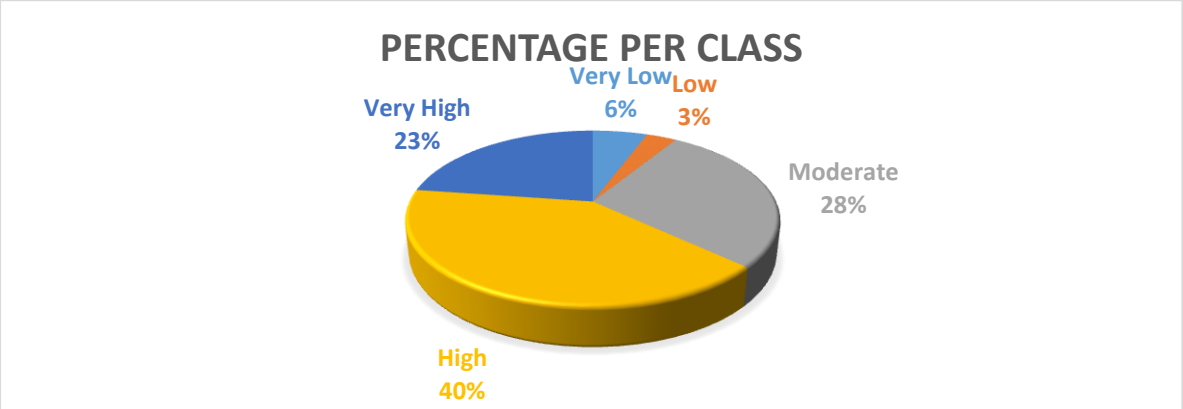

Figure 10: Pie chart showing the area distribution of ground water potential zone

3.2.1. Queries carried out in the project

- **Query one**

"DEPTH__M_"<=10 AND "DEPTH__M_">=3

This was carried out to show the VES station that their depth falls between 3 and 10 m as shown in Figure 11 below.

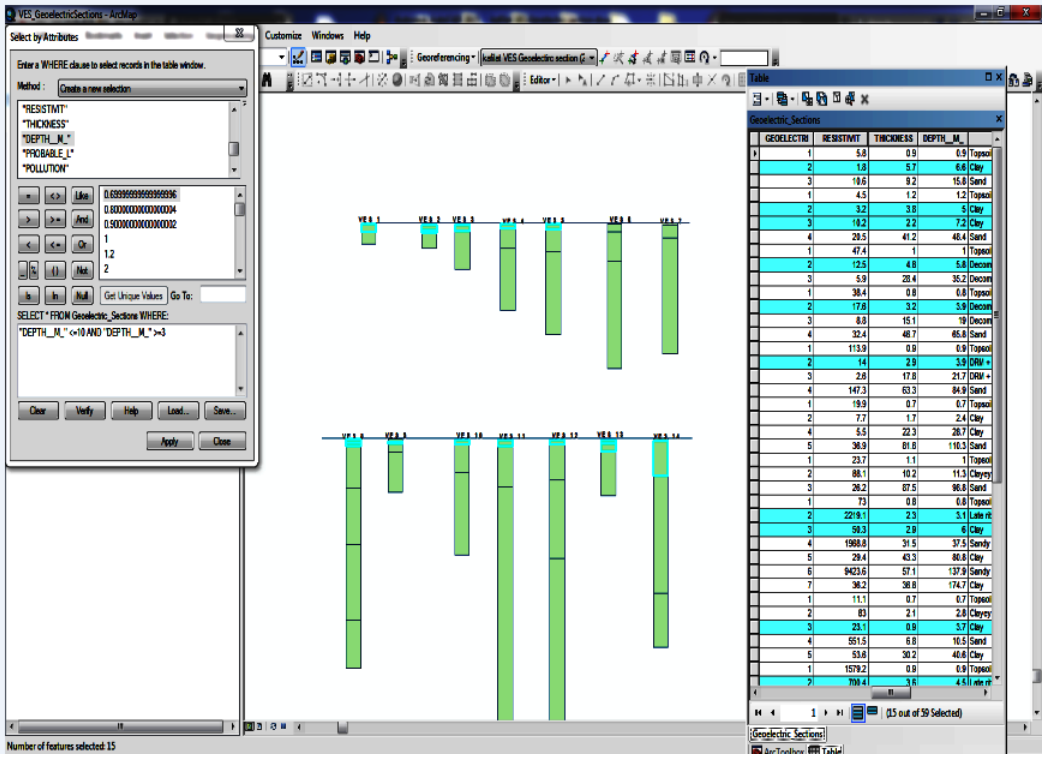

Figure 11: Borehole depths between 3 and 10 m

- **Query two**

"POLLUTION"= 'Polluted'. This is done to know areas that are polluted so that one will not bother to drill such areas. From the result, as shown in Figure 12, we found out that VES location 1, 2, 4, 6, 12 falls into that category.

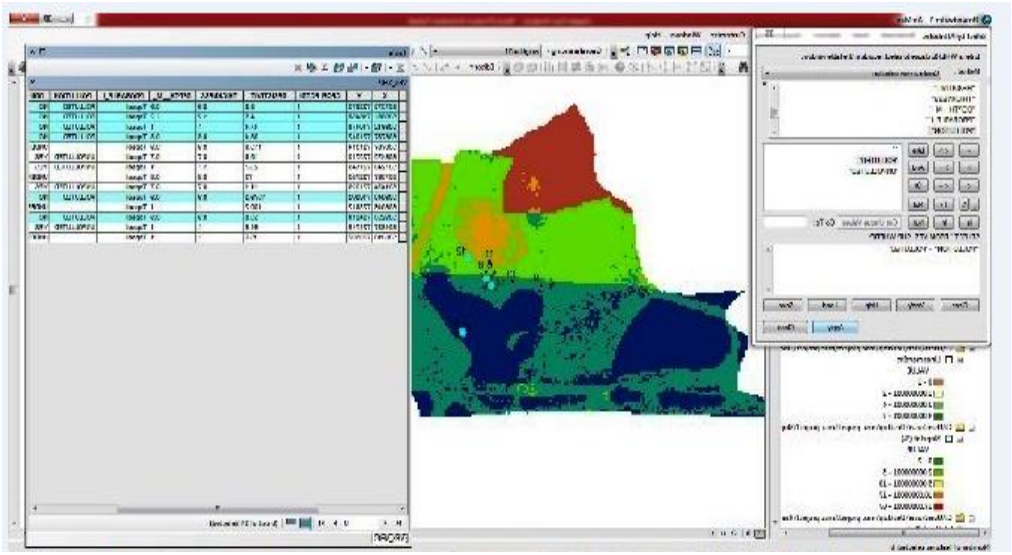

Figure 12: Overlay of ajao estate polluted point on potential ground

- **Query three:**

"DRILLABLE"='YES'. This shows areas that are drillable within Ajao estate. These areas according to VES result contain water that are beneficial. VES location 6, 7, 9, and 13 are found in this category. Relating the VES point to the groundwater map; as shown in Figures 13 and 14. It was discovered that they all fall into high potentiality category.

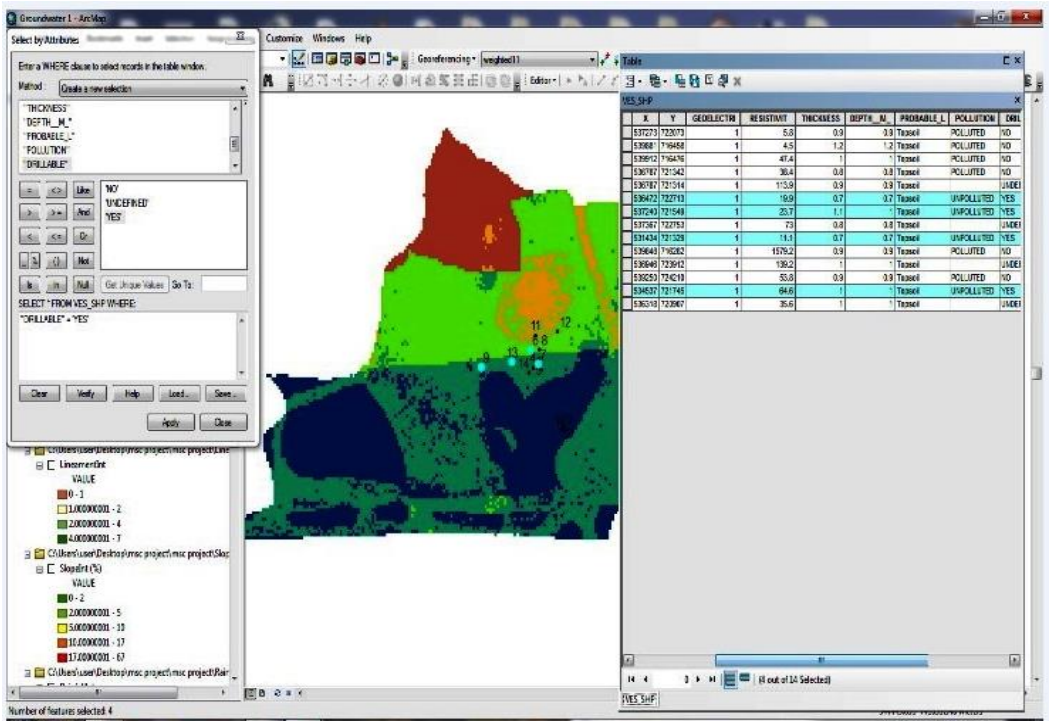

Figure 13: Drillable points or station

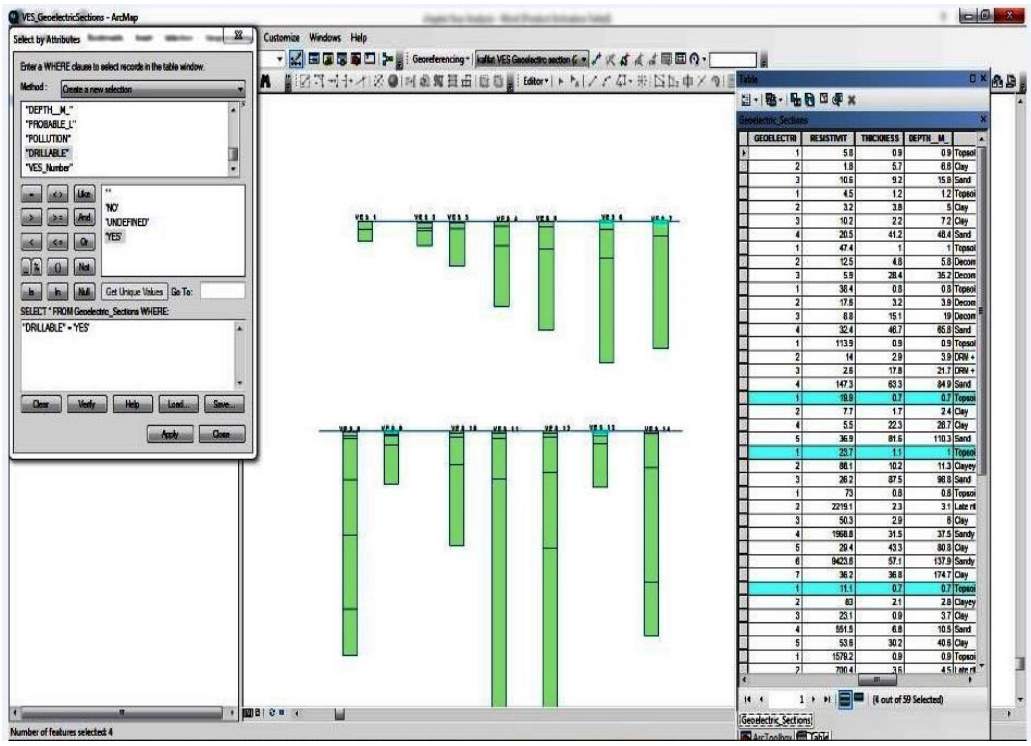

Figure 14: Geo-electric display of drillable points

- **Query four :**

"POLLUTION"= 'Polluted' OR "POLLUTION"= 'Unpolluted'. This entails areas that contain groundwater. VES location 1, 3, 5, 7, 9, 12 and 13 are found in this category. Figure 15 shows the VES locations with groundwater. The highlighted VES Locations are the ones with groundwater according to the VES data presented in the database.

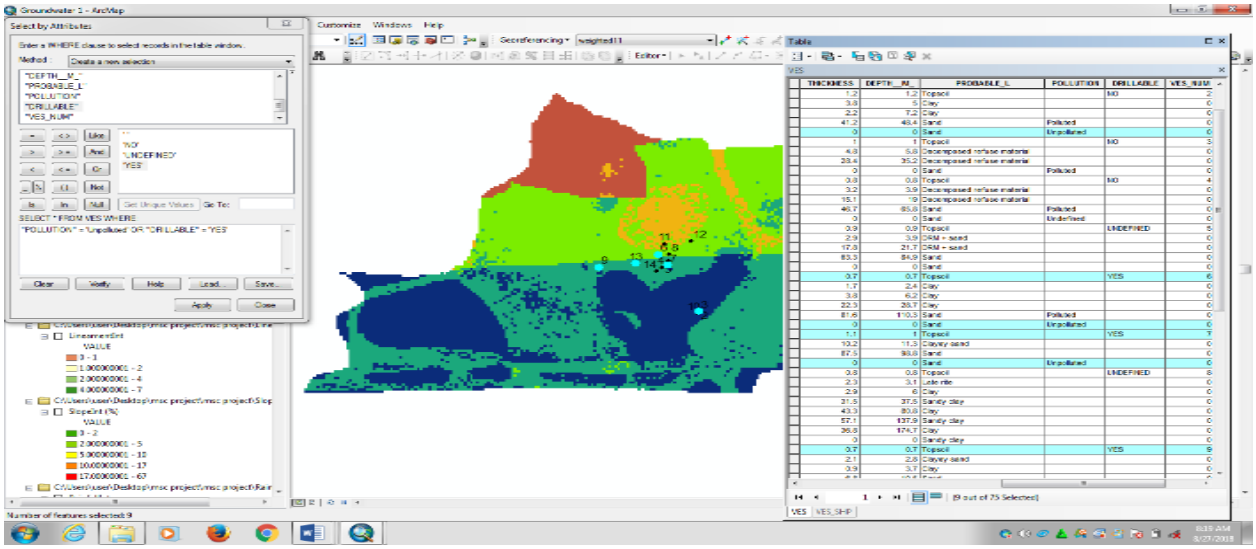

Figure 15: VES locations with groundwater

- **Query five:**

"POLLUTION" = 'Unpolluted' OR "DRILLABLE" = 'YES'. This entails area that contain clean water and are drillable within Ajao estate. This includes VES location 2, 6, 7, 9 and 13. Also, we found out that these VES station falls within very high, high and moderate potential of groundwater map. This has shown that the potentiality of groundwater map obtained is high as shown in Figure 16.

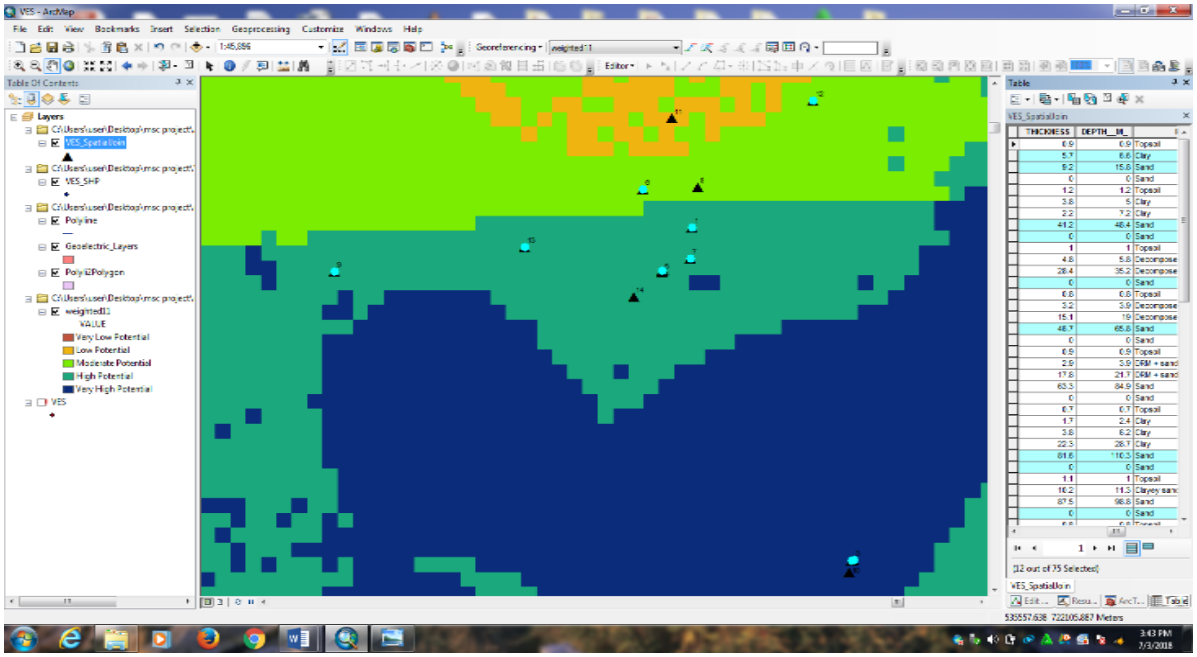

Figure 16: VES station that contain unpolluted clean water and are drillable

- **Query six:**

This was done to check the reason why some VES station was not selected within Ajao estate. We found out that it's because of the presence of buildings as shown in Figure 17.

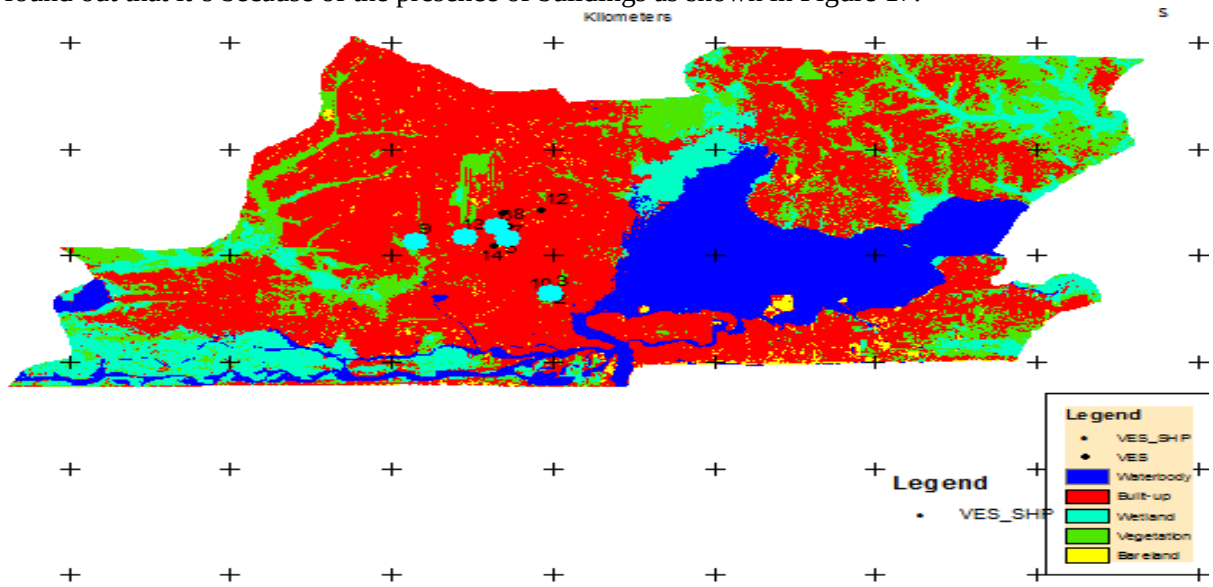

Figure 17: Overlay analysis of VES stations on land use map

4.0 Conclusion

It has been found that 23% of the total area comes under very high, 40% high, 28% moderate, 3% low and 6% of the total area falls under very low groundwater potential zone. Major portions of the study area has "high" as well as "moderate" prospect while a few scattered areas have "low" prospect. The very high potential areas are mainly concentrated along the River Alluvium while the "very low" prospect are majorly where there is sand and clay. The best groundwater potential zone is concentrated in the southern part of the study area due to the presence of fractures, swamp soils which have high infiltration ability as well as presence of waterbody which is chiefly accountable for the groundwater recharge in any area. Thus, the study reveals that; the integration of the thematic maps gives first-hand information to local authorities and planners about the areas suitable for groundwater exploration. Application of RS, GIS and Hydrogeophysics for the delineation of the groundwater potential zones in this study have proved to be efficient in terms of minimizing cost, time and labour. The study needs to be replicated in the areas with significant need of water for irrigation and drinking purpose. This map should be made available to serve as a base map before allocating lands for

residential. This would prevent constructing buildings on areas that are viable. Remaining aspects of ground water occurrence, movement and utilization like ground water table condition and water requirement of various locations may be considered for future studies. Similar VES of the entire study area should be done for proper and precise check.

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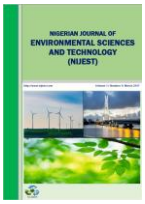

Assessment of the Water Quality Characteristics of Kaduna River Receiving Wastewater Discharges

Garba H.[1,*] and Elanu C. A.[2]

[1,2] Department of Civil Engineering, Nigerian Defense Academy, Kaduna, Nigeria

Corresponding Author: *garbaharuna84@gmail.com

ABSTRACT

An assessment of the chemical characteristics of industrial and domestic wastewater discharges on seven parameters into Kaduna River on a bimonthly basis was carried out. PH, dissolved oxygen (DO), chloride, nitrite, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and iron were analyzed to determine their concentration levels. From the analysis, the highest mean concentration of the parameters were 8.24 of pH, 7.7 mg/l of DO, 233.4 mg/l of chloride, 55.68 mg/l of COD, 27.95 mg/l of nitrite, 122.22 mg/l of BOD, and 17.05 mg/l of iron. After comparing with prescribed standards, it can be concluded that there is evidence of organic and inorganic accumulation of contaminants into River Kaduna.

Keywords: Chemical, Wastewater, Discharges, Concentration, Effluent

1.0. Introduction

Since Nigerian independence in 1960, there has been concerted effort to exploit the nation's various resources to meet various human needs. This has led to rapid technological development and industrialization. Industrialization has been concentrated in the urban cities and at such locations where the absorptive capacities of the natural environment can be easily exhausted. This practice according to Beecroft (1986) leads to serious degradation of the environmental resources of the area. Beecroft (1986) reported that about 80% of major industries in Nigeria are concentrated in Port Harcourt, Kano, Lagos and Kaduna. Ludwig and Gould (1988) observed that the disposal of various waste materials into marine waters is not a modern phenomenon.

Industrial wastewater according to Hanchang (2013) is one of the important sources in the pollution of water environment. During the last century a huge amount of industrial wastewater was discharged into rivers, lakes and coastal areas. This resulted in serious pollution problems in water environment and caused negative effects to the eco-system and human's life. The practice according to Islam and Tanaka (2004) has being used as a preferred disposal option since the beginning of modern civilization. Beecroft (1986), further identified that the physical, chemical and biological composition of the effluent waste discharges into Kaduna river indicate that effluent from textile industry are characterized by high concentration of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and colour. The food and beverages industry discharges according to Beecroft (1986) have high BOD, COD and solid waste; while the petrochemical effluent have high level of oil and grease, COD and a low BOD.

According to a report by the Kaduna State Environmental Protection Agency (KEPA) (2002), the industries in Kaduna discharge over 500m^3/d of untreated effluent into the Kaduna River. This has led to massive pollution of both surface and groundwater resources. Awale and Soubaneh (2004) observed that the world's chemical industries face formidable environmental regulatory challenges in treating their wastewater effluent. Various industrial wastewater treatment technologies currently available include physico-chemical and biological processes as well as constructed wetlands and conventional or advanced oxidation processes. Furthermore, Garba (2007) investigated the

effectiveness of immobilized cells of *F oxysporium* in the treatment of textile effluent as well as bio-sorption of heavy metals from textile wastewater discharged into Kaduna River.

Kaduna metropolis is one of the few industrialized cities in Nigeria with over ninety two (92) industries out of which twenty seven are classified as wet effluent discharges. The aim of this study is to assess the chemical concentrations of seven parameters of industrial and domestic wastewater discharges on a bimonthly basis as evidence of inorganic and organic pollutant accumulation in River Kaduna.

1.1. Study area

This study is focused on River Kaduna which takes its source from Sherri Hill in Plateau State. River Kaduna flows north-west towards the Kaduna metropolis and thereafter takes a south west direction at Mureji. River Kaduna covers a total distance of 540 km from source to mouth (Folorunsho, 2000). The drainage basin for this study is approximately 18,277.83 km2. Kaduna State which occupies a central position in the northern geographical region of Nigeria lies within the Northern Savannah Zone of Nigeria with an absolute location of Latitude 9°30'N to 11°45'N and Longitude 7°E to 8°30'E. It covers a total land mass of 2,896,000 km^2. The topography is that of undulating plateau, as shown in Figure 1.

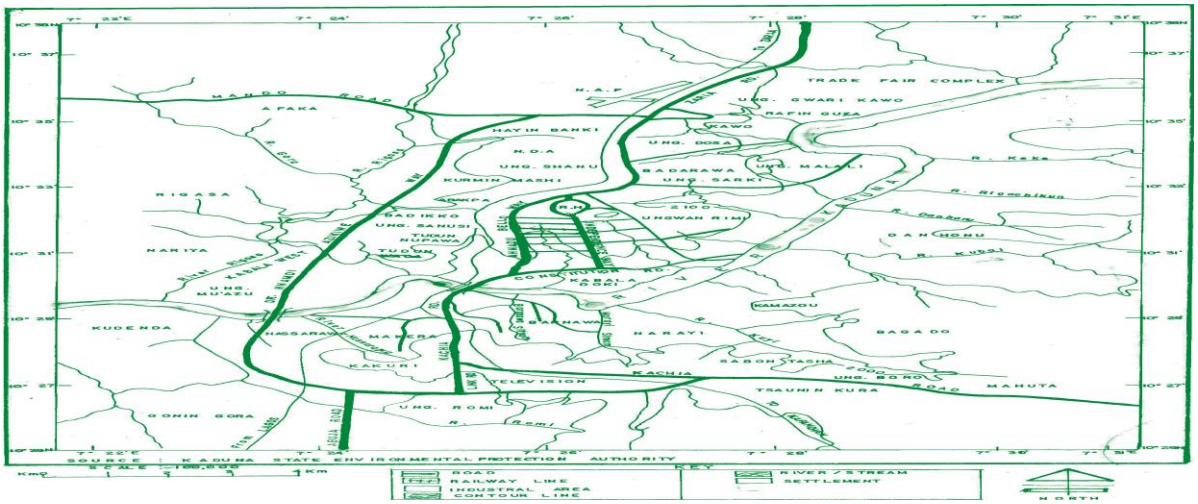

Figure 1: River Kaduna and tributaries
(Source: Kaduna State Environmental Protection Authority)

1.2. Climate

Kaduna State has two distinct seasons. The dry season last from November to mid-April while the rainy season which is cool last between 5-6 months starting from mid-April. The State extends from the tropical grassland known as Guinea Savannah to Sudan Savannah. The vegetation is thick and grasses about 3.6 metre tall with big trees which grow shorter towards the Sudan Savannah.

2.0. Materials and Methods

In this study, the concentration of chemical effluents from selected industries in Kaduna South as well as point discharges from domestic sources with abbreviations as shown in Figure 2 are as follows: Kabala West drain (KW), Unguwar Muazu domestic drain (UM), Kudenda village domestic drain (KV), Kaduna Polytechnic farms (KPF), Rigasa domestic drain(RGDD), Rafin drain (RD), Romi drain (RMD), River Kaduna bye pass bridge (RKBB), Kakuri domestic and industrial drain (KD), Makera drain (MD), Nasarawa domestic drain (NDD), Kaduna South water works (KSWW) and Kaduna North water works (KNWW). The locations of the points are as indicated in Figure 2 and the selection of these points was based on the location of the industries and domestic discharge outlets.

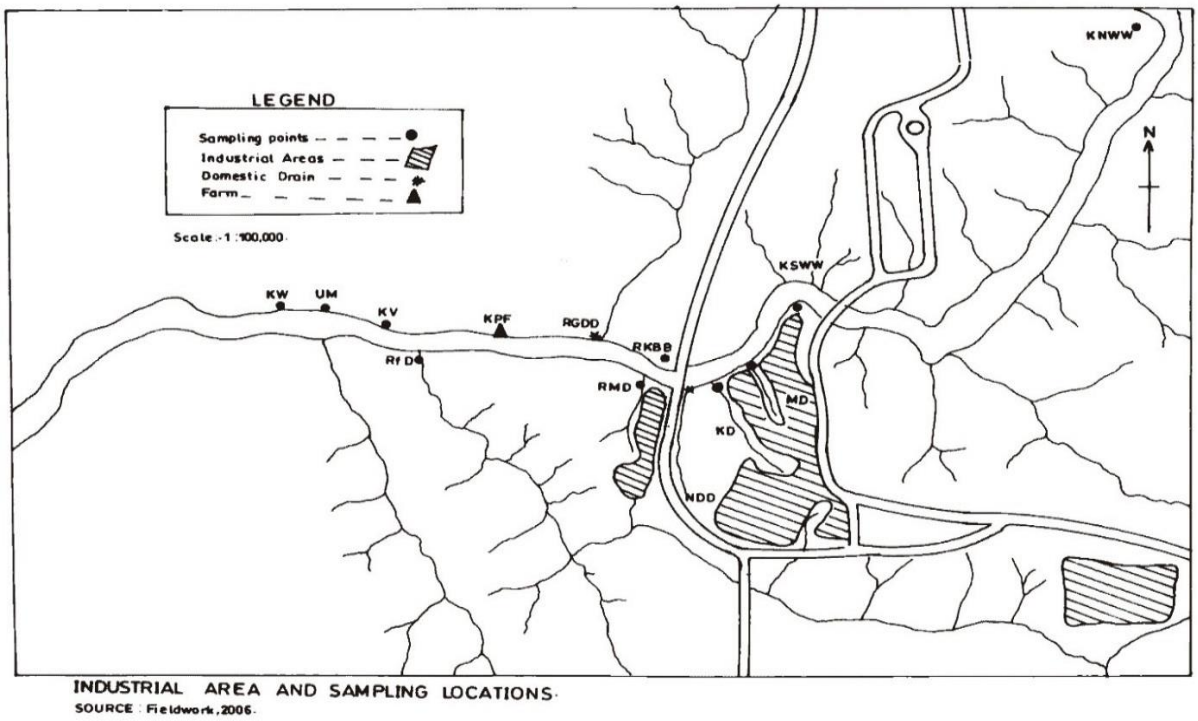

Figure 2: Sampling locations

The parameters were analyzed to ascertain their pollution levels at the point of discharge into the Kaduna River. The characteristics of the chemicals were compared to standards established by World Health Organization (WHO), Federal Environmental Protection Agency (FEPA), National Environmental Standards Regulation Enforcement Agency (NESREA) and the United States Environmental Protection Agency. However, some of the characteristics are within the standards specified above while some indicates that over time there will be pollution. The regulation limitations from the standards are as follows: pH (NESREA/FEPA = 6.0, WHO = 5 – 9); COD (NESREA/FEPA = 80 mg/l for agricultural chemicals, 15 mg/l for dyestuff and dye intermediate; WHO = 40 mg/l); BOD (NESREA/FEPA = 30 mg/l for agricultural chemicals, 15 mg/l for dye stuff and dye intermediates, 15 mg/l for food processing; WHO = 40 mg/l); Nitrites (NESREA/FEPA = 20 mg/l for agricultural chemicals, WHO = 10 mg/l); Iron (NESREA/FEPA = 20 mg/l, WHO = 2 mg/l).

The procedure for sampling involves dipping a transparent plastic container downwards below the surface of the water to about 300 mm, and allowing the container to be filled, two times every month from January to December. The following parameters: pH, chloride, nitrite, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Iron were analyzed based on the Standard Procedure for the examination of waters and wastewater by Arnold *et al*. (1992).

3.0. Results and Discussion

3.1. Results

The results are presented in Figures 3 – 9. The typical characteristics of the discharges due to different sources identified as follows: dissolved oxygen obtained from domestic wastewater discharges at KW, UM, KV, RKBB, KD and NDD; pH obtained from KNWW and KSWW; nitrites obtained from NDD, RFD, RKBB and KDF; BOD obtained from KW, UM, KV, RKBB and KD; COD obtained from RM and KV; iron obtained from KD and MD; and Chlorites obtained from MD, RFD and UM drains.

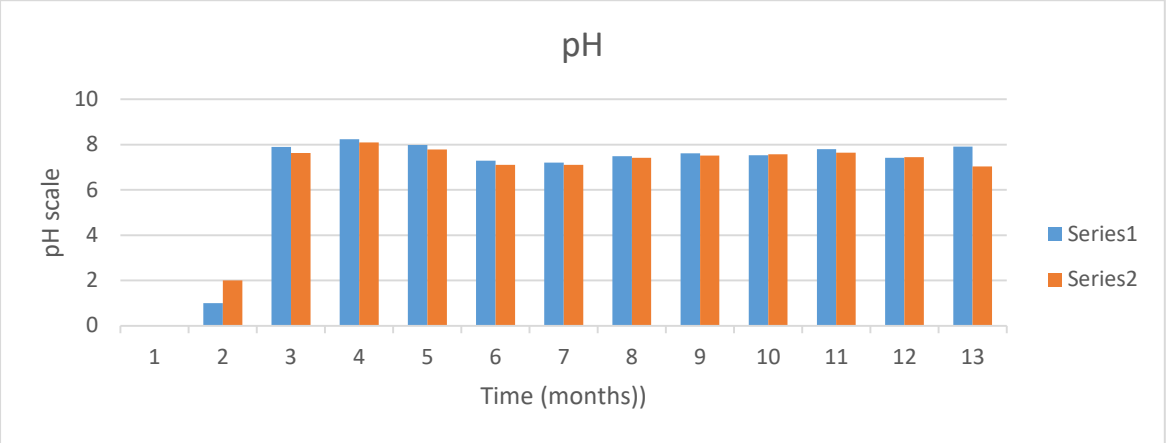

Figure 3: Monthly pH discharge concentration

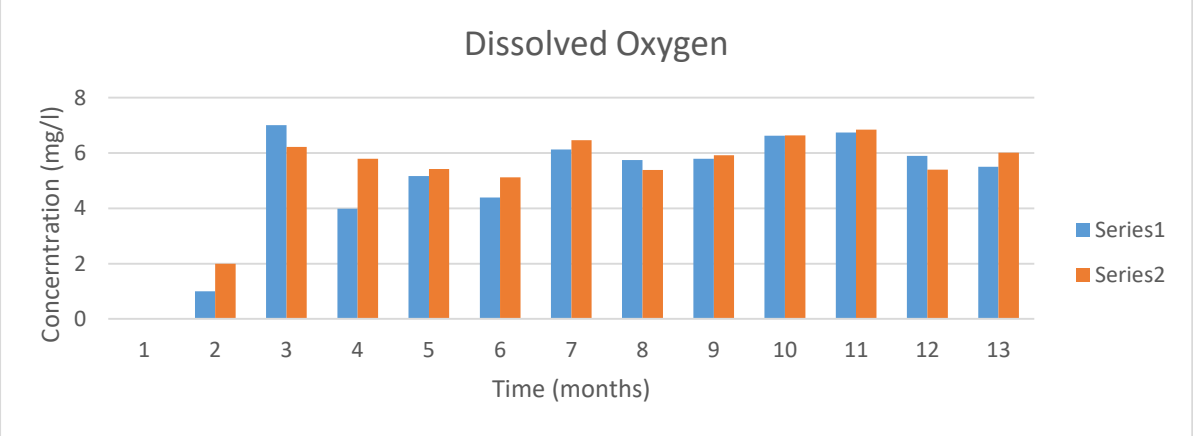

Figure 4: Monthly dissolved oxygen discharge concentration

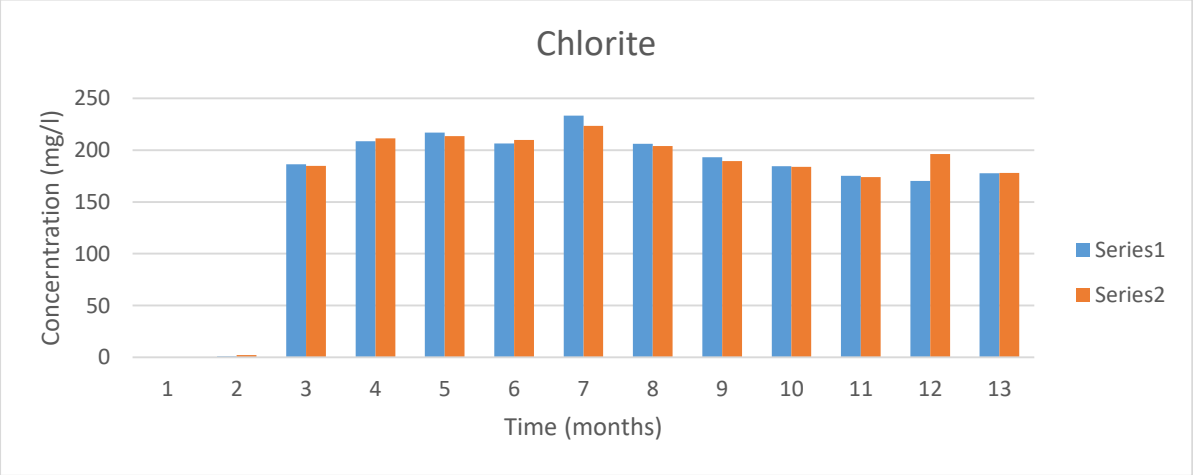

Figure 5: Monthly chlorite discharge concentration

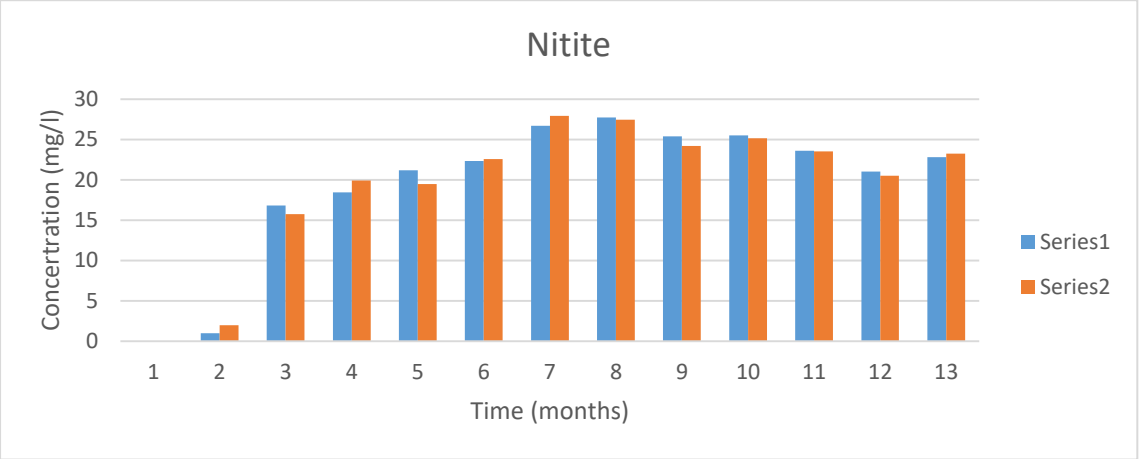

Figure 6: Monthly nitrite discharge concentration

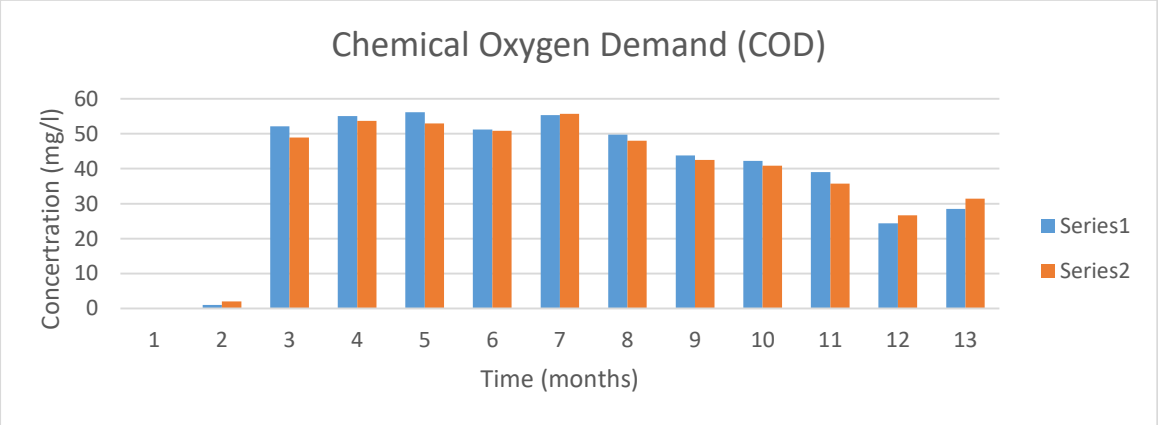

Figure 7: Monthly COD discharge concentration

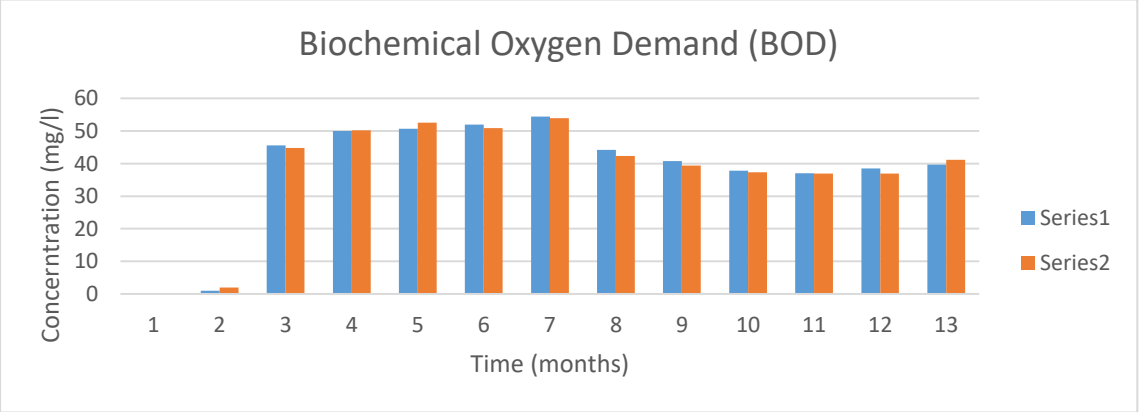

Figure 8: Monthly BOD discharge concentration

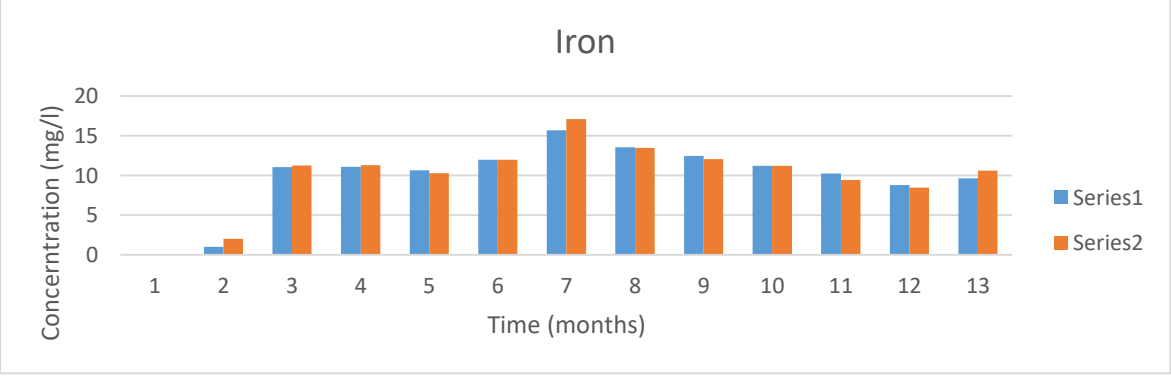

Figure 9: Monthly iron discharge concentration

3.2. Discussion

Results of the analysis are as depicted in Figures 3 – 9 for the seven parameters. For each parameter two separate samples were tested each month from January to December as indicated by series 1 and series 2. In the results for pH, the higher discharge concentration was recorded in February, March and April while the lowest was observed in January. The pH appears stable for the wet months under review. The stability is optimal for fresh water and can be ascribed to the fact that some portions of the river is on crusted formation and that basic rocks such as limestone contributes to high pH values.

Dissolved Oxygen concentration recorded higher value in February and then maintains a fairly level value in the wet months. The stability for wet months could be due to the fact that bacteria and others use much of dissolved oxygen for organism under wet weather flows. Chlorite and nitrite recorded higher values in August, possible due to fertilizers used by farmers which are soluble. The COD and BOD appear higher in the month of April through September. This increase is due to waste discharges from domestic drains containing starch, baking soda, carrots, vinegar juice, etc. Iron has a higher concentration in August.

4.0 Conclusion

This study was aimed at evaluating the concentrations of seven characteristics of discharges on bimonthly basis as an evidence of organic and inorganic pollutant accumulation into River Kaduna. From the results, the concentration of the seven chemical parameters: pH, dissolved oxygen, chlorite, Chemical oxygen demand, biological oxygen demand and iron, were obtained from effluents and discharges from petrochemical, textile, fertilizer and domestic waste. Table 1 showed the concentration of the parameters while Figures 1 to 7 depicted the change in trends of the concentration of the parameters against time in months.

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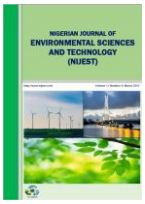

Genotoxicity of *Momordica charantia* Extract in Swiss Albino Mice (*Mus musculus)*

Adewumi O. O.[1,*], Oladele E. O.[1] and Taiwo I. A.[2]

[1]Biology Unit, Distance Learning Institute, University of Lagos, Akoka, Lagos State, Nigeria

[2]Department of Cell Biology and Genetics, University of Lagos, Akoka, Lagos State, Nigeria

Corresponding Author: *oluadewumi@unilag.edu.ng

ABSTRACT

The study aims at determining the safety of Momordica charantia (Bitter melon) for use by diabetic patient. This study was carried out to ascertain the genotoxic potential of Momordica charantia in mice using the micronucleus assays. A total of forty (40) laboratory albino mice weighing between 20 and 25 grams were obtained from the Zoological garden, University of Lagos. The mice were in eight groups comprising of five animals each. The doses of the extract administered were 50 mg/kg, 100 mg/kg and 150 mg/kg per body weight and the route of administration was oral by gastric gavages using a metal canula. The control groups A and B were fed with distilled water for 14 and 28 days respectively. The other groups were also treated with a daily dose of the extract for 14 and 28 days at different concentrations. The mutagenic potential of Momordica charantia was assessed with reference to the frequency of micronucleated polychromatic erythrocytes (MNPCE) in polychromatic erythrocytes (PCE) in the bone marrow of mice. During sacrifice, the bone marrow cells were collected from the femur and smeared on slides. For each mouse, polychromatic erythrocytes (PCE) were scored for the number of micronucleated polychromatic erythrocytes (MNPCE) and the percentage was calculated. The frequencies of MNPCE/PCE were 0.17 ± 0.09% and 0.13 ± 0.02% in the control group for 14 days and 28 days respectively, 0.33 ± 0.12% and 0.30 ± 0.08% in the 50 mg/kg group, 0.38 ± 0.06% and 0.34 ± 0.09% in the 100 mg/kg group, and 0.24 ± 0.08% and 0.35 ± 0.05% in the 150 mg/kg group. The results showed a significantly increased frequency of micronucleated polychromatic erythrocytes for the three doses administered. The results were considered statistically significant at $p < 0.05$. This indicates a warning signal to careless and indiscriminate use of the drug by humans.

Keywords: Genotoxicity, Micronucleus, Extract, Micro nucleated, Polychromatic erythrocytes

1.0. Introduction

Momordica charantia (MC) is commonly known as Bitter gourd, Bitter melon and Balsam pear. It is also identified as Bitter cucumber in the United States of America; Paroka in France and Kakle in East Africa. It is an annual herbage plant that belongs to the family Cucurbitaceae. Originally, it was found in the tropics but can now be found in most regions of the world and is usually seen on fences and shrubs (Grover and Yadav, 2004). It is an economically important edible medicinal plant that is cultivated all around the world especially in tropical areas. It is a plant that is composed of multifaceted range of beneficial compounds. These compounds include bioactive chemicals, vitamins, minerals and antioxidants which all makes it versatile in treating a wide range of illnesses (Chaturvedi *et al*., 2004). Seeds, fruits, leaves, and root of this plant have been used in traditional medicine for microbial infections, sluggish digestion, menstrual stimulation, wound healing, inflammation, fever reduction, hypertension, and as a laxative. However, clinical conditions in which *Momordica charantia* extracts (mainly from the fruit) are presently being used include diabetes, dyslipidemia, microbial infections, and potentially as a cytotoxic agent for certain types of cancer (Chaturvedi *et al*., 2004). *Momordica charantia* contains biologically active chemicals that include glycosides, saponins, alkaloids, fixed oils, triterpenes, proteins and steroids. The immature fruits are a good source of vitamin C, vitamin A, vitamin E, vitamins B_1, B_2, B_3, as well as vitamin B_9 (foliate), phosphorus, and

iron (Liu *et al.,* 2009). The medicinal value of bitter melon has been attributed to its high antioxidant properties (Budrat and Shotipruk, 2008; Myojin, *et al.,* 2008). This is because the herb contains phenols, flavonoids, isoflavones, terpenes, anthroquinones, and glucosinolates, all of which contribute to its bitter taste (Snee *et al.,* 2011).

Over the years, medicinal plants have been recognized to be of great importance to the health of individuals. The use of herbs for the management of different illnesses is gaining grounds because it is cheap and readily available. Herbal preparations have however been in use before the onset of pharmaceutical products and their use has increased in recent times. One of the commonest applications of the use of herbal extracts is in the control of blood glucose in diabetics. Different extracts have been reportedly used for the treatment of hyperglycemia. *Mormordica charantia* has been reported to be the most popular plant used worldwide to treat diabetes (Maries and Famsworth, 1995; Aloulou *et al*., 2012, Hfaiedh *et al.,* 2013). There are several reviews by different authors about anti-diabetic herbal plants (Ayodhya *et al*., 2010; Malviya *et al*., 2010; Patel *et al.,* 2012). Extracts from different parts of *Momordica charantia* have been reported to have a wide medicinal use in the traditional medical systems, most often as hypoglycemic and anti-diabetic agents (Ahmed *et al.,* 2001; Grover and Yadav, 2004). The glucose-lowering activity of *M. charantia* administered as both fresh juice and unripe fruit has been well documented in animal models of diabetes (Grover *et al.,* 2002). *Momordica charantia* has been used in expelling intestinal gas, promoting menstruation, wound treatment, rheumatism, malaria and vaginal discharge while its seeds are used to induce abortion (Taylor, 2005; Sofowora, 2006). It can also be used in treating heart diseases, measles, rheumatism, small pox, chicken pox, gastrointestinal disorder, gonorrhea as well as malignant ulcers and periodical pains.

In vivo and in vitro studies have shown that some natural constituents of plant parts (fruits, leaves, roots) play a modulating role in xenobiotic effects (Roncada *et al.,* 2004). Some herbs might be pharmacologically and clinically effective; they are not necessarily free of toxicity and side effects. Therefore, investigation into this traditionally used medicinal plant is valuable as a source for potential chemotherapeutic drugs. This study therefore sought to investigate the genotoxicity potential of *Momordica charantia in* mice using the micronucleus assay.

2.0. Materials and Methods

2.1. Test animals

Forty (40) albino mice weighing between 20 grams to 25 grams of both sexes were obtained from the Botanical and Zoological garden, Department of Zoology, University of Lagos. The animals were kept under standard laboratory conditions and allowed to acclimatize for two weeks. The animals were fed *ad libitum* with access to food and water.

2.2. Test chemical

2.2.1. Determination of plant extract concentration

This was done using the gravimetric method. Three evaporating dishes, A, B and C were obtained and weighed. Each dish was heated on a burner and weighed again. About 1 ml of *Momordica charantia* extract was pipetted into each of the dishes: A, B and C and then weighed again. The evaporating dishes containing the extract were heated on a burner until the extract became dry and concentrated. The dishes were finally weighed and the various weights in grams were taken.

The concentration of the extract was calculated using the formula:

$$Concentration\ in\ g/ml\ = average\ weight\ of\ dry\ extract\ on\ evaporating\ dish \quad (1)$$

$$Concentration\ in\ mg/l = concentration\ of\ extract\ in\ g/ml \times 1000 \quad (2)$$

2.2.2 Preparation of aqueous extracts

The fresh leaves of *Momordica charantia* were purchased from the local market and washed thoroughly with water. The plant materials were sorted out to eliminate all extraneous substances. The clean *Momordica charantia* leaves were air dried for 5 days and the dried plant materials were processed to fine powder with a laboratory mill (Weston manual miller) and stored in air and water-

tight containers at room temperature until needed. The water extract was prepared using 30 g portion of the powder dissolved in 500 ml of distilled water and was soaked for 4 days. The resultant liquid was filtered using a funnel plugged with a cheese cloth to remove the coarse fibers. The solution was later refrigerated for further use.

2.3. In-vivo exposure experiment

The animals were divided into eight (8) groups of 5 rats per group. The dose of the extract administered was 50 mg/kg, 100 mg/kg and 150 mg/kg body weight and the route of administration was oral by gastric gavages using a metal cannula. Animals in Groups A and B (control) were fed with distilled water for 14 and 28 days respectively. The other groups were treated with a daily dose of *Momordica charantia* aqueous extract for 14 and 28 days at different concentrations. Administration of the extract was done orally using a cannula to inject the extract.

2.4. Micronucleus (MN) assay

The Micronucleus (MN) Assay detects damage of the chromosome or mitotic apparatus of cells. Cells from the bone marrow, polychromatic erythrocytes (PCEs), are examined to visualize the MN, which may form under normal conditions. The assay is based on an increase in the frequency of micro nucleated PCEs in the bone marrow of treated mice. The preparation and staining of bone marrow cells were carried out according to Schmid (1976) and Hayashi *et al.* (1994). The experimental animals were sacrificed. The dissected femurs were opened and Foetal Bovine Serum was used to flush bone marrow cells from both femurs into Eppendorf tubes and cells were centrifuged at 6000 rpm for 5 minutes and the supernatant discarded. The pellet was re-suspended in a drop of serum for slides preparation. The cells were smeared on glass slides and air-dried and later immersed in methanol for 10 minutes and then stained with 5% Giemsa in Sorenson's buffer (pH 6.9) for 20 minutes and counter stained with May-Grunwald for 5 minutes. After dehydration through graded alcohol and clearing in xylene, slides were mounted in DPX (Distyrene, plasticizer and xylene). From each slide, about 1000 erythrocyte cells/animal were scored under the light microscope with plane objective at 100/1.25 oil mount magnification, for micronuclei in polychromatic erythrocytes (MNPCE) and normochromic erythrocytes (MNNCE). The PCE: NCE ratio in every 1000 cells counted was analyzed.

2.5. Statistical analysis

The micronucleus assay were carried in three replicates and results were subjected to one-way analysis of variance (ANOVA) and the Tukey-Kramer multiple comparison test using the Graph Pad Instat software (version 3.01). The results were considered statistically significant at $p < 0.05$.

3.0. Results

3.1. Induction of micronuclei

For each mouse, polychromatic erythrocytes (PCE) were scored for the number of micro nucleated polychromatic erythrocytes (MNPCE) and the percentage calculated. The percentage of PCE per 1000 blood cells is given in Table 1. Values shown are means ± standard deviations for five (5) mice per dose (in three replicates).

There was a significant induction of MN in the erythrocytes of exposed mice group at different concentrations of the extract as compared with their respective control groups (Figure 1 and Table 1). The treatments and sample days, the percentage of PCEs having MN and the percentage polychromatic erythrocytes (PCEs) per 1000 cells are shown. All animals survived to terminal sacrifice. As seen in Table 1, the MN assay of *Momordica charantia. L* extract revealed that for all the doses tested, the MNPCE frequency was increased and, in most cases, doubled. The frequencies of MNPCE/PCE were 0.17 ± 0.09% and 0.13 ± 0.02% in the control group for 14 days and 28 days respectively, 0.33 ± 0.12% and 0.30 ± 0.08% in the 50 mg/kg group, 0.38 ± 0.06% and 0.34 ± 0.09% in the 100 mg/kg group, and 0.24 ± 0.08% and 0.35 ± 0.05% in the 150 mg/kg group. The highest concentrations of the extract show significant induction of MN than their respective control groups. The significant highest MN frequency was observed in the 100 mg/kg concentration (0.38 ±0.06) and

the least MN frequency was observed at the 150 mg/kg (0.24 ±0.08). Generally, with increasing concentrations and exposure duration, the MN frequency increases.

Table 1: Effect of *Momordica charantia* in micronucleus formation in mice bone marrow cells

Treatments/ Exposure Days	MNPCEs		% PCE per 1000 cells
	Number	%MNPCE	
Control (Distilled Water)			
14 Days	21	0.17 ± 0.09	43.3 ± 6.75
28 Days	16	013 ± 0.02	40.3 ± 3.79
Extract 50 mg/kg			
14 Days	40	0.33 ± 0.1 2*	40.5 ±3.26
28 Days	37	0.30 ± 0.08*	39.4 ±3.56
Extract 100 mg/kg			
14 Days	46	0.38 ±0.06*	36.5 + 123
28 Days	41	0.34 ± 0.09*	37.5 ± 5.22
Extract 150 mg/kg			
14 Days	29	0.24 ± 0.08	34.7 ±4.07
28 Days	43	0.35 ± 0.05*	36.2 ± 3.50

** Significantly different to the negative control (Tukey-test, $p < 0.05$)*

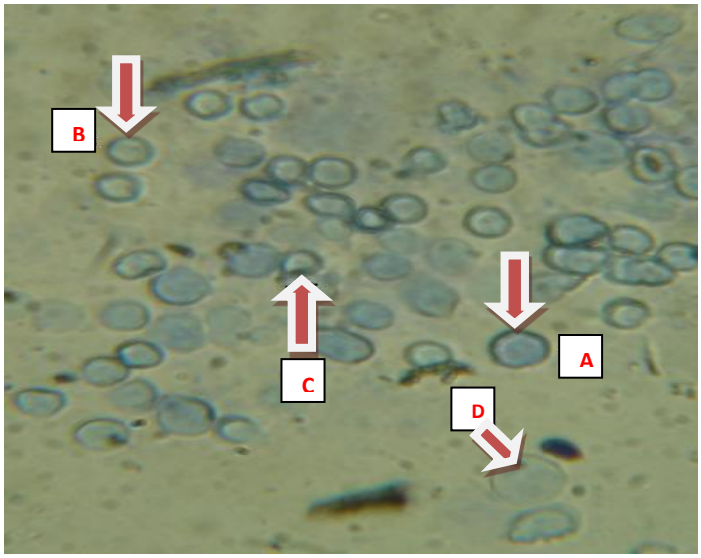

Figure 6: Effect of *Momordica charantia* on micronucleus assay: **A**-Polychromatic Erythrocyte **B**-Normochromatic Erythrocyte, **C**-Micronuclei in Polychromatic Erythrocyte, **D**-Micronuclei in Normochromatic Erythrocyte (x100)

For genetic toxicology studies, the formation of micronucleus in bone marrow and peripheral blood erythrocytes is recognized as one of the established methods for in vivo cytogenetic assays (Fenech, 2000). Micronuclei are formed in anaphase by chromosomal fragments or fagging chromosomes not included in the nucleus of the daughter cells. Micronuclei have been observed in plants and in numerous tissues of many animal species. Presently, micronuclei serve as an important endpoint to detect the genetic damage by chemicals or radiation in cultured cells and organisms (Heddie *et al.*, 1983).

The micronucleus assay using small laboratory animals is considered the best-documented in vivo assay for chromosome aberrations (clastogenic effects) in relation to the number of tested chemicals (Morita *et al.*, 1997). The mouse bone marrow micronucleus test is one of the several available in vivo mammalian test systems for the detection of chromosomal aberrations. The evaluation of micronucleus frequencies in mice remain one of the primary genotoxicity tests for product safety assessment. In this study, the MNPCE frequency was increased and, in most cases, doubled. An increase in the frequency (percentage) of micronucleated polychromatic erythrocytes (MNPCEs) in treated animals is an indication of induced chromosomal damages in mouse bone marrow cells. According to Krishna and Hyashi (2000), decrease in the PCE: NCE ratio due to either direct cytotoxicity or micronuclei formation and heavy DMA damages as observed in this present study in the lowest concentration of the extract, usually lead to cell death or apoptosis. However, Sumanth and

Chowdary (2010) in their study had a contrary opinion that *Momordica charantia* is devoid of genotoxic potential due to no significant variation in the total number of chromosomal aberrations; considering the P/N ratio when its anti-mutagenic activity was evaluated. The values observed in the *micronucleus* assay in this study must have arisen from loss of chromosomal fragments during the division of the nucleated precursor cells as stated by Salamone *et al.* (1980). The micronucleus results from this study, suggest that *Momordica charantia* extract could produce some aneugenic effects on erythrocyte precursors cells. Therefore, *Momordica charantia* is capable of inducing aneugenic and clastogenic effects in exposed mice. Research using animal model of diabetes has demonstrated that MC extracts increase glucose utilization by the liver (Sarkar *et al.*, 1996), decrease gluconeogenesis through the inhibition of two key enzymes (glucose-6-phosphatase and fructose-1, 6-bisphosphatase), and improve glucose oxidation by activating glucose-6-phosphaie dehydrogenase (Shibib *et al.*, 1993). Extracts of MC also enhance cellular uptake of glucose, promote insulin release (Welihinda *et al.*, 1982) and increase the number of insulin producing beta cells in the pancreas of diabetic animals (Ahmed *et al.*, 1998). Usually, medicinal plants are the potential sources of bioactive agents. Bitter melon extracts have also been shown to inhibit growth and proliferation of various types of cancer cells in animals (Kwatra *et al.*, 2013). Other research indicate MC extracts is able to modify the immune response in cancer patients via decreased intestinal secretion of interleukin-7, reduced lymphocyte number and increased T-helper and natural kilter cell populations (Manabe *et al.*, 2003) safety measure for the continued use of medicinal plants (Verschaeve *et al.*, 2004). This is often induced by clastogenic substances in dividing cells such as bone marrow. A simpler approach to assess chromosome damages in vivo is to measure the micronucleus (Fenech, 2000). Micronuclei frequencies have been considered to be a reliable index for detecting chromosome breakages and loss (Lajmanovich *et al*., 2005).

4.0 Conclusion

Over the years, researchers have verified the traditional uses of this bitter plant that is known as important natural remedy for various diseases. This present study draws our attention to the genotoxic capacity of bitter melon. The results of this current study demonstrated that bitter melon though with anti-diabetic effects such as, decreasing serum glucose concentration, increasing serum insulin level, increasing glucose uptake by the peripheral tissues and decreasing intestinal glucose absorption could be genotoxic at higher doses. However, it is clearly shown in this study that bitter melon can induce mutagenic and genotoxic effects in animal models. These indicate a warning signal to injudicious and indiscriminate use of the plant by humans. This observed genotoxicity can possibly occur in humans taking more than the required dosage or using *Momordica charantia* for a very long period of time. It is remarkable that bitter melon can cure diabetes and fight off a wide range of illnesses but can be seen to have side effects like genotoxicity as shown in this study. However, despite the abundance of scientific studies on the benefits of bitter melon, there is still need for several evidences on the long-term safety of the bitter melon consumption. Therefore, being cautious of the dosage and route of administration is important.

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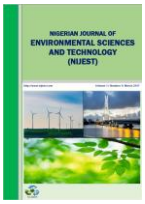

Problems and Prospects of Small Scale Industries in Kakuri, Kaduna South L.G.A, Kaduna State, Nigeria

Mukhtar S.[1,]*, Ahmed A.[2], Najib A.[3] and Jibrin M. A.[4]

[1]Department of Geography, Federal University, Gashua, Yobe State, Nigeria

[2,3]Department of Geography, Sule Lamido University, Kafin Hausa, Jigawa State, Nigeria

[4]Department of Geography, Bayero University, Kano, Kano State, Nigeria

Corresponding Author: *smukhtar27.sm@gmail.com

ABSTRACT

This study focuses on the problems and prospects of small scale industries in Kakuri, Kaduna south. The aim was achieved through the following specific objectives; identify the types of small scale industries, examine the problems of small scale industries and analyse the impact of small scale industries on the economic development of Kakuri industrial area. Data were collected through oral interviews and structural questionnaire administered to randomly sampled respondents. The study identified the major problems of small scale industries (SMIs) that hamper the growth of SMIs which includes; inadequate finance, shortage/ change in price of raw materials, poor infrastructures, etc. Based on the findings the study recommends that government should provide soft loans to small scale industries, adequate infrastructural facilities such as reliable power supply and roads. Government should also empower youth through training and financial assistance as a start-up capital.

Keywords: Small Scale Industry, Problems, Prospects, Economic development, Kakuri

1.0. Introduction

Manufacturing activities constitute only a small proportion of the economy of most developing countries. This is because agricultural activities dominate the economies of such countries as they are characterised by primary production. Where industries exist, they are mostly small scale and find it difficult to grow and reach to a level that can contribute meaningfully to the economic development of the countries (Adewunmi, 1970). Third world countries invariably lack the capacity to neither absorb nor even process raw materials into semi industrial goods. Hence, they seek external market to consume such semi-finished goods.

In many countries, small and medium scale industries have provided the system for encouraging indigenous entrepreneurship, enhancing greater employment opportunities per unit capital invested and aiding the development of local technology (Salisu, 2010). Small scale may sound small but actually play a very important role in the overall growth of an economy. Small scale industry (SMIs) can be characterized by the unique feature of labour intensiveness, simple management structure resulting from fusing ownership and management by one of few individuals. Thus, SMIs tend to strongly resolve the owner managers, rather than operate as a separate corporate entity. There is often greater subjectivity in decision making and prevalence of largely informal employer-employee relationship. They have very limited access to long term capital. The non-availability of fund often results in the non-adoption of modern technology and resort to modern processes (Shehu, 1989).

The importance of this industry increases due to the employment generating potentials it provides. It also provides a vehicle for reducing income disparities; develop a pool of skilled and semi-skilled workers as a basis for industrial expansion (Inang and Ukpong, 1993).

The major and remarkable breakthrough in small scale industry came about through the Indigenization Decree of 1972 and later the Nigerian Enterprises promotion Act of 1977. These were the genuine attempt by the federal government to make sure that Nigerians play an active and worth-while role in the development of small scale industries particularly in rural areas. This was in recognition of the role of small scale industries as the seed bed and training ground for entrepreneurship. According to Salisu (2010), despite the various importance of this sector to national and local development, significant attention has not been given by various administrations to the sector. As such small scale industries in Nigeria have been faced by a lot of problems such as difficulties in local source of raw material, capital inadequacy, poor managerial and technological knowhow as well as infrastructure deficiencies. Anyawu (2003), states that long term fund and working capital problem has pre-eminence in recognition of this and in order to address the problem, various effort and policies have to be put in place. To this end, the study concerns with the problems and prospects of small scale industries vis-à-vis to the economic growth and development in Kakuri industrial area, Kaduna south LGA, Kaduna state.

2.0. Materials and Methods

2.1. Study area

Kakuri industrial area is found in Kaduna south local government area of Kaduna state. It is situated in the Southwestern part of Kaduna metropolis which lies approximately between Latitude 10^0 33"N of the equator and Longitude 7^0 21"E of the Greenwich meridian of Kaduna state. It covers an area of about 30 km^2 which extends from United Textile Limited (UNTL) to Railway Line of Kurmin Gwari. It is bounded to the north by Saint Gerald Catholic Hospital, Nassarawa State at the south, River Kaduna at the east and Peugeot Automobile Company of Nigeria (PAN) at the west (Kaduna state, 2012). The study area is one of the most industrialised towns in Kaduna State with different land use especially the residential part of Kakuri, which has grown to full capacity in size and population of about 77,374 according to the 2006 census (NPC, 2006). The area has a population structure of 1:1 ratio of male – female with large number of secondary school leavers, polytechnics and university graduates which provides a growing skilled labour force for the growing industries (NPC, 2006). A substantial part of the population engages in commerce, industrial labour and agriculture. The area is a home to several factories which includes Kaduna Textile Limited (KTL), Defence Industries Corporation (DIC) and Nigerian brewery (Iwalaiye, 2004).

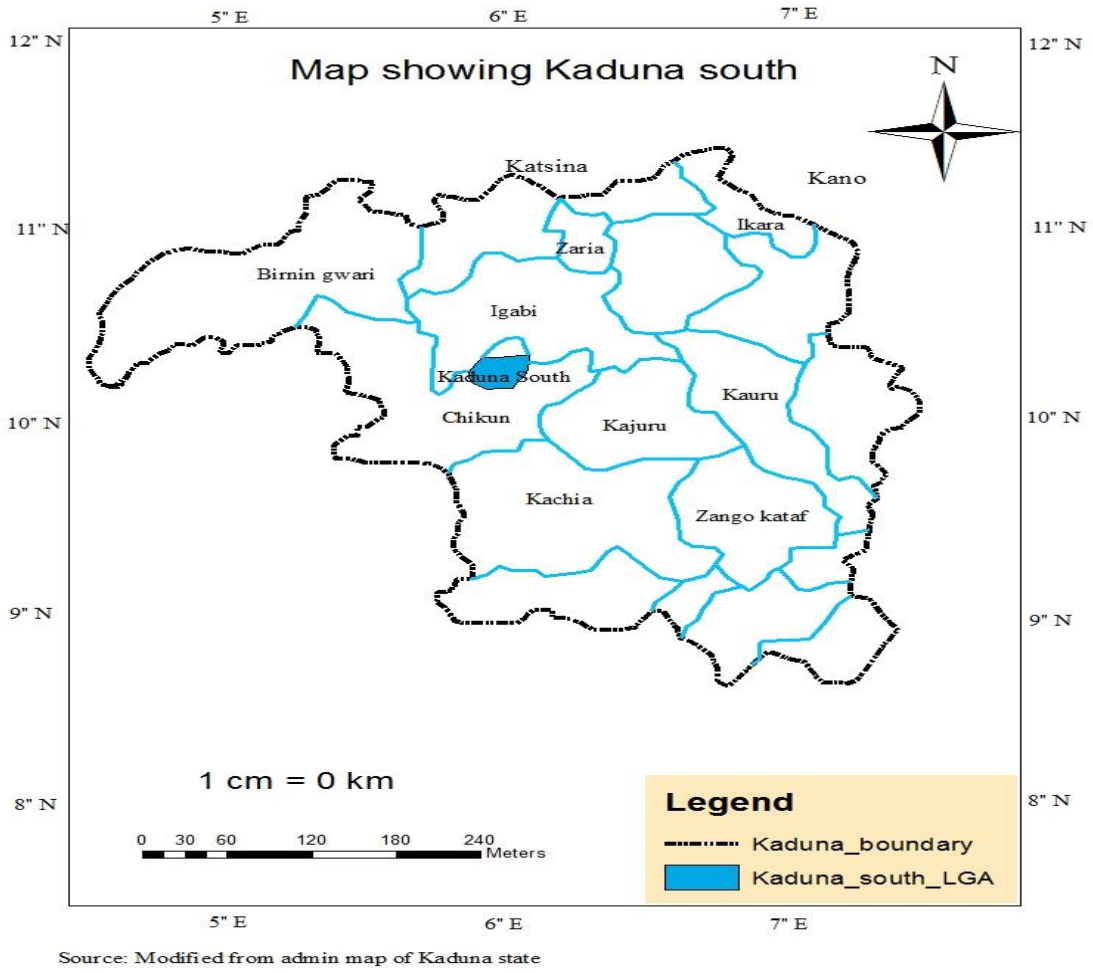

Figure 1: Map of Kaduna State showing the study area
Source: Modified from Administrative Map of Kaduna State, 2012

The primary data was obtained through the use of questionnaire which was distributed randomly among small scale firms in the study area. It was administered to the entrepreneur of the SMIs in Kakuri industrial area to get information in the capital used to start the business, number of workers employed, types of small scale industry and various problems limiting the industries. Kakuri-Makera axis with the major road that connects the area was sampled which is characterised with both residential and industrial sites. The sample size of 100 SMIs operators was sampled for this study relative to the concentration of the industries. One questionnaire was given to each manager of the SMIs among the randomly selected industries.

Descriptive statistics was used in presenting the data which includes the statistical preparation tools such as tables and figures. Results were analysed using simple percentage.

3.0. Results

3.1. Demographic characteristic of respondents

Table 1 indicates that 90% of the respondents are males while 10% are females. This is tied to the reason that the African culture permits women to stay at home and take care of the family while the males who are considered the breadwinners of the family are set to cater for the family, thereby allowing the men to have the advantage of operating SMIs in the study area. Secondly, most of the activities are male oriented such as shoe making, carpentry and welding. The SMIs in the study area is also dominated by the working age group of 25 – 39 years of age. This accounts for 62% of the sampled small scale industries. The result shows high rate of unemployment and under employment

which is attributed to the increasing population which exceeds job opportunities. Consequently, allowing them to engage in other businesses that offer alternative source of employment.

Table 1: Demographic characteristic of respondents

	Response	Percentage
Sex		
Male	90	90
Female	10	10
Age		
< 20	-	-
21 – 24	10	10
25 – 29	22	22
30 – 34	24	24
35 – 39	16	16
40 – 44	8	8
45 – 49	4	4
50 – 54	16	16
Educational Qualification		
No Formal	-	-
Primary	12	12
Secondary	54	54
Tertiary	30	30
Others	4	4

Source: Field survey, 2012

The results from the Table 1 above also shows that small scale entrepreneurs in the study area have low educational qualifications with secondary and primary school leavers having 54% and 12% respectively with few having tertiary education (30%). These points to the general low level of education of small scale industry operators which affects the production and efficient capacity of the industry in the area. Those with tertiary education are conceived to be those employed in the industries in Kakuri such as textile and brewery which was affected when these industries went on recession as such finds alternate means of survival.

3.2. Characteristics of industries in Kakuri industrial area

Capital is one of the factors of production which can be in form of cash to run the activities of the business or in form of machinery used in the production of a commodity in the industry. Majority of the respondents in the study area engage in small scale business that does not require much capital and labour. Table 2 indicates that shoe making and metal work accounts for 44% of the sampled SMIs while yoghurt making industry accounts for 2% only. Most of the respondents used to work in the industries located in Kakuri – Makera, but the recession of these industries made them to switch to other activities in order to earn a living. Consequently, this shows high level of unemployment and under employment in the State in general.

Table 2: Types of SMIs in Kakuri

	Response	Percentage
Shoe making	22	22
Aluminium (glass)	8	8
Bakery	8	8
Pure water	14	14
Yoghurt	2	2
Block industry	4	4
Carpentry	4	4
Fashion	16	16
Metal work	22	22

Source: Field survey, 2012

3.3. Source of income

Most of the small scale industries in the area are of low capital base because they are sourced from personal savings. Table 3 reveals that 94% of the SMIs source their capital or fund through personal savings by what is called “Asusu” in Hausa or “Adashi”, while 6% are supported by cooperative societies, relatives and banks. However, the crucial aspect of this analysis is the absence of

government and private organisation in financing small scale industries in Kakuri. It can be deduced that one of the major problem of SMIs in the area is inadequate capital which hampers the growth of SMIs. In connection to the low level of education as revealed in Table 1, they are unable to obtain loan from banks and other financial institutions due to their inability to present adequate collateral.

Table 3: Source of income

	Response	Percentage
Personal saving	94	94
Loan from bank	2	2
Loan from government	-	-
Loan from private organization	-	-
Cooperative society	2	2
Relatives	2	2

Source: Field survey, 2012

3.4. Capital and labour base of SMIs

SMIs in the study area start with a capital of less than 50,000 naira because they were generated through personal savings as revealed in Table 3 with 32% starting with capital base less than 50,000 naira, while very few SMIs start with capital of above 400,000 as seen in Table 4 as 14%. The results show that the bottleneck faced by SMIs in the study area is nothing but lack of finance which hinders the growth of small scale industries. Labour, which is an essential factor of production, is also inadequate as shown in Table 4, with 68% employing less than 9 workers. This is acknowledged due to inadequate capital base that can only support a few number of workers in SMIs like shoe making and metal work industries. It is worth noting that SMIs in the study area are owned by single individuals as shown with 96% of SMIs sampled. This could be attributed to the mistrust people in the area have against each other.

Table 4: Capital and labour base of SMIs

	Response	Percentage (%)
Capital (Naira)		
< 50,000	32	32
50,000 – 100,000	18	18
100,000 – 200,000	12	12
200,000 – 300,000	12	12
300,000 – 400,000	12	12
400,000 – 500,000	6	6
500,000 – Above	8	8
Number of workers		
< 5	40	40
5 – 9	28	28
10 – 14	18	18
15 – 19	10	10
20 – above	4	4
Ownership of SMIs		
Sole proprietor	96	96
Joint – family	2	2
Partnership	2	2
Public	-	-

Source: Field survey, 2012

3.5. The importance and problems of SMIs in Kakuri

Despite the inadequate labour force in the SMIs in the study area, the SMIs have proven to provide employment for the few that were affected by the recession that occurred to the industries in the area. Also, products from the small scale industries in the area are consumed locally with 56% response while 36% and 6% reached both national and international market respectively as shown in Table 5. This is also attributed to insufficient capital, low level of education and technology which hinders the growth of SMIs to producing for higher markets.

Small scale industries are confronted with some problems that hamper their growth. Majority of the respondents complained of various problems among which inadequate finance ranks high with 64%.

For an industry to start and flourish well it needs enough capital base to accommodate other factors such as labour, raw materials, etc. and when it is inadequate, the rest suffers it. Also, 14% of the respondents complained of dwindling price of raw materials which varies timely as a result of market fluctuation. Infrastructures such as electricity, roads and water are inadequate in the area. These infrastructures especially electricity serve as source of power to most industries both operating at small and large scale. The poor nature of these infrastructures has great influence on the cost of running the SMIs and caused some to go into recession. Other problems include poor management, government policy and decline in product which accounts for 10% of the respondents as shown in Table 5.

Table 5 also shows that 34% of small scale operators in the study area believed that their industries provides goods for the community and Kaduna State in general while 32% feel that their industry is a good training ground for them. Also, 30% of the respondents are of the belief that the industries have reduced unemployment in the area especially for semi- skilled and unskilled labour (Salisu, 2010). Due to the low level of education in the area people in the area engage in other business like shoe making, welding, and carpentry and tailoring.

Table 5: The importance and problems of SMIs in Kakuri

	Response	Percentage
Market extent		
Local	56	56
National	38	38
International	6	6
Major problems affecting SMIs		
Lack of finance	64	64
Low price of raw material	14	14
Poor infrastructure	12	12
Inadequate labour	-	-
Poor management	4	4
Government policy	2	2
Attitude of individuals	-	-
Decline in product	4	4
Contribution of SMIs to the area		
Reduced unemployment	30	30
Source of innovation	4	4
Provides local goods	34	34
Training ground	32	32

Source: Field survey, 2012

4.0 Conclusion

In general, Nigerian small scale industries make valuable contribution to the economy which this study has also shown. The observed weak performance of small scale industries occasioned by lingering constraints should however serve as lesson for our policy makers to fashion out strategy that will be sufficient and responsive to the small scale industries. However, this study has shown that small scale industries by their nature have insufficient access to formal financial institution and as a result rely much more on their personal savings and informal financial institution for their capital investment. It has also been observed that some government policies may be harmful to the small sale industries such as lower tariff on importation which can increase competition with foreign goods imported. Based on the findings of this study, policies formulated by government should be communicated to people via town hall meetings, workshops, seminars, media and publications. Adequate training like that of the Subsidy Reinvestment and empowerment program on (SURE-P) which was initiated by Federal Government of Nigeria should be established. This will serve as a better avenue to train small scale industrialist before they kick-start their businesses. Banks should provide soft loans to aid small scale industries. More so, infrastructural facilities should be rehabilitated by government especially roads in order to boost industrial activities. Electricity should be made available and affordable in order to provide high level productivity. Similarly, local goods consumption should be encouraged while importation should be discouraged.

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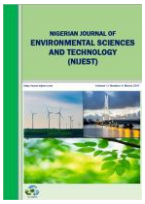

Estimates and Analysis of the Reference Evapotranspiration in Gassol, Taraba State

Ochoche G.[1,]* and Odeh C. I.[2]

[1,2]Department of Physics, Taraba State University, Jalingo, Taraba State, Nigeria

Corresponding Author: *ehiely@gmail.com

ABSTRACT

Reference evapotranspiration is very important because it correlates with the amount of water required by crops and also plays very key role in the hydrological cycle. Evaporation is the process of water loss from the earth surface in which temperature effect is significant while transpiration is water loss from plants. Studying evapotranspiration is also important because of the link between climate change and water scarcity. The reference evapotranspiration for Gassol was estimated and analysis done to observe its trend and variation. In this paper, the FAO Penmann-Monteith model was used to estimate the reference evapotranspiration for Gassol town located in the Sudan Savannah vegetation belt of Nigeria. The annual monthly estimates show a generally recurring seasonal pattern of variation from 1985 to 1991. January through June had lower ET_0 compared to July through December. The time series plot of the ET_0 estimates from 1985 to 1991 in monthly renditions gives a cyclical pattern of variability with most of the years showing bimodal peaks. Also, an evenly spread data was presented by the normal distribution curve. The periodogram of the estimated reference evapotranspiration gave a dominant periodicity of 9.33 months cycle. The estimates of and the pattern of variation of the reference evapotranspiration as observed for Gassol in this study will very likely experience a continuous downward trend. For proper irrigation management, January to March and October to December should be properly planned.

Keywords: Reference evapotranspiration, Irrigation, Water budget, FAO Penmann-Monteith, Hydrology, Variation

1.0. Introduction

In hydrology and meteorology, evapotranspiration is of immense importance. Different methods of its study were developed as a result of its complex nature both as a biological and a physical process (Rácz *et al*. 2013). The crisis of shortage of water due to high demand for agricultural and industrial applications as well as general societal use in developed and developing cities, are responsible for high pressure on irrigation agriculture practice (Abegunrin *et al*., 2015). Eruola *et al*. (2012) studied the application of "rainfall-potential" evapotranspiration model to the production of yam. At different stages of the research they measured indices for growth and its influence on the yield of tuber. The major role evapotranspiration plays in the hydrological cycle led to its inclusion in environment based models for water budgeting, function of yield, scheduling of irrigation, rainfall index, etc. (Wang *et al*., 2009). According to Ingale *et al*. (2015), timely and accurate estimates of reference evapotranspiration is a necessity if policies governing irrigation schemes must be effectively planned and executed. They also posited that in order to gain optimum productivity and crop yield, efficient utilization of water is necessary.

A phenomenon that poses great threat to food security particularly in the semiarid regions of Africa is draught and its attendant consequences like disease incidence. Loss of livestock and general hardship for rural dwellers will inform the suitability of developing a model for the prediction of reference evapotranspiration (Umara *et al*., 2012). Evapotranspiration takes place as water from plant surface escapes to the atmosphere by transpiration and from the soil through evaporation, where temperature plays a significant role (Edoga and Suzzy, 2008). In order to compute precisely crop water usage, it is

important to determine accurately the reference evapotranspiration. Developing countries are faced with the challenge of scarcity of water that can be linked to climate change, high water demand and environmental degradation (Adeboye *et al*., 2009). Increased population for countries that are developing comes with the demand for adequate water (Ufoegbune *et al*., 2011). There is a proportional relationship between evapotranspiration and water required by crop. A proper understanding of evapotranspiration aids in design and implementation of irrigation facilities and their upkeep (Bernadette *et al*., 2014). Alhassan *et al*. (2015) worked on the scheduling of irrigation and required water for tomato in the guinea savanna zone of Nigeria by applying the FAO-CROPWAT model.

Water is lost through evapotranspiration from different bodies of water including snow cover and equally water loss occurs through transpiration from plants. In order to estimate evapotranspiration it is fundamental to first calculate the reference evapotranspiration. The model has factors like wind speed, solar radiation, etc. The current extremes experienced in rainfall regimes alongside population growth in Nigeria inform the need for improvement in water management to boost food production (Chineke *et al*., 2011). Water use efficiency requires optimizing and maximizing water use through determining the actual water required by the crops (Rauf and Shittu, 2015). Water availability is a factor that determines crop productivity. In crop nourishment, water use is therefore of immense importance (Edoga, 2007). Adeleke *et al*. (2015) states that ground water is a system that comes to fore in the study of climate, hydrology and hydrogeology. They used the CROPWAT 8.0 software and different other models for estimating evapotranspiration in their work on ground water recharge in Odeda, Nigeria. The objective of this study is to specifically obtain estimates for the reference evapotranspiration for Gassol using the FAO Penmann-Monteith model and generally carry out analysis for these estimates to observe trends and pattern for each year of study.

2.0. Materials and Methods

2.1. Description of the study area

The study area is Gassol Local Government area located in the central zone of Taraba State. It falls within the Sudan Savannah vegetation belt of Nigeria with an estimated annual rainfall range of 500 mm to 1000 mm, according to Adekola *et al*. (2015). Gassol is characterized by the following coordinates Latitude 8°38′00″ North and Longitude 10°46′00″ East as shown in Figure 1.

2.2. Data source and analysis

The data for this research was obtained from the Upper Benue River Basin Development Authority of the Federal Ministry of Water resources. It contains minimum temperature, maximum temperature, relative humidity, wind speed and sunshine hours for 1985 to 1991. The FAO Penman-Monteith model for estimating the reference evapotranspiration $ET_{0,P\ M}$ was used as given by Equation 1 (Edebetu *et al*., 2014; Ogolo, 2014; Maina *et al*., 2014; Edebetu, 2015).

$$ET_{0,PM} = \frac{0.408\Delta(R_n - G) + \gamma \frac{37}{T + 273} U_2\{e_s - e_a\}}{\Delta + \gamma[1 + 0.34U_2} \quad (1)$$

Where:

ET_0	Reference evapotranspiration in mmday^{-1}
R_n	Net radiation value at the crop surface MJm^{-2}d^{-1}
G	Soil heat flux density MJm^{-2}d^{-1}
T	Mean daily air temperature
e_s	Saturation vapour pressure (KPa)
e_a	Actual vapour pressure (KPa)
$(e_s - e_a)$	Pressure deficit (KPa)
Δ	Slope of the saturation vapour pressure-temperature curve (KPa/°C)
γ	Psychometric constant (KPa/°C)

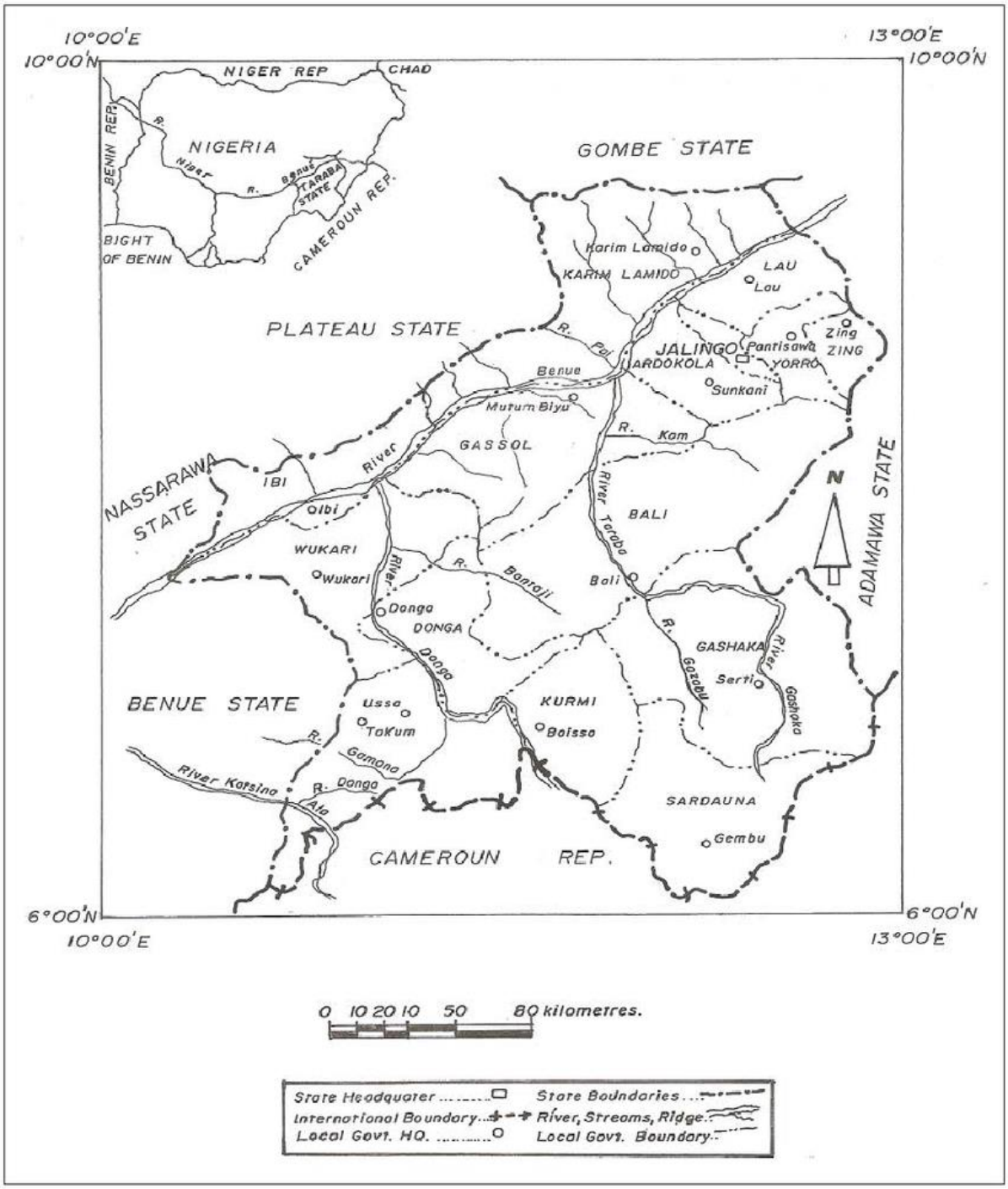

Figure 1: Map of Taraba State showing the sixteen Local Government Areas Gassol inclusive

3.0. Results and Discussion

The following charts are results of the analysis of the reference evapotranspiration for Gassol using FAO CROPWAT 8.0.

Figure 2 shows the estimated reference evapotranspiration of the study area for the year 1985. It contains the monthly variation and has a maximum of 5.80 $mmday^{-1}$ in February while the minimum was in the month of August with a quantity of 3.93 $mmday^{-1}$. A gentle decreasing trend was observed for the entire year. The annual average was 4.75 $mmday^{-1}$as similarly obtained by Alhassan *et al*. (2015). The first half of the year had higher ET_0 than the second half. The months of July and August experienced deviations below the annual mean value of the estimated reference evapotranspiration but not significant to affect the entire estimate. As clearly seen on the chart July and August had lower

ET_0 values compared to the other months. This might be due to lower temperature experienced in those months as corroborated by Edoga and Suzy (2008).

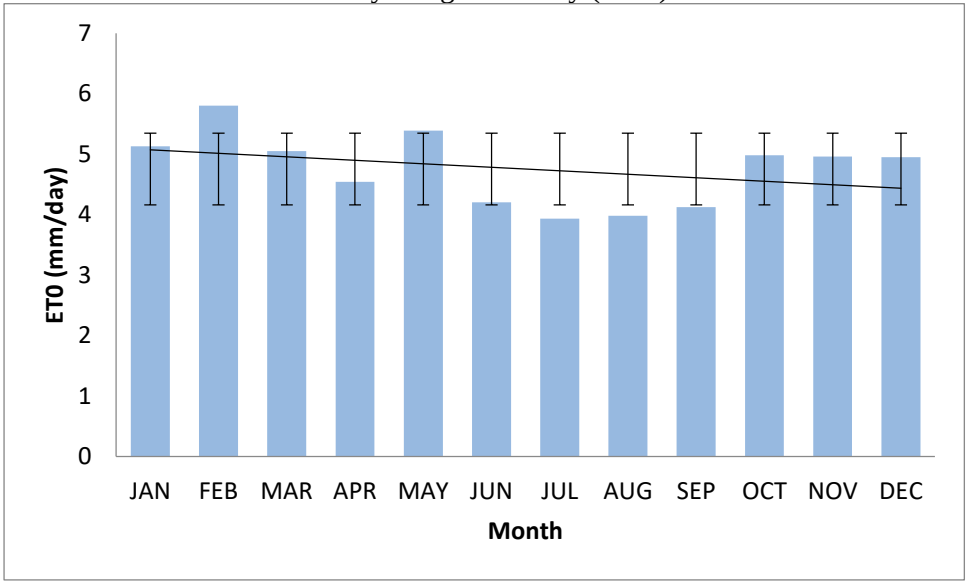

Figure 2: Gassol monthly evapotranspiration and standard deviation for 1985

Figure 3 is the estimated reference evapotranspiration for the year 1986. December had the minimum of 4.25 mmday^{-1} while the maximum value of 6.36 mmday^{-1} was in April. The annual average ET_0 for the year was 5.11 mmday^{-1} with a steep decreasing trend as the first half of the year experienced higher ET_0values. July had value below the annual mean and therefore not significant as to affect the entire estimate. The trend implies that changing pattern decreased from January to December while peak rainfall months of July and August experienced lower values of ET_0.

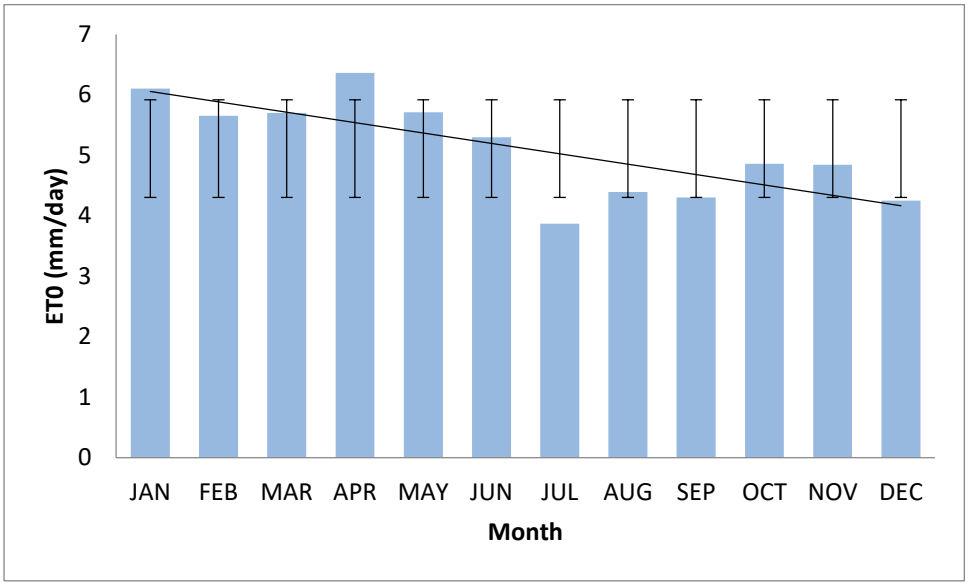

Figure 3: Gassol monthly evapotranspiration and standard deviation for 1986

Figure 4 shows the estimate of reference evapotranspiration for the study area. The minimum of 4.30 mmday^{-1} was in August while May had the maximum of 6.52 mmday^{-1}. The annual average was 5.29 mmday^{-1}. These are similar to Umara *et al*. (2012). Also, the first half of the year experienced higher ET_0 than the second half of the year. The year equally had decreasing trend. Only the month of August experienced deviations below the annual mean estimate. This implies that the estimates are within acceptable range for the FAO Penmann-Moneith model used.

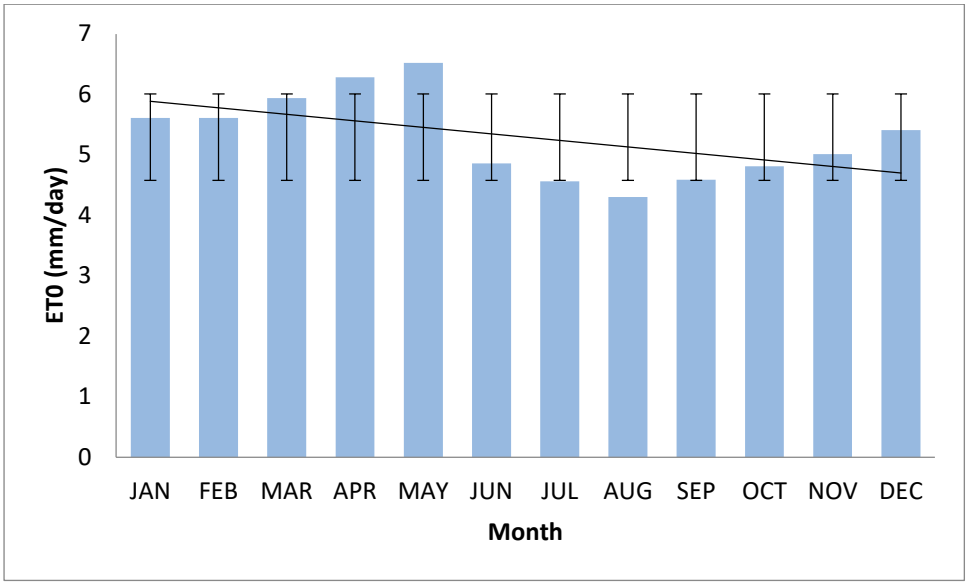

Figure 4: Gassol monthly evapotranspiration and standard deviation for 1987

Figure 5 is the chart for the estimated reference evapotranspiration for 1988. The minimum value of 3.79 mmday^{-1} was in July while the maximum value of 6.45 mmday^{-1} was in February, and the annual average of the ET_0 was 4.84 mmday^{-1}. The year also had a decreasing trend with the first half season having higher value than the second half season. This pattern is comparable to the estimates and analysis for the year 1998 as obtained in Figure 5.

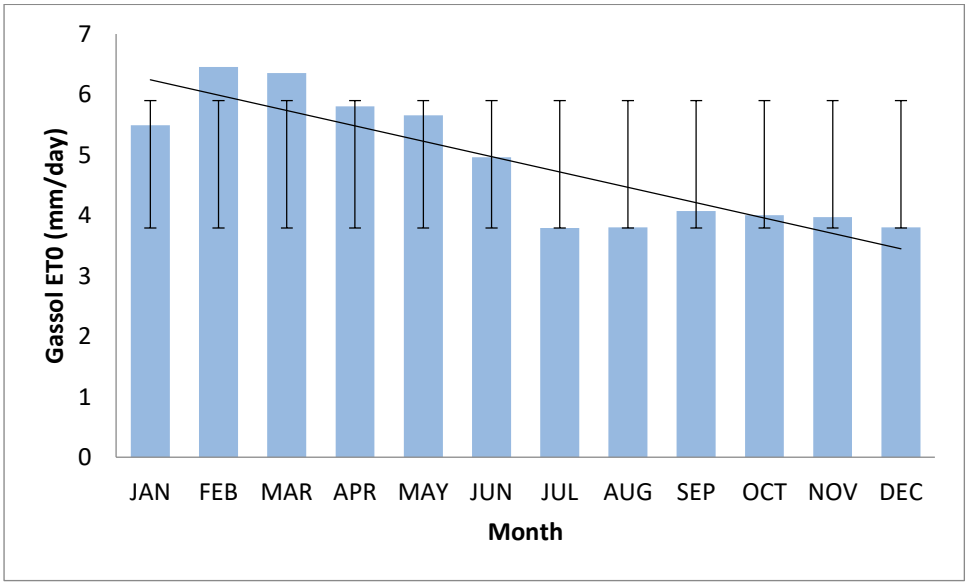

Figure 5: Gassol monthly evapotranspiration and standard deviation for 1988

Figure 6 is the 1989 estimated reference evapotranspiration for the study area. The month of October had the minimum value of 3.42 mmday^{-1} while the month of February had the maximum with a value 6.46 mmday^{-1}, and the annual average ET_0 for the year was 4.74 mmday^{-1}. The first half had higher ET_0 than the second half of the year and had a decreasing trend as previous years. The months of October and November had deviations below the annual mean estimate.

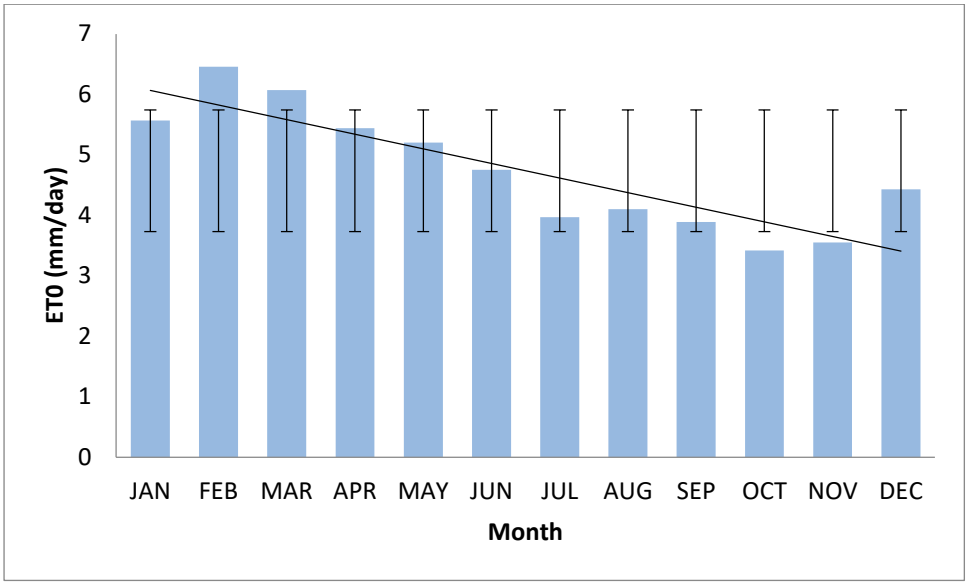

Figure 6: Gassol monthly evapotranspiration and standard deviation for 1989

Figure 7 is the 1990 estimated reference evapotranspiration chart. The minimum for the year was 3.39 mmday^{-1} at the month of December while the annual maximum was 6.53 mmday^{-1} at the month of April similar to Adeboye *et al*. (2009). The average ET_0 for the year was 4.92 mmday^{-1}. Generally, a decreasing gentle trend occurred with the first half of the year having higher values than the second half. The months of January and November had estimates below the mean annual estimate.

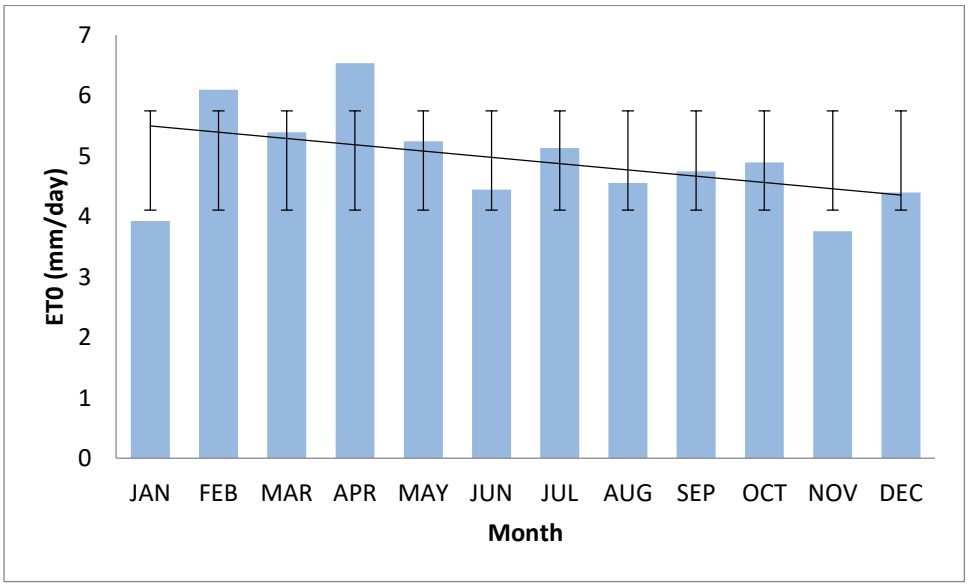

Figure 7: Gassol monthly evapotranspiration and standard deviation for 1990

Figure 8 is the estimated reference evapotranspiration for the year 1991. The minimum value of 3.34 mmday^{-1} occurred at the month of July while the maximum value of 6.34 mmday^{-1} occurred at the month of February, and the annual average was 4.69 mmday^{-1}. It had a steep decreasing trend as the first half of the year experienced higher ET_0 values than the second half of the year. July and December had deviations below the annual mean, as is seen in Edoga and Suzy (2008). The 1991 evapotranspiration for Gassol shows lower values for the months of May to August. This is attributed to lower temperature at the peak of the wet season.

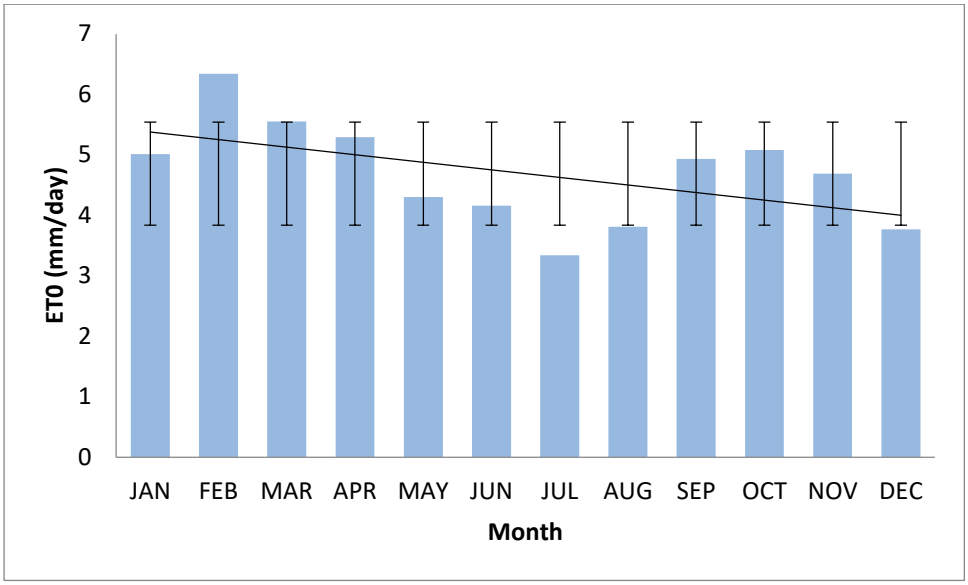

Figure 8: Gassol monthly evapotranspiration and standard deviation for 1991

Figure 9 is the time series chart of the estimated reference evapotranspiration for the study area. It covers ET_0 from 1985 to 1991 expressing a seasonal cyclical variability, with most years showing bimodal peaks. There was a general decreasing trend from year to year.

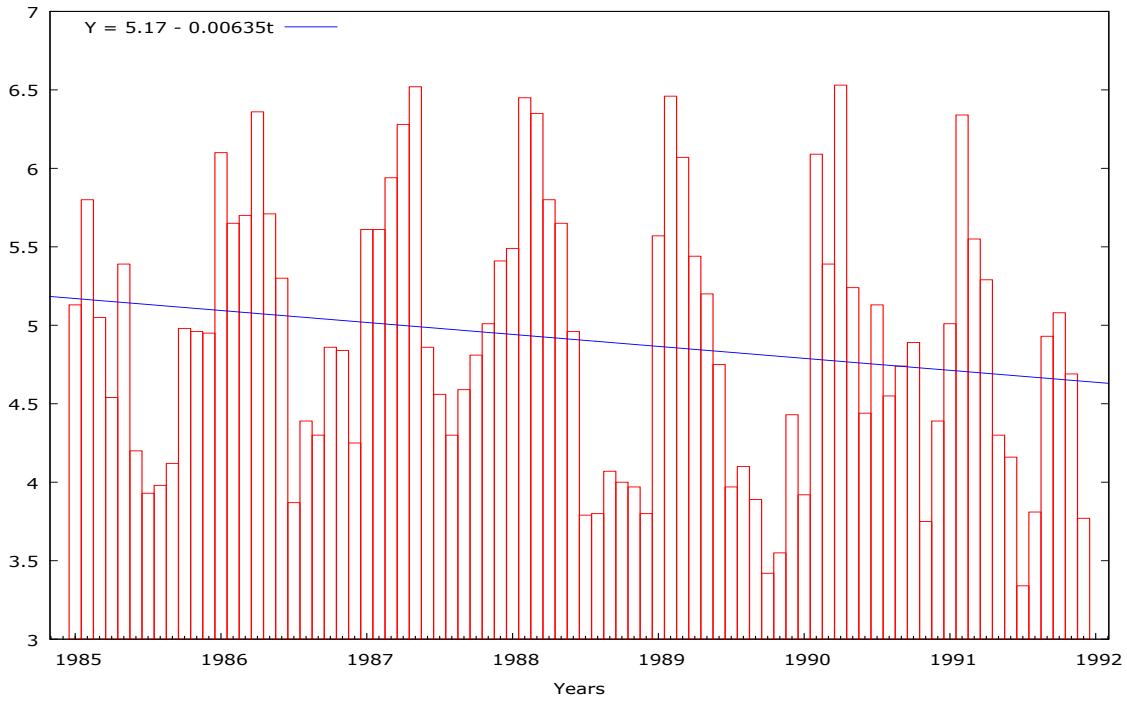

Figure 9: Gassol evapotranspiration (1985-1991)

Figure 10 is the frequency distribution of the reference evapotranspiration for Gassol. It shows an evenly spread data on the normal distribution curve. Figure 11 is the periodogram of Gassol reference evapotranspiration for the period 1985 to 1991. The dominant peak occurs at periodicity of 9.33 months.

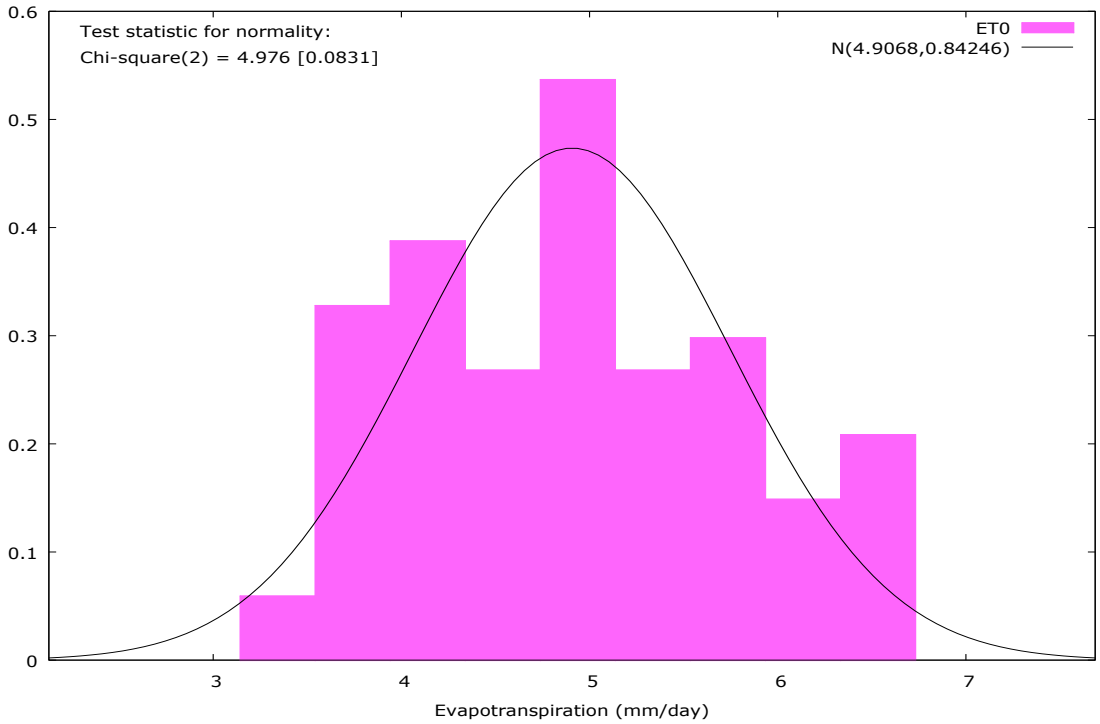

Figure 10: Gassol frequency distribution of evapotranspiration

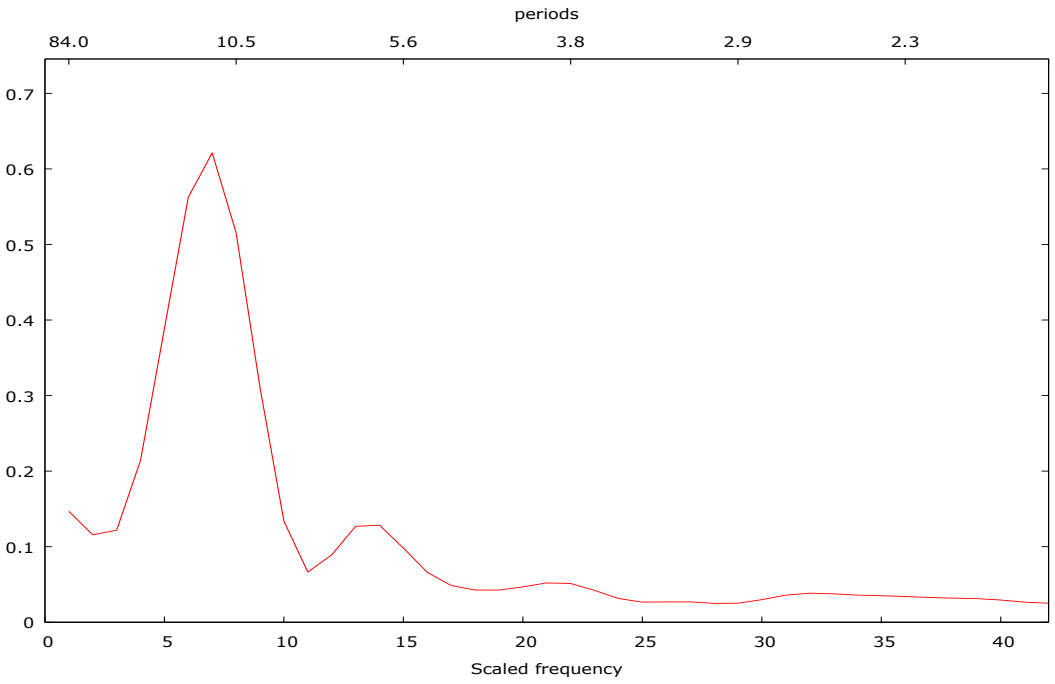

Figure 11: Gassol periodogram of evapotranspiration

4.0 Conclusion

The estimated values of reference evapotranspiration for Gassol from 1986 to 1991 generally had gentle decreasing trend. The first half of the years was of low values than the second half of the years. January-June estimates were more than the July-December values. For the monthly estimates the deviations experienced from the annual mean estimates were not significant to affect the accuracy of the estimates. The time series plot shows a near smooth pattern of variation with a generally decreasing trend. Knowledge of reference evapotranspiration is very important in micrometeorological applications, balance of energy over land surface and the effect of hydrology on climate change (Zhao, *et al*. 2013). Irrigation scheduling and water management are key agricultural practices that get properly done with a good understanding of the reference evapotranspiration of the area. There is the likelihood of further declining trend in subsequent years for the reference

evapotranspiration in Gassol. There is the need for an efficient water management scheme through proper irrigation scheduling practices. January through March and October through December should be prioritized.

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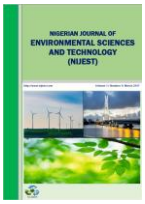

Climatic Variability and Estimation of Supplementary Irrigation Water Needs of Selected Food Crops in the Sokoto-Rima River Basin, Nigeria

Emeribe C. N.[1,]*, Ogbomida E. T.[2] and Enoma-Calus J. O.[3]

[1,2]National Centre for Energy and Environment, University of Benin, Benin City, Edo State, Nigeria

[3]Department of Geography, College of Education, Ekiadolor, Benin City, Edo State, Nigeria

Corresponding Author: *emeribe.c@ncee.org.ng

ABSTRACT

The study investigated the effects of rainfall and temperature variability on crop water requirements of selected food crops in the Sokoto-Rima River Basin, Northwest of Nigeria. Rainfall and temperature datasets were obtained from the Climatic Research Unit (CRU) TS 3.21 of the University of East Anglia, Norwich, for a period of 70 years (1943-2012). The suitability of CRU datasets were verified by correlating the datasets with measured rainfall data of Yelwa synoptic station, from the Nigerian Meteorological Agency. Selected food crops were used for estimating supplementary irrigation water needs in the River basin. Results of Mann-Kendal, Spearman's Rho and linear regression tests showed strong evidence of increasing annual temperature and potential evapotranspiration with corresponding decrease in rainfall amounts, especially in the northern parts of the basin which houses big irrigation projects and dams such as the Goronyo Irrigation and the Bakolori Dam and Bakolori Irrigation Project. This will impact on the water availability within the basin, through reduction in surface and ground water supply for ongoing irrigation and other water resources projects. Water requirements for selected crops were modeled to ascertain crop sensitivity to climatic variability which will aid in the design of supplementary irrigation water needs models. Results showed that even in the rainfall months, supplementary irrigation of varying quantity is required to complement rainfall, most especially, in the northeast of the basin. Surprisingly, the month of May which marks commencement of rainfall, recorded the highest water need and this has implication for agriculture yields in the region.

Keywords: Climatic variability, Supplementary irrigation, Food crops, Rainfall, Temperature

1.0. Introduction

The Sokoto-Rima River Basin is located in the Sudano-Sahelian belt of Nigeria, and has a population of more than 15 million (NPC, 2006). Of this population, 75% depends on rain-fed agriculture for the sustenance of livelihood and food security according to FAO (2018). Climate variability and change has triggered research into the future of water resources and its sustainability under the current situation of climatic uncertainty. Already, it has been reported that the belt is faced with serious environmental challenges arising from aridity in response to climate change, rainfall variability and repeated drought, linked to intensified anthropogenic and natural processes (IPCC, 2007; Bello, 2010; AbdulKadir *et al.*, 2013).

Researchers have also confirmed an increasing rate of desertification in the region (Zhao *et al*., 2005; Huang and Siegert, 2006; Susana and Kelley, 2006; Sonia *et al*., 2007; Sivakumar, 2007; Hanafi and Jauffret, 2008). These are threats to agricultural productivity, food security and sustainability of rural livelihood in the region, where subsistent farmers are dominant. Water deficit in the region since the wake of global warming is not expected to improve in the future (Abaje *et al.*, 2011). More importantly, taking into account the population growth and the expected negative effect of climate change on rain pattern in extreme northern Nigeria, the Sokoto-Rima River basin will most likely be faced with the problem of allocating adequate water for agriculture to maintain food security. The major crops involved in food security in the Sokoto-Rima River basin are: wheat, maize, rice, millet,

beans, guinea corn, tomato, cabbage, carrot, onion. The sensitivity of these crops to climate change has been classified by Allen *et al.* (1998) as ranging from medium to high in the face of hydrological stress.

Moreover, since agriculture in the basin is essentially rain-fed, changes in climatic variables in particular rainfall and temperature will adversely affect farming operations. For example, Adelana *et al*. (2003) found that infrequent and short period of rainfall (< 60 raining days) in most part of the basin prevent the development of agriculture and restrict crop production in a year to only one planting season per year. This has led to repeated crop failures and declining yields which have led to decrease in the income of farmers and the associated problems of food shortage, malnutrition and general impoverishment of local inhabitants (Ekpoh, 1999; Mortimore and Adams, 2001).

In order to meet the food security of the teaming population of the Sokoto-Rima River Basin, who are mostly subsistent farmers, there is need for scientific quantification of the effect of climate change on crop production. Evapotranspiration, crop factor and water requirements of popularly cultivated crops in the region need to be ascertained. Management of water based on evapotranspiration in river basins has become a developing trend in arid and semi-arid areas (Qin *et al*., 2009). Evapotranspiration is widely used in guiding agricultural irrigation schedule through the quantitative estimation of the crop water requirement in order to achieve water saving and agricultural yield increase (Dingman, 2002). Previous studies that attempted to examine impacts of climate change on agricultural production in many developing countries concentrated only on general analyses of potential impacts of climate change on crops production, food security and animal husbandry (Odjugo, 2001; Adejuwon, 2006a; Adejuwon, 20076b; Adefolalu, 2007; Jagtap, 2007; Nwafor, 2007). Not much has so far been done in quantifying the effects of climatic variability on crops and on developing supplementary irrigation schedule to guide farmers during long dry spell in rainy season in many developing countries and therefore forms the basis for this study.

2.0. Materials and Methods

2.1. Study area

The study area is located in Northwestern Nigeria and lies largely in the far North of Sudano- Sahel of West Africa in the zone of Savanna-type vegetation belt generally classified as semi-arid (Sombroek and Zonneveld, 1971). It lies between Latitudes 12° and 14° N and Longitudes 5° and 7°E. The basin is underlain by a sequence of inter-bedded semi-consolidated gravels, sands, clays and some limestone and ironstone of cretaceous to quaternary age resting on pre-Cambrain basement complex rocks which outcrop extensively to the east and south of Zamfara State as well as to the south of Kebbi State (Sombroek and Zonneveld, 1971). The Sokoto basin is a semi-arid region marked by distinct weather conditions-the wet and dry seasons. Rainfall is highly seasonal and usually starts from May or June of each year and lasts till September or early October depending on the rainfall pattern for that year. There is a marked seasonal variation in temperature and diurnal range of temperature. Daily maximum temperature of the basin is between 36°C-40°C. During the harmmattan season, daily minimum temperature may fall below 18°C. Between February and April which is the peak of heat, temperature reaches the highest of 44°C. In the extreme north, the shrubby and thorny vegetation of the Sahel zone is the dominant vegetation type.

2.2. Data collection and analysis

Precipitation and temperature datasets available on high-resolution (0.5 x 0.5 degree) grids from the Climatic Research Unit (CRU) TS 3.21 of the University of East Anglia, Norwich, United Kingdom (New *et al*., 2000; Mitchell and Jones, 2005) were used in this study and is available at http://www.cru.uea.ac.uk/. Data were collected for a period of 70 years for Bunza and Dakingari, Southwest of the basin, Gulma and Augi, North West, Goronyo and Galadi, North East and Maje and Dan-Dume South East for the period 1943-2012. Quality control of CRU datasets has been discussed in detail in New *et al*. (2000). In addition, the suitability of CRU datasets were verified by correlating the rainfall data from this source with measured rainfall data from Yelwa synoptic station, Nigerian Meteorological Agency, for the period 1950-2012. Only points from the CRU dataset that yielded positive relation with NIMET point-gauged data were used in the study (Tables 1 and 2).

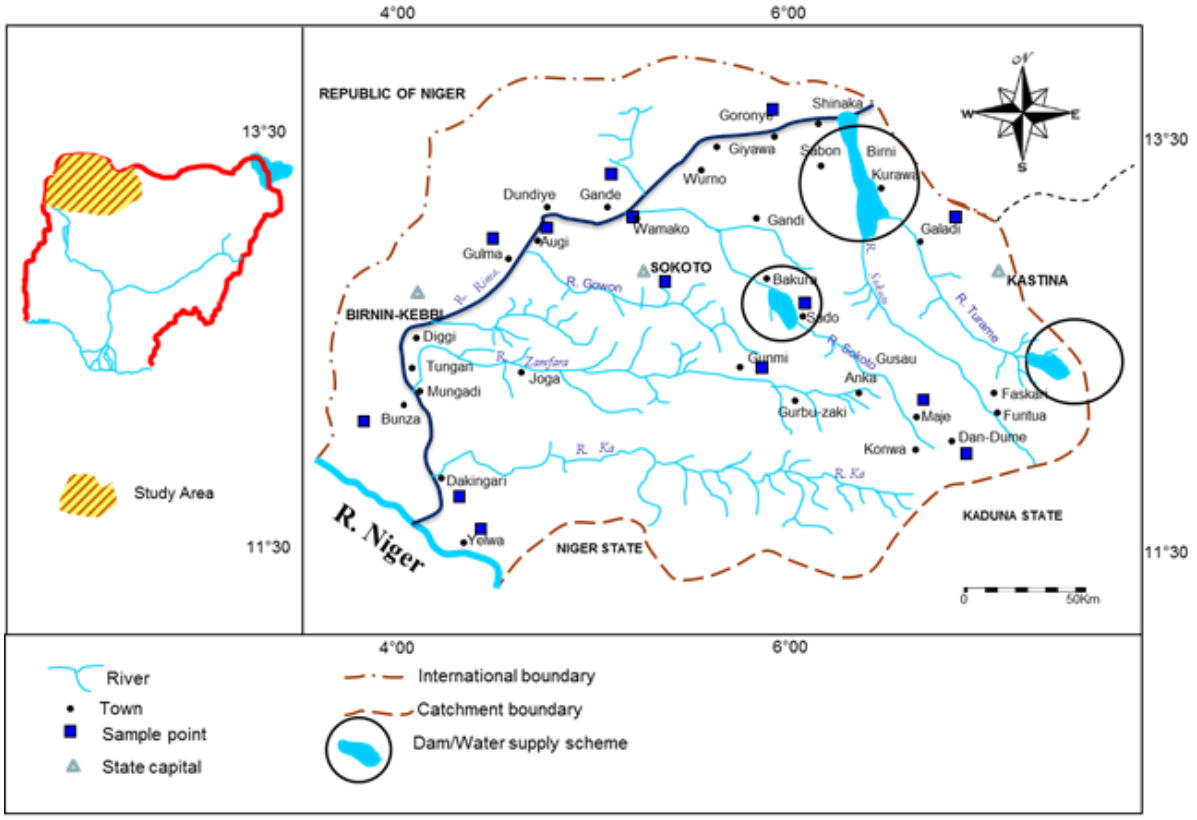

Figure 1: Sokoto River basin
(Source: Adopted from Ita, 1993)

Table 1: Result of correlation of rainfall data from CRU data set with measured data from NIMET (Yelwa Station)

Data Point	Multiple R	R Square	Adjusted R Square	Standard Error
Bunza	0.97	0.94	0.93	14.8
Dakingari	0.96	0.92	0.91	17.2
Gulma	0.97	0.95	0.95	13.5
Augi	0.98	0.96	0.96	12.1
Goronyo	0.95	0.90	0.89	29.7
Galadi	0.96	0.92	0.92	26.1
Maje	0.97	0.95	0.94	16.7
Dan-dume	0.97	0.94	0.93	18.8

Correlation was performed on monthly basis

Table 2: Result of correlation of temperature (°C) data from CRU data set with measured data from NIMET (Yelwa Station)

Data Point	Multiple R	R Square	Adjusted R Square	Standard Error
Bunza	0.96	0.92	0.91	0.6
Dakingari	0.98	0.96	0.96	0.42
Gulma	0.93	0.87	0.85	0.83
Augi	0.92	0.86	0.85	0.8
Goronye	0.82	0.67	0.64	1.32
Galadi	0.86	0.74	0.72	1.17
Maje	0.97	0.95	0.94	0.50
Dan-dume	0.88	0.77	0.75	1.66

Correlation was performed on monthly basis

2.3. Data analysis

Analysis of data was achieved using the excel analysis toolPak. The Thornthwaite water balance computer software version 1.10, developed by the United States Geological Survey Department was used for computing the components of water balance. The choice of this model is based on the nature of physical processes that interact to produce the phenomena under investigation (i.e. temperature rainfall relationship), availability of the required model components/data and wide applicability of the model for hydrological impact of climate change assessment. Although studies have shown, the

Penman (1948) equation is considered to be the most accurate and has widespread application (Ayoade, 1983; Anyadike, 1987), unfortunately, the model requires a lot of input data which are not readily available in most developing countries for example where net radiation data and soil heat flux. Monthly potential evapotranspiration (PET) was estimated from mean monthly temperature (*T*). In this study, *PET* was calculated using the Hamon equation (Hamon, 1961) shown in Equation 1.

$$PET_{Hamon} = 13.97 \times d \times D_2 \times W_t \quad (1)$$

where:

PET_{Hamon}	*PET* in millimeters per month,
d	Number of days in a month,
D_2	Mean monthly hours of daylight in units of 12 hrs, and
W_t	Saturated water vapor density term, in grams per cubic meter, calculated using Equation 2:

$$W_t = \frac{4.95 \times e^{0.062 \times T}}{100} \quad (2)$$

where:

T	Mean monthly temperature in degrees Celsius (Hamon, 1961)

2.4. Estimating monthly supplementary irrigation water for selected food crops

Monthly supplementary irrigation water need of selected crops was calculated by subtracting the effective rainfall from the crop water need. The crop water need is expressed in mm water layer per time unit, in this case mm/month. If the rainfall is sufficient to provide the water needs of the crops, irrigation is not required. To ascertain if monthly supplementary irrigation is required for any of the selected crops within the Sokoto-Rima River Basin, the model designed by Allen *et al.* (1998) for estimating supplementary irrigation need was used. The equation is given by:

$$IR = ET_{crop} - P_e \; mm \; month \; -1 \quad (3)$$

where:

IR	Supplementary irrigation in mm;
ET_{crop}	Consumptive water need (mm); and
P_e	Effective rainfall (mm)

ET_{crop} is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally. It is determined as:

$$ET_{crop} = ET_0 \times K_c \quad (4)$$

where:

ET_o	Reference crop evapotranspiration (mm d^{-1}) and also represents an index of climatic demand,
K_c	Varies predominately with the specific crop characteristics and only to a limited extent with climate.

This relationship enables the transfer of standard values for K_c between locations and between climates. This has been a primary reason for the global acceptance and usefulness of the crop coefficient approach and the K_c factors developed in past studies (FAO, 1986). Values of ET_o were determined using the modified Thornthwaite model (McCabe and Markstrom, 2007).

The K_c is a dimensionless crop coefficient. It is the ratio of the crop ET_c to the reference ET_o, and represents an integration of the effects of four primary characteristics that distinguish the crop from reference grass. These are crop height, albedo, canopy resistance and evaporation from soil, especially exposed soil (Allen *et al*., 1994). Because of the sparseness of data on crop coefficient in

developing countries, empirical estimates are usually employed and the most common is the FAO estimates (FAO, 1986) (Table 3). The K_c values are estimated under a standard climatic condition. This condition has been defined as crops grown in large fields under non-limiting agronomic and soil water conditions (FAO, 2002).

Table 3: Estimated values of crop factor (K_c) for various crops under a standard climatic condition and growth stages

Crop	Total growing period (days)	Initial stage K_c	Crop dev. Stage K_c	Mid-season stage K_c	Late season stage K_c
Maize (grain)	125-180	0.40	0.80	1.15	0.70
Groundnut	130-140	0.45	0.75	1.05	0.70
Tomato	135-180	0.45	0.75	1.15	0.80
Cabbage	120-140	0.45	0.75	1.05	0.90
Carrot	100-150	0.45	0.75	1.05	0.90
Green Bean	75-90	0.35	0.70	1.10	0.30
Onion (dry)	150-210	0.50	0.75	1.05	0.85
Melon	120-160	0.45	0.75	1.00	0.75
Millet	105-140	0.35	0.70	1.10	0.65
Sorghum	120-130	0.35	0.75	1.10	0.65
Soybean	135-150	0.35	0.75	1.10	0.60
Cucumber	105-130	0.45	0.70	0.90	0.75
Pepper	120-210	0.35	0.70	1.05	0.90
Bean (dry)	95-110	0.35	0.70	1.10	0.30
Potato	105-145	0.45	0.75	1.15	0.85

Source: FAO Irrigation and Drainage Paper, No. 24 (1986)

To determine the monthly water requirement per crop, K_c values for that crop for various stages of growth were averaged.

2.5. Trend analysis

Trend analysis of annual rainfall and temperature distributions were determined using a Trend/change detection software (TREND) version 1.0.2 developed by the Cooperative Research Centre for Catchment Hydrology's (CRCCH) Climate Variability Program, in Australia . The scientific development and testing of the software have been carried out at University of Melbourne and Griffith University (Chiew and Siriwardena 2005). TREND is widely adopted by researchers and considered as robust in detecting trends and changes in climatic time series data (Mu *et al*., 2007; Ma *et al*., 2008; Zhang and Lu, 2009).

3.0. Results and Discussion

3.1. Temporal trends in rainfall in the Southwest of the Sokoto-Rima basin

Annual trend of rainfall, southwest of the Sokoto-Rima River Basin is presented in Figure 2. The first three (3) decades from mid-1940, 1950, and 1960 were generally observed to be wet decades. This rising trend was interrupted by a break at the start of 1970 before another rise above rainfall mean value of 827.3 mm in 2000. There was a continuous downward trend in rainfall from 1970. Lowest rainfall was observed in 1973 with annual rainfall of 464.6 mm. Other years of much low rains are 1982 (529.2 mm), 1987 (391.2 mm) and 1987 (568.6 mm). Highest rainfall of amount 1096.6 mm was recorded in 1957. Other years of very high rainfall amounts were 1978 and 1946 with rainfall values of 1090.6 mm and 1087.2 mm respectively. An average rainfall of 927.7 mm was recorded in wet years (36 years in which rainfall was above mean value). In the dry years' episode (34 years), rainfall amounts were below the average (721.1 mm). Figure 3 shows the annual trend of rainfall, NW of Sokoto-Rima River basin (1943-2012).

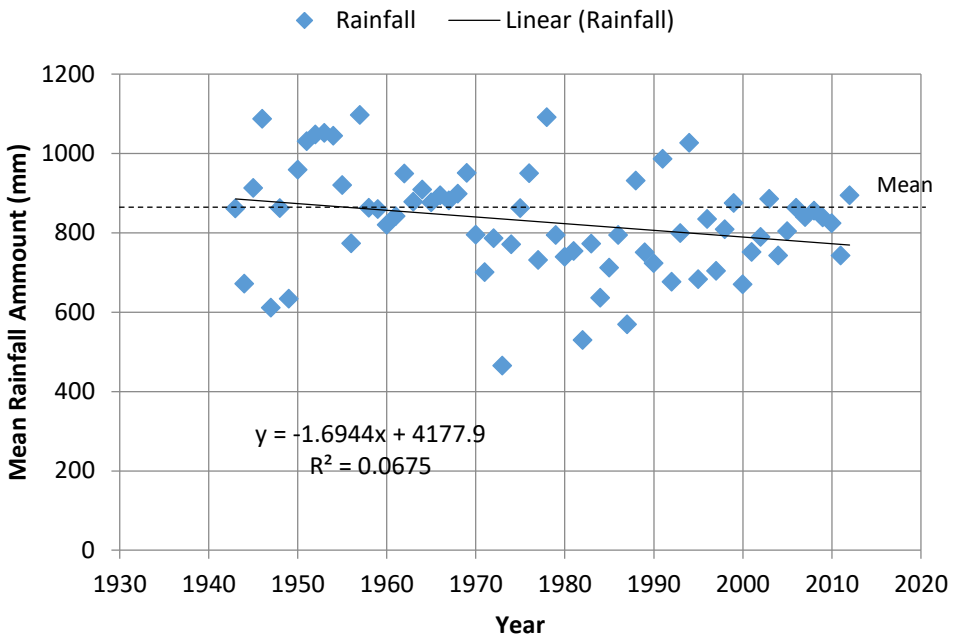

Figure 2: Annual trend of rainfall, SW of Sokoto-Rima River basin (1943-2012)

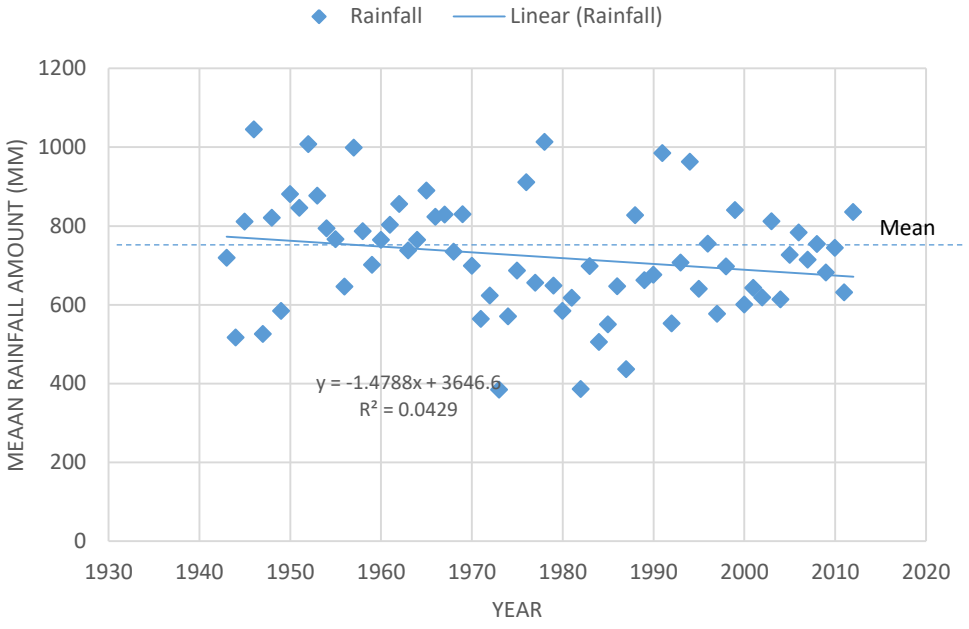

Figure 3: Annual trend of rainfall, NW of Sokoto-Rima River basin (1943-2012)

3.2. Trend of rainfall, NW of Sokoto-Rima River basin

In the Northwest of the Sokoto-Rima River basin, wettest years were seen clusterd between 1950, and 1960 as well as part of mid 1940s (Figure 4). This rising trend was interupted by breaks around the start of 1970 when rainfall predominantly decreased below a mean value of 722.3 mm. There was a continous downward trend in rainfall from 1970 which extended into 2000 with very weak sign of recovery in 2010. This is smiliar to the result obtained for China (Junliang *et al*., 2016). Lowest rain year was 1973 with rainfall amount of 384.4 mm. Other years of significantly low rains were 1982 (385.8 mm) and 1987 (385.8 mm). Maximum rainfall amount of 1044.7 mm was recorded in 1946. Other years of high rainfall amounts were 1978 and 1952 with rainfall values of 1012.6 mm and 1007.1 mm respectively. An average rainfall of 841.3 mm was recorded in wet years (34) years in which rainfall was above the mean value. In the dry years episode (36 years), rainfall amount was as low as 609.9 mm on the average. These values obtained were found to be higher than those of the upper East region of Ghana as reported in Abdul-Rahaman *et al*. (2016).

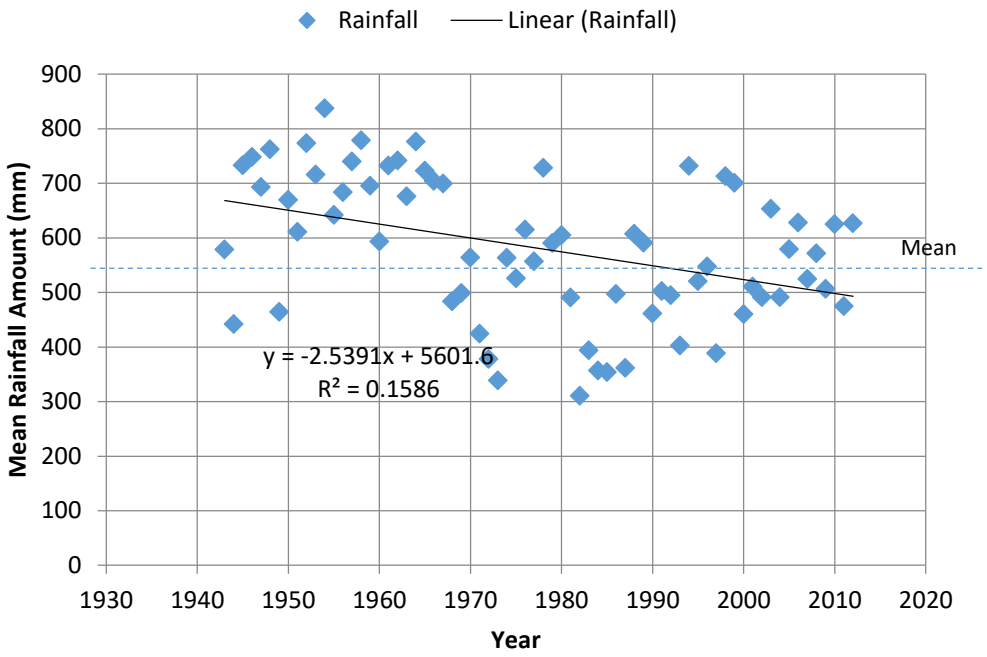

Figure 4: Annual trend of rainfall, NE of Sokoto-Rima River basin (1943-2012)

3.3. Trend of rainfall, NE of Sokoto-Rima River basin

In the Northeast of the basin, rainfall pattern varied widely as shown Figure 5. Wet rainfall episode was observed to cluster around mid-1940s, 1950s and 1960s. From 1970s, there was however, a downward trend below the mean value of 580.5 mm which continued into 2010 with an occasional few years in which rainfall was above the mean value. The lowest rainfall in the Northeast of the basin was observed in 1982 with annual rainfall of 310.6 mm. Other years of very low rains were 1973 (338.3 mm) and 1985 (353.6 mm). Highest rainfall of amount 837 mm was recorded in 1954. An average rainfall of 689.6 mm was recorded in wet years (35 years in which rainfall was above mean value of 580.5 mm). In the dry years' episodes (35 years) in which rainfall amounts were low, the average rainfall amount was 471.5 mm.

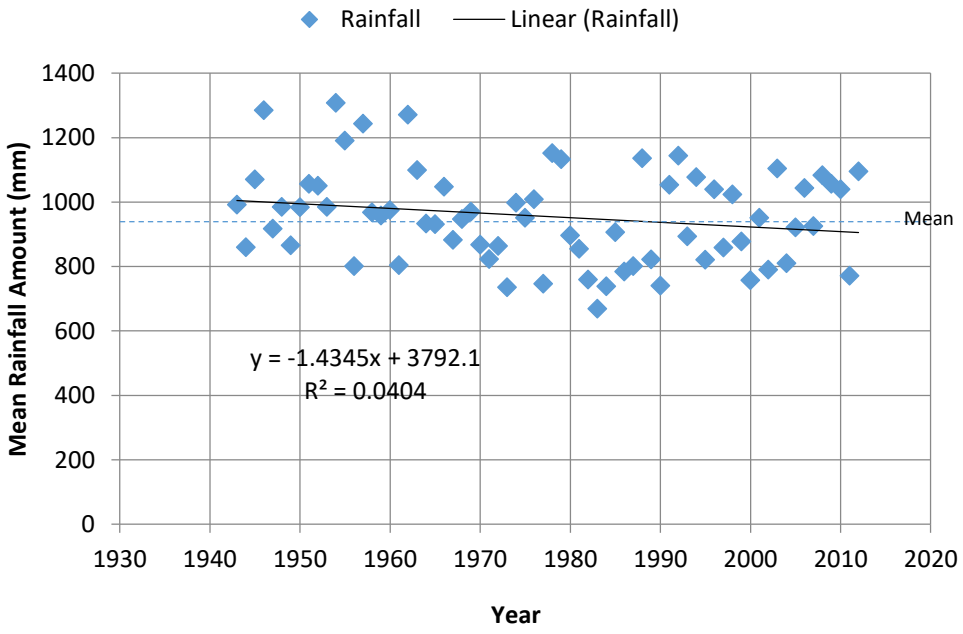

Figure 5: Annual trend of rainfall, SE of Sokoto-Rima River basin (1943-2012)

3.4. Trend of rainfall, SE of Sokoto-Rima River basin (1943-2012)

Unlike the patterns observed in some parts of the basin, there was a gradual decrease in the rainfall amount in the Southeast of the basin. The wettest years were however around 1940s, 1950s, 1960s and part of 1970s before an interrruption in the start of 1980. In 1990 and 2010, there was evidence of recovery though rainfall distribution varied around mean value of 955.3 mm (Figure 5). Lowest rain year was 1983 with rainfall amount of 668.8 mm. Other years of very low rains were 1973 (734.9 mm) and 1990 (740.1 mm). Highest rainfall of amount 1307 mm was recorded in 1954. Other years of very high rainfall amounts were 1946 and 1962 with rainfall values of 1284.6 mm and 1270.6 mm respectively. An average rainfall of 1076.7 mm was recorded in wet years (34 years in which rainfall was above mean value of 955.3 mm). In the dry years episode (36 years) in which rainfall amounts were below average, the average rainfall amount was 840.7 mm.

From Figures 2-5 trends in annual rainfall distribution over Sokoto Rima River basin is best described as experiencing moderate downward trend across 1940-2012. However, for locations in the extreme north of the basin declining annual rainfall amounts seem to be more pronounced when compared to distributions in the southern part of the basin. This is expected as rainfall amount in Nigeria decreases from the coastal south (south of the moisture that produces rain) to the north due to effect of continentality. Similarly, the decrease in rainfall amount for most locations in northwest and northeast of the study area may also be due to increased distance from the zone of influence of topography and the orography as well as in accordance with the general trend in rainfall distribution in Nigeria (Oguntunde *et al.,* 2011). Declining rainfall amount is an important limiting factor for rain-fed crop production. The observed decreasing rainfall amount in the extreme northern parts of the basin will exercerbate the ongoing impacts of climate change and variability, with serious implications for sustainable socio-economic lives, including decline in agricultural activities, drought, migration, health problems, farmer-herdmen crises. Also, pests attack and development of crop diseases, witting and desiccation of crops have been linked to reducing annual rainfall amount (Thompson and Amos, 2010; Obi, 2010; Aondoakaa, 2012; Singh *et al*., 2014). For example, Obi (2010) reported evidence of reducing pesticide sensitivity due to decreasing precipitation. His study added that pest population may increase across the northern Nigeria and threaten food production. NEMA (2010) has reported the outbreak of pests and diseases due to meteorological drought condition in part of Borno State. Pests and diseases reduce crop yield, quality and value. Since the basin houses big irrigation projects and dams such as the Goronyo Irrigation and the Bakolori Dam and Bakolori Irrigation Project, north of the basin, the observed decrease in annual rainfall trend with corresponding increase in temperature will impact on the water availability of the basin, through reduction in surface and ground water supply for ongoing irrigation and other water resources projects as a result of rapid moisure loss by evaporation and evapotranspiration.

3.5. Temperature trend in the Southwestern part of Sokoto-Rima River basin

In Figure 6, temperature varied widely around mean value of 28.7°C in the southwestern part of the Sokoto-Rima River basin. Temperature was generally below mean value from 1940 to 1970s. This was however interupted from 1980 and most parts of 2000 and 2010 when there were more years of higher temperature value than the mean. There was a general rising trend in temperature was observed. Lowest temperature was obtained in 1961 with value of 27.7°C. Other years of very low temperature were 1971 (27.8°C), 1965 (27.9°C) and 1975 (27.9°C). Highest temperature of 29.8°C was recorded in 2009, followed by 2011 and 1973 with temperature values of 29.6°C. Northwest of the basin, there was more cluster of temperature below mean value of 28.8°C (Figure 6). Temperature was generally below mean value from 1940 to 1970s with very few years in which temperature was above the mean. From 1980 down to 2010, temperature varied remarkable around the mean line, although there was a cluster of tempeture above mean line in 1980. Lowest temperature was observed in 1961 with temperature value of 27.8°C. Other years with very low temperature were 1965 (27.9°C) and 1975 (27.1°C). Highest temperature of 29.9°C was recorded in 2009, followed by 2010 with value of 29.8°C.

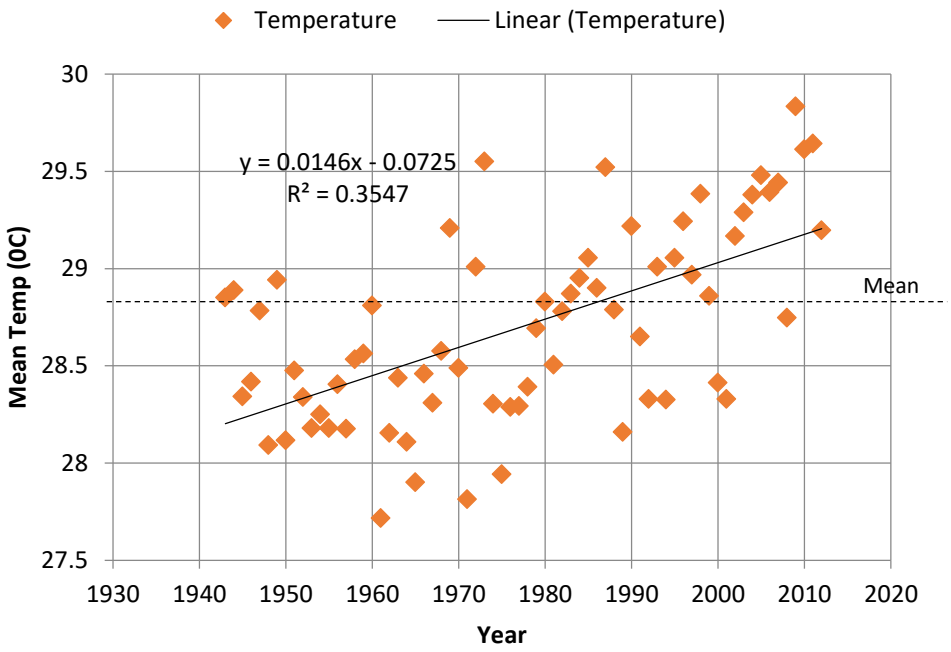

Figure 6: Annual trend of temperature, SW of Sokoto-Rima River basin (1943-2012)

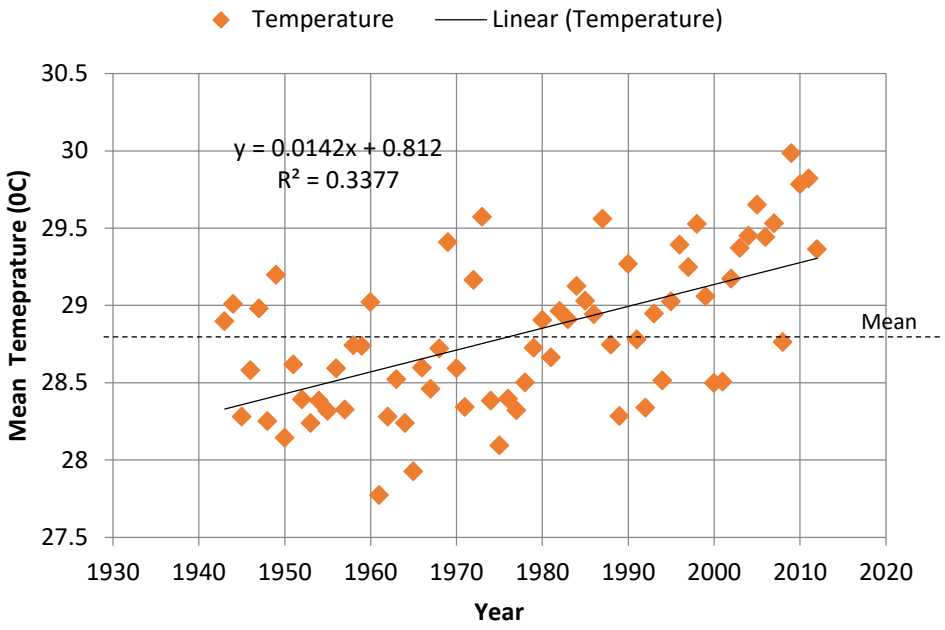

Figure 7: Annual trend of temperature, NW of Sokoto-Rima River basin (1943-2012)

3.6. Temperature trend in the Northwest and Northeast

In Figure 8, the annual pattern of temperature in the northeastern part of the Sokoto-Rima River basin is presented. Temperature was generally above mean value of 28.3°C from mid-1940 to the 1970s. This was however interupted from 1980 and most parts of 2000 and 2010 when there were more years in which temperature values were above the mean. A gradual rising trend in temperature was however observed. Lowest temperature was observed in 1961 with temperature value of 27°C. Other years of very low temperature were 1963 (27.01°C) and 1977 (27.5°C). Highest temperature of 29.4°C was recorded in 1943.

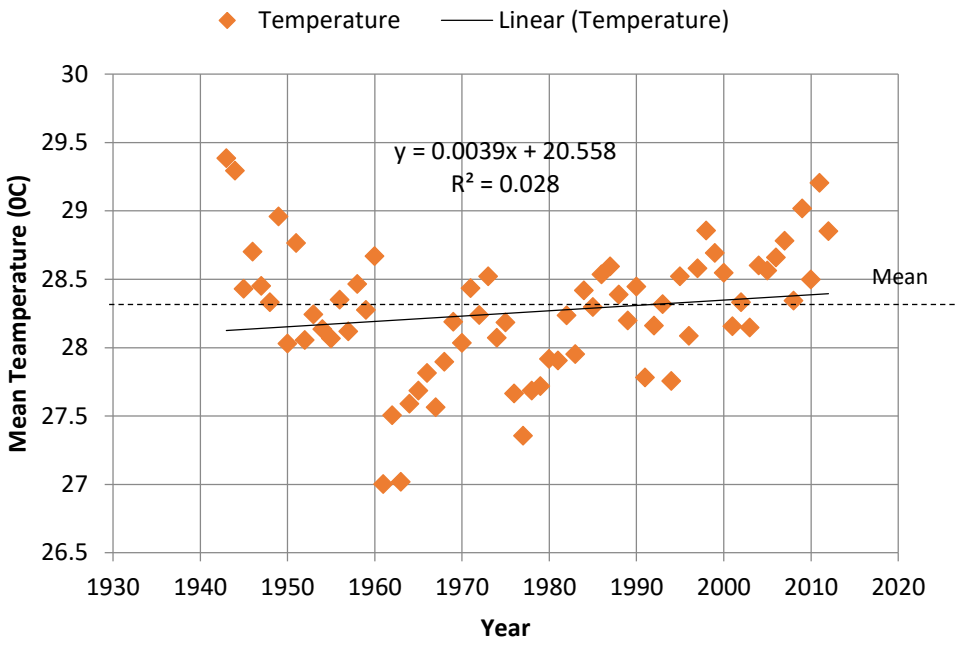

Figure 8: Annual trend of temperature, NE of Sokoto-Rima River basin (1943-2012)

In the Southeast of the basin, there was more cluster of temperature below the mean value of 26.2°C (Figure 8). Temperature was generally below mean value from the start of 1950 which extended into 1970. In 1980, however, temperature pattern assumed a rising patttern down to 2010. There were however few years in between, which temperature values were above the mean line. Lowest temperature was observed in 1961 with value of 25.2°C. Other years with very low temperature were 1989 (25.5°C) and 1975 (25.6°C). Highest temperature of 27.1°C was recorded in 2009, followed by 2010 with value of 27.0°C. Figure 9 shows the annual trend of temperature, SE of Sokoto-Rima River basin (1943-2012).

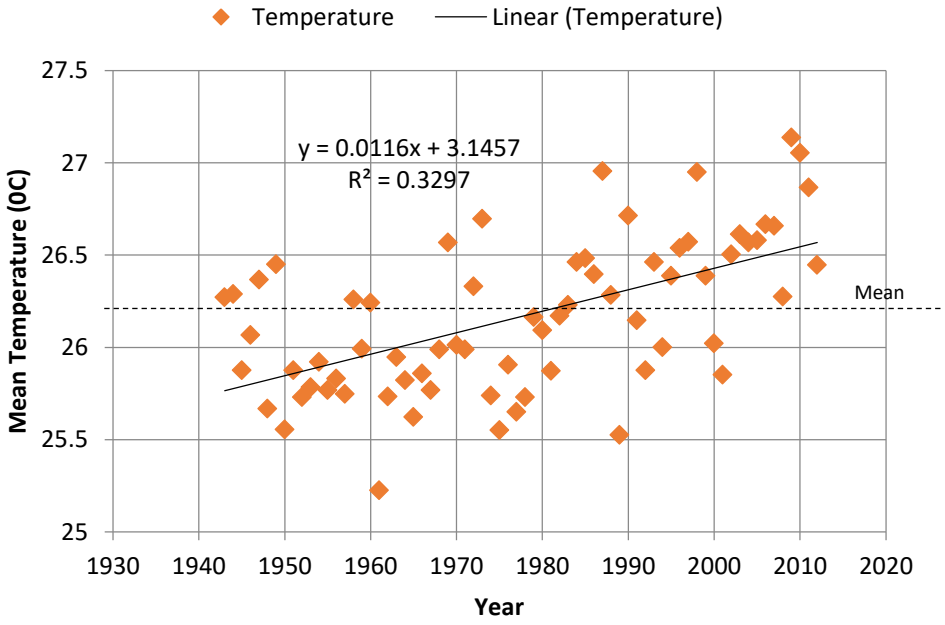

Figure 9: Annual trend of temperature, SE of Sokoto-Rima River basin (1943-2012)

Upward trends in the annual temperature tend to be more pronounced unlike rainfall pattern even though the values coefficients of determination ranges from 0.3-0.45. Rising temperature has been implicated as a direct consequences of global warming. If the present trends in the emission of GHGs through anthropogenic activities continues there is high probability of sharp rise in temperature with

corresponding decline in rainfall amounts in the region. The observed trends may also point to the fact that uncertainty in climatic variables is a major environmental concern in the basin as there are evidence of rainfall recovery in between extreme or near-extreme climate drought condition. Steady rise in annual temperature pattern has been linked to climate change (IPCC, 2007; Bello, 2010). Thus, the rising annual temperature trend across the basin as shown in this study is an indication of changing climate while the rapid fluctuation around mean value for some locations, south of the basin is an indication of unstable temperature condition. Both climate change and unstable climatic conditions have negative implications for social and economic development within the basin as both phenonemon have the tendency to trigger hydo-meteorological droughts. As temperature rises, crops will loss water rapidly through transpiration thereby increasing crop water need. High potential evapotranspiration (PET) is usually observed during high temperature conditon (Audu *et al.,* 2013). Thus, higher value of PET, means increased moisture loss, leading to deficit water balance which is unfavourable to crops. When plant water deficit is not met on time, it causes contingent drought. Crops growing under low soil moisture, yield little and poor quality seeds. As reported by Obi (2010), while increase in temperature is expected to elongate the growing season in temperate regions, such increase within the tropics is expected to decimate agricultural output by aggravating soil evaporation rate and invariably drought. Ayoade (1983) has also observed that excessive heat destroys the plant protoplasm and also decreases the reproductive capacities of animals. Increasing temperature weakens plants and their leaves wither easily hence poor photosynthesis (Audu *et al.,* 2013). Other studies have established that rising temperure will result in reduced crop quantity and quality due to the reduced growth period following high levels of temperature rise; reduced sugar content, bad coloration, and reduced storage stability in fruits; increase of weeds, blights, and harmful insects in agricultural crops; reduced land fertility due to the accelerated decomposition of organic substances (Kim, 2009). Apart from crops, animals also die in large number during prolonged drought as a result of heat stress, dehydration and attack by drought induced diseases.

3.7. Temporal trend of climatic variables over the Sokoto-Rima River basin

Table 4 shows statistical trend patterns of climatic variables over the Sokoto -Rima River basin. Rainfall in SW of the Sokoto-Rima River basin showed evidence of decreasing rainfall. Trend results of rainfall were -2.12 (Mann-Kendall), -2.19 (Spearman's Rho) and -2.18 (linear regression). Trend was detected in rainfall time series at $\alpha < 0.05$. Temperature pattern showed evidence of increasing trends for the entire basin. Results of temperature trend were 5.14 (Mann-Kendall), 4.85 (Spearman's Rho) and 6.15 (linear regression). Trend in time series of temperature distribution was detected at $\alpha < 0.01$. Potential evapotranspiration showed evidence of increasing trend with results of 5.46 (Mann-Kendall), 5.18 (Spearman's Rho) and 6.69 (linear regression) at $\alpha < 0.01$.

Northwest of the Sokoto-Rima River basin downward trend results of rainfall was -1.98 (Mann-Kendall), -1.954 (Spearman's Rho) and -2.03 (linear regression) at $\alpha < 0.05$ for all the three tests. Temperature showed evidence of increasing trend in the following order; 4.94 (Mann-Kendall), 4.65 (Spearman's Rho) and 5.71 (linear regression). Downward trend in time series of temperature distribution was detected at $\alpha < 0.01$ for all the three tests. Potential evapotranspiration showed evidence of increasing trend with trend results of 5.56 (Mann-Kendall), 5.16 (Spearman's Rho) and 6.55 (linear regression) at $\alpha < 0.01$.

Rainfall in the north-east of the Sokoto-Rima River basin presented evidence of decreasing trend as follows Mann-Kendall (-3.01), Spearman's Rho (-3.086) and linear regression (-3.56). Temperature pattern showed evidence of increasing trend with the following results; 5.74 (Mann-Kendall), 5.31 (Spearman's Rho) and 6.68 (linear regression). Potential evapotranspiration also showed evidence of increasing trend with trend results of 5.98 (Mann-Kendall), 5.64 (Spearman's Rho) and 7.59 (linear regression). Upward trend was found at $\alpha < 0.01$.

Trend results of rainfall southeast of the Sokoto-Rima River basin were -1.78 (Mann-Kendall), -1.81 (Spearman's Rho) and -2.08 (linear regression). Results of Mann-Kendall and spearman's rho present possible evidence of decreasing trend in rainfall pattern. Temperature pattern showed evidence of increasing trend. Results of temperature trend were 4.89 (Mann-Kendall), 4.67 (Spearman's Rho) and 5.83 (linear regression). Potential evapotranspiration distribution showed evidence of increasing trend with trend results of 5.52 (Mann-Kendall), 5.18 (Spearman's Rho) and 6.61 (linear regression). Results of the statistical trends buttressed earlier observations of increasing temperature, PET with

evidence of declining rainfall. Although changes in annual rainfall distribution are not as pronounced as pattern observed for temperature, the results are indication of changing climate in the basin. In addition to aforementioned direct impacts on crops, there is serious concern in the region concerning desertification. According to Thompson and Amos (2010), desertification is the insidious cause of the decline in Nigeria's agricultural productivity which has taken hold of 35% of previously cultivable land in eleven (10) northern states. Similarly, Ayuba and Dami (2011) pointed out that Nigeria is losing an estimated land of 351, 000sq.km to desert representing 38% of its total landmass, which corresponds to the landmass of the desert – threatened frontline states of the country (Bauchi, Gombe, Borno, Yobe, Jigawa, Kano, Katsina, Zamfara, Sokoto and Kebbi States). Regrettably, these states are known for grains (guinea corn, millet, maize, groundnut, beans onions, cucumber etc.) production in the country and now seriously affected by desertification thereby bringing a decline in agricultural produce and causing food insecurity (Audu, *et al.*, 2013). Soils become more loosed and less fertile when encroached by desertification. This threatens farming and affects food production.

Table 4: Trend pattern of climatic variables over the Sokoto-Rima River basin

Climatic station	Time series	Mann-Kendal	Significance level	Spearman's Rho	Significance level	Linear Regression	Significance level
	1943-2012	z-test		z-test		t-test	
SW	Rainfall (mm)	-2.12	α<0.05	-2.19	α<0.05	-2.18	α<0.05
	Temp (^{0}C)	5.14	α<0.01	4.85	α<0.01	6.15	α<0.01
	PET(mm)	5.46	α<0.01	5.18	α<0.01	6.67	α<0.01
NW	Rainfall (mm)	-1.98	α<0.05	-1.954	α<0.10	-2.03	α<0.05
	Temp (^{0}C)	4.94	α<0.01	4.65	α<0.01	5.71	α<0.01
	PET(mm)	5.56	α<0.01	5.16	α<0.01	6.55	α<0.01
NE	Rainfall (mm)	-3.01	α<0.01	-3.086	α<0.01	-3.56	α<0.01
	Temp (^{0}C)	5.74	α<0.05	5.31	α<0.05	6.68	α<0.05
	PET(mm)	5.98	α<0.01	5.64	α<0.01	7.59	α<0.01
SE	Rainfall (mm)	-1.78	α<0.10	-1.81	α<0.10	-2.08	α<0.05
	Temp (^{0}C)	4.89	α<0.01	4.67	α<0.01	5.83	α<0.01
	PET(mm)	5.52	α<0.01	5.18	α<0.01	6.61	α<0.01

3.8. Monthly supplementary irrigation needs of selected crops in the Southwestern part of the basin

Supplementary irrigation needs of selected crops in the southwestern part of the basin are presented in Tables 5a-5d. Monthly supplementary irrigation needs of maize (grain) was 100.6 mm in May, 52.9 mm in June, -8.4 mm in July, -59.8 mm in August and -1.6 mm in September. The negative value of supplementary irrigation need in July, August and September show rainfall is at the peak and maize does not require supplementary irrigation. Similarly, supplementary irrigation is not required for the months of April and October as April rainfall is not considered to be effective enough to commence farming. Thus the month of April a full irrigation may be required. In October which marks the cessation of rainfall in the basin, full irrigation is required. Supplementary irrigation needs for groundnut for the months of May, June, July, August and September were 97.1 mm, 49.9 mm, -11.1 mm, -62.1 mm and -3.9 mm respectively. Tomato, cabbage and carrot require supplementary irrigation needs of 105.9 mm, 57.4 mm, -4.3 mm, -56.1 mm and 1.9 mm for the months of May, June, July, August and September respectively. Monthly supplementary irrigation requirement in onion (dry) cultivation were estimated as 100.6 mm in May, 52.9 mm in June, -8.4 mm in July, -59.8 mm in August and -1.6 mm in September. Values of supplementary irrigation for selected crops were generally lower in this part of the basin than requirement for maize in North West as well as decrease with increasing rainfall amount.

Table 5a: Monthly supplementary irrigation water need for maize (grain) in mm, southwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	94.1	106.8	154.1	177.4	174.5	148.6	135.0	121.4	116.4	125.1	107.0	95.1
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	71.5	81.2	117.1	134.9	132.6	112.9	102.6	92.3	88.4	95.1	81.3	72.3
P_e, mm	0	0	0	2	32	60	111	152	90	8	0	0
IR, mm					100.6	52.9	-8.4	-59.8	-1.6			

Source: Author's computation, (2017)

Table 5b: Monthly supplementary irrigation water need for groundnut in mm, southwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	94.1	106.8	154.1	177.4	174.5	148.6	135.0	121.4	116.4	125.1	107.0	95.1
K_c	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
ET_{crop}	69.6	79.1	114.0	131.3	129.1	109.9	99.9	89.8	86.1	92.6	79.2	70.4
P_e, mm	0	0	0	2	32	60	111	152	90	8	0	0
IR, mm					97.1	49.9	-11.1	-62.2	-3.9			

Source: Author's computation, (2017)

Table 5c: Monthly supplementary irrigation water need for tomato/cabbage/carrot in mm, southwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	94.1	106.8	154.1	177.4	174.5	148.6	135.0	121.4	116.4	125.1	107.0	95.1
K_c	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
ET_{crop}	74.3	84.4	121.7	140.2	137.9	117.4	106.7	95.9	91.9	98.8	84.5	75.2
P_e, mm	0	0	0	2	32	60	111	152	90	8	0	0
IR, mm					105.9	57.4	-4.3	-56.1	1.9			

Source: Author's computation, (2017)

Table 5d: Monthly supplementary irrigation water need for onion (dry) in mm, southwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	94.1	106.8	154.1	177.4	174.5	148.6	135.0	121.4	116.4	125.1	107.0	95.1
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	71.5	81.2	117.1	134.9	132.6	112.9	102.6	92.2	88.4	95.1	81.3	72.3
P_e, mm	0	0	0	2	32	60	111	152	90	8	0	0
IR, mm					100.6	52.9	-8.4	-59.8	-1.6	87.1		

Source: Author's computation, (2017)

3.9. Monthly supplementary irrigation needs of selected crops in the Northwestern part of the basin

Tables 6a-6d show the supplementary irrigation needs of selected crops in the Northwestern part of the basin area. Monthly supplementary irrigation needs of maize (grain) was 127.7 mm in May, 74.4 mm in June, 11.7 mm in July, -32.3 mm in August and 32.02 mm in September. Values of supplementary irrigation were observed to decrease with increasing rainfall amount. Highest supplementary irrigation requirement was found in May. This very high value may be attributed to general high temperature value which characterize onset of rainfall in the study area. Supplementary irrigation needs for groundnut cultivation for the months of May, June, July, August and September were 123.9 mm, 71.1 mm, 8.9 mm, -34.8 mm and 29.6 mm respectively. Tomato, cabbage and carrot require supplementary irrigation needs of 133.3 mm, 79.3 mm, 15.9 mm, -28.6 mm and 35.7 mm for the months of May, June, July, August and September respectively. Monthly supplementary irrigation requirement in onion (dry) cultivation were estimated as 127.7 mm in May, 74.4mm in June, 11.7 mm in July, -32.3 mm in August and 32.0 mm in September.

Table 6a: Monthly supplementary irrigation water need for maize (grain) in mm, northwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	88.2	101.4	148.1	178.7	186.4	159.7	140.4	124.6	121.1	130.1	106.3	90.4
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	66.9	77.04	112.5	135.8	141.7	121.5	106.7	94.6	92.0	98.8	80.8	68.7
P_e, mm	0	0	0	0	14	47	95	127	60	2	0	0
IR, mm					127.7	74.4	11.7	-32.3	32.02			

Source: Author's computation, (2017)

Table 6b: Monthly supplementary irrigation water need for groundnut in mm, northwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	88.2	101.4	148.1	178.7	186.4	159.7	140.4	124.6	121.1	130.1	106.3	90.4
K_c	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
ET_{crop}	65.2	75.0	109.5	132.2	137.9	118.1	103.9	92.2	89.6	96.3	78.7	66.9
P_e, mm	0	0	0	0	14	47	95	127	60	2	0	0
IR, mm					123.9	71.1	8.9	-34.8	29.6			

Source: Author's computation, (2017)

Table 6c: Monthly supplementary irrigation water need for tomato/cabbage/carrot in mm, Northwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	88.2	101.4	148.1	178.7	186.4	159.7	140.4	124.6	121.1	130.1	106.3	90.4
K_c	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
ET_{crop}	69.6	80.1	116.9	141.2	147.3	126.1	110.9	98.40	95.65	102.7	84.01	71.4
P_e, mm	0	0	0	0	14	47	95	127	60	2	0	0
IR, mm					133.3	79.1	15.9	-28.6	35.7			

Source: Author's computation, (2017)

Table 6d: Monthly supplementary irrigation water need for onion (dry) in mm, northwest, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	88.2	101.4	148.1	178.7	186.4	159.7	140.4	124.6	121.1	130.1	106.3	90.4
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	66.9	77.04	112.6	135.8	141.7	121.4	106.7	94.6	92.0	98.8	80.8	68.7
P_e, mm	0	0	0	0	14	47	95	127	60	2	0	0
IR, mm					127.7	74.4	11.7	-32.3	32.0			

Source: Author's computation, (2017)

3.10. Supplementary irrigation needs of Selected Crops in Northeastern part of the basin

Supplementary irrigation needs of selected crops in Northeastern part of the basin area are presented in Tables 7a-7d. Monthly supplementary irrigation needs of maize (grain) was 125.2 mm in May, 125.2 mm in June, 7.5 mm in July, -37.9 mm in August and 34.6 mm in September. The negative value of supplementary irrigation need in August shows rainfall is at peak and maize does not require supplementary irrigation. These values are generally higher than water needs of maize in southwestern part of the basin. Supplementary irrigation needs for groundnut cultivation for the months of May, June, July, August and September were 121.7 mm, 72.4 mm, 4.8 mm, -40.4 mm and 32.2 mm respectively. These values are generally higher in this part of the basin compared to the requirement for groundnut in southwest. Tomato, cabbage and carrot require supplementary irrigation needs of 130.6 mm, 80.2 mm, 11.6 mm, -34.3 mm and 38.1 mm for the months of May, June, July, August and September respectively. Monthly supplementary irrigation requirement in onion (dry) cultivation were estimated as 125.2 mm in May, 75.5 mm in June, -7.5 mm in July, -37.9 mm in August and 34.6 mm in September. These values are generally higher when compared to water requirement for onion in southwest and north-western parts of the basin.

Table 7a: Monthly supplementary irrigation water need for maize (grain) in mm, northeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	81.4	92.5	136.9	168.5	177.9	154.7	134.9	121.1	117.9	123.1	99.3	83.2
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	61.9	70.3	104.1	128.0	135.2	117.5	102.5	92.0	89.6	93.5	75.5	63.2
P_e, mm	0	0	0	0	10	42	95	130	55	2	0	0
IR, mm					125.2	75.5	7.5	-37.9	34.6			

Source: Author's computation, (2017)

Table 7b: Monthly supplementary irrigation water need for groundnut in mm, northeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	81.4	92.5	136.9	168.5	177.9	154.7	134.9	121.1	117.9	123.1	99.3	83.2
K_c	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
ET_{crop}	60.2	68.5	101.4	124.7	131.7	114.4	99.8	89.6	87.2	91.1	73.5	61.6
P_e, mm	0	0	0	0	10	42	95	130	55	2	0	0
IR, mm					121.7	72.4	4.8	-40.4	32.2			

Source: Author's computation, (2017)

Table 7c: Monthly supplementary irrigation water need for tomato/cabbage/carrot in mm, northeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$ET_{o,}$ mm	81.4	92.5	136.9	168.5	177.9	154.7	134.9	121.1	117.0	123.1	99.3	83.2
K_c	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
ET_{crop}	64.3	73.1	108.2	133.1	140.6	122.2	106.6	95.7	93.1	97.2	78.5	65.7
$P_{e,}$ mm	0	0	0	0	10	42	95	130	55	2	0	0
IR, mm					130.6	80.2	11.6	-34.3	38.1			

Source: Author's computation, (2017)

Table 7d: Monthly supplementary irrigation water need for onion (dry) in mm, northeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$ET_{o,}$ mm	81.4	92.5	136.98	168.5	177.9	154.7	134.9	121.1	117.9	123.1	99.3	83.2
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	61.8	70.3	104.1	128.0	135.2	117.5	102.5	92.0	89.6	93.5	75.5	63.2
$P_{e,}$ mm	0	0	0	0	10	42	95	130	55	2	0	0
IR, mm					125.2	75.5	7.5	-37.9	34.6			

Source: Author's computation, (2017)

3.11. Supplementary irrigation needs of selected crops in Southeastern part of the basin

Supplementary irrigation needs of selected crops in south-eastern part of the basin are presented in Tables 8a-8d. Monthly supplementary irrigation needs of maize (grain) was 81.0 mm in May, 33.7 mm in June, -39.5 mm in July, -99.6 mm in August, -26.0 in September and 72.6 mm in October. These values are generally lower than water needs of maize in other parts of the basin. Supplementary irrigation needs for groundnut cultivation for the months of May, June, July, August, September October were 77.9 mm, 31.1 mm, -41.8 mm, -101.8 mm, -28.1 mm and 32.2 mm respectively. These values are lower in this part of the basin compared with water requirements for groundnut in the northwest, southwest and northeast parts of the basin. Tomato, cabbage and carrot require supplementary irrigation needs of 85.6 mm, 37.6 mm, -35.9 mm, -96.4 mm, -22.9 mm and 75.9 mm for the months of May, June, July, August, September and October respectively. Monthly supplementary irrigation requirement in onion (dry) cultivation were estimated as 81.0 mm in May, 33.7 mm in June, -39.4 mm in July, -99.6 mm in August, -26.0 mm in September and 72.6 mm in October.

Table 8a: Monthly supplementary irrigation water need for maize (grain) in mm, southeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$ET_{o,}$ mm	82.7	92.2	131.6	151.4	151.3	129.9	117.8	108.4	103.9	108.7	92.8	82.5
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	62.8	70.1	100.0	115.1	115.0	98.7	89.6	82.4	78.9	82.6	70.6	62.7
$P_{e,}$ mm	0	0	0	3	34	65	129	182	105	10	0	0
IR, mm					81.0	33.7	-39.5	-99.6	-26.0	72.6		

Source: Author's computation, (2017)

Table 8b: Monthly supplementary irrigation water need for groundnut in mm, southeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$ET_{o,}$ mm	82.7	92.2	131.6	151.4	151.3	129.9	117.8	108.4	103.9	108.7	92.8	82.5
K_c	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
ET_{crop}	61.2	68.2	97.4	112.1	111.9	96.1	87.2	80.2	76.9	80.4	68.7	61.0
$P_{e,}$ mm	0	0	0	3	34	65	129	182	105	10	0	0
IR, mm					77.9	31.1	-41.8	-101.8	-28.1	70.4		

Source: Author's computation, (2017)

Table 8c: Monthly supplementary irrigation water need for tomato/cabbage/carrot in mm, southeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	82.7	92.2	131.6	151.4	151.3	129.9	117.8	108.4	103.9	108.7	92.8	82.5
K_c	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
ET_{crop}	65.3	72.9	103.9	119.6	6	102.6	93.1	85.6	82.1	85.9	73.39	65.19
P_e, mm	0	0	0	3	34	65	129	182	105	10	0	0
IR_{mm}					85.6	37.6	-35.9	-96.4	-22.9	75.9		

Source: Author's computation, (2017)

Table 8d: Monthly supplementary irrigation water need for onion (dry) in mm, southeast, Sokoto-Rima river basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET_o, mm	82.7	92.2	131.6	151.4	151.3	129.9	117.8	108.4	103.9	108.7	92.8	82.5
K_c	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
ET_{crop}	62.8	70.1	100.0	115.1	115.0	98.7	89.6	82.4	78.9	82.6	70.5	62.7
P_e, mm	0	0	0	3	34	65	129	182	105	10	0	0
IR, mm					81.0	33.7	-39.4	-99.6	-26.0	72.6		

Source: Author's computation, (2017)

4.0 Conclusion

The first three decades 1940, 1950 and 1960 were the wet decades in the Sokoto-Rima River Basin. This rising trend was interrupted by a break in 1970. There was a continuous downward trend in annual rainfall distribution from 1970 with a sign of weak rising trend around 2000. Temperature on the other hand showed evident of rising trends for all the sections of the basin from 1970 into 2010. Between 1940-1960 mean temperatures clustered below mean line. These correspond to periods of drought in the arid and semi-arid Nigeria. For example using the Standard Precipitation Index (SPI), Abubakar and Yamuda (2013) showed that drought occurrence was first noticed in this zone in 1968 with a Standardized Precipitation Index value of (–0.34), indicative of a mild drought. These negative SPI values of drought episodes continued up to 1973, with the exception of 1970. From 1981-1997, the zone again witnessed the longest drought episodes, which lasted for nearly a decade and half. This period was characterized by absolute dryness except. However, there were moments of respite in the later years (1996-2004) during which drought episodes were fast recovering from dryness to wetness. Cause of drought in this zone during the 1970s, 1980s and 1990s has been linked to the prevalence of a stagnated anti-cyclonic circulation of the tropical atmosphere over areas that normally should be exposed to the rising arm of the tropical Hadley Cell circulation by mid-summer (Kalu, 1987; Adefolalu, 1986; Kamara, 1986). These conditions are themselves related to the tropical component of the global general circulation system. This study present evidence of changing climate and variability and since the basin houses big irrigation projects and dams such as the Goronyo Irrigation and the Bakolori Dam and Bakolori Irrigation Project, north of the basin, we must be concerned regarding the impact of this observation on the water availability within the basin for ongoing irrigation and other water resources projects as a result of rapid moisture loss by evaporation and evapotranspiration. Results of supplementary irrigation showed that water of different quantity is required in the months of onset and cessation of rains. This has a lot of implications for early crop plantation. A temporal water deficit is fatal to crop development especially during the vegetative and flowering stages of the crops. Finding from the study also showed that an all-year- round planting can be carried out adopting the supplementary irrigation schedule provided in the study.

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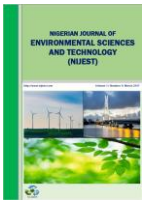

Elephant Grass (*Pennisetum Purpureum*) Mediated Phytoremediation of Crude Oil-Contaminated Soil

Bobor L. O.[1,*] and Omosefe B. E.[1]

[1]Department of Civil Engineering, University of Benin, Benin City, Edo State, Nigeria

Corresponding Author: *lulu.akhigbe@uniben.edu

ABSTRACT

Phytoremediation is an economic and environmentally friendly method for the remediation of hazardous crude oil contaminated soils. In this study, phytoremediation of crude oil contaminated soils by elephant grass (pennisetum purpureum) was investigated over a 40-day period. Grass clumps were harvested and transplanted into plastic buckets filled with 1kg of soil contaminated with 30 ml and 40 ml of crude oil and an uncontaminated control sample. An additional control sample was contaminated with 30 ml of crude oil with no elephant grass. The samples were analyzed periodically for changes in pH, total hydrocarbon content, total viable bacterial count, and total fungal count. The pH of the soil samples generally ranged from 5.26 to 7.85. After 40 days of treatment, the total hydrocarbon content decreased from 320 mg/kg to 38 mg/kg and from 590 mg/kg to 46 mg/kg in samples contaminated with 30 ml and 40 ml of crude oil respectively. Plant growth was uninhibited in contaminated and control samples as the heights increased by 34.5-42.8 cm. The results of the study further demonstrate the phytoremediation capabilities and tolerance of elephant grass in crude-oil contaminated microcosms.

Keywords: Phytoremediation, Elephant grass, Crude oil, Hydrocarbon, Contaminated soil

1.0. Introduction

In oil-producing developing countries, environmental degradation is a major problem due to accidental crude oil spillages resulting in the pollution of vast amounts of agricultural land and aquatic systems (Ugochukwu and Ertel, 2008). Adverse effects of crude oil contamination include, loss of fertile soils, air and water pollution, destruction of ecosystems, plant and animal poisoning and the potential ingestion and subsequent risk to human health (Abii and Nwosu, 2009; McGuinness and Dowling, 2009). Due to their chemical structure, organic compounds such as petroleum hydrocarbons are resistant to natural breakdown processes and persist for years when released into the environment (McGuinness and Dowling, 2009). Crude oil spillages on land may be due to land disposal of wastes from refineries, leaking oil storage facilities, accidental or criminal damage of pipelines, corrosion of old pipelines and oil tanker accidents (Fine *et al*., 1997; Abii and Nwosu, 2009; Izinyon and Seghosime, 2013). The presence of crude oil in soil pore spaces causes depletion of oxygen reserves and hinders soil-atmosphere gas exchange (Ayotamuno *et al*., 2006). Volatilization of light hydrocarbon fractions from contaminated soils releases substantial amounts of potentially carcinogenic compounds which are detrimental to human health. Petroleum hydrocarbon contamination has also been reported to affect plants by retarding seed germination and reducing shoot height, stem density, photosynthetic rate and biomass yield (Lin and Mendelssohn, 1996; Fine *et al*., 1997).

Conventionally, physicochemical treatment methods such as thermal desorption, incineration, solvent extraction, landfilling, etc. have being employed in the remediation of hydrocarbon-contaminated soils (Jain *et al*., 2011). However, the high costs and negative environmental impacts of these methods have resulted in heightened interest in exploring the potentials of phytoremediation as a relatively less expensive alternative (Frick *et al*., 1999; Nedunuri *et al*., 2000). Phytoremediation involves the use of

plants and their associated microbes in the extraction, sequestration and degradation of contaminants in aqueous and solid phases. Studies have shown that certain plants have the ability to clean-up several pollutants including metals, pesticides and hydrocarbons (Frick *et al*., 1999; Nedunuri *et al*., 2000; Merkl *et al*., 2005). This remediation method is environmentally friendly, and the soil structure is preserved. It is particularly suited to tropical climates due to the inherent favorable conditions for microbial growth and activity, nutrient availability and biomass production (Merkl *et al*., 2005). Several plants including *tithonian diversifolia*, cyperus rotundus, *phyllantus amarus*, *centrosena pubescen*, *ipomoea batatas*, *pennisetum pupureum*, etc. have been investigated for the remediation of soils contaminated with various petroleum hydrocarbon fractions with findings published in the literature (Ayotamuno *et al*., 2006; Ogbo *et al*., 2009; Nwaichi and Onyeike, 2011; Izinyon and Seghosime, 2013; Udo-Inyang *et al*., 2013; Efe and Elenwo, 2014; Omovbude and Udensi, 2016).
In this study, phytoremediation of crude oil- contaminated soil using locally abundant elephant grass (pennisetum purpureum) was investigated. The specific objectives were to evaluate the phytoremediation capabilities of the plant within the study period and examine the impact on plant growth.

2.0. Materials and Methods

2.1. Collection and preparation of soil samples

Soil samples and elephant grass used in this study was obtained from a farmland close to the University of Benin, Nigeria. Bonny light crude oil was collected from a company in Port Harcourt, Nigeria. The pH, moisture content, total hydrocarbon content (THC) was determined according to procedures described in Adesodun and Mbagwu, 2008 and Akpe *et al*., 2015. The pH of the soil was determined using a pH meter immersed in soil-water slurry consisting of air-dried and sieved soil mixed at 1 g/ml and left to equilibrate for 30 minutes. The moisture content of the soil was determined using the gravimetric method. The soil sample was oven-dried at 105°C and the moisture content was calculated as a percentage of the oven-dried weight. THC was determined by hexane extraction. 5g of soil was mixed with 23 ml of hexane for 20 minutes and filtered. The absorbance of dilutions of the sample was measured using a spectrophotometer and the concentration of THC was determined based on standard curves for petroleum fractions. The total viable bacterial count and total fungal count were estimated using the standard spread plate technique (APHA, 1992). Serial dilutions of a soil suspension (1 g soil/10 ml distilled water) were spread on the surface of nutrient agar and incubated at 35˚C for 5 days for bacterial isolation and potato dextrose agar incubated at ambient temperature for 7 days for fungal isolation.

2.2. Experimental Set-up

Phytoremediation studies were conducted over a 40-day period in four plastic buckets filled with 1 kg of soil (Figure 1). Two buckets were contaminated with 30ml and 40ml of crude oil respectively and treated with elephant grass. Two buckets served as controls (one bucket was contaminated with 30ml of crude oil with no elephant grass, while the second bucket contained uncontaminated soil with elephant grass). The samples are described in Table 1.

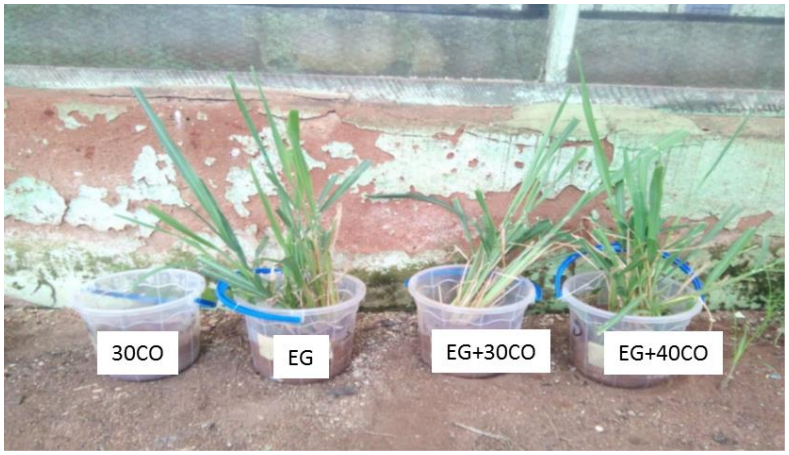

Figure 1: Experimental set-up showing contaminated samples and controls

Table 1: Description of experimental samples

Sample	Description
EG+30CO	Elephant grass planted in soil contaminated with 30 ml of crude oil
EG+40CO	Elephant grass planted in soil contaminated with 40 ml crude oil
30CO	Control (Unplanted soil contaminated with 30 ml crude oil)
EG	Control (Elephant grass planted in uncontaminated soil)

The plants were watered daily and soil samples were collected at 10-day intervals for 40 days. The samples were analyzed for changes in pH, total hydrocarbon content, total viable bacterial count and total fungal count. Plant growth was assessed at 5-day intervals by direct measurement using a meter rule.

3.0. Results and Discussion

3.1. Crude oil removal performance

The analysis of a representative soil sample prior to contamination and treatment revealed that the soil moisture content was 15.4%, pH was 6.80, total hydrocarbon content was < 0.001 mg/kg, total viable bacterial count was 188cfu/g and the total fungal count was 212 cfu/g.

The residual THC concentrations in the contaminated samples and control were determined as shown in Figure 2 and Table 2. It can be observed that the total hydrocarbon content decreased from 320 to 38 mg/kg in EG+30CO, 590 to 46 mg/kg in EG+40CO and 360 to 142 mg/kg in the contaminated control sample (30CO) after 40 days of treatment. The reduction in THC in the soils undergoing treatment is in agreement with the findings from similar studies (Ayotamuno *et al*., 2006; Udo-Inyang *et al*., 2013).

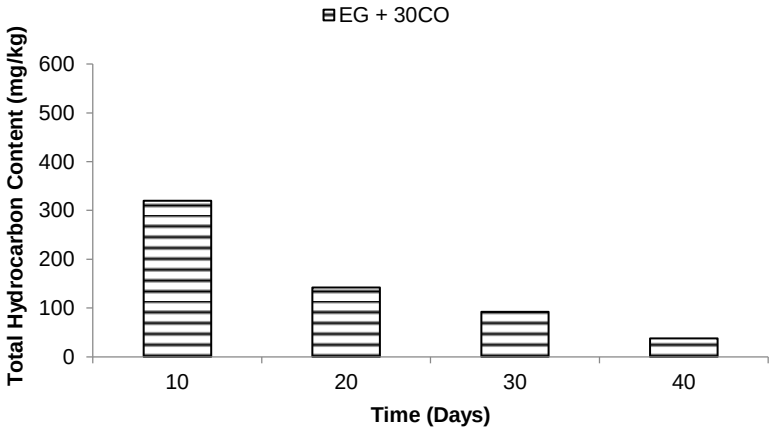

Figure 2a: Reduction in total hydrocarbon content (sample contaminated with 30 ml of crude oil)

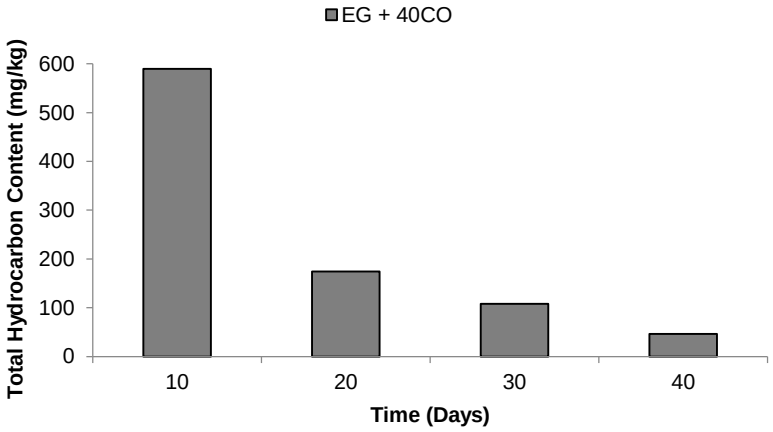

Figure 2b: Reduction in total hydrocarbon content (sample contaminated with 40 ml of crude oil)

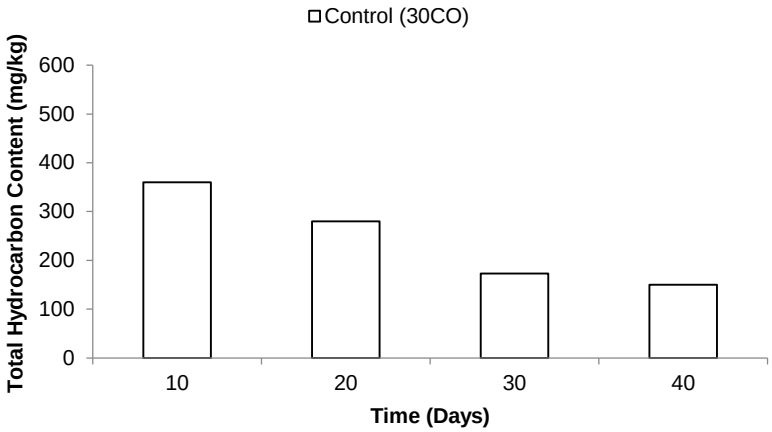

Figure 2c: Reduction in total hydrocarbon content (sample contaminated with 30ml of crude oil)

Phytoremediation of petroleum hydrocarbons may be due to the combined mechanisms of phytodegradation of complex organic molecules taken up by the plant, rhizodegradation involving plant associated bacteria and fungi in the root zone (rhizosphere) and phytovolatilization of the volatile organic fractions (Etim, 2012; Omovbude and Udensi, 2016). The reduction in THC in 30CO can be attributed to biodegradation by some microbial species present in the soil as reported in other studies (Van Hamme *et al*., 2003; Akpe *et al*., 2015). The soil pH ranged from 5.26 to 7.85, with a general decrease observed after 40 days of treatment (Table 2). This suggests the possible presence of sulfur forming minerals which produce acidic conditions on exposure to air or an inherent low buffering capacity (USDA, 1998). The observed increase in microbial counts, particularly in the remediated soil samples indicate the importance of microbial activity and rhizodegradation occurring in the root zone.

Table 2: Characteristics of contaminated soil and control samples

	EG+30CO	EG+40CO	Control (30CO)	Control (EG)
Time (Days)	pH			
10	5.93	7.11	6.90	6.53
20	6.88	6.80	6.82	6.71
30	7.30	7.14	7.05	7.65
40	5.80	5.80	5.53	5.26
	Total Hydrocarbon Content (mg/kg)			
10	320	590	360	<0.001
20	142	174	280	<0.001
30	92	108	173	<0.001
40	38	46	142	<0.001
	Total Viable Bacterial Count (cfu/g)			
10	192	168	107	252
20	206	180	124	274
30	248	290	352	308
40	414	432	514	486
	Total Fungal Count (cfu/g)			
10	160	124	86	234
20	178	152	106	246
30	232	258	188	352
40	362	384	438	410

3.2. Impact of crude oil contamination on plant growth

The growth of plants in contaminated soils and controls was evaluated by direct measurements. The plants grew steadily, with no evidence of inhibition due to crude oil contamination (Figure 3). The average plant heights increased by 33.7 cm, 42.8 cm and 34.5 cm in EG+30CO, EG+40CO and EG respectively. This resilience suggests the ability of the plant to grow in contaminated environments and the appropriateness of the plant for phytoremediation applications (Wenzel *et al*., 1999; Izinyon and Seghosime, 2013).

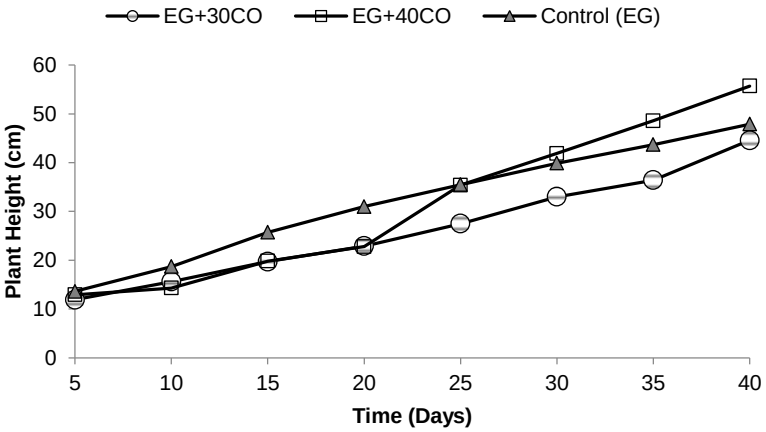

Figure 3: Impact of crude oil contamination on plant height

4.0 Conclusion

The phytoremediation capabilities of elephant grass planted in crude oil contaminated soil has been investigated. There was a gradual decrease in the total hydrocarbon content, with > 80% removal achieved within 40 days in 1 kg samples contaminated with 30 ml and 40 ml of crude oil. The pH, total viable bacterial count and total fungal count were monitored during the study. The observed increase in total viable bacterial counts and total fungal counts particularly in the treated soil samples may indicate that rhizodegradation involving associated bacteria and fungi in the root zone was a principal removal mechanism. The plants grew steadily with no evidence of inhibition due to crude oil contamination at the levels considered in this study, further confirming their suitability for environmental remediation applications.

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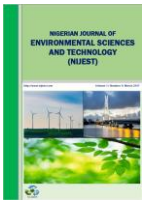

Effects of Seasonal Flooding in Benin City and the need for a Community-Based Adaptation Model in Disaster Management in Nigeria

Butu A. W.[1], Emeribe C. N.[2,*] and Ogbomida E. T.[2]

[1]Department of Geography, Faculty of Arts and Social Sciences, Nigerian Defence Academy, Kaduna, Nigeria

[2]National Centre for Energy and Environment, University of Benin, Benin City, Nigeria

Corresponding Author: *emeribe.c@ncee.org.ng

ABSTRACT

The present study aimed to investigate the effects of hydrologically induced environmental problem in Benin City and how communities (considered as non-state actors) can be sustainably integrated/participate in monitoring of environmental change, disaster preparedness, post disaster management mechanisms and influence water resources development/management decisions. The study focused on the seasonal flood events of years 2016 and 2017. The study showed that the impacts of flooding in Benin City ranges from submergence of physical infrastructures, loss of agricultural lands/ farms. Using the Focused Group Discussion and Interview methods, 61.9% of flood affected persons agreed that their houses were submerged, 80.5% indicated that their farms, including fish farms, piggery, snail farms, crops and poultry were damaged by floods, 9.6%, indicated having experienced food stock losses due to floods. Most common diseases/sicknesses experienced were diarrhoea (27%), malaria (37%); cough (20%), while sickness due to snake bite was the least (4%). Fe and fecal coli form count values were high during seasonal flood event. Most of the hydraulic regulation projects have failed mainly due to poor feasibility study, inadequacy of hydrological data, non-involvement of relevant stakeholder and the complete absence of community based groups during engineering construction works. The study proposed a State-Non-state actors Integrated Model, which will be registered as a Corporate organization to plan and monitor environmental changes relating to climate change, flood and gully erosion disasters and with the active involvement of NEMA, SEMA, LEMA and other related agencies and NGO. Depending on the size of each Local Government Area in Benin, the proposed committee will comprise of 25-50 members. The study recommends capacity building of members in the form of training and re-training in the areas of early warning, preparedness, adaptation, emergency plan, data collection method/analysis, writing of research grants proposals to fund the activities of the committee and monitoring for environmental changes.

Keywords: Non-state actors, Flooding, Gully erosion, Community participation, Disaster management

1.0. Introduction

The incidences of flood related disaster and gully erosion have increased in Nigeria especially since the 20th century due to industrialization, population expansion and rapid urbanization. In fact, with the exclusion of droughts mostly in the semi-arid part of the country, almost 70% of damages arising from natural disasters are caused directly or indirectly by floods (Urban and river floods) and gully erosion. The effects of river flooding in recent years are well documented. For example in 2010 flood killed about 1,555 people and displaced 258,000 people and destroyed properties worth millions of naira (Babatunde et *al.*, 2011; Adejuwon and Aina, 2014). The 2012 flood reports had far higher casualties than any other in the history of the country (NEMA, 2012). The Nigerian authorities contained the initial excess run-off through contingency measures, but by the end of September, water reservoirs were overflowing and authorities obliged to open dams to relive pressure in both Nigeria

and neighboring Cameroon and Niger Republic. By September ending, the floods had affected 134,371 people, displaced 64,473, injured 202 and killed 148. By the end of October, more than 7.7 million people had been affected by the floods, and more than 2.1 million were registered as Internally Displaced People (IDP). In all, about 363 people were reported dead and almost 600,000 houses were damaged or destroyed (NEMA, 2012). Out of Nigeria's 36 states, 32 were affected by the 2012 floods including Edo state where the present study is carried out. The significance of the year 2012 flood disasters in Nigeria lies in the fact that they were unprecedented and unlike past flood event since forty years. Most parts of the States of Nigeria along the rivers Niger and Benue were devastated by these floods, causing huge destruction to the rural and urban infrastructures (farmlands/crops, roads, buildings, drainages, bridges, power lines, etc.) and socio-economic lives of affected areas (Ojigi *et al.*, 2013; Ubachukwu and Emeribe, 2017). Flooding in Nigeria is compounded by the problems of improper solid waste management and unplanned housing. It should be noted that flood in itself is not a disaster, except for the nature of impact, the characteristics of the affected population and functionality of institutional framework to respond to flood hazard. For the purpose of this study, the term flood is taken to mean River, flash floods and flood poundage within an urban setting both of which are caused by excessive rainfall.

Gully erosion on the other hand is the single major process responsible for the loss of billion tonnes of soils worldwide (Matthew and Suleiman, 2012). Murck (1996) estimated the global rate of soil loss through erosion at over 25 billion tonnes per year for both rural and urban environment. In southern Nigeria, gully erosion is responsible for the widespread degradation of arable land, destruction of homes, transportation and communication systems, contamination of water supply, isolation of settlements, migration of communities, etc. In Edo state, Jeje (2005) estimated that 531,417.6 and 329,436.5 tonnes of sediment were removed from gullies in Auchi and Ikpoba slope, Benin City respectively. Apparently, soil erosion has been recognized not only within the rural but also in urban environment (Hughes, 2001; Wall *et al.*, 2003, 2005; Ibitoye, 2006). The effects of gully erosion in Nigeria have been articulated by authors ranging from loss of soil fertility, low crop yields, loss of farm lands, loss of scared sites, damages to infrastructures such as residential buildings, schools, hospitals roads (Hassan and Momoh, 2006; Obiadi *et al.*, 2011; Nwilo *et al.*, 2011; Aliyu *et al*., 2017) all of which have implications on the socio-economic lives of affected populations. River flooding and gully erosion are climate related and since climate change cannot be stopped, a lot can be done in the area of adaptation.

Nigeria government at national and state levels has made serious efforts at mitigating and management of river flood-related disaster and gully erosion in Nigeria through physical infrastructural interventions. Most recent is the World Bank Nigerian Erosion and Watershed Management Project (NEMAP), ratification of international agreements on disaster management, setting up of Internally Displaced Person's Camps (IDP). The Federal Government has also established the National Emergency Agency (NEMA) to respond to emergency cases in terms of provision of relief and mitigation to victims of disaster such as fire, flooding, storm, and accident, among others. NEMA is structured along: Search and Rescue, Policy and Strategy, Information, Education and Prevention, Administration, Finance and Logistics, Relief and Rehabilitation, Research and Planning.

At the state level there is the State Emergency Management Agency (SEMA) which coordinates Disaster Risk Reduction at the State. At local government level is the Local government Emergency (LEMA).Whereas, SEMA is established at all State levels, LEMA is non- existent in most areas (Ogboi, 2013). While the present NEMA operation structure (Top-Bottom approach) in administering disaster risk reduction policies and regulatory provisions has returned significant benefit to most vulnerable communities, studies have shown that there is more to achieve in terms of disaster risk reduction if complemented with local knowledge (e.g. Marfai *et al*., 2008; Anderson and Holcombe, 2013; Rowlands, 2013; Slotterback, 2013). As the moment the top-down approach of disaster management lacks an institutional framework for the involvements of community-based groups in the monitoring of environmental changes (both quantity and quality), pre and post disaster management (taking into accounts socio-economic and cultural factors income level, literacy level, cultural differences and local knowledge/perception of community populations). Although at community levels, NEMA established volunteer schemes from local communities examples are the Grassroots Emergency Volunteers Corps (GEVC) and Emergency Management Vanguard (EMV).

Unfortunately, the activities of these groups are short-lived and unsustainable as they only engage in advocacy, awareness campaigns during a disaster event as well as provide immediate response to emergency when they occur before the arrival of relevant agencies (Alaci *et al*., 2017).

Similarly, the present method of IDP camps to cater for the needs of flood affected victims is proven to be highly unsuitable, economic losses (Akujobi, 2013; Alaci *et al*., 2017), diversion of humanitarian aids and humanitarian crises (Essoh and Abutu, 2018), insecurity, cases of rapes, sexual harassment, forced marriage, infant marriage and outbreak of diseases at these camps (Akuto, 2017). To exacerbate the problem of the present disaster management structure in the country is the dearth of hydrological data for most rivers in Nigeria which is prerequisite for building predictive models. Even where these data exist, they are grossly inadequate or disjointed (Olayinka *et al.*, 2013; Iguniwari, 2018), the implication of which is unsustainable water resources management decisions as well as poor development of models for understanding hydrological response relationship. In the light of the above, it has become very urgent that a study be conducted to evaluate how communities (considered as non-state actors) can be sustainably integrated/participate in monitoring of environmental change, disaster preparedness, post disaster management mechanisms and influence water resources development/management decisions. This underpins the aim of the present study.

2.0. Materials and Methods

2.1. Study area

Benin City is located on Latitude 06°19' E to 6°21' E and Longitude 5°34' E to 5°44' E with an average elevation of 77.8 m above sea level. Benin City is a pre-colonial city, the capital of defunct Mid-Western Region, Bendel State and the present day Edo State. The City consists mainly of three local government areas Oredo, Egor and Ikpoba Okha Local Government Areas; it also consists partly of Ovia Northeast and Uhunmwonde Local Government Areas (Figure 1). The land area of the three main local government areas is as follows: Oredo, 249 km^2; Egor, 93 km^2 and Ikpoba Okha, 862 km^2. The total land area of all the three local government areas is 1,204 km^2. According to Google Earth, the total land area of the continuous urbanized Benin City in 2016 is 531sq km.

Socio-economic activities include commerce, agriculture (farming/fishing), industry, with the oil industrial sub-sector providing the major income for the economy. Available data shows that Edo State is the 25^{th} most populated state in Nigeria with a population of 3,218,332 (NPC, 2006). The 2006 census, which is the most recent, recorded the population of the three main local government areas (Oredo, Egor and Ikpoba Okha) which make up Benin City as 1,085,676 (NPC, 2006). For the purpose of this research, this population is projected from 2006 to be 1,433,620 in 2016.

Benin City occupies a lowland plain in the south and rises slowly to the Esan Plateau towards the north. This region is endowed with fertile soil. The city is underlain by sedimentary formation of the Miocene-pleistocene age often referred to as the Benin Formation. The Benin Formation comprise of mainly consolidated sand and sandy clays covering the whole of the Niger Delta. The topography is predominantly uniform, comprising of a gently undulating surface area rising from about 505m in the south-eastern parts to about 215m in the northern parts giving a mean elevation of about 83m above sea level.

The City is located in the humid tropical rain forest belt of Nigeria with a mean annual rainfall ranging from 2050 mm to 2161 mm. Temperature values in the area are usually on the high side throughout the year with a minimum annual temperature of 21.90 °C and a mean annual maximum temperature of 25.10 °C. The vegetation of the area is rain forest, however the original vegetation has been undergoing modifications due to urban expansions, mining and industrial activities. This influx of human activities in the region has impacted on the Benin City environment resulting in series of ecological problems such as flooding and erosion as is been experienced in the city year-in and year-out.

The study adopted both secondary and primary data sources. Secondary data include, archival review of literatures, including government gazette, online and offline articles, newspapers and periodicals.

Primary data were through the administration of structured questionnaires, Focused Group Discussion (FGD) and utilization of oral interviews in each sampled quarter to evaluate the impacts of flooding in Benin City. Target populations are household heads, religious leaders, youth leaders, market women, community heads.

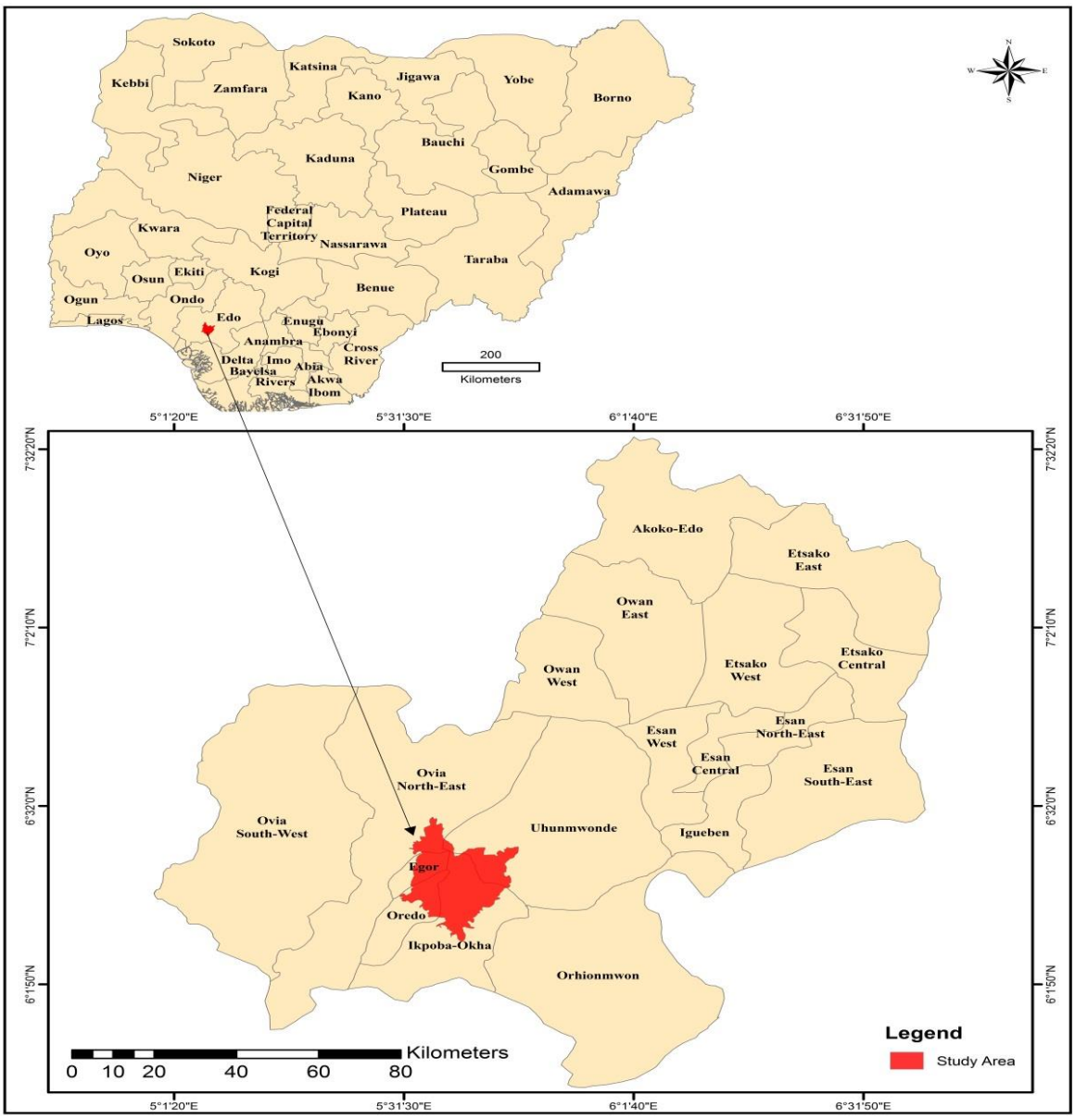

Figure 1: Benin City showing the study area
Source: Modified from Edo State Ministry of Lands and Survey (2014)

Interviews were conducted with stakeholders from the national and state disaster management agencies, water resources development offices of the Federal Water resources and non-governmental Organizations, NGOs. The questions covered existing pre and post disaster responses approaches at community level. Purposive sampling method was adopted in the study to generate information from householders on the impacts of flood disaster and gully erosion. Field surveys/research was used to verify and complement information gathered from literature review. The field surveys covered all relevant elements of the ecological, water sampling and socio-economic environment. Specifically, the following thematic socio-economic indicators were examined in the questionnaire:

- Gender
- Age Distribution
- Marital Status
- Level of Education
- Nature of trade/occupation of APs
- Impacts of flood/gully erosion

For the purpose of collecting data on the above thematic socio-economic indicators, the study area was divided into five (5) quarters. These five quarters were purposively chosen due the area's history of seasonal floods and impacts. A total of 500 questionnaires were randomly administered during the focused group discussion platforms, 100 questionnaires per sample location (Table 1). Since the study adopted Focused group discussion platform as primary method of data generation, all the questionnaire were answered as the FGD allowed for formal meetings with victims of seasonal floods.

Table 1: Questionnaire administered per quarter

Street Name	Number of Questionnaire	%	Valid %	Cumulative
Upper Mission/Lawani	100	20	20	20
Imuetinyan Avenue	100	20	20	40
Ekosodin/University of Benin quarters	100	20	20	60
Ogbeson quarter/ Ikpoba Hill	100	20	20	80
Osunde Road, East of Murtala Mohammed Way	100	20	20	100
Total	500	100	100	

2.2. Water quality analysis of Ikpoba River

Water quality of Ikpoba River was investigated to determine the impacts of seasonal floods on its water quality. Water samples were collected during the flood event. Parameters considered in the study include pH, DO (mg/l), TSS (mg/l), TDS (mg/l), Turbidity (NTU), Chloride (mg/l), Sulphate (mg/l), Nitrate (mg/l), Phosphate (mg/l), Sodium (mg/l), Fe (mg/l), Cu (mg/l), Mn (mg/l), Cd (mg/l), Pb (mg/l), Zn (mg/l), Cr (mg/l), Ni (mg/l). Samples were taken from several designated points of the river: upstream (control point) and 2 points downstream. The upstream sampling was done at Sakponba Road, while downstream points sampling was done at Ikpoba Hill axis. In each site, sampling was done at points or near points of abstraction i.e. where the community comes to draw water. This is consistent with a well-known criterion for selecting points for sampling (Hunt *et al.*, 1986). The polyethylene wide-mouth bottles with a firm cover were used for sampling water from streams. During sampling, the bottle was opened at the desired depth of sampling and when the sampler/bottle is full, it was covered firmly before bringing it out of the water. The composite sample was then transferred into two sample containers; 2 polyethylene bottle for physical and chemical analysis and a 100ml sterilised glass bottle for microbiological analysis in the laboratory. These bottles were pre-cleaned with a detergent and 1M hydrochloric acid, acetone, and hexane (pesticide grade) and rinsed with water three times, then filled with 500 ml of the sample water and capped. Two (2) ml of HCl was added to the water samples collected to prevent microbial activity. Sterilization of the bottle for microbiological was done by an electric oven or by boiling in the absent of electricity. Sampling was carried out between July-October, 2017 (within the period of flood event).

3.0. Results and Discussion

The impact of flooding in Benin City ranges from submergence of physical infrastructures, loss of agricultural lands/farms. Using the FGD method, on the average 61.9% of flood affected persons from the five quarters agreed that their houses were submerged during seasonal flooding, leading to property damages, 80.5% indicated that their farms (fish farms, crops, piggery and snail farms) were damaged by floods, 9.6% also indicated having experienced food stock losses due to floods. Most of the sampled quarters are characterized by traditional Courtyard House-Types (Impluvium Design); these include the palace and family compound house-types. Thus both modern water closet and pit latrine are the two major types of sanitary facility in these areas. The study shows that during previous seasonal flood events, 75.4% indicated that their sanitary facility was unaffected. This has a lot of implications for microbial quality of Ikpoba River which is the receiving River. Flood in the Benin City follows rainfall pattern, September and October is usually the peak of rainfall and this corresponds to flood peak. Usually, submerged houses and farmlands can last into October except when there are interventions. There are also reported cases of disruption of school activities arising from damages to class room blocks, offices, laboratories and even general absence of children from school due to fear of another flood event. Of all the interviewed respondents, an average of 77.1%

indicated having at least one member of their household getting sick during each flood event. From FGD, an average of 27% of the household were affected by diarrhea during flood events, Malaria (37%), Cough (20%), Measles (13%) and Snakebite (4%) (Table 2). The spread of these diseases may be attributed to increased contamination as a result of diffuse pollution during flooding events. Open dump solid waste disposal method is common in Benin City. The fact that cases of diarrhea and malaria were on the increase due to seasonal flood in Benin City, confirms a similar observation by UNICEF that cases of diarrhea, cholera and malaria increased during the 2012 floods in Nigeria (UNICEF, 2014). Similarly, UNICEF (2014) also found that floods cause environmental pollution through contamination of water; disrupt livelihoods and loss of social network with 21million people displaced. Plates 1-4, illustrate some of the effects of seasonal flood on physical infrastructures in Benin City.

Table 2: Diseases/Sicknesses experienced by household members during the floods in Benin City

Diseases experienced by household members during seasonal flood events	No. of response	Valid Percent
Diarrhoea	37	27
Malaria	50	37
Cough	27	20
Measles	18	13
Snake bite	5	4
Total	137	100

Plate 1: Flooding of teachers house area on Siluko Road, Benin City

Plate 2: Flooding of Textile Mill Road, Benin City

Plate 3: Flooding of Ugbowo/Oluku quarters, Benin City

Plate 4: Flooding of Ugbowo/Oluku quarters, Benin City

These wastes which are usually a commingle of organic and inorganic materials are washed down to the Ikpoba river, which is an important source of water for domestic uses and washing bathing as well as source of water supply to the urban water scheme.

Result of the water quality of Ikpoba River, Benin City is presented in Table 3. It should be noted that Ikpoba River is a receptor of most overland flows from Benin metropolis. It can be seen that turbidity, Fe and fecal coli form count values were high during flood event. This is expected due to the impacts of diffuse pollution from urban activities. The fact that other pollution indicators are within range may be attributed to the effect of dilution from rainfall.

The continuous flooding and resultant erosion in Benin City has ravaged the community around these gullies over the years causing its inhabitants to either vacate their damaged homes or permanently relocate away from the gully area. This in turn has created a state of social isolation for the communities located around the gully sites. The agricultural activity within this region has reduced drastically and farm produce are left to rot during the wet season as a result of inaccessibility to farm lands.

Table 3: Water quality of Ikpoba River, Benin City (data collected in July-October, 2017) during flood event

Parameter	Station			Mean	WHO MPL
	UPS1	DS1	DS2		
pH	6.7	6.33	6.3	6.44	6.5-8.5
DO (mg/l)	7.9	13	3.8	8.23	6.5
TSS (mg/l)	12.1	107	198.7	105.93	20
TDS (mg/l)	7.9	13	11.3	10.73	500
Turbidity (NTU)	10	19	18	15.67	5.0
Chloride (mg/l)	1	5	13	6.33	250
Sulphate (mg/l)	0	7	11	6	250
Nitrate (mg/l)	0.003	0.024	0.03	0.019	10
Phosphate (mg/l)	0.21	0.53	1.15	0.63	5.0
Sodium (mg/l)	0.47	1.41	0.82	0.9	200
Faecal coliform (cfu/100ml)	110	120	140	277	0
Heavy metals concentrations of Ikpoba River					
Fe (mg/l)	0.478	1.329	1.01	0.939	0.3
Cu (mg/l)	0.033	0.11	0.036	0.05967	2.0
Mn (mg/l)	0.023	0.044	0.034	0.03367	0.5
Cd (mg/l)	0.797	0.31	0.003	0.37	0.003
Pb (mg/l)	0.032	0.33	0.005	0.12233	0.01
Zn (mg/l)	0.026	0.02	0.005	0.017	3.0
Cr (mg/l)	0.139	0.02	0.01	0.05633	0.05
Ni (mg/l)	0.204	0.34	0.025	0.18967	10

The continuous flooding and resultant erosion in Benin City has ravaged the community around these gullies over the years causing its inhabitants to either vacate their damaged homes or permanently relocate away from the gully area. Generally, most gullies begin as a rill and the erosion progresses downwards by cutting near vertical walls in the partially cemented lateritic soils and/or formations which is typical of the case in Benin City. One rainy season is sufficient to initiate a severe gully and once initiated, the gullies are difficult to control or stop. When the gully reaches the unconsolidated, loose, sand formation (Coastal Plain Sands or Benin Formation), the erosion process accelerates by lateral undercutting resulting in massive slumping (mainly rotational and block slumping) (Plates 5-10).

Plate 5: Queen Ede erosion site, Benin City, 2km long with an average width of about 70m

Plate 6: St. Thomas of Aquinas Catholic Church is being threatened by Queen Ede erosion site, Benin City

Plate 7: Queen Ede Secondary School being threatened by Queen Ede erosion

Plate 8: One of the residential buildings in Ogbeson quarters being threatened by Queen Ede erosion

Plate 9: Road completely cut-off by erosion in Ogbeson quarter Benin City

Plate 10: Erosion off major road in Ekehuan, Benin City

The rate of gully growth in Benin City is governed mostly by the geotechnical properties of the soils and the energy of the surface run-off. Gully growth rates and initiation have increased in recent years because of increased population pressure and resultant vegetation cover denudation. This in turn has created a state of social isolation for the communities located around the gully site. The agricultural activity within the affected region has reduced drastically and farm produce are left to rot during the wet season as a result of inaccessibility to farm lands.

Table 4 shows that over 30.5% of the respondents loose about N40,000-N100,000 to the 2012 flooding while 20.3% 0f the respondents loose N130,000-N150,000 to flooding. Also, 10.2% of the respondents declined this item. Common farm activities in the study area include fish farms, poultry, piggery and crop farming. These activities are carried out on both subsistent and commercial levels.

Table 4: Questionnaire result of amount lost due to farm submergence

Amount lost due to farm submergence	No. of response	Valid Percent
Below N30,000	19	16.1
N40,000-N100,000	36	30.5
N100,000-N130,000	15	12.7
N130,000-N150,000	24	20.3
N150,000 and above	12	10.2
No response	12	10.2
Total	95	100.0

The gender distribution of the respondents in Benin City is presented in Table 5. On the average majority of the respondents are male (79%). This is expected in a patriarchal society where the head of the household is almost exclusively male. It can be seen that 92.6 per cent of the respondents said they were married (Table 5). This confirms the well-known fact that marriage is the preferred mode of adult life. We may also assume that on account of their maturity, the respondents fully understood our questions and the purpose of the survey and may have given valid answers. Benin City is inhabited by people with mixed occupational and economic backgrounds (Table 5). There are private and public servants, traders, small/subsistent farm holders, artisans and apprentices as well as housewives and

unemployed persons. Many of these operate in the informal sector of the economy, a sector reputed to be outside the tax circle of government. Against the above background, it goes without saying that the affected persons and the general population could be classified as relatively poor. Most of the affected households keep some domestic animals and birds and also grow different types of crops, cassava, plantains and bananas, pawpaw, sugarcane, and sundry vegetable, which have been affected by flood and gully erosion. All domestic animals and birds as well as the various crops are used to supplement household food as well as for commercial purposes. Therefore agricultural activity within flooded and/or gully erosion affected areas is certainly on both subsistent and commercial scales.

Table 5: Respondents sex, marital status and livelihood

	Sex		Marital status					Nature of livelihood in Benin City				
	Male	Female	Sing	Marr	Div	W/W	Sep	PPS	SF	ART	TRD	APP
Freq	395	105	25	463	4	7	1	122	101	97	118	62
%	79	21	5	92.6	8	1.4	0.2	24.4	20.2	19.4	23.6	12.4

Sing: Singles; Marr: Married; Div: Divorced; W/W: Widow and Widower; Sep: Separated; PPS: Public/Private servants; SF: Subsistent Farmers; ART: Artisians: TRD: Traders; APP: Apprentices

In Table 6, over 70 per cent of the respondents claimed to be over 35 years. This clearly shows that our respondents fall within very active and virile age categories, the implication of which is that they belong to very important segment of the population in terms of economic production. In addition this age group is ideal for participation in any water resources development scheme.

Table 6: Mean age of respondents

Age	No. of Respondents	Percent	Valid Percent	Cumulative Percent
17-25	32	6.4	6.4	6.4
26-35	73	14.6	14.6	21.0
36-45	201	40.2	40.2	61.2
46-55	78	15.6	15.6	76.8
56-65	54	10.8	10.8	87.6
66 & above	22	4.4	4.4	92.0
NA	40	8.0	8.0	100.0
Total	500	100.0	100.0	

Edo State is one of the most educational States in Nigeria. The high educational standing of our field respondents is therefore not unexpected. A majority of 58.2 per cent of the respondents claimed to have one tertiary educational qualification or the other, that is, NCE (National Certificate in Education) or above (Table 7).

Table 7: Highest educational qualification of respondents

Qualification	Distribution	Percent	Valid %	Cumulative %
B.Sc.>	92	18.4	18.4	18.4
NCE	199	39.8	39.8	58.2
TC2	37	7.4	7.4	65.6
SSCE	101	20.2	20.2	85.8
Others	71	14.2	14.2	100.0
Total	500	100.0	100.0	

Of the remainder, 14.2 per cent belong to the category of unclassified qualifications. This category is made up of respondents with some primary or high school education. Benin City has several higher educational institutions including the University of Benin, Benson Idahosa University and a few diploma awarding private institutions. High educational qualifications imply that respondents belong to the educational elite who are very conscious of the environment and may be easy to mobilize to engage in some form of action to ameliorate disasters such as flood and gully erosion in the area.

3.1. Existing water resources development programmes in Benin City

Generally some gullies are too severe to remedy, and will require huge engineering efforts (hydraulic regulation works); others can be tackled through a variety of best land management practices (agronomic) and low-cost approaches. The engineering measures includes the construction of

engineering structures such as catch pits and soak-away pit, interceptor open drains, canals and underground pipes, with the objectives of preventing runoff from reaching the gullies and enhancing slope stability. The agronomic method provides the soil with physical protection against scour and in slowing down the velocity of flow by increasing the hydraulic resistance of the channel (Lal, 1998). The cover crops help in shading the land and reducing the impact of rain drop (erosivity), the roots help to hold the soil together. The upper parts of trees intercept precipitation and thereby reduce the kinetic energy of the raindrops. When the velocity of flow is sufficiently reduced, some of the sediment load will be deposited and this can lead to the desirable rigorous vegetation, siltation of the gully and densification of the soil until the gully is refilled with soil (Hudson, 1971). The application of any of the two mentioned methods requires a good knowledge of hydrometeorology, surface hydrology land use, catchment topography. Table 8, illustrates the causes of gully erosion in Benin City.

Table 8: Cause of gully erosion in Benin (Modified from EDO-NEWMAP, 2014)

Cause of gully erosion
Roads without proper drainage or catchments pits
Unsound cultivations leading to flooding
Indiscriminate channeling of flood water on sloped terrain, especially in loose soil structure area ***
Intense rainfall (Benin city is in the Tropical Rainforest Zone)
Unregulated sand excavation
Poor drainage systems

*** The Benin formation comprise of mainly consolidated sand and sandy clays. The soils have low silt/clay content which decreases with depth. The soils are cohesionless, very permeable and have high infiltration rates, making control of gullies difficult after they have cut through the red soils at the surface. In addition, the rise in the water table due to heavy rain falls in the rainy season contributes to an increase in hydraulic head, high subterranean flow rate, and the enhancement of gully formation in the area (Nwankwoala and Ngah, 2014; Abam *et al.,* 2016).

Regrettably, most of the hydraulic regulation projects have failed mainly due to poor feasibility study; inadequacy of hydrological data and even when such data is available, they are dis-jointed; non-involvement of relevant stakeholder and the complete absence of community based groups during engineering construction works. For example Morgan (1986) showed that rainfall data collected for some Nigerian roads and observations on the performance of road culverts and roadside gutters during periods of heavy rainfall revealed major flaws in the design of highway drainage throughout in some parts of southern Nigeria (Morgan, 1986). As a result, gullies tend to form, where the concrete-lined drains and culverts are too small to accommodate peak surface runoff. Amangabara (2012) also showed that in most cases culverts are not terminated at base of- slope locations and are allowed to decay and become clogged with debris. The overflowing water erodes beneath the roadside gutter or culvert, which eventually falls away to provide a site of localized erosion. By the accumulation of larger quantities of water or by the gradual deepening, rills and erosion gullies of various sizes and forms come into being. Plates 11 and 12 illustrate some failed engineering interventions in the control of gully erosion in Benin City.

Meanwhile, public response to disasters including flooding in Nigeria commenced in 1976 with the creation of the National Emergency Relief Agency (NERA). It was renamed National Emergency Management Agency (NEMA) in 1999 to:

a. Formulate policy on all activities relating to disaster management in Nigeria and coordinate plans and programmes for efficient and effective response to disaster at the national level;
b. Coordinate and promote research activities relating to disaster management at National level;
c. Monitor the state of preparedness of all organizations or agencies which may contribute to disaster management in Nigeria;
d. Collate data from relevant agencies so as to enhance the forecasting, planning and field operation of disaster management;
e. Educate and inform the public on disaster prevention and control measures; and,
f. Coordinate and facilitate the provision of necessary resources for search and rescue and other types of disaster curtailment activities and distress call


Plate 11: Failed Engineering Intervention at Queen Ede Gully erosion site/West Moat catchment in Benin City


Plate 12: Failed Engineering Intervention at Ekehuan erosion site, in Benin City

NEMA is meant to be supported by its counterparts in each State of the Federation to manage ensuing disaster operations at respective local levels. Some NGOs are also visible in the country especially the Nigerian Red Cross Society (NRCS). In discharging its duties, NEMA adopts the disaster model of prepare, response, recover and mitigate (NEMA, 2011). By the Act establishing NEMA, all States in the Federation shall ensure the establishment of a body to be known as State Emergency Management Agency (SEMA) backed up by State Legislation. The legislation shall include provisions that will ensure that Local Governments in the State also establish authorities with similar functions. Community participation include to ensure commitment and preparedness of community members to disaster management; sensitize and build the capacity of communities that constitute disaster fronts in preparation for initial response to disaster threats; mobilize community resources and build community capacity and resilience to prepare for, respond to and mitigate the impact of disasters. Local Emergency Management Authority (LEMA) is to function with support from SEMA and NEMA (Figure 2).

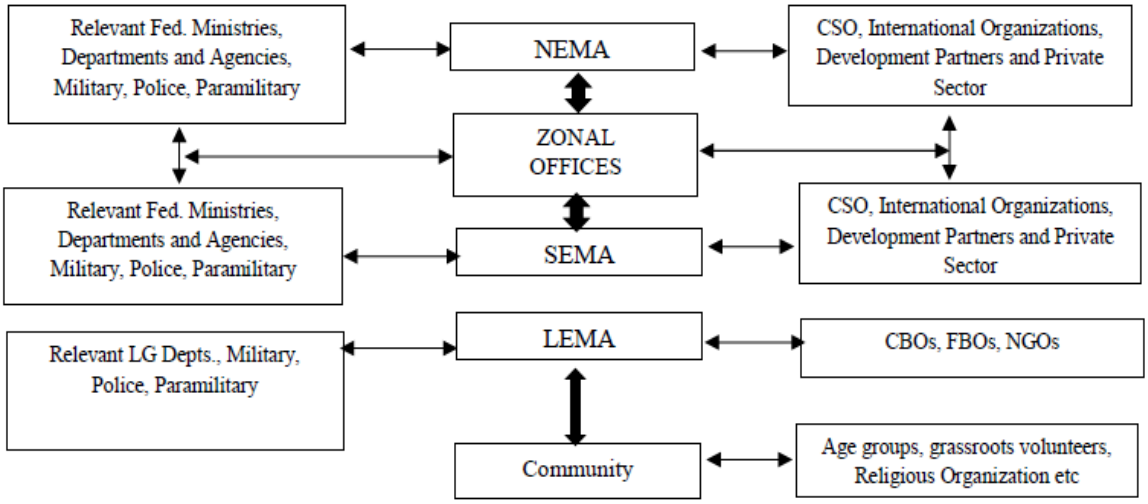

Figure 2: Horizontal and vertical coordination of disaster management in Nigeria
Source: NEMA (2011)

However, these efforts in respect of disaster management have been grossly inadequate. With respect to flood disaster, there is a complete absence of community participation in the national disaster response model in terms of preparation, recovery and mitigation phases. Instead the common practice is to involve community-based groups during response phase as vigilante groups, Faith-Based Organizations (FBOs), grass-root volunteers, i.e. that local based groups being considered as filling the 'gaps' in services not provided through formal government channels. According to NEMA, (2011); Olorunfemi and Adebimpe, (2008), NEMA's mandate has been hampered by inadequacies of strategy and resourcing; and other factors such as inadequate funding and equipment, weak executive capacity and lack of decentralization (Okoli, 2014). Another challenge to NEMA arises from the inability of the states and local Governments in Nigeria to buy into the national disaster management agenda.

The Federal Government had mandated the States to establish State Emergency Management Agencies (SEMAs). This is expected to be replicated at the Local Government level by creating Local Government Emergency Management Agencies (LEMAs). This directive has not been quite fruitful. While some States and Local Governments are yet to come up with their own SEMAs and LEMAs, those that have established theirs have not been making much significant impacts, which raise concerns concerning the strategic importance of such an endeavor (Adebimpe, 2011; Okoli, 2013). There is also the fear of non-state actors, taking the law into their own hands. This can be seen, first in the glaring disconnect between NEMA, SEMA, LEMA and community groups in the coordination of rescue and recovery operations and the fact that for the locals, there is no formal connections with NEMA and SEMA.

These limitations poses a serious challenge for disaster management in Nigeria and thus underlines the need to build local capacity for community population in terms of definition of structure and control framework (putting into consideration socio-economic), monitoring of changes, modes of reporting/documentation of management plans, funding mechanisms that include public and private sector participation. This is also in line with the standard set by the Hyogo Declaration (2005), which emphasizes on developing and strengthening institutions, mechanisms and capacities, particularly in communities, which can contribute systematically to improving resilience to hazards.

3.2. Proposed hydrologically induced disaster management State-Non-state actors integrated model

In this study we propose a model named Environmental Change Monitoring Committee (ECMC), which will be registered as a corporate organization to plan and monitor environmental changes relating to climate change, flood and gully erosion disasters and with the active involvement of NEMA, SEMA, LEMA and other related agencies and NGO, hence minimize the impacts of these hydrologically induced risks and disaster on the community (Figure 3).

Depending on the size of each Local Government Area, the proposed committee will comprise of 25-50 members which are to nominated by community based groups (religious bodies, youth groups and committees of village meetings) and according to the procedure set by the constitution guiding each nominating group. In nominating the representatives of the committee, efforts must be taken to ensure equitable representation from different sections of society, in particular women and vulnerable groups. Minimum qualification for nomination is senior secondary school certificate (SSCE) and the fact the nominee is a member of the community. Since LEMA is already established by Act, the proposed committee should have an office space in the local government headquarter.

The Chairmanship and Vice Chairmanship of the committee will be headed by official of State Emergency Management Agency (SEMA) and Local Emergency Management Agency (LEMA) respectively, who will nominate two (2) secretaries from the members. There will be different sub-committees with various responsibilities. Each sub-committee is to be led by a sub-committee chairperson. The chairperson of each sub-committee will report to the central committee chair who will in turn report to advisory council for detailed review and action. The activities of committee, financial and other operations must be guided by a constitution to promote accountability and transparency.

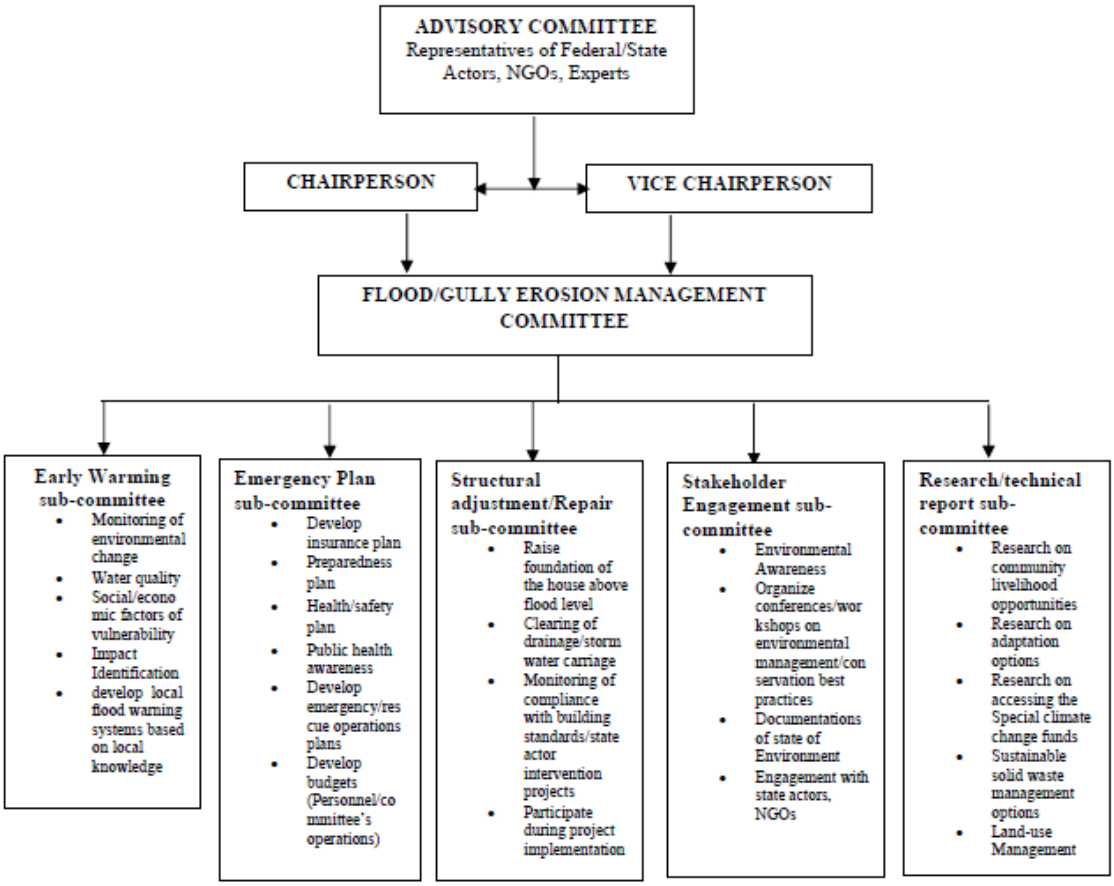

Figure 3: Structure and Responsibility of proposed *State-Non-state actors Integrated Model*
Source: Authors Field Work (2018)

The committee is to be overseen by advisory committee consisting of representatives of NEMA, SEMA, LEMA and other federal and state agencies such as representative of ministries of environment, education, planning and physical infrastructure, water resources, lands and survey, climate change prediction centres, school teachers, local health workers, women affairs, research institutions, civil society groups, doctors and Nigerian Society of Engineers. Selection of members of the advisory council will be the prerogative of a joint committee of Federal/State Government. The roles of the advisory council will include; supervisory, funding, conflict resolutions, provision of institutional frameworks, implementation of action plans and oversee elections into committee executive positions. This advisory council will be headed by a representative of NEMA who will nominate a Vice and secretary from SEMA and Ministry of Environment. A comparison of all the FGDs data suggested the following factors of participation as follows (Table 8).

3.3. Funding the Committee

The committee's activities (vehicle, mobility, research, data collection, documentation) will require funding. Thus, the ECMC must be captured in the year-year appropriation bills of Federal and State Government. At least 5% to 10% of annual budgets of target Ministries, Departments and Agencies, MDAS should be set aside for the operations of ECMC. At the moment, proposed potential funding agencies for this model include:

1) Federal, State and Local Governments of Nigeria, through NEMA, SEMA and LEMA
2) Federal Government of Nigeria, through National Ecological Fund
3) Federal Government of Nigeria through the preparation of the Nigeria Erosion and Watershed Management Project (NEWMAP)
4) Federal Government through Federal Ministry of Environment
5) State and Local Government through SEME
6) State Government through Ministries of Environment, State Rapid Response Teams

7) International donors (some of the residents of the sampled arears are graduates and experienced researchers)
8) NGOs
9) Religious Bodies
10) Private sectors

Table 8: Proposed factors for sustainable community participation in Benin City

Factor	Effects on Participation
Continuous community engagement/participation with NEMA/SEMA	Creating a strong sense of belonging Provision of supports and constant revenue to the monitoring/mobility Enhance collaborations in the areas of early warming, emergency response, resettlement or relocation of flood or gully erosion affected persons Ensure sustainability of community participation in disaster management
Formation of flood/water quality monitoring groups, solid waste management groups and good land management units	Facilitate operations and maintenance processes Facilitate networking and collaboration among water users and/or with other related water resources management agencies Enlighten community members on the formation of community Interest Groups (CIGS)
Networking and collaborations with NGOS, International donors and state-actors	Facilitate Sharing of new skills and training which help the various water resources programmes (flood and gully erosion control/monitoring) meet their goals and missions Facilitate experts inputs/ development of change monitoring models Enlighten communities on the criteria for accessing the Special Climate Change Funds (SCCF) Development of understanding, knowledge and skills to support partnership working Facilitate information sharing
Structural Coordination and organizational management	Facilitate monitoring and evaluation i.e. performance evaluation Facilitate budget planning process and execution of water resources development/management projects Quick response/solution to early flood events and gully erosion formation and post disaster intervention Efficient, transparent and accountable revenue management Reduces the stress of reaching state partnership
Livelihood development	Community empowerment/Community empowerment through additional financial liberation through additional financial liberation Enlighten community members on their roles in the delivery of livelihood activities Enlighten communities on eligible livelihood enhancement activities

Transparency and accountability of the funds used in the course of disaster management, monitoring and payment of members (payment structure is to determine by advisory council) is very important towards the sustainability of the committee. Therefore there must be six (6) months interval audit of the financial book of the committee by external certified auditors and the financial report presented to the advisory council, State/International donors, including stakeholders at community levels such as the Enogies (chiefs) and council of chiefs.

3.4. Capacity building of committee members

This involves capacity building of members in the form of training and re-training. Every sub-committee has different responsibilities in keeping with the mandate of the committee. More so every member in each subcommittee has different backgrounds, thus training and knowledge-sharing opportunities must be organized to empower these actors. Such training must cover skill development in the areas of early warning, preparedness, adaptation, emergency plan, data (rainfall) collection method/analysis and documentation, application for grants/ writing of research proposals to fund the activities of the committee, monitoring for environmental changes in including water quality monitoring, presentation of research findings. At least each member of the committee should be trained twice in a year.

4.0 Conclusion

This research serves as a pilot study for an integrated water resources management model. The success of the study will imply that similar committee should be created in each of the senatorial district in each state of the country. Edo state for example, where the study was undertaken similar

committee can be created in the three senatorial zones whereas the advisory council can serve the three districts. The study shows potentials for sustainable disaster/environmental management, increase in income level of community members, informed policy on environmental management in the country, livelihood diversification, and improved economic development. Benin City is predisposed to flooding and gully erosion due to its geographical location (rainfall amount, soil type and increasing pressure on natural resources arising from population expansion). The trend is not expected to change; however, by involving community members in a sustainable way towards the management of these problems as against the top-down approach, is expected to be economical as well as holds the potentials for a lasting solution to minimize conflict of interest and also give the people a sense of ownership. The researchers are confident in the effectiveness of this model as age brackets, educational qualification and level of location knowledge of local environment of the respondents were considered.

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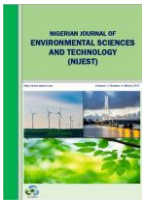

A Survey of the Factors Affecting Market Patronage on the Path to Regional Development of Okitipupa, Nigeria

Rotowa O. O.

Department of Urban and Regional Planning, Federal University of Technology, Akure, Ondo State, Nigeria

Corresponding Author: *oorotowa@futa.edu.ng

ABSTRACT

Markets are economic institutions serving as social entities. Diverse people based on ethnic groups, racial backgrounds and cultural traits are linked by a market. Socio-cultural, religious and political activities equally take place in the markets. This study was carried out in Okitipupa the regional headquarter of Ikale people of Ondo State. The sample size of 120 was selected by the purposive sampling technique, taking cognizance that they were fully representative of the populations of the study area. The questionnaires retrieved, were coded and analysed using SPSS (Statistical Package for Social Sciences) Version 16 computer programs and the Excel spreadsheet software. The findings of the study reveal that infrastructure such as road, water, electricity, and waste management facilities were in a deplorable state. This in effect created a problem for market women and a discomfort to patrons of the market. It is recommended that the community should embark on self-help development of the market, create market management committee, seek for the intervention from the government and provide sustainable redevelopment programs for quick improvement of the market.

Keywords: Market, Patronage, Region, Regional development, Okitipupa

1.0. Introduction

The Sustainable Development Goals (SDGs) are plans of action for people, planet and prosperity. They seek to strengthen universal peace in larger freedom. It recognizes that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development. Specifically, Goal 2 is to end hunger, achieve food security and promote nutrition and promote sustainable agriculture in particular. Target 2c of the SDG sought to adopt measures to ensure the proper functioning of food commodity markets and their derivatives. In addition, it is to facilitate timely access to market information, including food reserves in order to help limit extreme food volatility.

It has been observed that Africa's extensive rural areas contain the continent's greatest poverty concentrations of hunger and poverty (Baba-Mousa, 2005). Nevertheless, they also offer the greatest potential for near-term growth, through increased agricultural production and processing. Unlocking the potentials requires rural transport infrastructure adequately maintained to permit farmers to obtain inputs and information at reasonable cost and sell their output at realistic prices to cover their overall cost at regional and traditional markets.

The Okitipupa central market is located in Okitipupa local government area of Ondo State. The existence of this regional market as a formal transaction place with its own unique characteristics, offer a wide range of merchandise, especially for agricultural products and a face-to-face transaction. It has a direct relationship with history, culture, social interaction of the Ikale region and the settlements patronizing the market. Thus, in Okitipupa region, the existence of the market is inseparable with the growth and development and for the survival of the surrounding rural people. Certainly, the market has an impact on agricultural production and other daily products for local inhabitants. In spite of these, the major challenge threatening the functionality and sustainability of

the market is poor infrastructure and accessibility, especially from agricultural production centres to the market. These problems had further affected the satisfactory functioning of the market, which is evident in the decline of socioeconomic development and poor interaction of activities in space, which has affected the revenue mobilisation capacity of the market, sustainability of the market and the general living condition of Okitipupa and the countryside which contain the rural people.

1.1. Literature review

Regional planning is the planned development of the resources of a unit area in order to maximize returns on investment and to improve the living conditions of the inhabitants of the area concerned (Barbour, 1972). It is a conscious attempt to demonstrate which, among several alternatives for development in any particular case will contribute to national income and Gross Domestic Product (GDP). Olamiju and Olujimi, (2011), submitted that regional planning is for a region or group of regions. A region by definition is a definite geographical setting which possesses the largest degree of homogeneity measured by the largest of economic, cultural, administrative and external indices to the largest number of objectives (Friedman and Alonso, 1968).

Planning region is an area displaying some coherence or unity of economic decision. It is an area large enough to enable substantial changes in the distribution of population and employment taking place within its boundaries, yet which is small enough for its planning problems to be seen as a whole. In retrospect, a planning region implies a specific geographical space (supra-urban space) created for the purpose of analysis, synthesis and planning (Glasson, 1974). Invariably, the presence or absence of uniformity in space is the central theme in the definition of a region. To qualify as a region, it must have a delineated geographic space.

1.1.1. Marketing

Marketing is the process of planning, executing the conception, pricing, promotion and distribution of ideas, goods and services to locate exchanges that satisfy individual and organizational objectives (Omole, 2003). It is a necessary activity that encompasses the entire business and is vital to sound business health. Marketing view the entire business from the customer's viewpoint, taking into account every aspect of the marketing mix from product to price, distribution channels and marketing communication (Adalemo, 1979). Marketing is a process that is intended to find, satisfy and retain customers while business makes a profit. Central to these definitions is the role of the customer and his relationship to the product (whether he considers the product or services to meet a need or want) (Nwafor, 1982). Market from Economics perspective is a social structure developed to facilitate the exchange of right services or product ownership. Market enable people, services, firms and products to be evaluated and priced (Olujimi, 2002).

The rate of market patronage varies with the location of the market, duration of marketing and the facilities within the market and accessibility to the market. The general problem associated with regional markets in Nigeria includes the shortage of infrastructural facilities, low level of patronage and the effect of public facilities (such as water supply, drainage, power supply, and sewage disposal and the income of the patrons of the market). In most African cities, the population has contributed significantly to the considerable expansion of the informal sector and the rising number of petty traders (Wikipedia, 2013 as cited in Omosuyi, 2014). This results in substantial increase in demand (by traders) for marketing infrastructure and related facilities. A significant increase in the supply and distribution of food (especially locally produced foodstuff), oversubscribed market stalls that lack basic storage facilities, parking spaces, sanitation and security facilities, characterizes the retail food trade (Olujimi, 2002).

1.1.2. The marketing function

The market is the lowest level of the economy where traditional exchange and barter take place within village groups or isolated tribes who produce virtually and daily. The dominant interest is the ingestion of local foodstuffs and craft product into the exchange economy by buying and selling. A market is a place which allows the purchaser and the seller to invent and gather information. It allows them to carry out exchange of various products and services. A market therefore refers to a place where the trading of goods and services take place. This can be a market place or a street.

The marketing function is there so that the satisfaction of the buyers and sellers during a transaction can be ensured. The market generally depends on the adjustment of the price so that it can inform the participants involved in a transaction. This is done so that both buyers and sellers are well informed and can bargain the right price out and satisfy themselves somewhat. Another function of the market is to keep the prices under check and control fluctuations in supply and demand to reach locative efficiency.

Market therefore, connotes an authorized public concourse of buyers and sellers of commodities, meeting at a place more or less strictly limited or defined at an appointed time (Omole, 2002). Market centres are fundamental to the economic, social, cultural, religious and political life of the people. Omole (2002) submits that markets can grow anywhere there are goods to sell and where buyers are available for patronage. He equally posited that markets are man-made features established for the use of man.

1.1.3. Periodicity of market

Two basic classes of markets have been mentioned in literature, these are the daily and periodic markets. A further classification of markets include morning, full-day, night, periodic, provincial and inter kingdom markets (Omole, 2002). Nwafor (1982) held the view that a daily market requires the existence of many full-time traders and that it is a more convenient type of market in that it provides the daily needs to the people on a daily basis. It is pertinent to point out that the daily market is so significant that large towns in Nigeria have at least one large daily market. For example, Lagos has at least seven daily markets; Ibadan has ten, while cities like Aba, Onitsha and Kano have at least one daily market. The majority of the villages on the other hand have periodic markets, which usually hold at four to eight day intervals.

Jin and Kim (2003) developed a typology of discount shoppers based on shopping motives, store attributes and outcomes. The differences in store patronage and attitude towards retail store environments, leading to the devise of the shopping orientation segment were the focus of Kincarde and Moye (2003). They were of the opinion that consumer choice is related to the store location and what they have to offer, as well as a number of consumer specific factors such as social class, type of family unit, age and lifestyle, the amount of goods purchased and brand and store loyalty. The influence of usage situation and consumer shopping orientations has an impact on the importance of the retail store environment, which also affect sales, product evaluations and satisfaction (Bitner 1990). There are four categories of shoppers' motivations, which are: consumer based economies which tend to pay attention to price, quality and variety of merchandise; consumer-based on personality which tend to seek a personal relationship in the context of shopping; consumer ethical shopping by moral principles and certain types of protection from the store; and consumer apathy, weak implicated in shopping activities.

Marketing and behavioural science had demonstrated the breadth of consumer motives for shopping. Hoffmann (2004) submits that consumers were motivated by more than the utilitarian motive to get the desired items. Six forms of shopping activities based on motivation and behaviour identified are: adventure, social, gratification, idea, role and value shopping. Adventure shopping likens shopping to an adventure activity because consumers feel a different atmosphere due to a visit from one place to another and the urge to get the goods, services or new experiences. Social shopping is shopping activity driven by the desire to socialize with how to shop with friends. Gratification shopping is impulse shopping to get satisfaction as a result of previous shopping experience, besides aiming to relieve stress. Motives are the reasons behind the will of man to do anything different from one customer to another.

1.1.4. Market infrastructure

In economics, a market that runs under laissez-faire policy is a free market. It is free in the sense that the government makes no attempt to intervene through taxes, subsidies, minimum wages and price ceiling, etc. Market prices may be distorted by a seller with monopoly power or a buyer with monopoly power. Such price distortions can have an adverse effect on market participant's welfare and reduce the efficiency of market outcomes. Also, the relative level of organization and negotiation power of buyers and sellers markedly affects the functioning of the market. Markets where price negotiations meet equilibrium still do not arrive at desired outcomes for both sides are said to

experience market failure (Wikipedia, 2011 as cited in Omosuyi, 2014). Markets are a system and systems have structure. The structure of a well-functioning market is defined by the theory of perfect competition. Well-functioning markets of the real world are never perfect, but basic structural characteristics can be approximated for real world markets, for example, many small buyers and sellers have equal access to information products and are comparable.

Efficient marketing infrastructure such as wholesale, retail and assembly markets and storage facilities is essential for cost effective marketing to minimize post-harvest losses and to reduce health risks. Market infrastructure is required at all stages of the supply chain, from local retail and assembly markets through to wholesale and retail markets in major urban centres. Governments and local authorities generally have a poor appreciation of the importance of markets and a reluctance to invest in them. As a consequence, markets are often congested, unhygienic and inefficient. They are also fire risks. Local authorities frequently see markets as revenue raising opportunities, not as institutions that necessitate investment. Although there have been significant developments with regards to supermarket development and the improvement of farm-to-agro processor linkages, the great bulk of food products are still distributed through more traditional channels using traditional market infrastructure. Food and Agricultural Organization (FAO) has for years concentrated on market infrastructure improvement, both through technical assistance projects with national and provincial governments and local authorities and through the publication of a wide range of guides on the topic (Gaurav and Hoffmann, 2004 as cited in Balogun, 2012).

Facilities and services that are relevant to the development of market centres as listed by (Balogun, 2011 as cited in Balogun 2012) are as follows:

i. Access roads within the market must be motorable for ease of movement of people and good, vehicles for loading of goods;
ii. The provision of adequate drainage system that is well maintained to guide against erosion at the market site;
iii. Provision of adequate toilet facility for the market users;
iv. Adequate parking space, loading and off-loading bays must be provided to guide against on-street parking;
v. Provision of hydrants in case of fire outbreak;
vi. Provision of adequate water supply;
vii. Social cultural facilities;
viii. Provision of health care facility in case of emergency;
ix. Provision of adequate waste disposal facility;
x. Provision of security services to safeguard properties; and
xi. Market council of elders in place saddled with the responsibility of managing the market.

It is disheartening to observe that markets in third world countries have many defects. These defects are physical, social and managerial, which, according to the Food and Agriculture Organization include, but not limited to, market management, which establishes no clear relationship between revenues and costs, leading to the market being under-funded, especially for repairs and maintenance (Kuye and Agbabiaka, 2016).

2.0. Materials and Methods

Many markets exist in Okitipupa region, which includes: Okitipupa main market, Okitipupa night market, Ode-Aye market, Ilutitun market, and Ikoya market. Others are Igbotako Omotosho, Mile 49 and Wekaye markets. Okitipupa main market is situated on Longitude 6° 30' North of the Equator and Latitude 4° 48' East of the Greenwich Meridian. It is the biggest market in Okitipupa region, with control by the Local and State Governments. Though it had been patronized for more than thirty (30) years, its present structure was built by the Mimiko Administration in 2011. It is patronized in 5 day interval and has about 150 lock-up shops. The research instrument used was a well-structured questionnaire, which was designed to elicit data on the condition of the central market. The questionnaire was written in English Language and was translated into Yoruba when the respondent is illiterate.

The sample size for the study is 120 and was selected by the purposive sampling technique, taking cognizance that they were fully representative of the populations of the study. The 120 questionnaires were retrieved and analysed using SPSS (Statistical Package for Social Sciences) Version 16 computer programs and the Excel spreadsheet software.

3.0. Results and Discussion

3.1. Characteristics of respondents

Consumer evaluation of a regional market has a positive impact on their attitude towards it. For this reason, the identity of target groups in the region must be aligned with the needs of stakeholders. The results of gender disparities (Table 1) show that 52.5% of respondents covered by the study are female while 47.5% are male. The implication of this is that a larger percentage of people patronizing Okitipupa central market as buyers and sellers are females. This is in conformity with earlier findings by Omole (2002) that market centres in most south western Nigeria are dominated by women. It further reveals that women should be considered in market planning for regional development.

Table 1: Sex of respondents in Okitipupa market

Sex	Frequency	Percentage (%)
Female	63	52.5
Male	57	47.5
Total	120	100

Source: Field survey, 2016

Attitude towards a region reflects individual mental pictures and association that individuals hold with regard to a specific regional market. Locals or visitors know the regional market and rely on their own impressions and experiences, whereas, external stakeholders possess secondary information. The age of respondents in Okitipupa market (see Figure 1) shows that the highest percentage of respondents falls between the age limit of 36-45 years (30%). This was followed by respondents who are within age bracket 18-25 years (23.3%). Respondents who were above 65 years were 13%, while 10% of the respondents were in the age bracket 46-64 years. It can therefore be implied that the working group able-bodied, are the majority of people conducting marketing in the market.

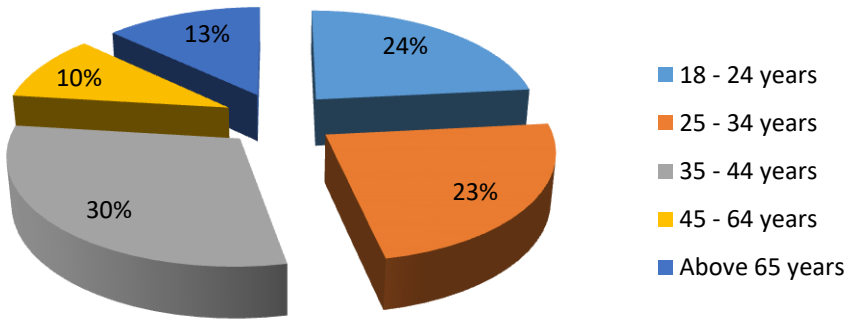

Figure 1: Age of Respondents in Okitipupa Market
Source: Field survey, 2016

The survey as reported in Table 2 reveals that respondents who earned less than 20000 Naira monthly were 30%. In the same vain, respondents who earned between 21000 and 50000 Naira were 30%. It was also discovered that while 28% earns between 60000 and 90000 Naira, 12% of respondents reports that they earn more than 100000 Naira monthly.

There is a nested constellation of regional marketing projects as an element that forms the attitude towards a region. It is expected that the attitude towards the regional marketing project influences the attitude towards the regional market. Figure 2 indicates the occupational distribution of respondents

covered at Okitipupa market. It reveals that 24.2% of them are farmers. Next to this are the artisans (21.7%) and the unemployed (21.7%). The proportions of respondents who are traders are 16.7%, while the civil servants were 7.5%. The agrarian economy surrounding Okitipupa really account for the high volume of Agro-allied professionals captured in the survey. Hence, it is evident that most of the goods traded in the market will be agro-based.

Table 2: Monthly income of respondents

Monthly Income (Naira [$1 = N260])	Frequency	Percentage
Below 20000	36	30
21000 – 50000	36	30
51000 – 90000	33	28
Above 91000	15	12
Total	120	100

Source: Field survey, 2016

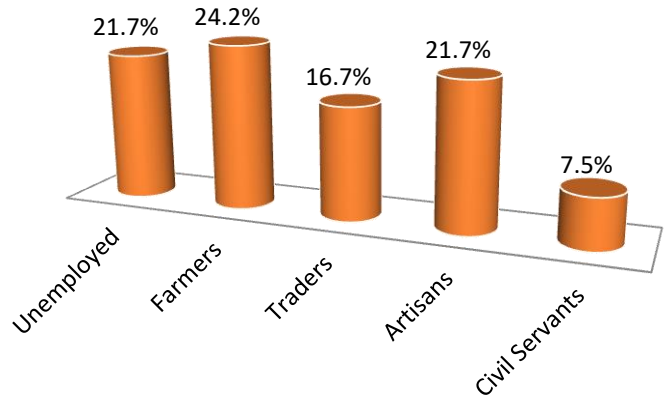

Figure 2: Occupation of respondents in Okitipupa market
Source: Authors' Fieldwork, 2016.

In addition, the marital status of respondents (see Figure 3) shows that 55% of them were married. The study discovered that 19.2% of the respondents were single, while 15% are divorced. The proportion of the respondents who are widowed was 10.8%. This reveals that the majority of the people patronizing the market were married men and women.

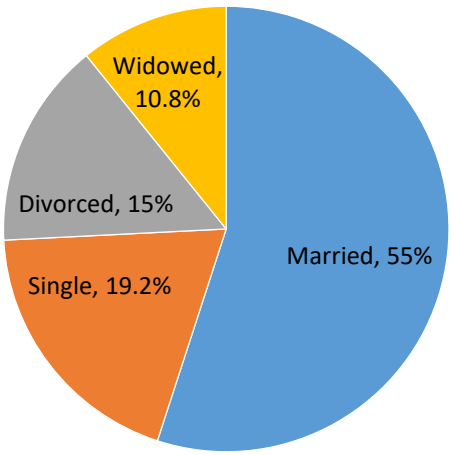

Figure 3: Marital status of respondents
Source: Authors' Fieldwork, 2016

Figure 4 depicts the educational level of the respondents; it shows that the majority of them (28.3%) have completed the primary school. This was followed by respondents who are illiterate who cannot

read nor write with understanding (25%). Respondents who have secondary school education were 18.3%, while 13.3% have the National Certificate in Education (NCE). The proportion of respondents who have the polytechnic education and university education were 10% and 5% respectively.

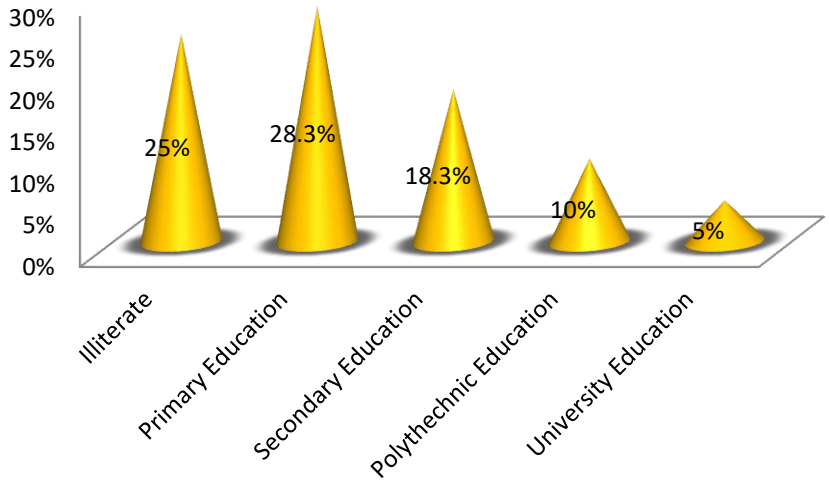

Figure 4: Educational level of respondents
Source: Authors' Fieldwork, 2016

3.2. Facilities in Okitipupa market

Accessibility is key to market patronage. This section presents the facilities available in Okitipupa regional market. Figure 5 shows accessibility to the market. The outcome from this research reveals that 30% of the roads were fairly accessible, particularly during market hours. On the other hand, 17% of the roads were hardly accessible. The other 11% of accessible roads were tarred hence, can be classified as good. Roads without kerbsides, untarred, with potholes and without drainage, and therefore are not accessible were 36%. The high proportion of respondents claiming that road accessibility is poor in this study stems from the fact that the survey was conducted on market days. These are days when most of the roads are congested due to marketing activities.

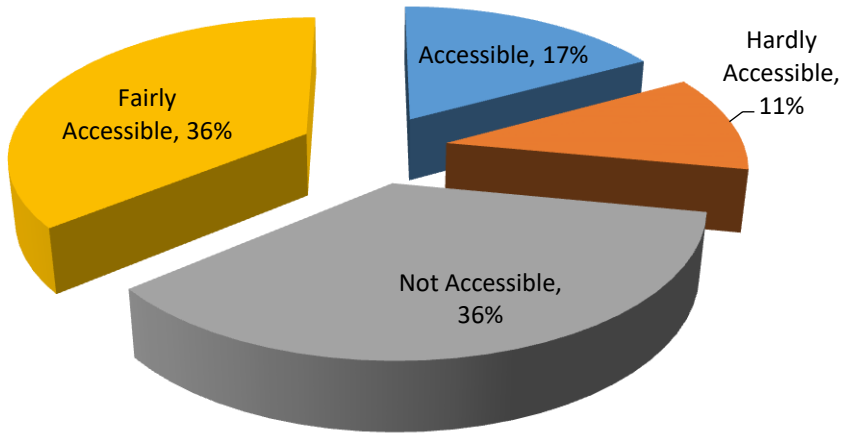

Figure 5: Road accessibility during market hour
Source: Authors' Fieldwork, 2016.

The common methods for urinating and defecating in the market are through the Pit Latrine, Water Closet, and Open Defecation. The study reveals that 50.8% of market users use the pit latrine, while 17.5% use water closet to defecate (see Figure 6). The proportion of respondents that defecate openly

are 31.7%. The outcome of findings from the study is not unexpected because most markets in Nigeria are not equipped with improved toilet facilities (Kuye and Agbabiaka, 2016).

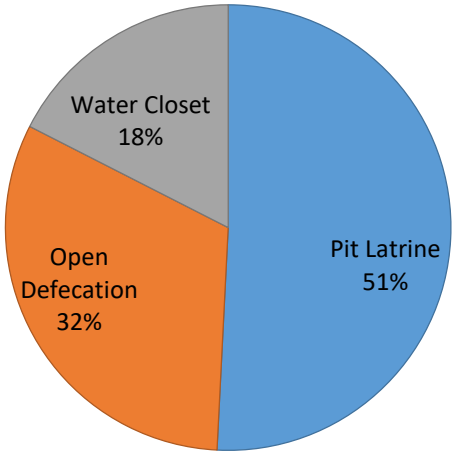

Figure 6: Type of toilet facility in Okitipupa market
Source: Authors' Fieldwork, 2016.

The sources of water available in the market are: borehole, hand-dug well, pipe borne water, and steam water. The result of this survey reveals that 31.7% of the respondent use hand-dug wells as a water source. The proportion of respondents having access to pipe borne water is 28.3%, while 25.8% have access to stream water. Respondents that depend on other sources of water is 1.7% (see Figure 7). The water from hand-dug wells often dries up during the dry season (October-March), and are only reliable for supply during the rainy season.

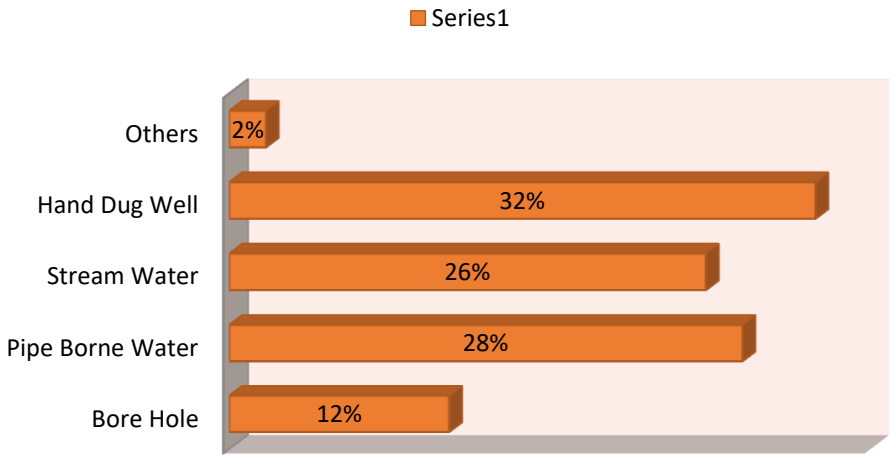

Figure 7: Water source in Okitipupa market
Source: Authors' Fieldwork, 2016.

Wastes are generated in the market during market hours, which need to be evacuated. In Okitipupa central market, most of the solid wastes are disposed through burning (32.5%). The proportion of wastes that are disposed through incineration is 24.2%. Dumping of refuse inside gutters, nearby streams is carried out with 25.8% of respondents (see Figure 8). It was also discovered that only 17.5% of the refuse generated in the market is evacuated by Ondo State Waste Management Board (OSWMB). The proportion of wastes evacuated by OSWMB is paltry and there is the need to increase this proportion for environmental safety.

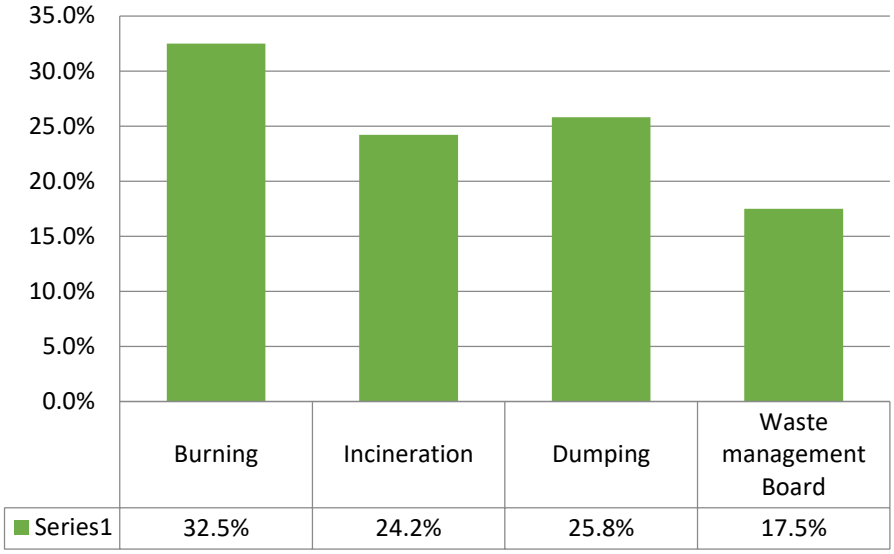

Figure 8: Mode of waste management in the market
Source: Authors' Fieldwork, 2016.

Most of the stalls and stores in the market were connected to the public electricity main. Electricity supply was, however epileptic and was only available to the majority of the market between 6 and 12 hours a day. The sources of energy supply are majorly from the Benin Electricity Supply Company (BEDC) that supplies energy to about 43.3% of respondent (as shown in Figure 9). This is followed by 26.7% that uses generator, while 25% uses both public electricity from BEDC and generator. The rest of the respondents (5%) have no source of energy.

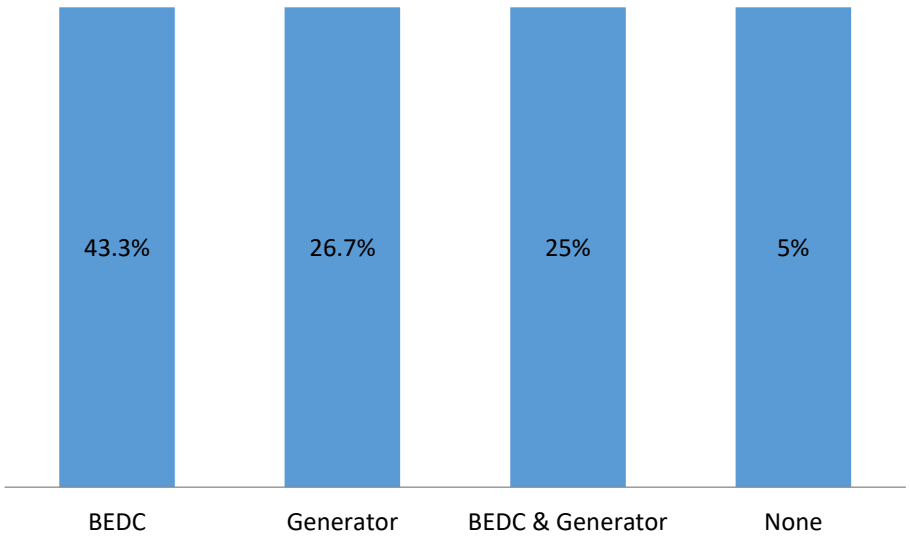

Figure 9: Sources of energy supply in the market
Source: Authors' Fieldwork, 2016.

3.3. Levels of market patronage

This section presents results and analyses of market patronage and regional development in Okitipupa. Okitipupa is the headquarters of the old Ikale region of the Ondo Province until 1976 when it became the headquarters of Okitipupa local government. It is therefore expected that the site of the market will have a significant effect on the region. The research finding from this study (Figure 10) reveals that the majority of the goods on display are food items (49%), such as garri, bean, cassava yam and others. This was followed by trading in clothing and electronics (40%). The proportions of traders of raw materials are 30%, while 1% deals on other goods.

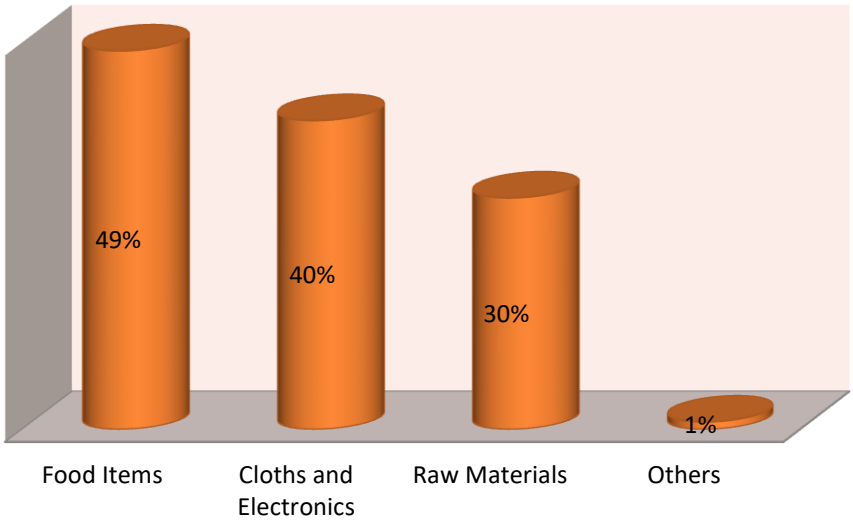

Figure 10: Classes of goods sold in Okitipupa market
Source: Authors' Fieldwork, 2016.

Figure 11 shows the positive impacts of the market in the region; 25% of respondents' affirmed that the market provides jobs for them. On the other hand, 29% get infrastructural development through the market, while 21% reported that the market contributed to community development of the region. The proportion of respondents who claimed that they derive other benefits from the market was 25%. This implies that the location of this market as attested to by the respondents has positive impacts on the development of the region in terms of infrastructure and employment generation among others. Hence, it can be concluded that it contributes to the economic and social development of the area.

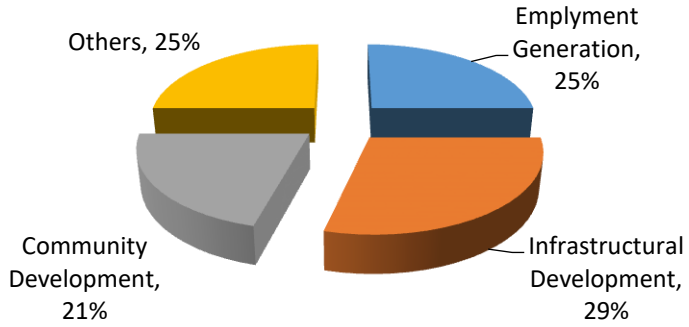

Figure 11: Positive effects of Okitipupa market location on the community
Source: Authors' Field, 2016

The respondents were asked to comment on the negative effect of the location of the market. Figure 12 show that the highest on the list of such effects was noise pollution accounting for 34%. This was followed by land pollution due to various items being traded in the market. The problem of crowding due to over population accounts for 20% of the negative effects as submitted by respondents. Traffic congestion was reported as a problem caused by the market by 18% of respondents. Other negative effects were mentioned by 4% of the respondents as part of the negative effects of the regional market.

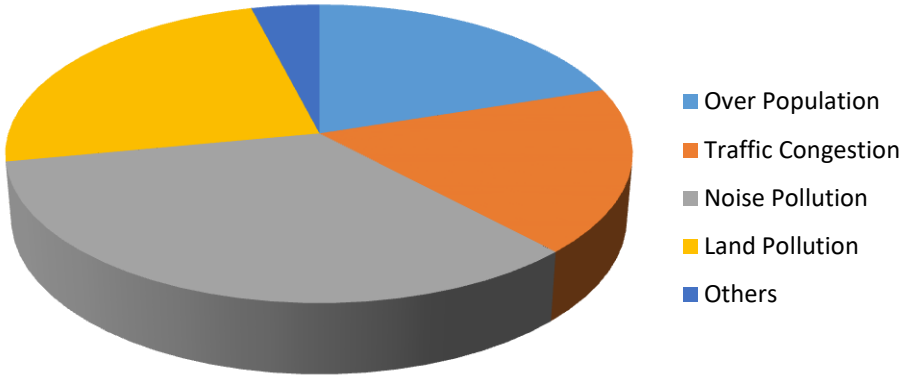

Figure 12: Negative effects of market location
Source: Authors Fieldwork, 2016

The research reveals the factors that affect the level of market patronage in the study area (see Figure 13). The first such factor is a dirty environment as adduced to by 24% of the respondents. The next factor is the bad road as submitted by 24%. In addition, 23% attribute low patronage to inadequate market facilities. Also, 21% of respondents submits that long distance from the market constitute a deterrent to market patronage, while 8% are of the opinion that inhospitable sellers constitute an adverse effect on market patronage.

Figure 13: Factors affecting patronage in Okitipupa market
Source: Authors' Fieldwork, 2016.

The research further observed that the level of patronage of the market was faced with some problems as shows in Table 3. It was observed that the seasonality of production was cited by 35% of the respondent. This was followed by 24.2% of the respondents who agreed that problem of the high cost of stores is a problem. Lack of or inadequate stalls was cited by 20% of respondents, while 13.3% agreed that the market has the problem of insecurity, while 7.5% submits that poor transportation is a problem facing the market.

Table 3: Solution to problems of market patronage

Factors affecting Levels of Patronage	Frequency	Percentage (%)
Lack of Stalls	24	20
Seasonality of Production	42	35
High Cost of Stalls and Stores	29	24.2
Insecurity	16	13.3
Poor Transportation	9	7.5
Total	120	100

Source: Authors' Fieldwork, 2016

Testing of Hypothesis:
The hypothesis tested the condition of market facilities with level of patronage in Okitipupa regional market. The result revealed a correlation coefficient of $r = 0.12$ significant at $p < 0.05$ using $t = r$ SPOT (n-2) (1+r) according to Kothari (2004) a value of 3.28 was obtained which was higher that the table value of 1.67 and 2.91 at $P < 0.01$ and 0.05 respectively; hence, the null hypothesis was rejected. The alternate hypothesis was accepted that there is an association between market facilities and market patronage in Okitipupa region.

4.0 Conclusion

This study has brought into focus the market facilities available in Okitipupa central market and the level of patronage of the market. The main facilities that were available in the market are fairly accessible road characterised by on-street parking; the pit latrine as the main toilet; and hand-dug well as the main water source. Solid wastes generated are mostly disposed through burning, while the main electricity is from the national grid and generator. The products on display in the market include food items, clothes, electronics, raw materials, cement, plastics, building materials and so on. The positive impacts of the market are felt in the areas of employment generation, infrastructural development, and community development. On the other hand, the negative effects of the market are in the area of traffic congestion, noise pollution, and land pollution (through open defecation). In addition, the market is equally faced with problems of inadequate stores/stalls; seasonality of the produce in the market; high cost of stalls/stores; insecurity; and poor transportation.

It is recommended that the market be expanded and the Government should build more stalls/stores; the access road should be re-constructed and provided with a good drainage system. In addition, modern waste bins and trucks should be provided and complemented by an efficient and effective waste disposal system. The market should be equipped with public toilet equipped with adequate water.

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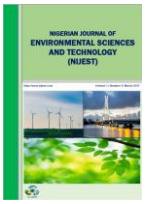

Physicochemical and Microbiological Water Quality Assessment of Aba Waterside River, Aba, Nigeria

Bobor L.O.[1,*] and Umeh C.M.[1]

[1]Department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Nigeria

Corresponding Author: *lulu.akhigbe@uniben.edu

ABSTRACT

The indiscriminate disposal of industrial effluents and solid wastes in surface water bodies is detrimental to humans and aquatic organisms. Water quality monitoring is critical to identify pollutants of concern and develop effective management strategies. Hence, this study was conducted to assess the impact of waste disposal on the water quality of Aba Waterside River, Ogbor hill, Aba. Grab samples were collected upstream, midstream and downstream and some physicochemical and microbiological parameters were analyzed in accordance with standard methods for the analysis of water and wastewater. The results were compared with the Nigerian standard for drinking water quality and the national environmental effluent limitation regulations. Turbidity levels (10 -31mg/l) exceeded the maximum permissible levels for drinking water (5mg/l) and may be associated with higher levels of embedded disease-causing microbes and potentially harmful organic and inorganic substances. The biological oxygen demand midstream (1960mg/l) was remarkably high due to the effluent discharged from the abattoirs at that point. Fecal coliforms (3-198MPN/100ml) were detected in all samples, indicating the presence of other potentially harmful microorganisms. The findings of this study indicate that the water is unsuitable for direct drinking water purposes and stringent water quality control measures should be implemented.

Keywords: Water Quality, Pollution, Aba Waterside River, Drinking Water, Effluents

1.0. Introduction

Surface water pollution and the consequent deterioration of aqueous systems is a major problem in developing and densely populated countries (Dahunsi et al., 2014; Ayandiran et al., 2018). Increased urban, industrial and agricultural activities and failure to enforce environmental laws have resulted in the indiscriminate disposal of large volumes of untreated wastewater and solid wastes in rivers and streams. These wastes contain harmful substances which are detrimental to human health, aquatic organisms and the ecosystem (Amadi, 2012; Tyagi et al., 2013; Dahunsi et al., 2014; Tchakonte et al., 2014; Onajoke et al., 2017; Ayadiran et al., 2018). Long term pollution alters the physical, chemical and biological nature of the receiving water bodies and affects the surrounding food web (Ewa et al., 2011; Amadi, 2012). According to Umalua et al. (2007), consumption of contaminated marine organisms capable of transmitting toxic elements or diseases to consumers is a major associated risk. Microbial pollutants cause waterborne and water-related diseases such as typhoid, cholera, bacillary dysentery, etc. (Ayadiran et al., 2018). The discharge of untreated sewage and industrial effluents with high nutrient loads into rivers also results in eutrophication (increased growth of aquatic plants and toxic algal blooms). This may cause depletion of dissolved oxygen leading to the death of aquatic animals (Morrison et al., 2001; Ewa et al., 2011; Ahwange et al., 2012).

Aba Waterside (Aba) river is a deep freshwater river in Aba, Abia State, Nigeria which is used for domestic, agricultural and industrial purposes. There are several industries, abbatoirs and laundry services and dumpsites located near the river. Due to poor waste management practices and non-enforcement of environmental laws, the river receives large volumes of untreated effluents and refuse (Nkwocha and Emeribe, 2005; Ubalua et al., 2007; Amadi, 2012; Atasie and Egbonu, 2017; Udo and

Elendu, 2019). Some researchers have carried out studies investigating the extent of pollution in Aba Waterside/Aba River, with particular emphasis on heavy metal pollution and impact on aquatic organisms (Ubalua et al., 2007; Amadi, 2012; Atasie and Egbonu, 2017; Udo and Elendu, 2019). The heavy metal content of water, fish and shellfish in Aba River was evaluated in a study, with the metal concentrations exceeding allowable limits (Ubalua et al., 2007). Amadi (2012) investigated the impact of municipal and industrial wastes and agricultural runoff on Aba River by assessing the levels of heavy metal pollution. Atasie and Egbonu (2017) examined some water quality indicators and the impact of water samples from Aba Waterside River, Aba on the hematological indices of rats. In their study, water quality analysis was limited to biochemical oxygen demand, chemical oxygen demand, dissolved oxygen and total hardness. Udo and Elendu (2019) examined the public health implications of Aba river pollution.

The aim of this study was to assess the impact of indiscriminate waste disposal/anthropogenic activities on the water quality of Aba Waterside River, Ogbor hill, Aba by examining selected physicochemical and microbiological parameters and comparing them with relevant drinking water quality and effluent discharge standards.

2.0. Materials and Methods

2.1. Study Area

Aba Waterside (Aba) river is a deep freshwater river that passes through Ogbor hill area, Aba, Abia State, Nigeria (Figure 1). The river which is a tributary of Imo river is located between Latitude 5˚ 05N to 5˚30N and Longitude 7˚15E to 7˚40E is recharged by rainfall and groundwater (Amadi, 2012). It is a major source of water employed for domestic, agricultural and industrial purposes. The river continuously receives effluents and solid wastes from several industries, breweries, abattoirs, auto mechanic workshops and laundry services sited along its course. Domestic activities such as car washing, rearing of farm animals take place close to the river. There is also a refuse dumpsite located near the river (Atasie and Egbonu, 2017).

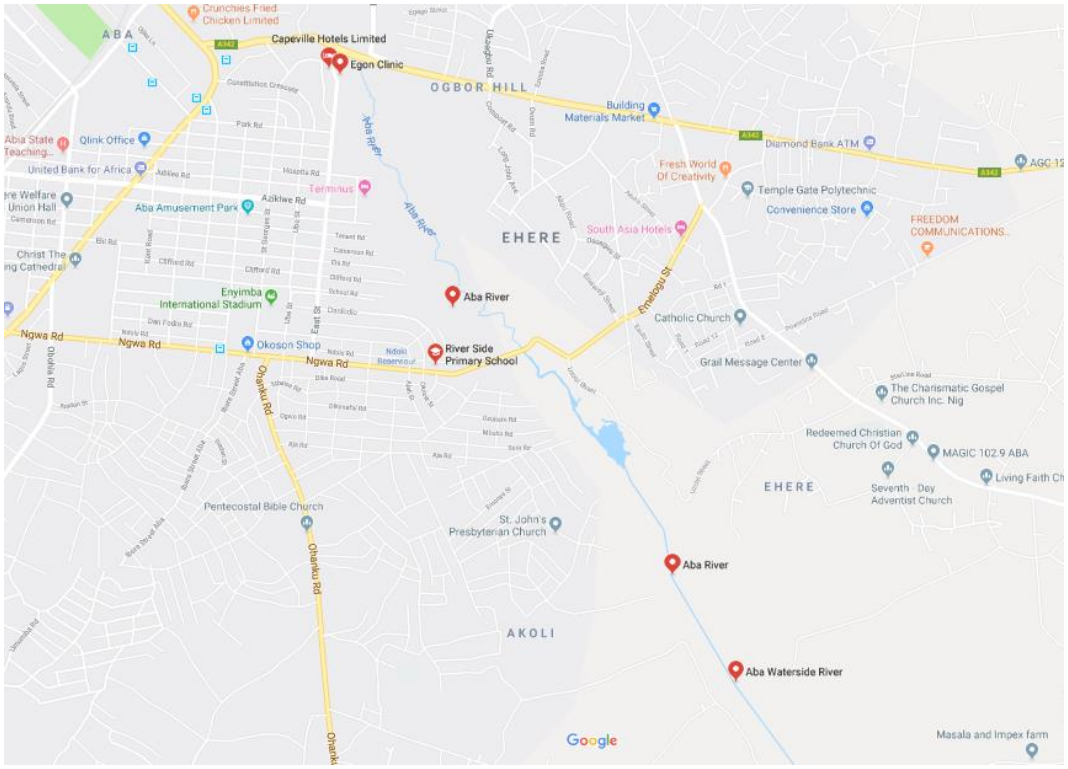

Figure 1: Map of the study area showing Aba Waterside River (Google maps, 2019)

2.2. Surface Water Sampling and Analysis

Water samples were collected using thoroughly pre-rinsed 75cl plastic bottles with screw caps. Grab sampling was done upstream (the discharge point of a cosmetics factory), midstream (the discharge point of the abattoir under the Ogbor hill bridge) and downstream. The samples were then transported in a cooler packed with ice to Yemac consulting and analytical services limited, Aba for analysis.

The physicochemical parameters analyzed in accordance with standard methods for analysis of water and wastewater (APHA, 2012) include temperature, electrical conductivity, turbidity, pH, total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total hardness, iron, manganese, lead and zinc. The pH was determined using a calibrated pH meter and the temperature was determined using a thermometer. The DO was determined using Winkler's method (APHA, 2012). The determination of DO was done by adding manganese (II) sulfate to the water sample, followed by potassium hydroxide in a glass stoppered bottle, resulting in the oxidation of manganese and the formation of a brown precipitate. The solution was then acidified with sulfuric acid and alkaline iodide-azide reagent was added and the iodide was converted to iodine. The iodine was then titrated with a standard sodium thiosulfate ($Na_2S_2O_3$) solution. The DO was then determined in direct proportion to the amount of thiosulfate required to reach the endpoint, using the stoichiometric relationship

$$DO(mg/l\,O_2) = \frac{V_{Na_2S_2O_2} \times N_{Na_2S_2O_2} \times E_{O_2} \times 1000}{(V_a\,(V_w - V_{mk})/V_w)} \quad (1)$$

Where $V_{Na_2S_2O_2}$ is the volume of sodium thiosulfate used in titration (ml), $N_{Na_2S_2O_2}$ is the normality of sodium thiosulfate solution, E_{O_2} is the equivalent weight of oxygen, V_a is the volume of analyte taken in solution (ml), V_{mk} is the volume of manganese (II) sulfate and alkaline iodide reagent added (ml) and V_w is the total volume of the water sample (ml).

The BOD was determined by measuring the difference in the DO concentration of the samples before and after incubation at 20˚C for five days using the equation:

$$BOD_5 = \frac{DO_1 - DO_2}{p} \quad (2)$$

Where DO_1 and DO_2 are the initial DO concentration of the sample before incubation and the DO concentration after 5-day incubation at 20˚C respectively (mg/l). *P* is the fraction of water sample to the total combined volume.

The COD was determined by refluxing the sample with a known excess of potassium dichromate in a high strength sulfuric acid solution. The excess potassium dichromate after digestion was titrated with ferrous ammonium sulfate to determine the amount consumed and the oxidizable matter (COD) was then calculated using Equation (3) (APHA, 2012).

$$COD(mg/l\,O_2) = \frac{8000(A-B)N}{V} \quad (3)$$

Where A and B are the volume of ferrous ammonium sulfate used for the blank and the sample respectively (ml), N is the normality of ferrous ammonium sulfate and V is the volume of the water sample (ml).

The Conductivity, turbidity and TDS were measured directly using a Horiba U-10 water quality checker. Total hardness was determined by complexometric titration with a standard solution of ethylene diamine tetraacetic acid (EDTA), using erichrome as an indicator to a pure blue end point from pink. Elemental analysis was done using atomic absorption spectrophotometer (AAS). Enumeration of fecal coliforms was done using the most probable number (MPN) method (APHA, 2012; Ahmed et al., 2013).

3.0. Results and Discussion

The result of physicochemical and microbiological analysis of the water samples is presented in Table 1. The results were compared with the Nigerian standard for drinking water quality (NIS-554-2015) (SON, 2015) and the national environmental effluent limitation regulations (FEPA, 1991). The comparison with drinking water quality standards was to assess the suitability of the water sources for direct potable use, as practiced by some inhabitants of the area.

The pH of water samples taken upstream (6.06) and midstream (6.58) did not exceed the maximum permissible limits for drinking water (SON, 2015) and discharge into surface water (FEPA, 1991). However, the water downstream was slightly acidic at pH 5.7. This is similar to observations in a different study area (Ewa et al., 2011) where pH was lower downstream than upstream. This may be due to high carbon dioxide emissions from increased organic matter decomposition rates resulting in the formation of a weak carbonic acid which decreases the pH of the water (Venkatesharaju et al., 2010). The temperatures ranging from 29-33˚C were within acceptable limits for effluent discharge. The conductivity upstream was 1360µ/cm which is higher than the maximum permitted value in drinking water. The conductivity is a measure of the capacity of water to conduct electrical current and is directly related to the amount of mineral salts dissolved in the water/ high TDS (Onojake et al., 2017). Liquid wastes from cosmetic industries such as soap factories located upstream are often characterized by heavy mineral loads (Ehouman et al, 2017). The TDS upstream (826mg/l) was higher than the maximum permissible limit for drinking water, and the midstream value (2500mg/l) was higher than the maximum permissible limits for drinking water and effluent discharge. The TDS is a strong indicator of organic waste discharge into the river (Onojake et al, 2017).

Table 1: Water quality characteristics of samples obtained from Aba Waterside river, Aba.

Parameter	**Upstream**	**Midstream**	**Downstream**	**NIS-554-2015 (SON, 2015)**	**FEPA (1991)**
pH	6.06	6.58	5.7	6.5 - 8.5	6 - 9
Temperature (˚C)	33	30.5	29		< 40
Conductivity (µ/cm)	1360	150	101	1000	
TSS (mg/l)	906	2100	140		30
TDS (mg/l)	826	2500	60	500	2000
Turbidity (NTU)	27	31	10	5	
Total Hardness (mg/l)	195	5	16	150 (as $CaCO_3$)	
DO (mg/l)	4.7	6.7	2.6		
BOD (mg/l)	40	1960	21.t4		30
COD (mg/l)	96	122	102		
Fe(mg/l)	3	0.89	0.05	0.3	20
Mn(mg/l)	2.8	1.2	1.85	0.2	5
Pb(mg/l)	0.01	0.32	0.01	0.01	< 1
Zn(mg/l)	0.015	0.01	0.05	3	< 1
Fecal Coliforms (MPN/100ml)	3	198	28	0	400

The total hardness varied from 5-195mg/l, with the hardness upstream (195mg/l) exceeding the maximum permissible limits for drinking water. There are no associated health impacts, however at levels greater than 200mg/l, hardness may cause scale deposition and result in high soap consumption. Levels less than 100mg/l (as observed midstream and downstream) may lower the buffering capacity

of the water and increase corrosivity (WHO, 2017). The TSS ranged from 140 -2100.33mg/l and exceeded the FEPA guideline values. The turbidity levels (10 -31mg/l) were higher than the maximum permissible limits for drinking water (SON, 2015). Turbidity is a measure of suspended matter which reduces water clarity. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms and harmful organic and inorganic substances. Suspended / colloidal solids can protect microorganisms and hinder effective disinfection (SON, 2015; WHO, 2017).

The BOD values were 40mg/l, 1960mg/l and 21mg/l upstream, midstream and downstream respectively. The BOD upstream and midstream were greater than effluent discharge limits (FEPA, 1991). The BOD midstream was remarkably high due to the effluent discharged from the abattoirs at that point. High BOD levels result in the depletion of oxygen which is detrimental to aquatic life. Furthermore, the low dissolved oxygen measurements (2.6-4.7mg/l) were due to the presence of organic matter in the water which consumes dissolved oxygen, and photosynthesis of proliferating aquatic plants. The concentration of manganese (1.2-2.8mg/l) exceeded the permissible limit for drinking water. The Mn values are greater than those reported in Amadi (2012), where Mn concentrations ranges from 0.050-0.508 mg/l. According to the WHO (2017), at levels exceeding 0.1mg/l manganese will cause an undesirable taste and stains. The concentration of Pb midstream (0.32mg/l) was more than the permissible limit for drinking water (SON, 2015). The Pb values obtained (0.01-0.32mg/l) were greater than those reported in Amadi (2012), where Pb concentrations ranged from 0.001-0.015mg/l for the same river. This implies the continuous deterioration of the river quality and highlights the need for regular monitoring and environmental control. Pb is carcinogenic and toxic to the nervous system and may affect mental development in infants (SON, 2017). The concentration of zinc (0.01-0.05mg/l) was less than the maximum permissible limits for both drinking water and discharge into surface water, thus indicating that zinc was not a pollutant of concern at the time of this study. The concentration of Fe ranged from 0.05-3mg/l and was higher than the stipulated maximum values for drinking water (SON, 2015) upstream and midstream. These values were similar to the range reported in other heavy metal studies in Aba river (Amadi, 2012). The fecal coliform counts (3-198MPN/100ml) were within the acceptable range for effluent discharge, however they were greater than the maximum limits for drinking water. The presence of fecal coliforms from human and animal waste indicates the presence of other potentially harmful microorganisms which cause gastrointestinal illnesses which may result in fatalities in vulnerable segments of the population such as children and the elderly (Cliver, 2000).

4.0. Conclusions

The impact of anthropogenic activities on some water quality parameters of Aba Waterside river, Aba has been investigated. Generally, the results of physicochemical analysis revealed that levels of turbidity, manganese and iron at all points, conductivity and BOD upstream, and Pb and BOD midstream exceeded the stipulated values in the Nigerian standard for drinking water quality and/or the national environmental effluent limitation regulations. The BOD midstream (1960mg/l) was remarkably high due to the effluent discharged from the abattoirs at that point. Fecal coliforms (3-198MPN/100ml) were detected in all samples, indicating the presence of other potentially harmful microorganisms. The findings of the study indicate that the water is polluted and unsuitable for use as a drinking water source without appropriate treatment. More importantly, there is the need for continuous environmental monitoring and control to ensure that industries desist from discharging untreated effluents into the river to prevent further deterioration of the water quality.

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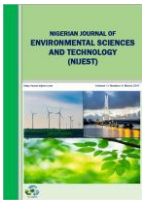

Applications of Surveying and Geoinformatics for Planning New Routes to Solve Traffic Congestion in part of Minna Metropolis (Kpakungu, a case study)

Onuigbo I. C.[1,*], Adewuyi T.[1], Odumosu J. O.[1] and Oluibukun G. A.[1]

[1] Department of Survey and Geoinformatics, Federal University of Technology, Minna, Nigeria

Corresponding Author: *anyi.onuigbo@futminna.edu.ng

ABSTRACT

The volume of traffic generated by land-use pattern varies during different periods of the day but there is usually a predictable pattern of such traffic volumes. Most often, the structure of urban land-use fails to provide easy and convenient traffic movement, which in the case of the study area is usually that of vehicles and pedestrian traffic. The fact is that Minna is presently experiencing rapid urban growth. Both the authorities and citizens seem to simply ignore this and its impact on human existence. The research is based on Road Traffic Network Analysis in Minna, to develop a road network map and determine the causes of Traffic Congestion in Kpakungu specifically. Quickbird satellite imagery was used in analyzing and mapping out the existing road network within the study area. Field survey aspects involving measuring of roads, traffic count, coordinates captured were also undertaken. It was discovered that the causes of the traffic pressure in the study area was as a result of the relocation of Federal University of Technology, Minna to its permanent site in Gidan Kwanu and the relocation of National Examination Council(NECO) Headquarter. Majority of the traffic pressure in the area were as a result of vehicles coming from Maikunkele, Bosso, Maitumbi, Minna central, Dutsen Kura, Chanchaga, Tunga, Sahuka-kahuta and Barikin-Sale going to Bida, Gidan-Kwanu or NECO office. It was concluded that alternative roads should be provided for vehicle diversion to limit the congestion of traffic on the road.

Keywords: Traffic, Development, Mapping, Traffic congestion, Satellite imagery

1.0. Introduction

Traffic in an urban area is necessitated by the need for various parts to relate with one another. The volume of traffic generated varies during different periods of the day but there is usually a predictable pattern of such traffic volumes. Inconvenient traffic movement generates many problems such as unnecessary longer travel times, environmental pollution, crime, emotional and psychological stress (Leke, 2007).

Minna is the capital city of Niger State, largely populated because of the commercial activities going on within the town. Considering the fact that Minna is the capital, one should expect the influx of civil servants into the city. Both State and Federal Government workers within the state will most likely reside in the city for easy access to their different places of work.

In 2007 the population of Minna was estimated to be 304,113 and it is growing steadily. Minna is in west central Nigeria and is the headquarters of Chanchaga Local Government Area. Traffic and transportation problem in Minna capital city of Niger State have become grave matters of concern to the government. A strategic planning of transport systems will alleviate these problems to a greater extent. Transportation planning process consists of analysis of interaction between supply in the form of existing facilities and the demand in the form of traffic load. It also involves forecasting for the future and evaluation of the alternatives arrived at the planning stage (Garba, 2002).

The fact is that Minna is presently experiencing rapid urban growth. Both the authorities and citizens seem to simply ignore this and its impact on transportation. High population density, the bumps put by people of that area, narrow route, high vehicular movement at the peak hours because of the schools located in that route, hawkers along the route, motor parks along the route, road works, as well as trucks and vehicle stopping by the road side to offload goods are all causes of traffic congestion in that route.

The effects of these are parking problems, long delays to and from work, less productivity from employees, accident due to frustration or anger due to traffic jams, pollution as a result of car emission, and less attractive place to live. This research seeks to find out possible solutions for solving the traffic congestion of this area.

The aim of the research is to solve the problem of traffic congestion at Kpakungu. The objectives include: (1) mapping out the existing road network within and around Kpakungu area in Minna (2) obtaining the geospatial related attribute information, such as road name, road network, traffic volume, etc. for each of the roads (3) using satellite image to map out the congestion area (4) finding alternative route to take in order to bypass traffic congestion on the major road.

1.1. Overview of Geographic Information System in routing

Longley *et al.* (2001) view GIS from viewpoints of professionals and what they can do with the tool. In succinct form, a GIS is an integrated system for handling and analyzing geographic data. The power of a GIS lies in its ability to bring both spatial and attribute data within a common framework to form a unified database system; and its ability to compare different entities based on their common geographic occurrence through the overlay process.

Ogunbodede (2011) explained that GIS is a tool that can be used to sustain an endurable flow of traffic in urban environment, provided it is built on a properly designed database, which must also be amenable to constant updating.

Ammar *et al*. (2011) examined the value of real-time traffic information gathered through GIS for achieving an optimal vehicle routing within a dynamically stochastic transportation network. These features will help users and vehicle drivers in improving their service levels and productivity as the web application enables them to interactively find the optimal path to reach their destinations**.**

Mukti *et al*. (2011) developed a GIS based model with an objective of minimizing travel distance and travel time of users. GIS provides a powerful, logical, and intuitive means to store, manipulate, and retrieve data. In addition to promoting linkage between various types of data and maps GIS is able to manipulate and visually display numerous types of data for easy comprehension. GIS is a tool for managing and processing location and related information. It visually displays the results of analyses thus enabling sophisticated analysis and quick travel distance and travel time of users (Rodrigue *et al*., 2006).

Dynamic data relevant to route performance including details such as current traffic flow or speed, weather, road surface conditions and variations in road usage patterns due to events such as accidents, road maintenance or sports fixtures should be provided to emergency service providers (Harrington and Cahill, 2004). This database and GIS together can be helpful in finding the accidents on the road network and the shortest and fastest route to the accident site.

GIS based transportation data is collected from different sources such as GPS, topography, photos, remote sensors, etc. When GIS is applied to transportation, this is more than just a sphere of application of their generic functionality (Thill, 2000). GIS is used for modeling of road networks offering algorithms to analyze and find the shortest or minimum route through a network. GIS can be used to calculate distance, set locations and assign demand to sites. Street addresses can be converted to map coordinates (address Geocoding) (Golderg, 2011).

GIS is mostly employed today in operational research as a one way data feeder for mathematical models (Erkut *et al*., 2001) and successfully provides distance and time for their emergency services districting and location problems.

A graphical user interface allows displaying and manipulating graphical objects; data storage and processing allows an eased interaction with the mathematical optimizer. However, the efficiency of a combined use of GIS, GPS, and a modelling language relies on the capacity to handle the huge amount of data related problem (Fabien *et al.*, 2005).

Various forecasting methods including historical profile approaches, neutral networks, non-time series models, traffic assignment models are being developed by researchers of intelligent transportation system (ITS). One of the critical elements of intelligent transportation system (ITS) is forecasting the travel time.

Although network analysis in GIS has been largely limited to the simplest routing functions, the recent past has seen the development of object oriented data structures, the introduction of dynamic networks (Sutton and Wyman, 2000), the ability to generate multi-modal networks, and the use of simulation methods to generate solutions to network problems. Some network flow modeling functions have also been implemented, although there are substantial opportunities for additional theoretical advances and diversified application.

2.0. Materials and Methods

2.1. Study area

The study area is Minna, which is the capital of Niger State. It lies between Latitude 9º 33' N and 9º 40' N and Longitude 6º 29' E and 6º 35' E. Minna lies on a valley bed (i.e. lowland) bordered to the east by Paida hill stretching eastwards toward Maitumbi and northwards to Maikunkele village. To the west and the southward is highland, with an area essentially savanna and quite conducive for farming. It has a distinct wet season as well as dry season.

2.2. Data acquisition

Data acquisition is the process of data gathering. This process involves the use of high resolution remote sensing images in analyzing, and mapping out the existing road network within the study area. The field survey aspects involved measuring of road parameters, traffic count; coordinates captured were also taken, with this computer assisted surveying method the quality and integrity as well as the completeness of the data are ensured. Verbal interview was adapted to capture relevant attribute data from commuters, and transporters and other well-placed citizens in areas of implementation. For the purpose of this study, a street guide map of Minna and High Resolution Satellite Imagery of Minna were used.

The positions in terms of spatial data *x* and *y* coordinates of the map were taken before on-screen scanning and digitization in order to provide spatial information about the project area. In this study, two types of data were captured.

In Geographic Information System (GIS), there is wide variety of data sources, though all fall into two categories of primary and secondary data. Data used in the Geographic Information system are primary in nature. Quick Bird image with 0.6m resolution was acquired from GIS Vendor; traffic counts data were collected during the field survey.

Satellite image was acquired to aid in digitizing the road network of the study area. The QuickBird satellite is a high-resolution satellite operated by space imaging. This satellite image was used because of its high level of accuracy in mapping. Its capabilities include capturing a 3.2m multispectral, near infrared (NIR)/0.82 panchromatic resolutions at nadir. It can yield relevant data for transportation study.

It is essential to convert spatial and attribute data collection into a form which can be used for a geographic information system (GIS) where it is not in that format. Analogue maps, aerial photos and satellite imageries have to be converted into digital forms before they can be used; this can be achieved using GIS software and can be carried out in two ways - tablet and on-screen digitization. In this study ArcGIS 9.3 was used for digitizing, and analysis.

To ensure accuracy and certain level of precision, points that are identifiable on the QuickBird images acquired were selected for image geo-referencing. A minimum of four (4) ground control points were selected for the geo-referencing. The ground control point's readings were taken using hand held global positioning system (GPS) receiver (Garmin 12xs). These points were used to geo-reference the satellite image in readiness for digitization. The images were geo-referenced using Minna street guide map with its coordinates. The map was produced by the process popularly known as map-to-spatial data registration.

Tablet or manual digitizing was used for map encoding where it is important to reflect the topology of features since information about the direction of line feature can be included. The digitizing tablet senses *X* and *Y* position of the puck as the feature of the map placed on the digitizing tablet are traced and communicate these to digitizing software. Most digitizing software allows the "user" register the map on the digitizing tablet. This process establishes the relationship between the tablets coordinates system and the coordinate system of the paper map. The software compares the tablet coordinates and the map coordinates for a set of control points and then derives a best-fit translation function. This translation function is then applied to all the coordinates sent from the tablet to the software.

3.0. Results and Discussion

Road network map of the study area was produced using a high resolution satellite imagery of Minna. Analysis of Road Traffic Network of Kpakungu was developed showing the positioning of the major roads within and around the study area, to obtain road related attribute data and produce an alternative route in an event of traffic congestion. Geographical Information System adopted was very relevant in this analysis. The High Resolution Satellite Imagery of Minna used made it very easy to digitize the existing road network of Minna and was later used for proposing an alternative road. Road Network of Minna was digitized and labelled accordingly (Figure 1).

Field survey was carried out in the study area to collect related attribute information about traffic congestion in the area; traffic count was carried out at peak and off peak periods. Four major roads were focused on in the study, section "A" are vehicles coming to Kpakungu from various places like Bosso, Dutsen Kura, Maitumbi, Kateren Gwari, Fadikpe. Section "B" are vehicles coming to Kpakungu from Chanchaga, Tunga, Sauka-kahuta and Barikin-Sale and section "C" are vehicles going towards Bida Road. The traffic count was carried out at different periods. The first period was in the morning between 7am to 10am and the second period was between 4pm to 7pm.

3.1. Use of satellite imagery to map out congestion area in Kpakungu

Analysis from the field survey and statistical analysis have shown the high number of motorcycles (Okada), taxis and private cars that ply the roads. This was complimented with GIS analysis to produce congestion area map of the study area. The satellite imagery of the study area (Kpakungu) is shown in Figure 2 and traffic congestion area map in Figure 3.

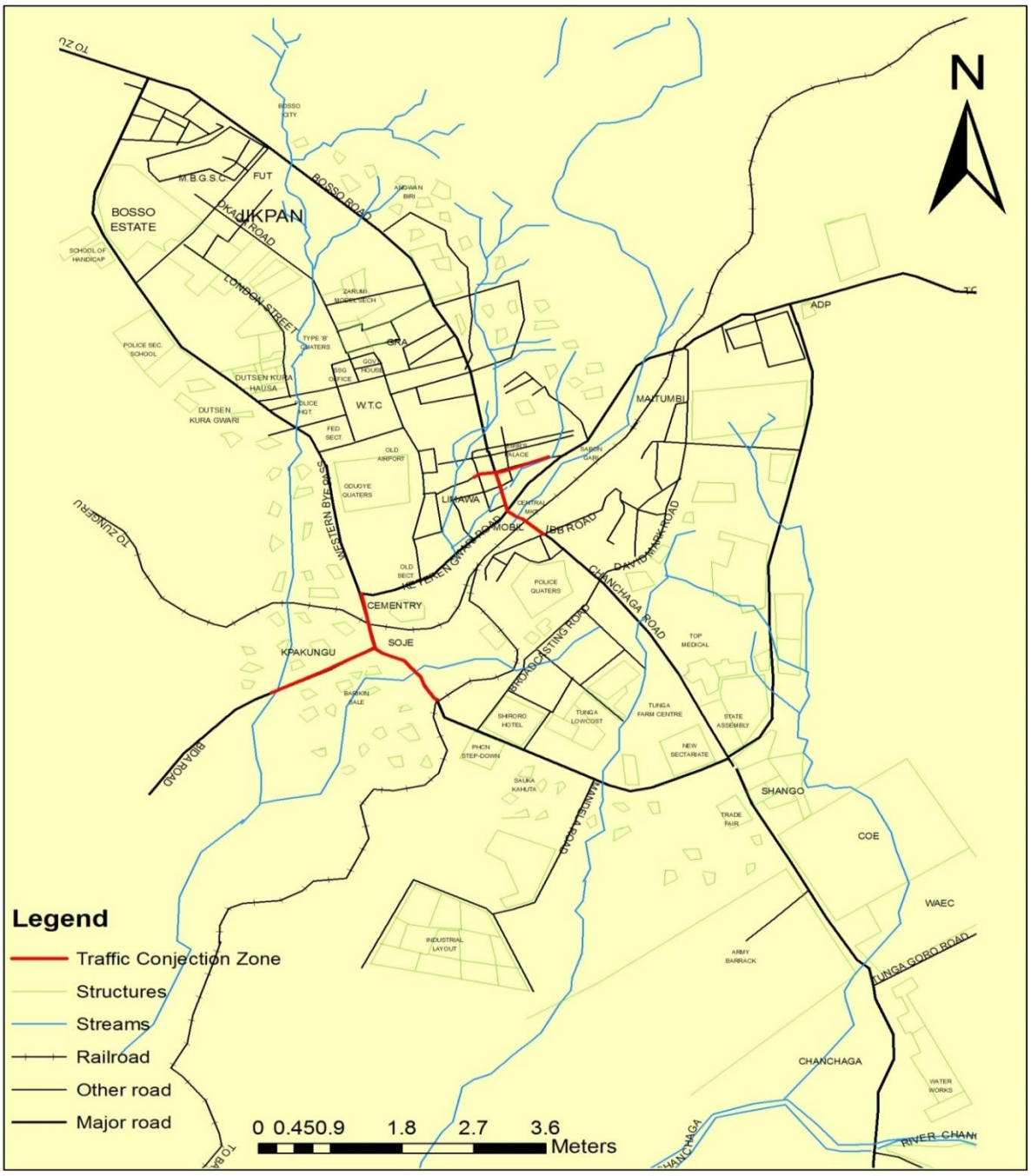

Figure 1: Digitized road network map of Minna

Figure 2: Satellite imagery of Kpakungu

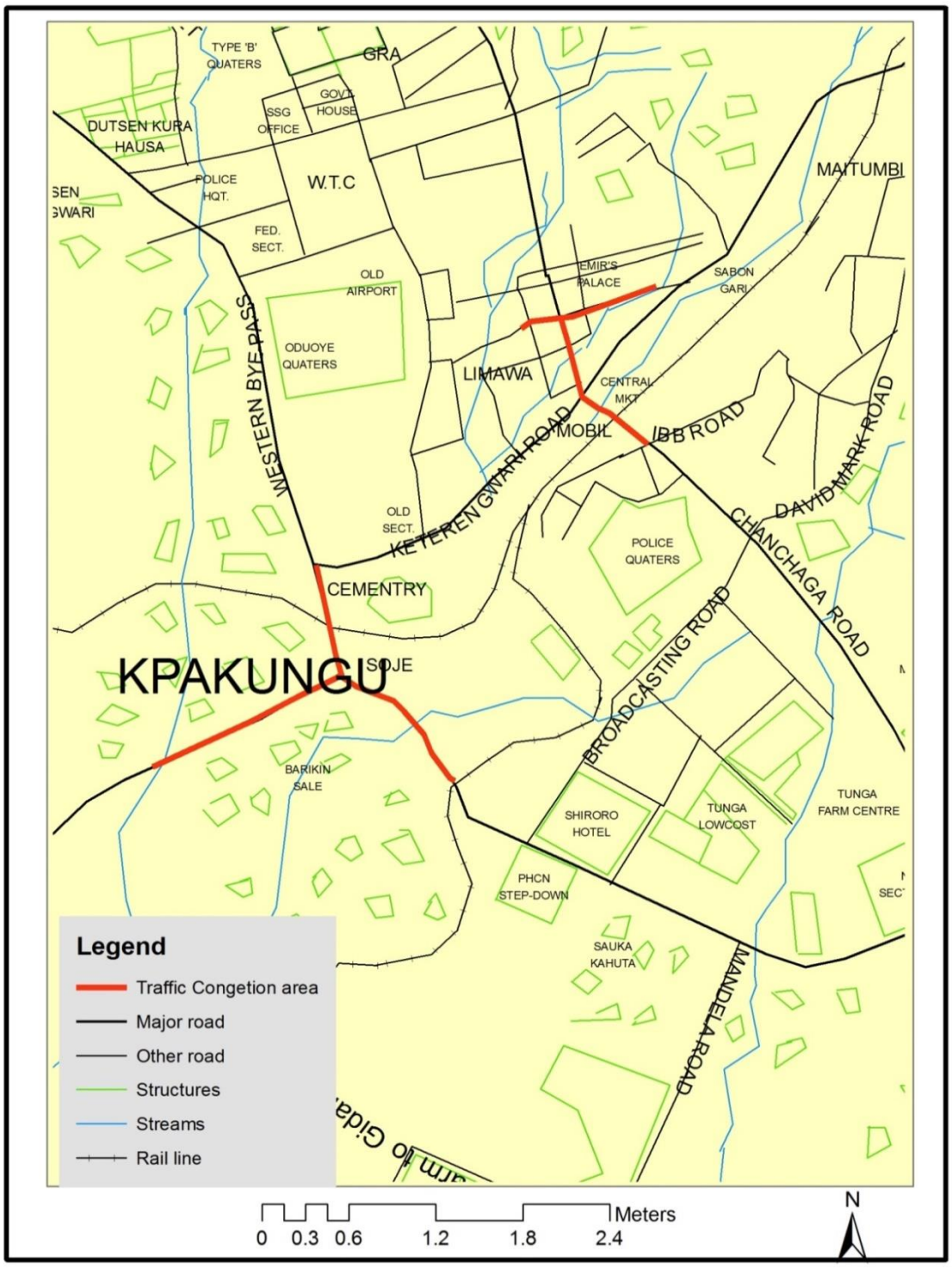

Figure 3: Traffic congestion map of Kpakungu

3.2. Alternative route to take in order to bypass traffic congestion at Kpakungu (alternative routes)

In proposing an alternative route to ply by different vehicles to reduce the pressure of traffic congestion in Kpakungu, field survey was carried out in selection and mapping of new roads in the area. GPS was used to track new route that can serve as an alternative route in order to reduce the pressure of traffic along Kpakungu road. The first alternative tracking was carried out from Aliyu Maiyaki Street opposite the Central Market to Gbeganu in order to reduce the traffic of vehicles coming from Bosso and Dutsen Kura going to Gidan Kwanu or Bida as well as NECO office (Table 1). The second was from Keteren Gwari Roundabout to reduce pressure of vehicles coming from

Maitumbi and Minna Central going to Bida road (Table 2) and the third was from Industrial layout road (Talba Farm) to reduce traffic coming from Chanchaga going to Gidan Kwanu or Bida (Table 3). Alternative route was mapped out through the high resolution satellite map of the study area.

Table 1: GPS tracking coordinates of first alternative route (Aliyu Maiyaki Street to Gbeganu)

S/N	Latitude	Longitude
1	09º 35' 37.2''	006º 31' 11.5''
2	09º 35' 47.7''	006º 31' 07.3''
3	09º 36' 03.14''	006º 31' 06.3''
4	09º 36' 03.7''	006º 31' 06.9''
5	09º 36' 22.4''	006º 31' 06.3''
6	09º 36' 22.0''	006º 31' 07.5''
7	09º 36' 39.3''	006º 31' 05.1''
8	09º 36' 41.3''	006º 31' 05.5''
9	09º 36' 44.6''	006º 31' 08.8''
10	09º 37' 03.9''	006º 31' 12.1''
11	09º 37' 06.2''	006º 31' 13.9''
12	09º 37' 08.0''	006º 31' 14.6''
13	09º 37' 09.1''	006º 31' 14.9''

Source: Field survey, 2016

Table 2: GPS tracking coordinates of second alternative route (Ketren Gwari roundabout to Nice Travel Bida Road)

S/N	Latitude	Longitude
1	09º 35' 47.6''	006º 31' 45.1''
2	09º 35' 53.0''	006º 31' 38.4''
3	09º 35' 59.7''	006º 31' 35.5''
4	09º 36' 01.7''	006º 31' 34.3''
5	09º 36' 04.6''	006º 31' 33.7''
6	09º 36' 05.5''	006º 31' 34.7''
7	09º 36' 10.2''	006º 31' 35.9''
8	09º 36' 06.7''	006º 31' 39.0''
9	09º 36' 07.2''	006º 31' 43.9''
10	09º 36' 06.1''	006º 31' 47.0''
11	09º 36' 06.1''	006º 31' 48.0''
12	09º 36' 05.4''	006º 31' 50.9''
13	09º 36' 02.1''	006º 31' 53.2''

Source: Field survey, 2016

Table 3: GPS tracking coordinates of third alternative route (Industrial layout road to Gidan Kwanu)

S/N	Latitude	Longitude
1	09º 34' 15.0''	006º 33' 11.2''
2	09º 34' 34.9''	006º 33' 03.7''
3	09º 34' 23.9''	006º 32' 56.5''
4	09º 34' 02.0''	006º 32' 45.3''
5	09º 33' 55.8''	006º 32' 29.7''
6	09º 34' 14.2''	006º 32' 00.9''
7	09º 33' 59.4''	006º 31' 51.8''
8	09º 33' 54.7''	006º 31' 42.5''
9	09º 33' 47.6''	006º 31' 32.7''
10	09º 33' 41.5''	006º 31' 24.2''
11	09º 33' 24.8''	006º 31' 01.8''
12	09º 33' 04.1''	006º 30' 34.4''
13	09º 32' 57.7''	006º 30' 31.3''

Source: Field survey, 2016

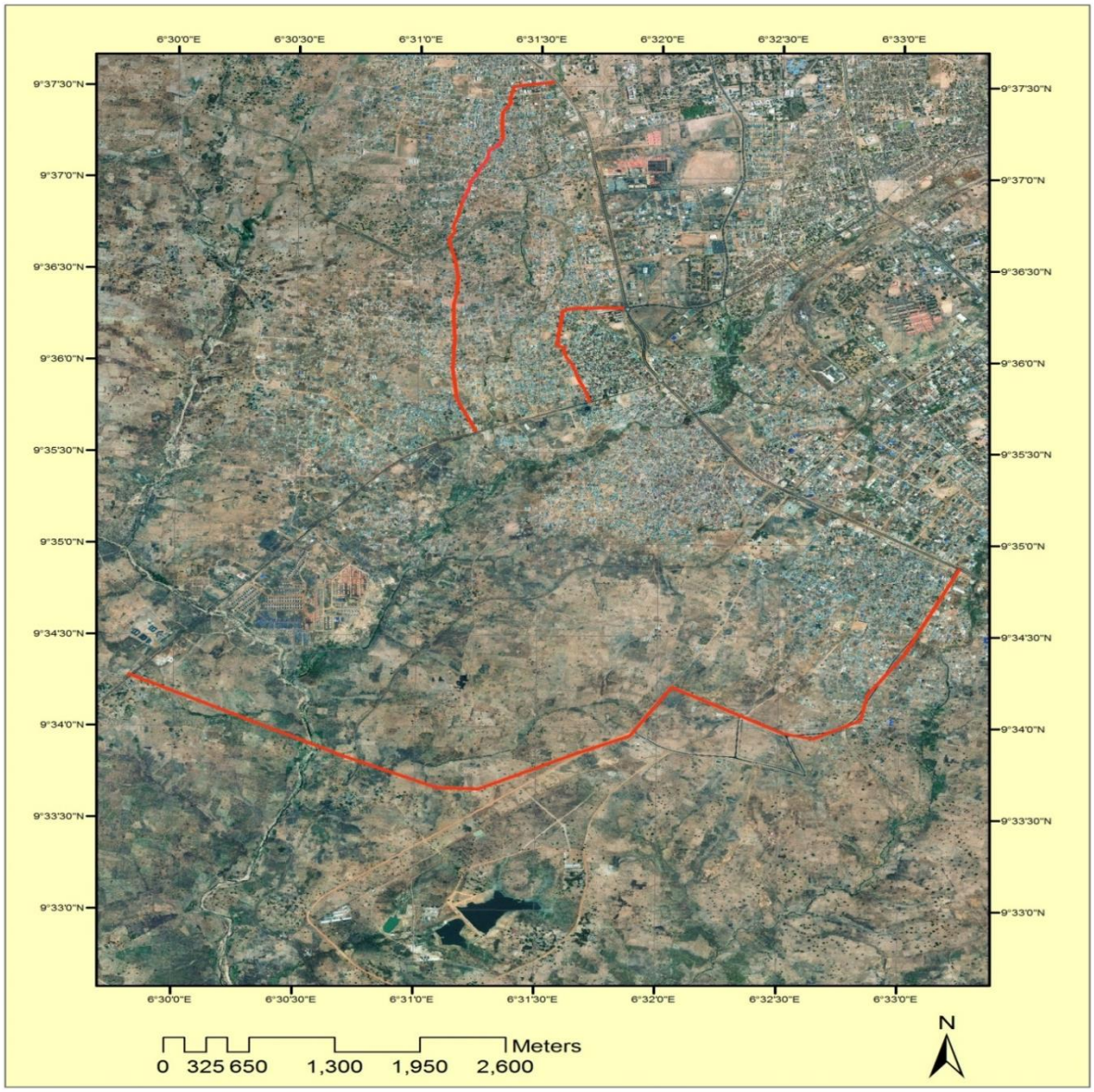

Figure 4: Satellite imagery showing the three proposed alternative routes

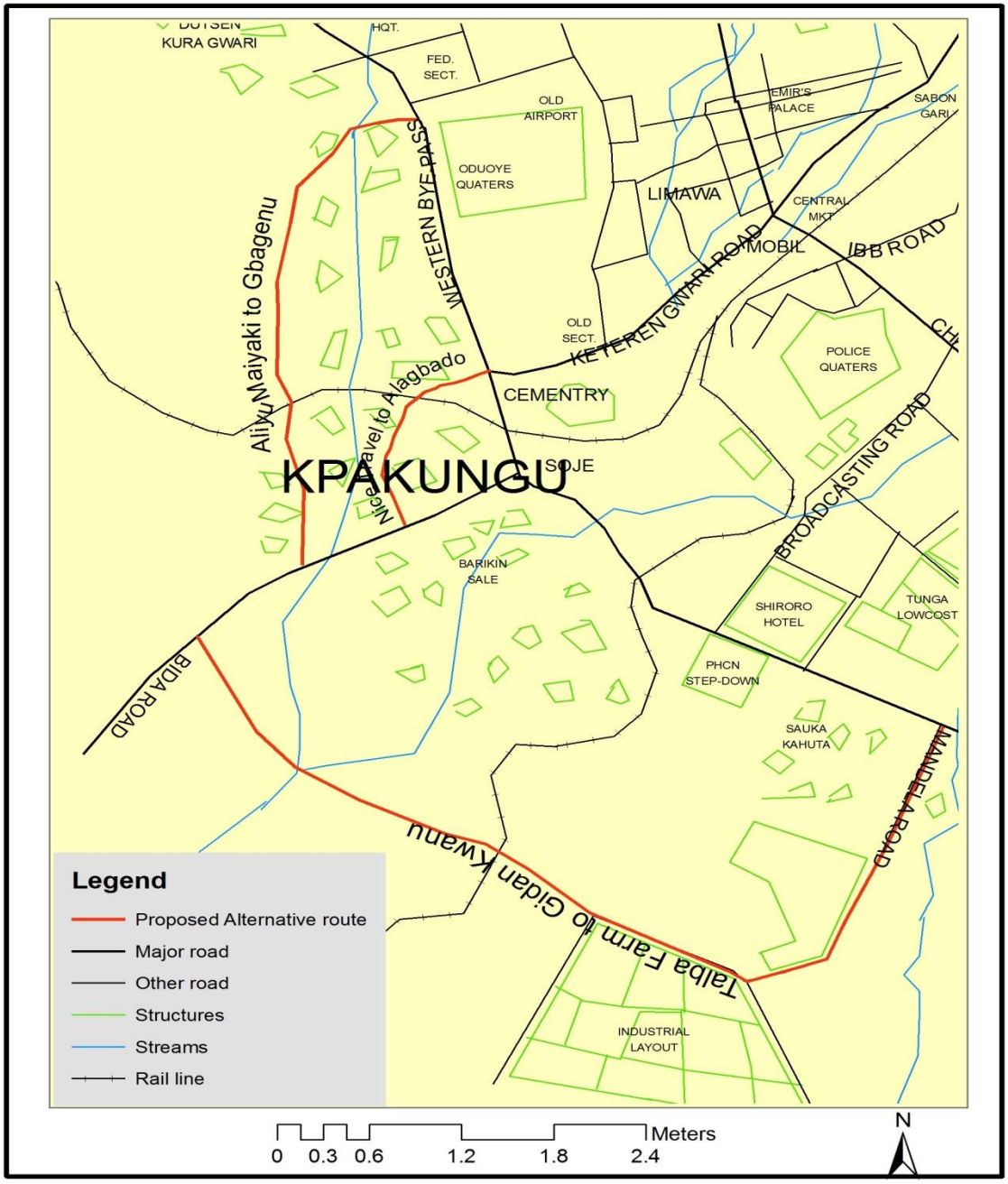

Figure 5: Digitized proposed alternative routes

It was also discovered that the causes of the traffic pressure in the study area was as a result of the relocation of FUT to its permanent site in Gidan Kwanu and the relocation of NECO Headquarter. Majority of the traffic pressure in the area are as a result of vehicles coming from Maikunkele, Bosso, Maitumbi, Minna central, Dutsen Kura, Chanchaga, Tunga, Sahuka-kahuta and Barikin-sale going to Bida, Gidan-Kwanu or NECO office.

4.0 Conclusion

Road traffic volumetric and spatial traffic distributions in Kpakungu have been studied to ascertain the road networking system of the area. GIS technique used was very useful to generate the road network of the study area. The importance of this research work is to map out the road network, identify congestion area and propose an alternative route to reduce congestion on the road.

The analysis was interpreted to compute the volume of vehicles on the road network at the time of data acquisition and the possible ways to avoid overcrowding (traffic congestion) of cars in the area. Manual traffic count was carried out in Kpakungu for ground truthing and to make available first-hand information by creating geo-spatial attribute of traffic situation in Kpakungu.

It was also gathered that traffic congestion in the study area was as a result of the poor intercity road network, people going to Bida road like NECO Office, FUT Gidan Kwanu from Maikunkele, Bosso, Dutsen Kura, Minna central, Maitumbi, Chanchaga from any part of Minna must pass through the study area (Kpakungu Roundabout) which makes the place to be more congested. An alternative route need to be made available for people coming from Chanchaga to bypass the roundabout, as well as people coming from Bosso to have an alternative and people within Minna central area should also have an alternative in order to reduce the congestion on the road.

Based on the results of this study, the following recommendations are made:

i. The relevant authorities concerned with management of road and traffic control should be computerized to facilitate the use of geospatial data.
ii. The government should make the Bida road a dual carriage road by expanding the road.
iii. Geoinforrmatics techniques should be adopted in traffic control and planning.
iv. A map showing the available road network should be produced and updated to make research like this easier.

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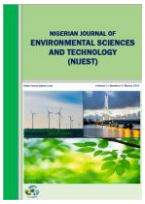

Gully Erosion Problems in Selected Areas of Edo State: Factors and Control

Kayode-Ojo N.[1,]*, Ikhide A. O.[2] and Ehiorobo J. O.[3]

[1,2,3]Department of Civil Engineering, University of Benin, Benin City, Edo State, Nigeria

Corresponding Author: *engrngozi@yahoo.com

ABSTRACT

Gully erosion is a serious ecological problem in Edo State and has negative impact on agricultural productivity, lives and properties in both urban and rural environments. This paper therefore aims at identifying factors contributing to the formation of gullies and methods of controlling them so that further environmental degradation would be averted. Three gully sites were selected from the three geo-political zones of the State. Data were collected through remote sensing, field topographical survey and soil sampling on gully walls and gully beds. Meteorological and hydrological data were also collected. Slope stability analysis was also carried out. The Kerby-Kirpich equation was applied to estimate the overall time of concentration and Rational formula used to determine the peak discharge. The study revealed that the selected study areas possess all the characteristics of an erosion prone area which are: rainfall of very high intensity, steep slopes resulting in large runoff and soil with low organic content and relatively low shear strength obtained from the geotechnical investigations. Results from the studies revealed that the gully width and depth varied considerably from top to bottom. The cross section shows that the gully is U-shaped for Ekehuan gully and V-shaped for Auchi and Ewu gullies, indicating a large catchment area and a large volume of discharge passing through the gully.

Keywords: Gully erosion, Topographical survey, Meteorological survey, Hydrological survey, Slope stability

1.0. Introduction

Gully erosion is caused when runoff concentrates and flows at a velocity sufficient to detach and transport soil particles. A waterfall may form, with runoff picking up energy as it plunges over the gully head. Splash back at the base of the gully head erodes the subsoil and the gully eats its way up the slope (Bruce, 2006).

Urban degradation is drawing concern in Edo state, it has been estimated that land loss due to gully erosion, sheet - rill erosions constitute about 5% of degraded land. High land use pressure as a result of increasing migration of population to urban areas renders the landscape more vulnerable to gully erosion. Many of the gullies within urban landscape in Edo State were formed mainly as a result of improper termination of drains and water courses. A major cause of gully erosion in the study area is roads constructed with inappropriately terminated drainage network. While damages by surface runoff to the roads may be limited, offsite effects can be severe (Ehiorobo and Izinyon, 2011).

The road is said to induce a concentration of surface runoff with a concentrated diversion of concentrated runoff to other catchment and an increase in catchment size enhances gully development after road construction (Nyssen *et al.*, 2002). Changes in drainage pattern associated with urbanization result in gullying particularly where illegal settlement without urban infrastructure exist (Ehiorobo and Izinyon, 2012). One of the most basic but non-renewable resource is soil and once lost, is difficult and costly to replace within near future. Gully processes are usually the main sources of sedimentation (Hum *et al.*, 2005). Research carried out by various researchers have shown that gully erosion represents one of the most soil degradation process in Nigeria as it causes considerable soil

loss, and produces large volume of sediment. Gullies are also catalyst for transferring surface runoff and sediment from upland to valley floors and creating up channels that aggravate the problem of flooding and water pollution. Many cases of damages to water courses and properties by runoff from agricultural land relate to the occurrence of gully erosion (Verstraeten and Poesen, 1999; Boardman, 2001; Poesen *et al.*, 2003).

By the day, gully erosion has attained a larger and devastating dimension in Edo state that has attracted international interventions. All the senatorial districts in the state have their fair share of the problem. In Edo south, the main gully erosion sites are; Queen Ede, West moat Ekehuan Road, University of Benin (Ugbowo campus) and Costain. In Edo North, the main gully sites are; Auchi gully complex and Ikabigbo gully while the main gully sites in Edo Central are; Ewu gully and Ibore gully. The aim of this research work is to identify factors contributing to the formation of gullies and methods of controlling them so that further environmental degradation would be averted.

2.0. Materials and Methods

2.1. Description of study area

Edo State is located in the south-south zone of Nigeria between Latitude 5°44'60"N to 7°33'45"N and Longitude 5°05'45"E to 6°38'18"E (see Figure 1). It covers an area of about 19,853 km^2. The State is made up of 18 local government areas (LGAs) and a total population of 3,233,366 (based on the 2006 National Population census).

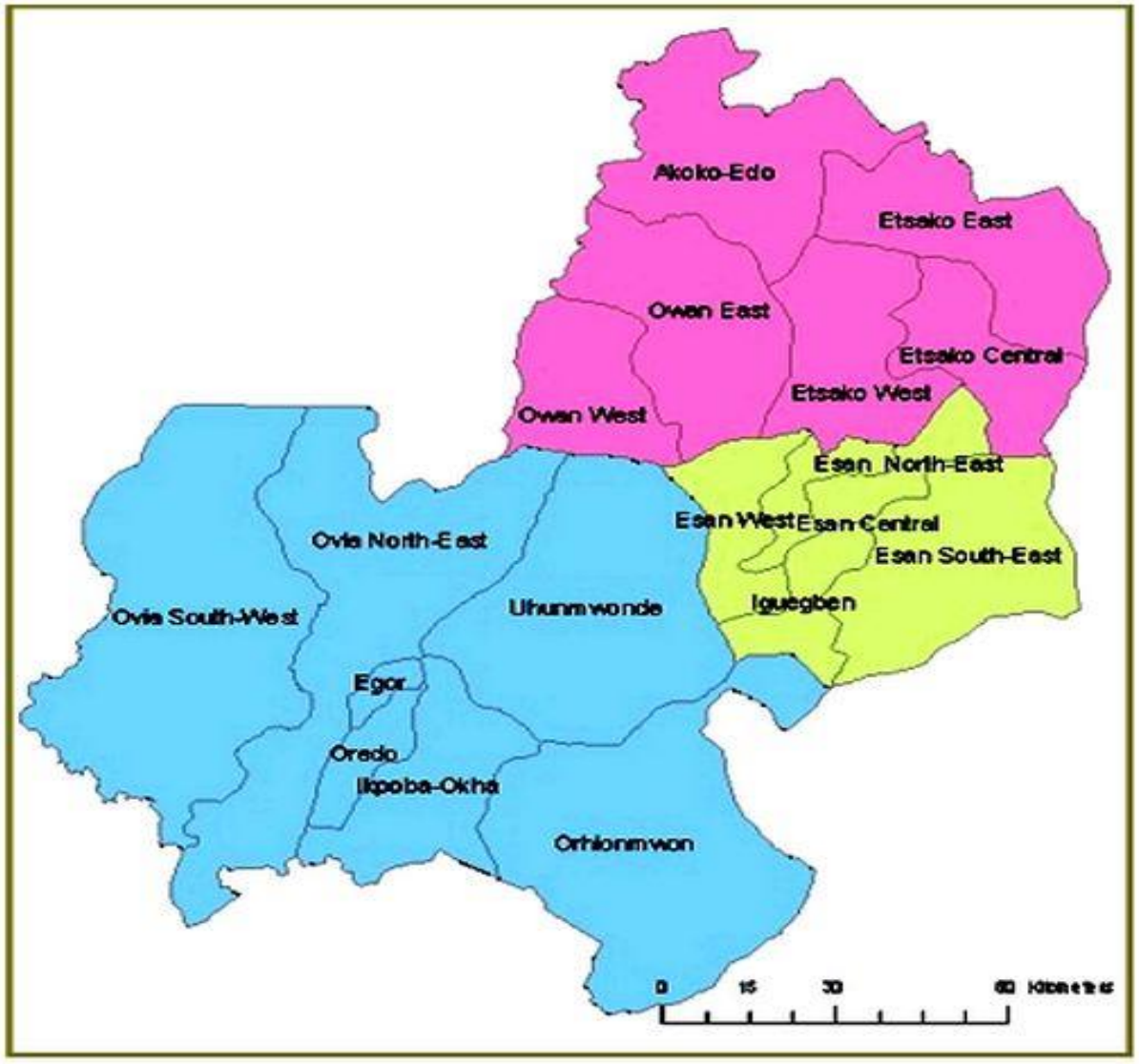

Figure 1: Map of Edo State showing the 18 Local Government Areas (www.nigerianmuse.com)

The region has a low land of roughly 16,992 km^2 and high land of approximately 1,586 km^2 (Fabiyi *et al.*, 2012). Basically, the topography of the State consists of a rugged high land in the north which extended down to the central part of the region. The high land is dissected by a wide valley which stretches from the Niger River floodplain in the east to the western margin of the State. In the south, the topography is a gentle sloping plane that extends into Delta State (Asikhia and Nkeki, 2014).

2.2. Data collection

Edo state is divided into three senatorial zones; Edo South, Edo Central and Edo North. For the purpose of this study, one gully site was selected from each of the three senatorial zones. In the south; West Moat Ekehuan Road gully erosion site, Benin City, Egor Local Government Area was selected. In the central; Ewu gully erosion site in Esan Central Local Government Area was selected. In the north; Auchi gully complex in Etsako West Local Government Area was selected. For the collection of data for the above selected gully sites, the following methods were adopted.

2.2.1. Reconnaissance survey

Desk studies for the evaluation of topographical maps, satellite images and other data collected from Edo State Ministry of Environment and Sustainability to determine the erosion devastated area along the flood routes, erosion gullies, direction of storm runoff, etc. as well as field reconnaissance and in-depth site appraisal.

2.2.2. Topographical survey

Here, ground survey is carried out and this involves the determination of the gully elevation, profile, longitudinal and transverse sections at a regular interval not more than 25m, catchment area, and the gully dimensions using Total Station.

2.2.3. Collection and analysis of meteorological data

Rainfall data as provided by the Nigerian Meteorological Agency was analyzed to determine the Rainfall Intensity (mm/hr), Rainfall Duration (how many hours it rained at that intensity) and Rainfall Frequency (how often that rain storm repeats itself).

2.2.4. Geotechnical investigations

Here the geotechnical condition of the gully sites was studied, sampling (disturbed and undisturbed) was carried out to determine soil properties and assess foundation condition. The soil investigations that were conducted are Particle Size Analysis, Specific Gravity Test, Natural Moisture Content, Atterberg Limit Test, Compaction Test, Undrained Triaxial Test, and Shear Box Test and California Bearing Ratio (CBR) test. All the laboratory tests were conducted in accordance with the general specification given in the British Standard Specifications B.S 1377: 1975; - "Method of Testing Soils for Civil Engineering Purposes" and American Standard Testing Method (ASTM) and also Unified Soil Classification System (USCS).

2.2.5. Hydrological studies

This involves the generation of a safe design runoff rate. The factors involved in this are mainly rainfall and watershed characteristics. The rainfall characteristics are the rainfall amount, intensity and its distribution pattern. Similarly, the watershed characteristics such as shape, size and land use pattern affects the runoff rate. The hydrological data obtained from Nigerian Meteorological Agency was used for this analysis. To account for the extreme climatic variability in the future due to climate change (analyzing the worst case scenario), a 20% increase in rainfall was assumed to occur using the historical data set (FEWS NET, Nigeria Special Report, June 1, 2016).

3.0. Results and Discussion

3.1. West Moat Ekehuan Road Gully

This study was conducted at West Moat Ekehuan road gully, Egor Local Government Area of Benin city, Edo State. The gully is located at geographical co-ordinates N06°19'43.07" and E05°35'24.24" as shown in Figure 2.

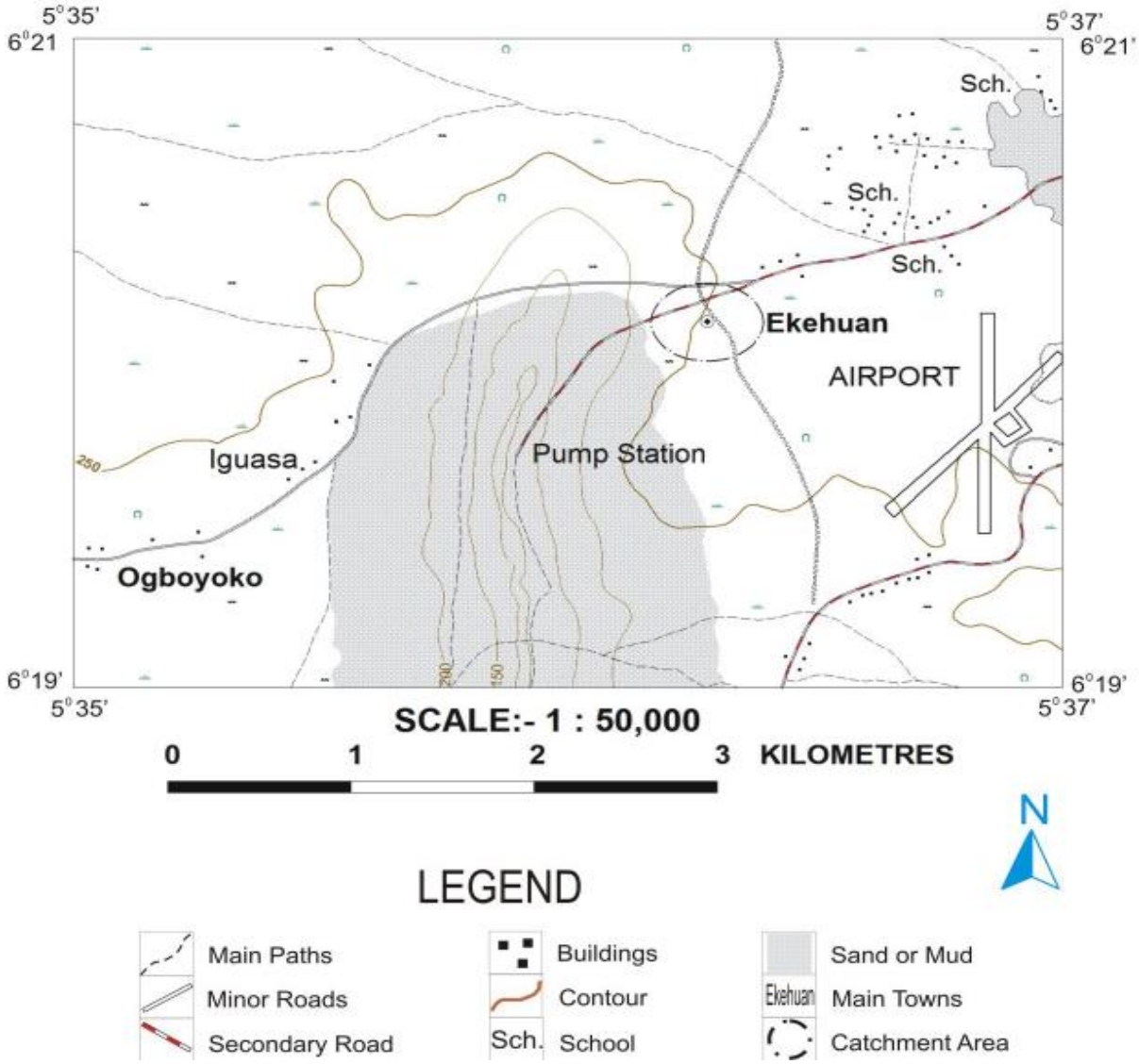

Figure 2: Location Map of Ekehuan Delineated from the Federal Ministry of Lands and Housing (1989)

The gully problem in this area started as a result of the inadequacy of the side drains along Ekehuan road and the diversion of all runoff from the slope running right through Ekehuan road from Agbomwonba through the University of Benin and end down to the culvert crossing the road into the current gully location. Originally, the current gully was a moat but as a result of excessive runoff into the moat channel, it started cutting both headways at the banks and floor. Recent efforts made by the State Government to control the gully by filling the head with boulders has not been successful as the storm runoff undermined the boulders cutting new gullies along the banks and eventual bank slumping and collapse of the walls occurred, particularly at the area around the wood factory (EDO NEWMAP, 2014).

3.1.1. Findings of the hydrological study (West Moat, Ekehuan Road Gully)
Table 1 shows the values derived from ArcView GIS for West Moat Ekehuan Road Gully Station for a 24-hour duration while the Rainfall Intensity-Duration-Frequency (IDF) curve is shown in Figure 3.

Table 1: West Moat Ekehuan Road Gully Station's value for 24-hour duration as derived from ArcView GIS

Return Period	100-Year	50-Year	25-Year	10-Year	5-Year	2-Year
Rainfall Intensity (mm/hour)	8.21	7.81	7.41	6.71	6.20	5.30

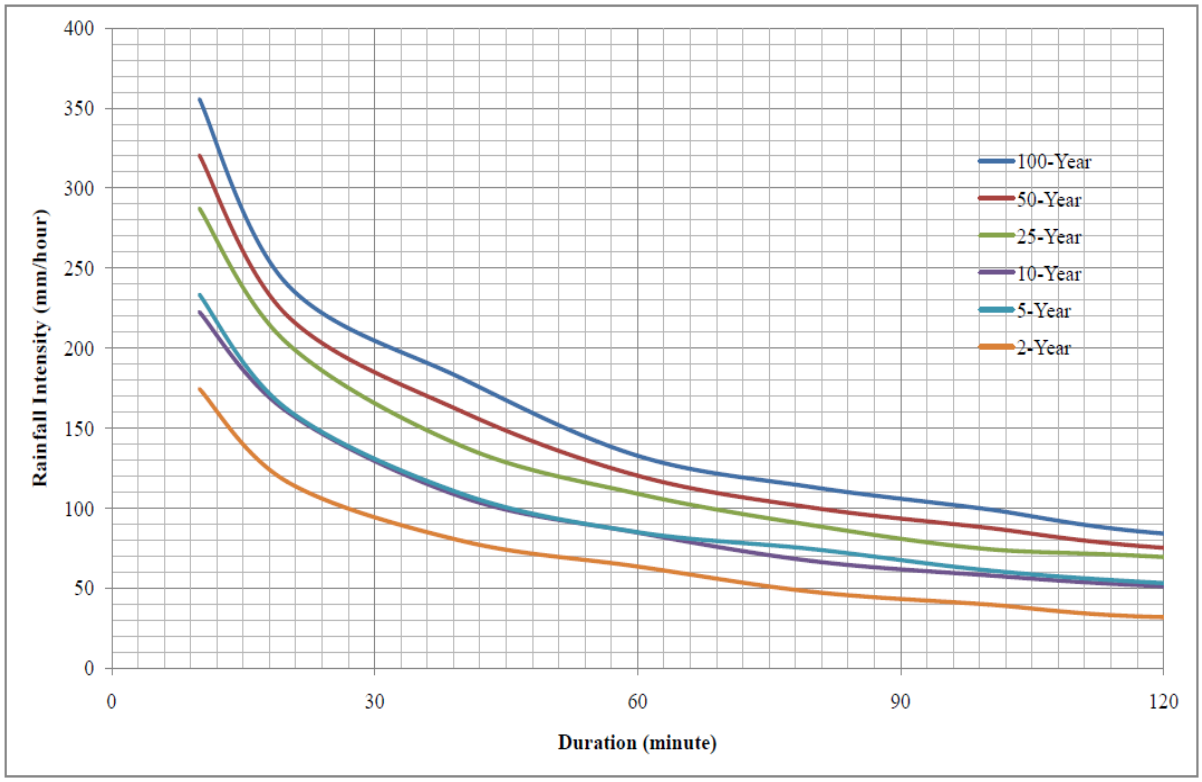

Figure 3: Developed rainfall intensity-duration-frequency curve for Ekehuan Road gully

According to the IDF curve, rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall duration in all return periods. The model (curve) predicted higher intensities within durations less than 30 minutes across the different return periods, which indicate a higher erosive power of the surface runoff during this period (duration) when compared to durations of 60 minutes, 90 minutes and 120 minutes. Rainfall intensities rise in parallel with the rainfall return periods.

The watershed/catchment area for Ekehuan road gully erosion site is about 176.19 ha at the gully head, about 201.60 ha at the middle of the gully, and about 439.10 ha at the outlet of the gully as shown in Figure 4.

Based on the findings of the hydrological studies, the cross section shows that the gully is U-shaped, indicating a large catchment area and a large volume of discharge passing through the gully. Also taking into consideration the size of the gully (length and depth), the continuation of the gully, the discharge of runoff and the size of the watershed/catchment area, it is described as a large discontinuous gully. The study also revealed that the study area possesses all the characteristics of an erosion prone area because of the high intensity of rainfall over the area.

3.1.2. Findings of the Geotechnical study (West Moat, Ekehuan Road Gully)
The results of the laboratory tests are shown in Table 2.

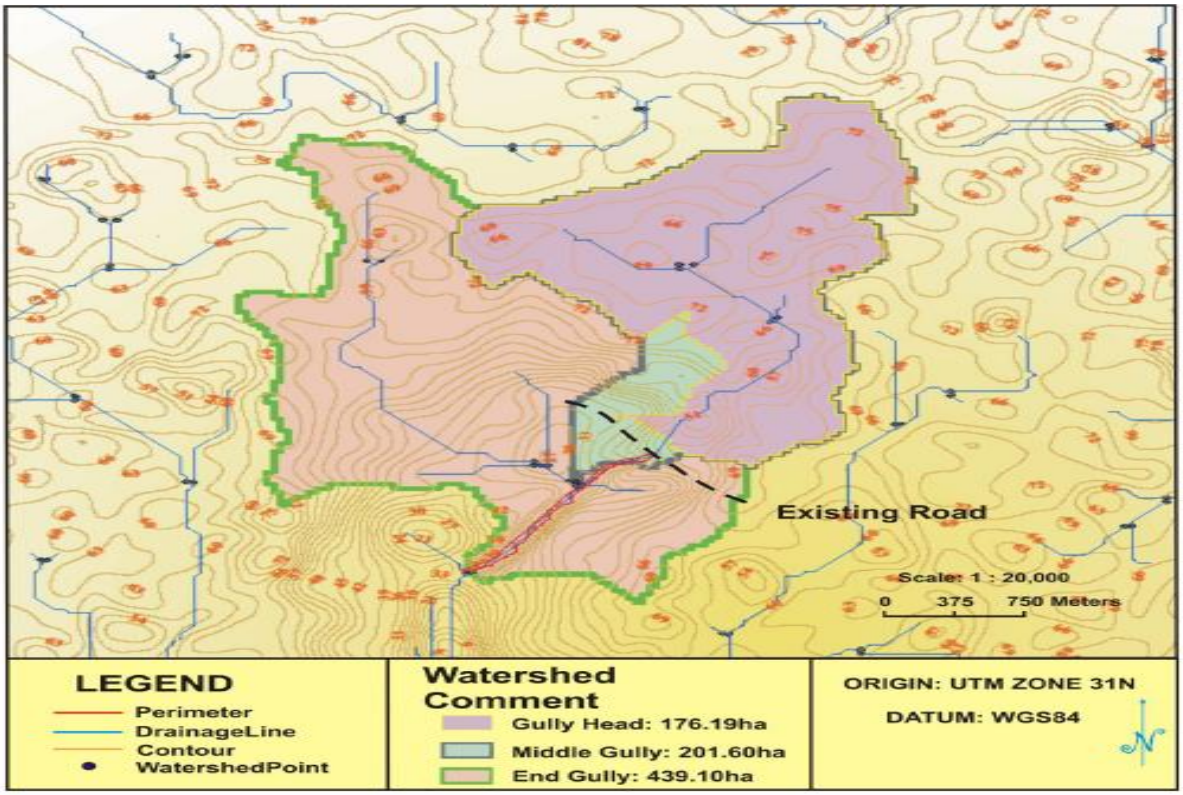

Figure 4: Catchment area delineation for Ekehuan (EDO NEWMAP, 2014)

Table 2: Soil test summary sheet

S/N	BH No	Specific Gravity	Percentage passing sieve			Atterberg limit test			MDD (g/cm^3)	OMC (%)	Compression		Shear strength	
			1.18 mm	0.425 mm	0.075 mm	LL (%)	PL (%)	PI (%)			C (kN/m^2)	Φ (°)	C (kPa)	Φ (°)
1	PT1	2.51	98	70	31	39	17	22	1.76	15	42	17.5	58	24
2	PT2	2.60	97	68	32	42	17	25	1.80	13	38	13	50	20
3	PT3	2.55	98	67	36	52	16	36	1.77	15	57	21	45	22
4	PT4	2.58	98	69	39	51	19	32	1.79	15	37	24.5		
Ave.		2.56	98	68	34	46	17	29	1.78	14	43.5	19	51	22

From the soil summary sheet, specific gravity of the soil samples ranged from 2.51 to 2.60 with an average of 2.56, indicating that the soil is sandy with a higher presence of porous particles. The liquid limit ranged from 39% to 52% with an average of 46%. The plastic limit ranged from 16% to 19% with an average of 17%, indicating that the soil is non-plastic. From the compaction properties of the soil conducted, it showed that the optimum moisture content ranged from 13% to 15% with an average of 14%, indicating the presence of clayey soil. The minimum plasticity showed that the soil has a tendency to be eroded by water. Therefore, in the period of the rainy season, the soil in the area is likely to be eroded; and this is usually the period of gully recession and bank slumping.

The maximum dry density ranged from $1.76g/cm^3$ to $1.80g/cm^3$ with an average of $1.78g/cm^3$. The soil sample showed cohesion that ranged from $38kN/m^2$ to $57kN/m^2$ with an average of $43.5kN/m^3$. The angle of internal friction ranged from 13° to 25° with an average of 19°, indicating that the soil is very loose. From the shear strength, the cohesion of the soil ranged from 45kPa to 58kPa with an average of 51kPa and the angle of internal friction (φ) value ranged from 20° to 24° with an average of 22°, indicating that the soil is soft-firm silty clay/clayey silt.

From the sieve analysis test conducted, see Figure 4.4, the percentage passing sieve No 1.18mm ranged from 97.24% to 98.07% with an average of 97.83%. The percentage passing sieve No 0.425mm ranged from 69.67% to 66.90% with an average of 68.30% while the percentage passing sieve 0.075mm ranged from 31.19% to 38.67% with an average of 34.46%. This indicates that the soil is silty or clayey sand. It is deduced that the soil(s) is fine grained with its drainage characteristics rated as fair to poor and also practically impervious. Based on the above results, using the unified soil

classification system, the soil lies above the "A line" in the plasticity index chart. Therefore, the soil sample can be classified as under Soil Group SM with the name, silty sands poorly graded and non-plastic. The result of the above assertions is that the soil has a tendency to be eroded by weathering agent mostly by water. Therefore, adequate control measures should be put in place to prevent further expansion of the gully.

3.2. Auchi gully complex

3.2.1. Findings of the hydrological study

Table 3 shows the values derived from ArcView GIS for Auchi gully site station for a 24-hour duration and the Rainfall Intensity-Duration-Frequency (IDF) curve is shown in Figure 5.

Table 3: Auchi gully site station's value for a 24-hour duration as derived from Arcview GIS

Return Period	100-Year	50-Year	25-Year	10-Year	5-Year	2-Year
Rainfall Intensity (mm/hour)	8.64	8.05	7.45	6.59	5.91	4.75

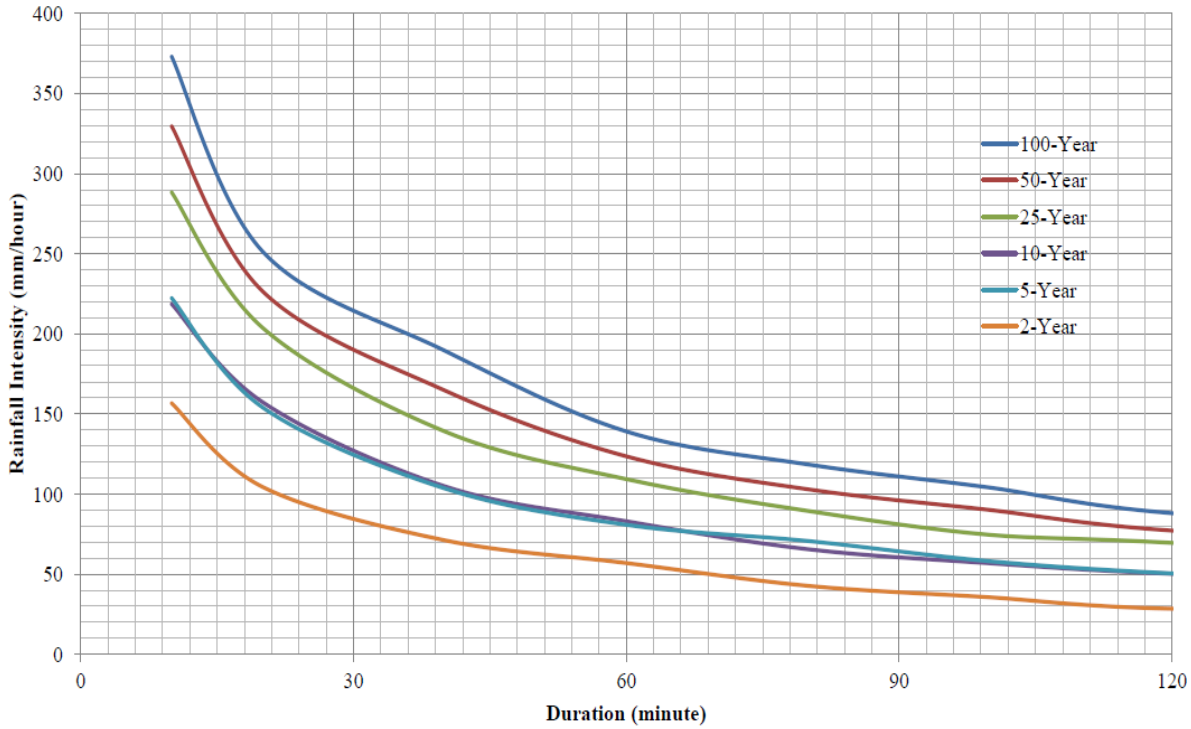

Figure 5: Developed rainfall intensity-duration-frequency (IDF) curve for Auchi

According to the IDF curve, rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall duration in all return periods. The model (curve) predicted higher intensities within durations less than 30 minutes across the different return periods which indicate a higher erosive power of the surface runoff during this period (duration) when compared to other durations e.g. 60 minutes, 90 minutes and 120 minutes.

The delineations of the catchments (to the head of the gully heads) are shown in Figure 6.

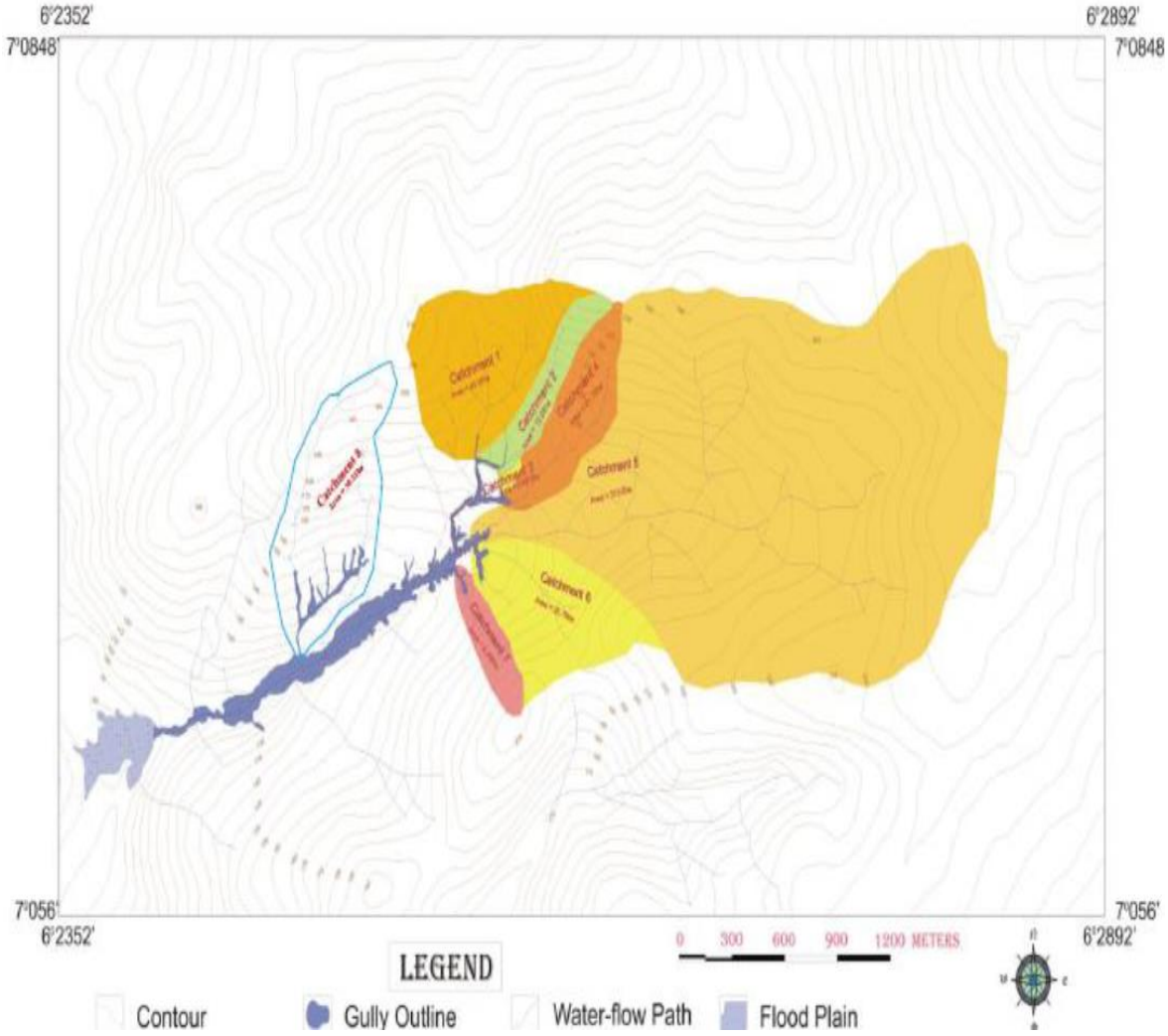

Figure 6: Catchment Area Delineation of Auchi Gullies (EDO NEWMAP, 2014)

Based on the findings of the hydrological studies, the cross section shows that the gully is V-shaped. Also taking into consideration the size of the gully (length and depth), the discharge of runoff and the size of the watershed/catchment area, it is described as a large gully. Also, due to the high intensity of rainfall over the area, it would be deduced that the study area possesses all the characteristics of an erosion prone area. Based on continuation, the Auchi gully complex can also be described as a continuous gully because it consists of many branched gullies.

3.2.2. Findings of the Geotechnical study (Auchi Gully Complex)

Table 4: Soil Test Summary Sheet

Sample No	Depth (m)	Sieve analysis Sieve size (mm) 2.360	1.180	0.212	0.150	0.125	0.075	NMC (%)	Specific Gravity G_s	Compaction OMC (%)	MDD (g/cm^3)
Sample A	0.00 – 3	99.98	98.99	19.60	6.33	4.09	1.43	13	2.61	10	1.90
Sample B	0.00 - 4	99.96	98.26	17.67	7.08	4.83	1.88	14	2.65	10	1.94

Physical observation of the gully cuts shows that the material is dry reddish fine silty sand underlain by whitish fine sand. The thickness of the fine silty sand varies from gully to gully. From the summary test sheet, it is deduced that the soil profile is loose and as such erodible. Auchi town is located in a rolling hill area and part of the town especially where gully erosion has occurred is a low lying pan with water flowing from north, south and east directions. The general soils of the area can be characterized as medium dense reddish silty sand (residual weathering product of an underlying sandy soil) underlain by fine whitish sand. At deeper location in the main gully, underlying shale was noticed. The gully materials are erodible and series of gullies were exacerbated by topography, high rainfall and manmade interferences.

3.2.3. Assessment of existing slope stability

Figures 7, 8 and 9 provide the findings of the slope stability analysis obtained from SLOPEW software.

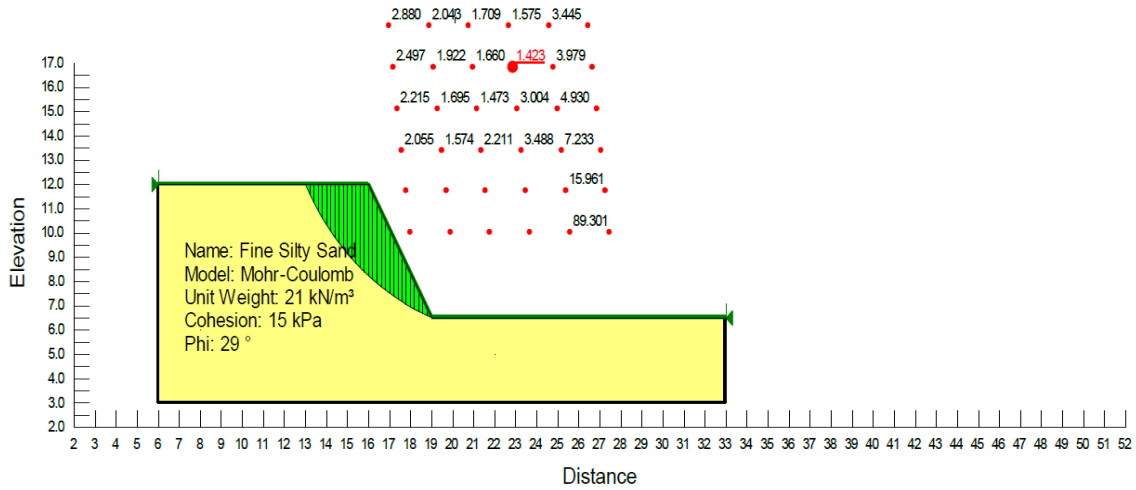

Figure 7: Slope stability analysis at 63^{o} at a height of 5.5m for cohesion of 15kPa.

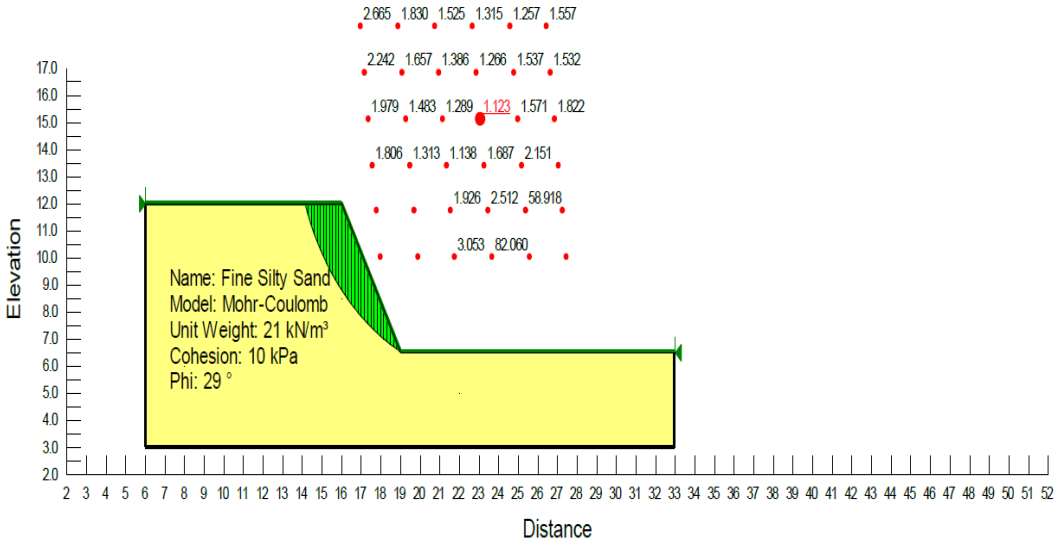

Figure 8: Slope stability analysis at 63^{o} at a height of 5.5m for cohesion of 10kPa

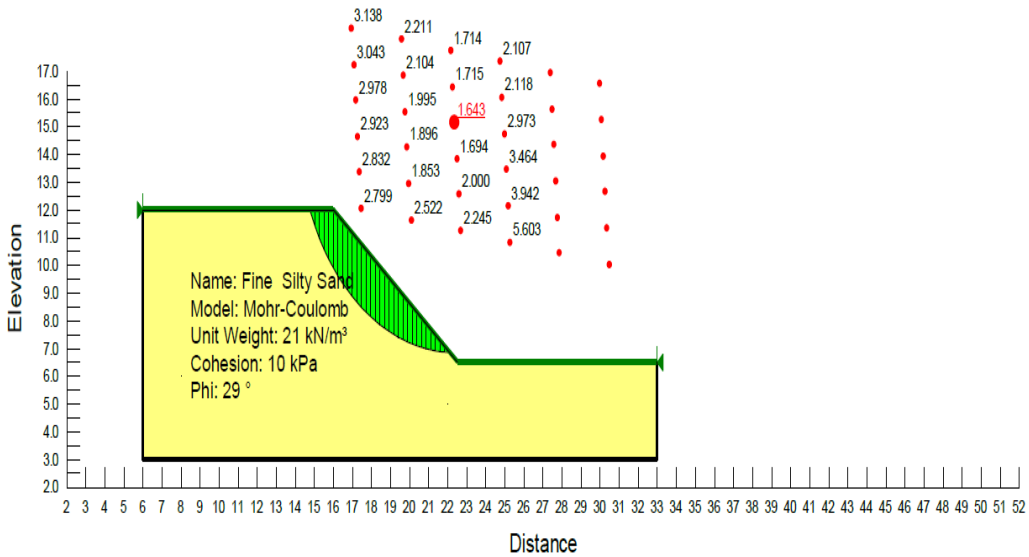

Figure 9: Slope stability analysis at 45^{o} at a height of 5.5m for cohesion of 10kPa

Figure 7 indicates that for cohesion of 15 kPa, the factor of safety is 1.4; the slope is stable in the long term. For cohesion of 10 kPa, the safety factor is 1.1; the stability in the long term is not ensured (Figure 8). As the existing slopes have been stable for more than 10 years, one can conclude that soil cohesion is close to or even higher than 15 kPa. Similarly, for slope at Figure 9, the factor of safety is 1.6. As could be deduced from the analysis, the existing slopes are stable and required to be made equal or gentler than 3H:2V in consideration of lower heights at 45^{o}. However, it is recommended that slopes in areas of infrastructure need to be made equal or gentler than 3H:2V in consideration of better safety and probable effect of moisture.

3.3. Ewu gully site

3.3.1. Findings of the hydrological study (Ewu gully site)
Table 5 shows the values derived from ArcView GIS for Ewu gully site station for a 24-hour duration and Figure 10 shows the Rainfall Intensity-Duration-Frequency (IDF) curve.

Table 5: Ewu gully site station's value for a 24-Hr duration as derived from ArcView GIS

Return Period	100-Year	50-Year	25-Year	10-Year	5-Year	2-Year
Rainfall Intensity (mm/hour)	8.2011	7.8009	7.4008	6.7008	6.2005	5.3000

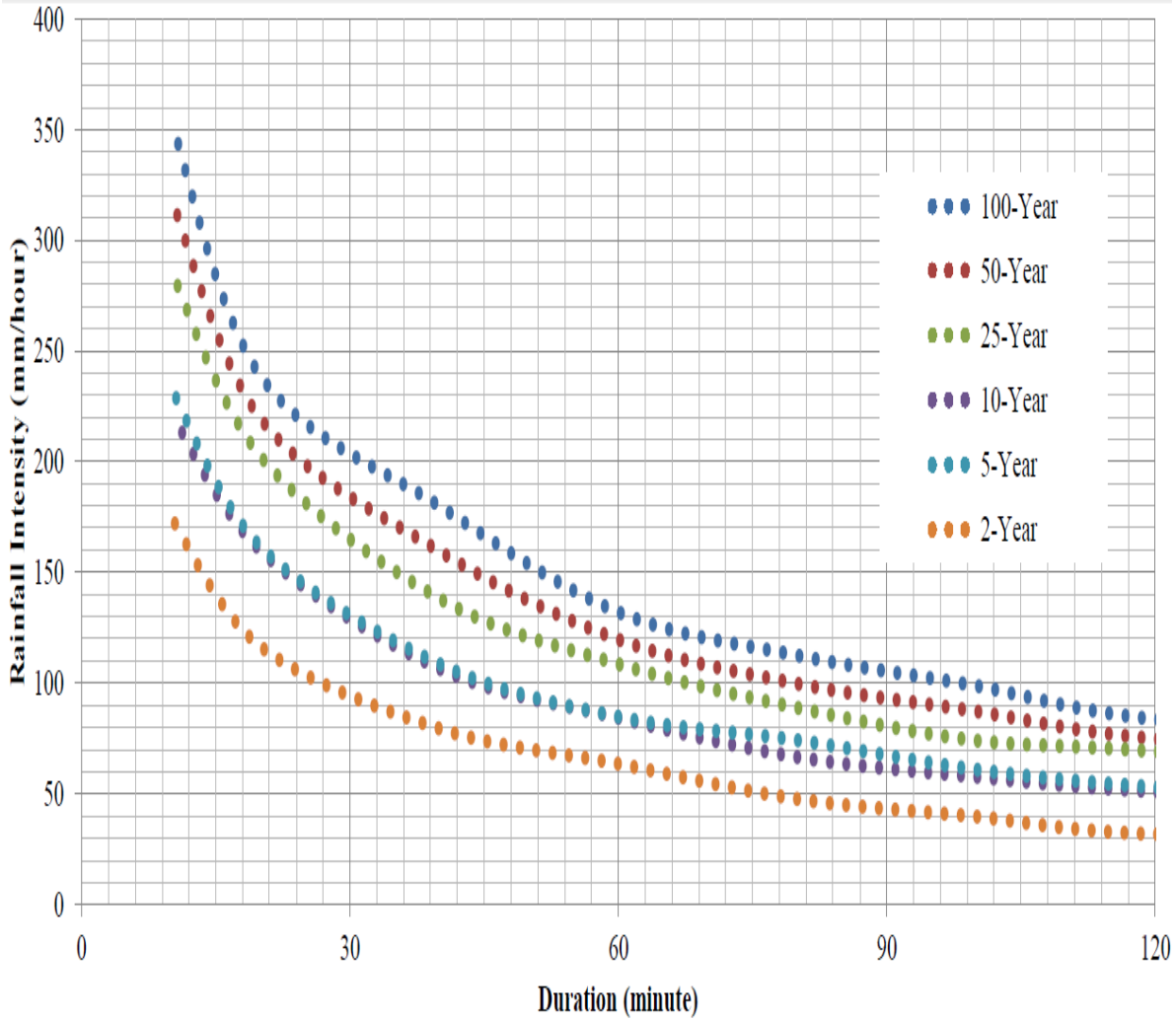

Figure 10: Developed rainfall intensity-duration-frequency curve for Ewu

According to the IDF curve, rainfall estimates are increasing with increase in the return period and the rainfall intensities decrease with rainfall duration in all return periods. The model (curve) predicted higher intensities within durations less than 30 minutes across the different return periods, indicating a higher erosive power of the surface runoff during this period (duration) when compared to durations of 60 minutes, 90 minutes and 120 minutes.

The catchment that drains to the gully at Ewu is approximately 317.79 ha in size. The catchment is shown in Figure 11.

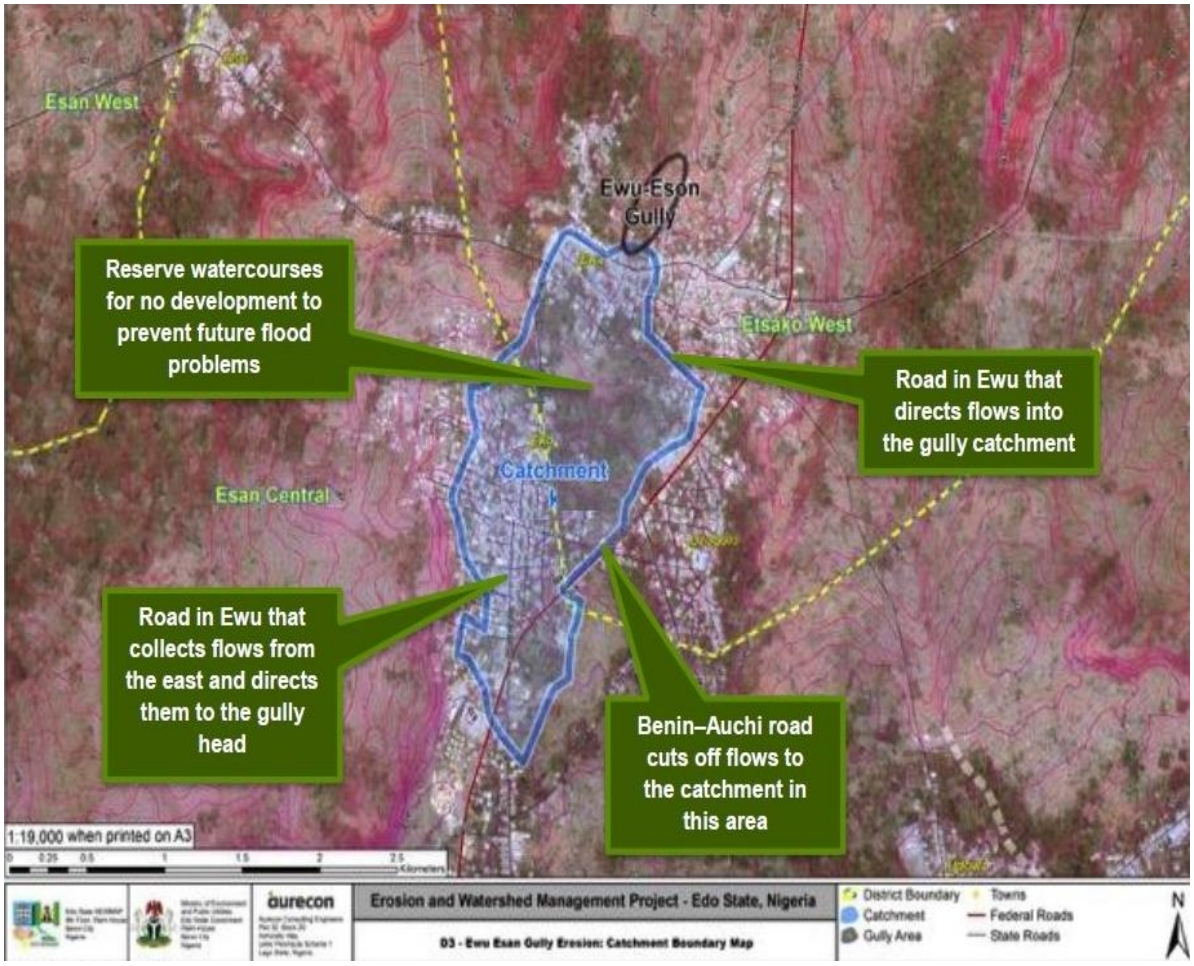

Figure 11: Catchment area delineation for Ewu gully (EDO NEWMAP, 2014)

Based on the findings of the hydrological studies, the cross section shows that the gully is V-shaped. Also taking into consideration the size of the gully (length and depth), the discharge of runoff and the size of the watershed/catchment area, it is described as a large gully. Based on its continuation, this gully is a discontinuous gully. The study also revealed that the study area possesses all the characteristics of an erosion prone area because of the high intensity of rainfall over the area.

3.3.3. Findings of the geotechnical study (Ewu gully site)

Table 6 shows the summary of the soil test result. The result of the soil test carried out showed that the specific gravity of the soil obtained varied between 2.42 to 2.66 (the soil is finely graded). The plasticity index of the soil sample varies from 13% to 33%, and the soil optimum moisture content is about 15%, indicating the presence of clayey soil. The minimum plasticity showed that the soil has a tendency to be eroded by water. The laboratory observation shows from AASHTO T180 – 70: BS 1377:75 that the material has from low to high plasticity and high compressible clay.

The triaxial compression in accordance with BS1377:75 had average friction angle of 30° and average cohesion of 74kN/m^2 indicating that structures like drains and check dams could be constructed on the gully corridors. It is deduced that the soil(s) is fine grained with its drainage characteristics rated as fair to poor.

Table 6a: Soil test summary sheet

		Atterberg Limit			Compaction	
Chainage	Specific Gravity	LL (%)	PL (%)	PI (%)	MDD (g/cm^3)	OMC (%)
LHS 0+250	2.64	52	20	32	1.67	17.2
LHS 0+500	2.64	44	20	24	1.76	14.4
LHS 0+750	2.58	36	13	23	1.79	11.40
RHS 0+250	2.45	52	19	33	1.62	20.26
RHS 0+500	2.51	49	19	30	1.72	15.40
RHS 0+750	2.60	28	19	13		

Table 6b: Soil test summary sheet

	Compression		B.S Standard Sieve Size (mm)				
Chainage	Cohesion C (kN/m^2)	Angle of internal friction (°)		CH 0+000	CH 0+250	CH 0+500	CH 0+750
0+000	28	33	3.35	100	100	100	100
Trial pit Depth 3m	130	29	2.36	99.94	99.38	97.46	100
Depth 3m	104	29	2	99.94	98.83	97.2	100
0+250	53	34	1.18	97.48	96.43	94.62	99.79
0+750	58	18	0.6	83.14	86.79	78.07	99.22
			0.425	69.05	71.32	58.74	98.54
			0.3	61.01	59.75	45.52	98.19
			0.212	53.79	37.18	26.18	97.83
			0.15	48.95	26.73	9.94	97.64
			0.075	44.36	16.47	2.81	97.24

4.0 Conclusion

The study concluded that the selected study areas possess all the characteristics of an erosion prone area which are: rainfall of very high intensity, steep slopes resulting in large runoff and soil with low organic content and relatively low shear strength obtained from the geotechnical investigations. It also revealed that the gully width and depth varied considerably from top to bottom. The cross section shows that the gully is U-shaped for Ekehuan gully and V-shaped for Auchi and Ewu gullies, indicating a large catchment area and a large volume of discharge passing through the gully.

In controlling the gullies, the following three control measures can be taken in order of priority (Desta and Adugna, 2012):

1. Improvement of gully catchments to reduce and regulate the runoff volume and peak rates.
2. Diversion of runoff upstream the gully area.
3. Stabilization of gullies by structural measures and accompanying revegetation.

In tropical and subtropical regions, such as Edo State, which receive large rains, all three methods will be useful for successful gully control.

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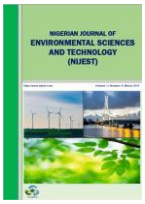

Investigating the Reaction and Transport Controlled Mechanism for the Sorption of Cr(III) and Mn(II) Ions onto Acid Activated Shale using Non-Linear Error Functions

Ilaboya I. R.[1,*] and Izinyon O. C.[2]

[1,2]Department of Civil Engineering, University of Benin, Benin City, Edo State, Nigeria

Corresponding Author: *rudolph.ilaboya@uniben.edu

ABSTRACT

Time dependent adsorption study on the sorption of Cr(III) and Mn(II) ions onto acid activated shale was conducted using batch adsorption techniques to investigate the effect of initial metal ion concentration on the process of adsorption. Experimental data obtained were fitted into different kinetic models to analyze the mechanism of adsorption in terms of reaction controlled and transport controlled mechanism. Some of the selected kinetic models include; Pseudo-first order, Pseudo-second order, Elovich, Film diffusion, Parabolic diffusion and Intra-particle diffusion model. From the result, it was observed based on the linear coefficient of determination (r^2) that the experimental data fitted well into the various kinetic model tested. Application of non-linear error function such as error sum of square (SSE), root mean square error (RMSE) and residual average (RA) revealed that the rate limiting step for the adsorption of Cr^{3+} and Mn^{2+} ions on acid activated shale was chemical attachment (chemisorption) and the reaction mechanism follows the Pseudo-second order kinetic model.

Keywords: Chemisorption, film diffusion, intra-particle diffusion, pseudo-first order and parabolic diffusion model

1.0. Introduction

The simplicity and cost effectiveness of adsorption process in the treatment of effluent wastewater has made it one of the most popular techniques employed by most researchers in the field of environmental pollution studies (Lin and Juang, 2002). To understand the mechanism of adsorption process and provide a clear description of the rate of metal ion uptake onto porous solid adsorbent, there is need to undertake a comprehensive study of the kinetics of adsorption process (Hong *et al*., 2009). Adsorption kinetic study will not only help describe the rate of metal ion uptake, it will also provide suitable information regarding the transport mechanism involved in the process (Yuh-Shan, 2006).

Although, several researchers have employed different kinetic models to predict the mechanism involved in the sorption process such as pseudo-first order model, pseudo-second order model, Weber and Morris sorption kinetic model, first-order reversible reaction model, Bhattacharya and Venkobachar diffusion model, Elovich model, parabolic diffusion model, intra particle diffusion model, Ritchies's equation and film diffusion model. It is pertinent to also note that adsorption mechanism is both reaction controlled and transport controlled hence the need to distinguish between kinetic model that are reaction based and model that are transport based (Hossain and Hossain, 2013). Recently, attempts have been made by several researchers to draw distinction between reaction controlled and transport controlled mechanism. In a research by Hossain and Hossain (2013) on the dynamic modelling of the transport mechanism of malachite green absorption onto used black tea leaves, a clear distinction was presented when the authors employed the film diffusion, parabolic diffusion and intra particle diffusion model to analyze the transport mechanism. Shanthi *et al*. (2014) employed film and pore diffusion model in addition to the popular pseudo-first order and pseudo-second order kinetic model for the adsorption of reactive red-4 onto shell waste as activated carbon.

Other researchers, namely; Ho and McKay (1999) and McKay *et al*. (1983) have also shown that adsorbent particle size can influence the rate and efficiency of metal ion adsorption.

Except for few literatures on adsorption kinetic studies, determination of the overall rate limiting step using both the reaction controlled and transport controlled model have been based on the application of linear coefficient of determination obtained by least square regression analysis involving the transformation of non-linear kinetic equation to its linear form. This method has been proved incorrect due to the violation of the error structure brought about by such transformation as reported in (Ho and McKay, 2000).

In this study, an attempt has been made to analyze the sorption mechanism of Cr(III) and Mn(II) onto acid activated shale using selected reaction based and transport based kinetic model and determine the overall rate limiting step using selected non-linear error function such as root mean square error (RMSE) and residual average.

2.0. Materials and Methods

2.1. Collection and preparation of adsorbent

Shale was collected from its deposit site at Okada the administrative headquarter of Ovia North East Local Govt Area of Edo State, Nigeria. First, it was soaked in a plastic containing 5% hydrogen peroxide to remove any carbonaceous matter that can interfere with the metal adsorption capacity of the shale. Thereafter, it was washed with distilled water to remove any water soluble impurities before been dried in hot air oven at 50-70°C for 8 hours. The dried shale was then reduced to fine particles and sieved using sieve size of 212µm before use (Mariadas *et al*., 2012).

For acid activation, 500 g of the dried sieved shale mineral was placed in a furnace at a temperature of 550 °C for 10 hours. About 200 g of the calcinated shale mineral was then mixed with 1 liter of 0.25 M sulphuric acid, the mixture was heated at 105 °C for 30 minutes. After slow cooling, the slurry was filtered and washed free of acid using distilled water as indicated by a pH meter. The shale was dried at a temperature of 100 °C for 30 – 45 minutes, ground using mortar and pestle, sieved to 212 µm and stored in a desiccator to cool before use (Krishna *et al*., 2006).

2.2. Preparation of aqueous solution

All the chemicals used in this research were analytical grade. Stock solution of chromium and manganese were prepared by dissolving accurate quantities of manganese (II) chloride tetrahydrate ($MnCl_2.4H_2O$) and chromium (III) hydroxide [Cr_2 $(OH)_3$] in one liter of distilled water. All working solutions were obtained by diluting the stock solution with distilled water and the concentration of metal ion present in solution was analyzed by atomic absorption spectrophotometer (AAS). A duplicate was analyzed for each sample to track experimental error and show capability of reproducing results. The pH of the solution was adjusted to the desired values for each experiment.

2.3. Adsorption studies

Adsorption study was carried out to determine the effect of pH, adsorbent dose, adsorption temperature, contact time and initial metal ion concentration using batch adsorption technique. The adsorption experiment was performed at different variable range as follows; pH (2, 4, 6, 8, and 10), adsorbent dose (0.2, 0.4, 0.6, 0.8 and 1.0 g), contact time (20, 40, 60, 80, 100, and 120 minutes), adsorption temperature (288, 293, 298, 303 and 308 °K) and different initial metal ion concentration. A 250 ml conical flask containing the adsorbent and 50 ml aqueous solution of the metal was agitated at 150 rpm using a mantle fitted with magnetic stirrer. The pH values of the aqueous solutions were kept at the optimum for each heavy metal.

The separation of the adsorbent and aqueous solution of heavy metals was carried out by filtration with 150 mm Whatman filter paper and the filtrates were stored in sample cans in a refrigerator prior to analysis. The residual metal ion concentration was also determined using an Atomic Absorption Spectrophotometer (AAS).

The amount of heavy metal ions removed during the series of batch investigation was determined using the mass balance equation of the form (Badmus *et al*., 2007):

$$q = \frac{v}{m}[C_0 - C_e] \quad (1)$$

where:

q defines the metal uptake (mg/g);

C_0 and C_e are the initial and equilibrium metal ion concentrations in the aqueous solution (mg/l) respectively;

V is the aqueous sample volume (ml) and m: is the mass of adsorbent used (g).

The efficiency of metal ion removal (%) was calculated using the mass balance equation reported in Gunay *et al*. (2007), Gimbert *et al*. (2008) and Hong *et al*. (2009).

$$Efficiency\ (\%) = \left(\frac{C_0 - C_e}{C_0} \times 100\right) \quad (2)$$

where:

C_0 and C_e are the metal ion concentrations (mg/l) in aqueous solution before and after adsorption respectively.

2.4. Adsorption kinetics study

Kinetically, adsorption mechanism can be described by reaction-controlled (chemisorption) or transport-controlled (diffusion) model as in the case of film and intra-particle diffusion (Tse and Shang, 2002). Pseudo-first order, pseudo-second order and elovich kinetic model were applied in this study to describe the reaction-controlled mechanism for the sorption of Cr(III) and Mn(II) ions onto acid activated shale.

To determine the mechanism of reaction that characterized the uptake of Cr^{3+} and Mn^{2+} ions onto shale and identify the rate limiting step, data obtained from the batch adsorption experiment were analyzed using reaction controlled and diffusion controlled kinetic models presented in Table 1.

Table 1: Definition of selected kinetic models

Kinetic Model	Kinetic Equation	Plot Parameters	References
Pseudo-First Order	$\ln(q_e - q_t) = \ln(q_e) - kt$ (3)	$\ln(q_e - q_t)$ against (t)	(Lagergren and Svenska, 1998)
Pseudo-Second Order	$q_t = \frac{k_2 q_e^2 t}{1 + q_e k_2 t}$ (4)	$(\frac{t}{q_t})$ against (t)	(Shamik and Papita, 2010)
Elovich	$q_t = \frac{1}{\beta}\ln(t + t_0) - \frac{1}{\beta}\ln(t)$ (5)	q_t against ln(t)	(Chien and Clayton, 1980)
Parabolic Diffusion	$X = Dt^{\frac{1}{2}} + \text{constant}$ (6)	(X) against $(t^{\frac{1}{2}})$	(Mohammad and Hossain, 2013)
Film Diffusion	$\ln\left(\frac{C_t}{C_0}\right) = -\left[\frac{K_f . W . S_w}{V_f}(t)\right]$ (7)	$(\frac{C_t}{C_0})$ against (t)	(Van-Lier, 1989)
Intra-Particle Diffusion	$q_t = K_{ad} t^{\frac{1}{2}} + I$ (8)	(q_t) against $(t^{\frac{1}{2}})$	Ashtoukhy *et al*. (2008)

3.0. Results and Discussion

To study the reaction mechanism for the adsorption of Cr^{3+} and Mn^{2+} ions onto acid activated shale, time dependent adsorption data were fitted into pseudo-first order, pseudo-second order and the Elovich kinetic model and the results are presented in Figures 1a, 1b, 2a, 2b, 3a and 3b respectively.

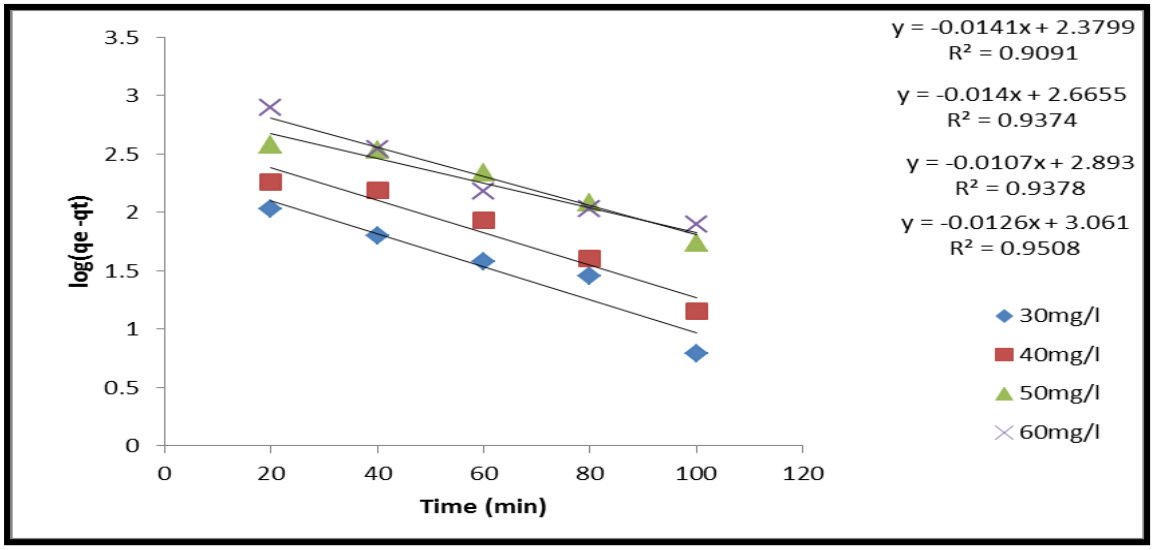

Figure 1a: Pseudo-first order kinetics for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion concentration.

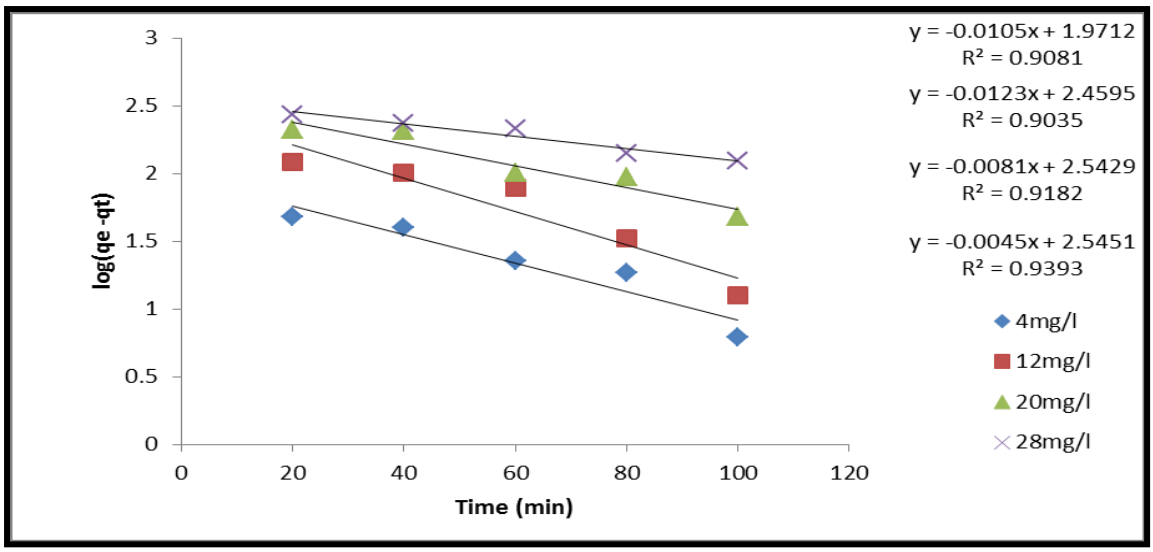

Figure 1b: Pseudo-first order kinetics for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration.

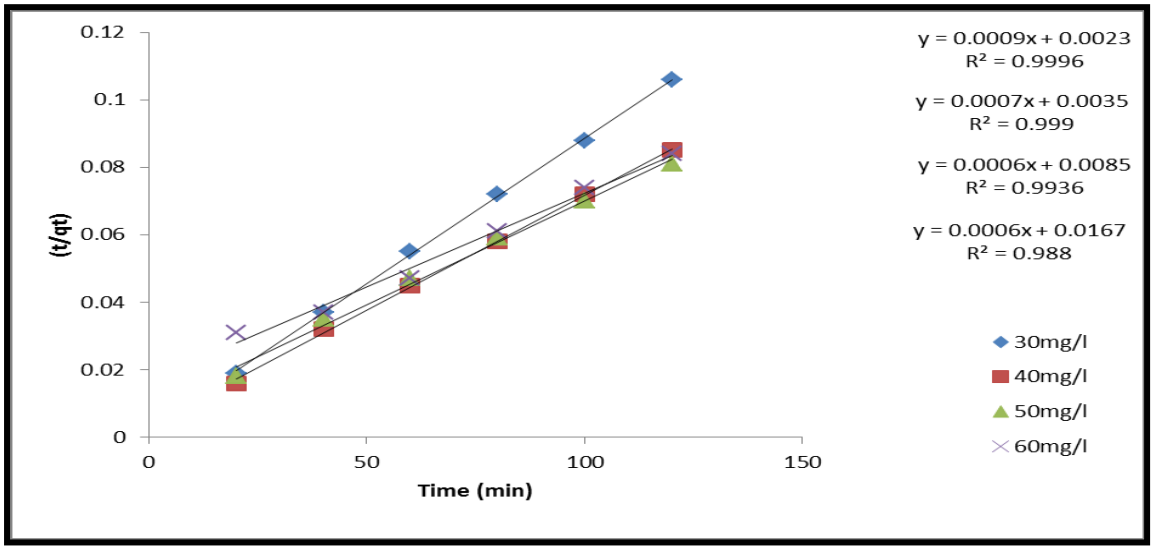

Figure 2a: Pseudo-second order kinetics for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion concentration

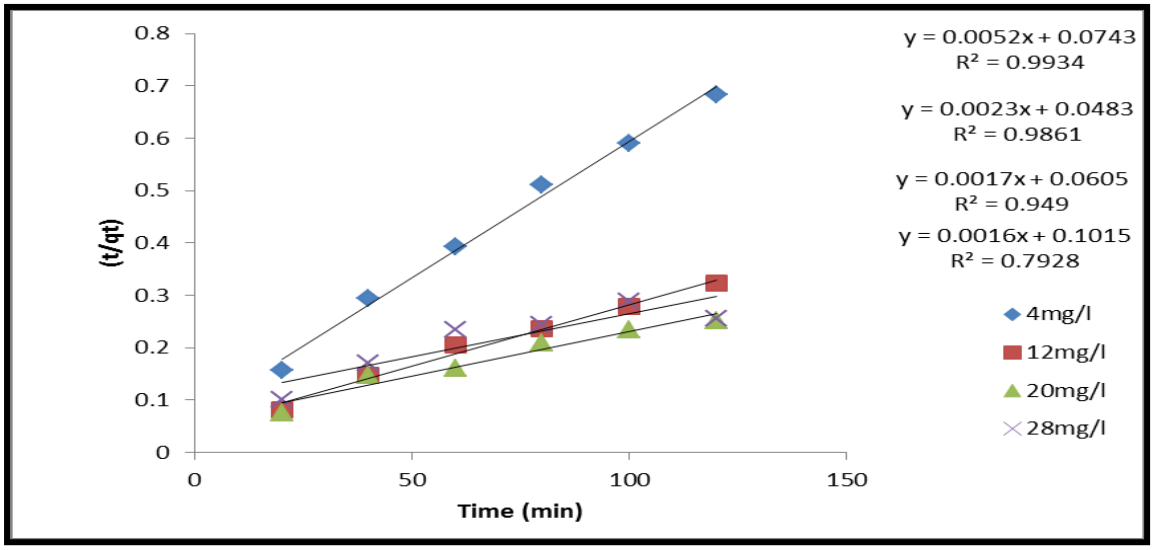

Figure 2b: Pseudo-second order kinetics for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration

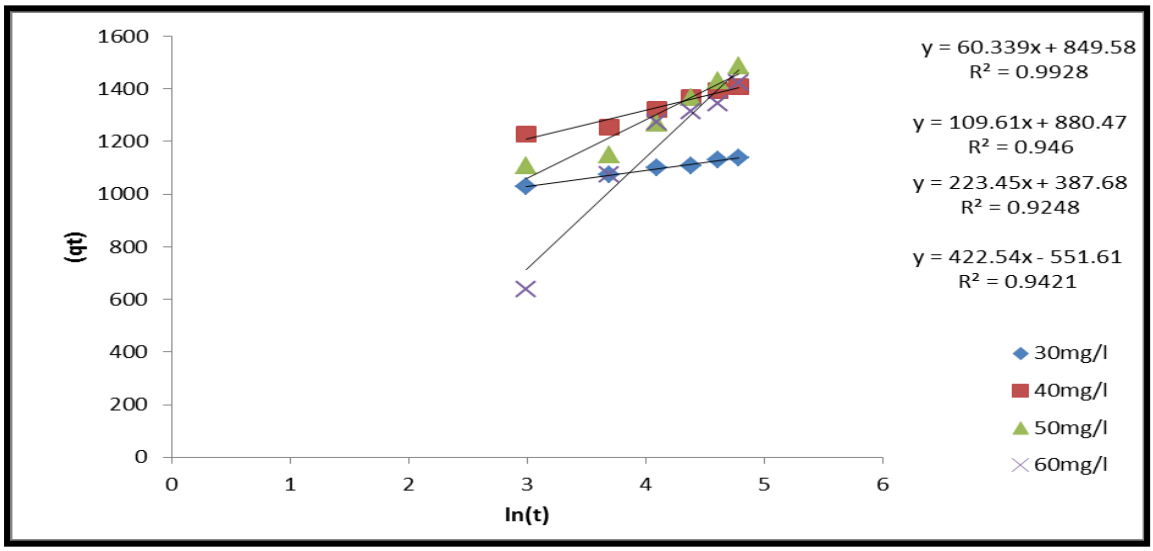

Figure 3a: Elovich kinetics for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion concentration

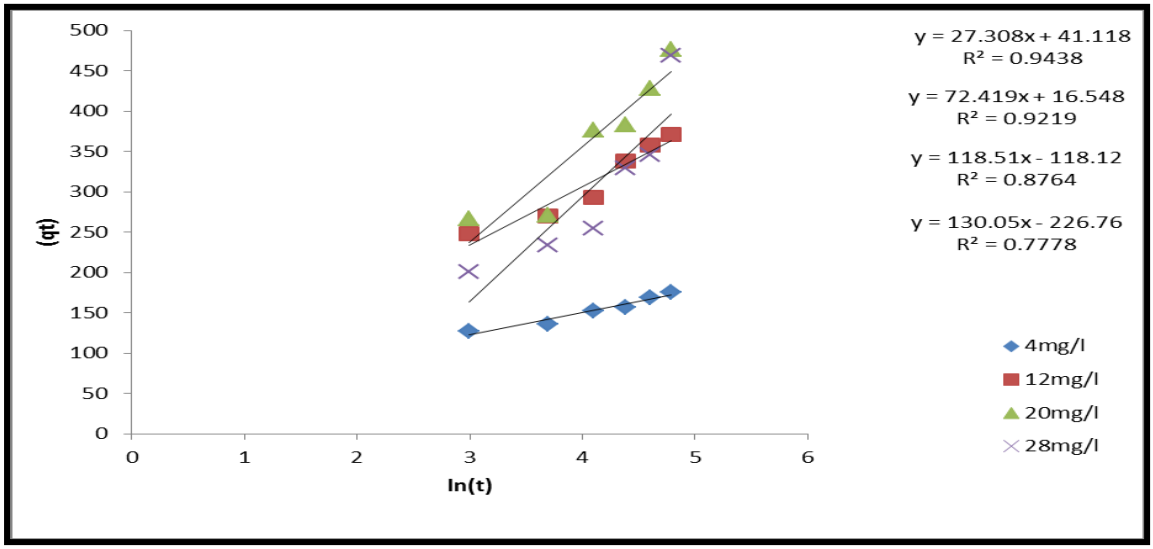

Figure 3b: Elovich kinetics for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration

From the result of Figures 1a, 1b, 2a, 2b, 3a and 3b, it was observed based on the computed coefficient of determination (R^2) that pseudo-second order kinetic model had a better fit to the adsorption data compared to pseudo-first order and the simple elovich kinetic model except for the sorption of Mn (II) ion at 28 mg/l. Determination of R^2 value and its subsequent application in the selection of best fit kinetic model is not satisfactory owing to the alteration in the error structure associated with the transformation of non-linear kinetic equation to its linear form (Oboh, 2011). In addition, R^2 value only account for the difference associated with each individual point fitted by the model in relation to the overall average of the fitted curve. Therefore, to have an accurate judgement in the selection of best fitting kinetic model, non-linear error functions were employed. Error functions such as error sum of square (SSE), root mean square error (RMSE) and the residual average (RA) unlike R^2 accounts for the difference associated with each individual point fitted by the model in relation to each experimental point measured. Results of the computed kinetic parameters using the selected error functions are presented in Table 2.

Table 2: Computed kinetic parameters for Cr(III) and Mn(II) ions adsorption onto acid activated shale at different initial metal ion concentration

	Cr(III)				Mn(II)			
	30	40	50	60mg/l	4	12	20	28mg/l
Pseudo-First Order Kinetic Model								
q_e(mg/g)	162.54	168.62	293.18	277.82	142.39	119.74	210.47	278.59
K_1(min^{-1})	0.0010	0.0007	1.4E-07	9.3E-08	0.0013	0.0007	0.0004	0.0001
R^2	0.9989	0.9990	0.9974	0.9985	0.9998	0.9966	0.9999	0.9932
SSE	0.0120	0.0163	0.0236	0.0346	0.0163	0.0160	0.0191	0.0174
RMSE	0.0515	0.1017	0.0958	0.1187	0.0656	0.0817	0.0815	0.0534
Average Residual	-0.433	-0.599	-0.642	-0.513	-0.479	-0.591	-0.451	-0.369
Pseudo-Second Order Kinetic Model								
q_e(mg/g)	2.8456	2.4456	2.6478	2.8376	21.233	11.167	10.546	13.247
K_2(g/mg/min)	0.3333	0.3333	0.3333	0.3333	0.3339	0.3334	0.3334	0.3335
R^2	1.0000	1.0000	0.9999	0.9999	0.9990	0.9991	0.9896	0.9788
SSE	3.8E-06	0.0001	0.0002	0.0006	0.0014	0.0008	0.0018	0.0018
RMSE	0.0002	0.0011	0.0018	0.0025	0.0129	0.0092	0.0156	0.0166
Average Residual	-0.002	-0.004	-0.008	-0.008	-0.061	-0.045	-0.062	-0.080
Elovich Model Kinetic Model								
A(mg/g/min)	74.320	86.605	79.328	74.401	10.058	18.947	19.918	16.072
B(g/mg)	271.47	316.79	289.94	271.77	34.415	67.203	70.786	56.598
R^2	0.9963	0.9995	0.9998	0.9998	0.9849	0.9948	0.9711	0.9831
SSE	6.6514	6.8827	3.7916	10.677	0.3796	0.6867	1.2395	0.6881
RMSE	28.413	19.271	2.9190	17.033	0.2430	2.5233	14.802	8.4383
Average Residual	-90.31	-58.84	23.744	6.7846	0.7388	16.081	48.716	43.750

From the result of Table 2, it was observed that pseudo-second order kinetic model had a better fit to the experimental data for the two metallic ions studied compared to pseudo-first oreder and the elovich kinetic model. for Cr(III) and Mn(II) ion adsorption, it was also observed that pseudo second order kinetic model had the highest R^2 value and the lowest SSE, RMSE and residual average compared to pseudo-first order and the elovich kinetic model. The simple explanation is that pseudo-second order had predicted data which were closer to the experimental data compared to the other kinetic models. The residual analysis also confirm the fact that pseudo-second order was better since the average values of the residuals are closer to zero than those of pseudo-first order and Elovich kinetic model indicating that on the average, the difference in the amount adsorbed (q) fitted by pseudo-second order kinetic model was closer to amount adsorbed (q) measured experimentally. The accurate fitting of the experimental data to pseudo-second order kinetic model explained the fact that Cr(III) and Mn(II) ions uptake by acid activated shale was due to the chemical interaction between the metallic ions and the hydroxyl group present in the shale structure. This result supports the application of non-linear error function for the evaluation and selection of best kinetic models as previously reported in Jacques *et al*. (2007). In addition, the result recommends the adoption of pseudo second

order kinetic equation in the derivation of empirical model for computing the sorption capacity of acid activated shale for the removal of Cr(III) and Mn(II) ions.

To study the transport mechanism of Cr(III) and Mn(II) ions from the bulk aqueous solution through the boundary film to the surface of the adsorbent (acid activated shale) and subsequently from the adsorbent surface to the intra-particle active sites, batch adsorption experiment was conducted to investigate the effects of initial metal ion concentration on the sorption of Cr(III) and Mn(II) ions onto acid activated shale. Experimental data obtained were thereafter fitted into film, parabolic and intra-particle diffusion model as presented in Figures 4a, 4b, 5a, 5b, 6a and 6b respectively.

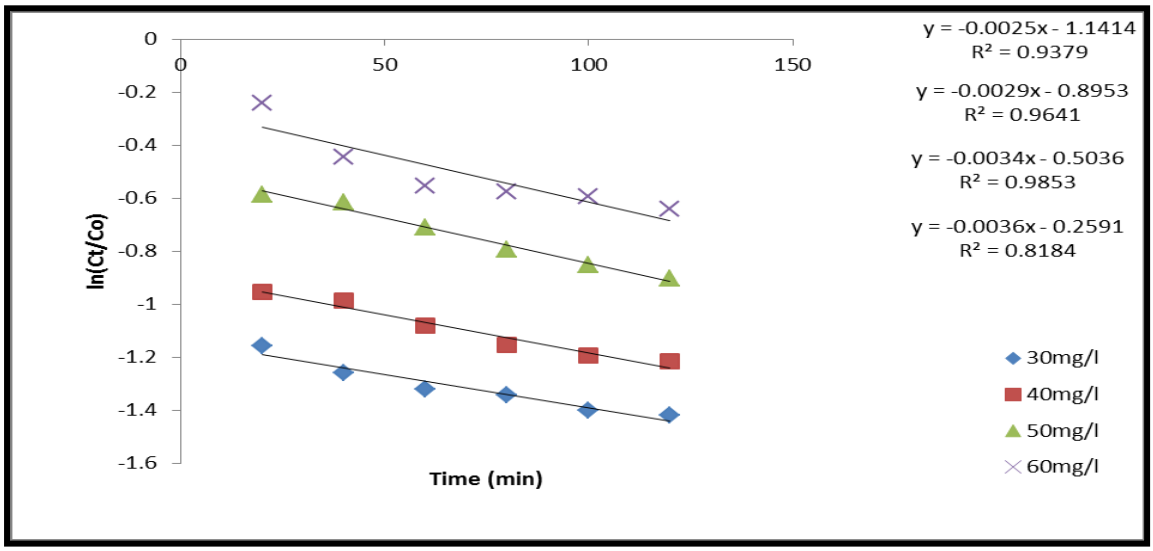

Figure 4a: Film diffusion modelling for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion Concentration

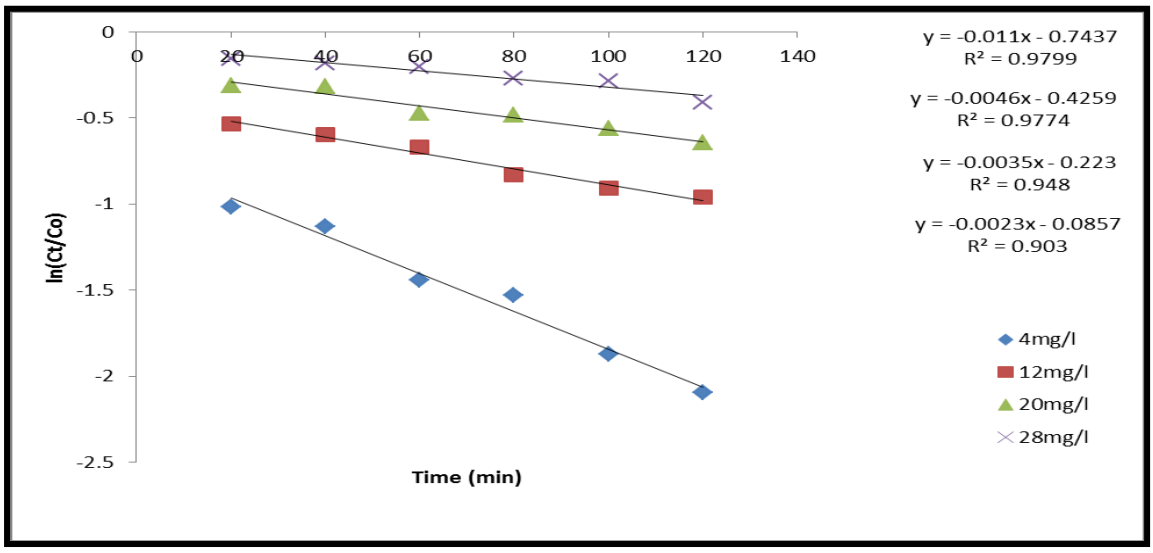

Figure 4b: Film diffusion modelling for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration

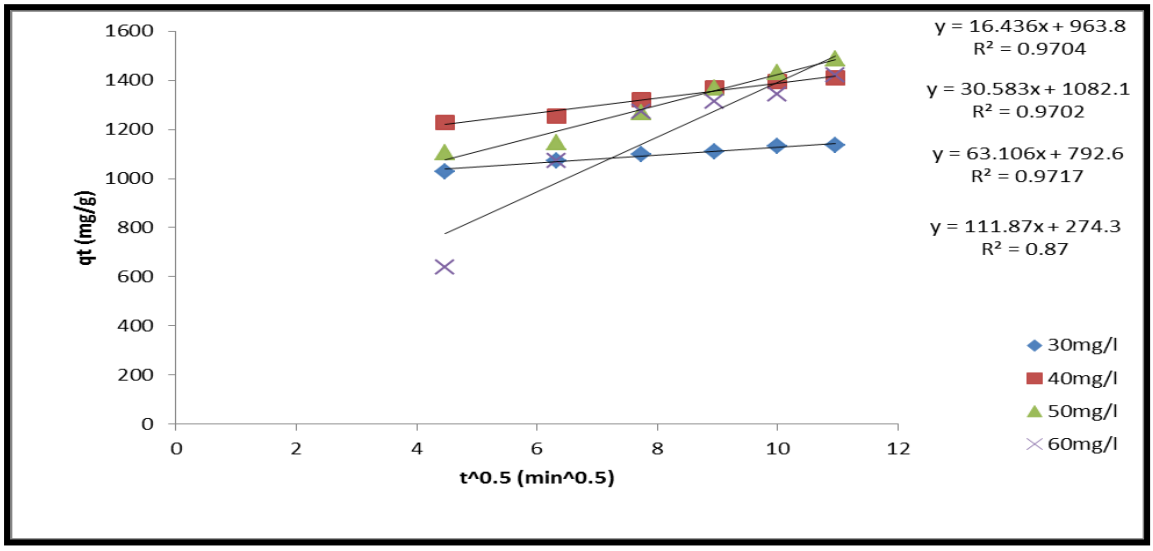

Figure 5a: Intra-particle diffusion modelling for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion concentration

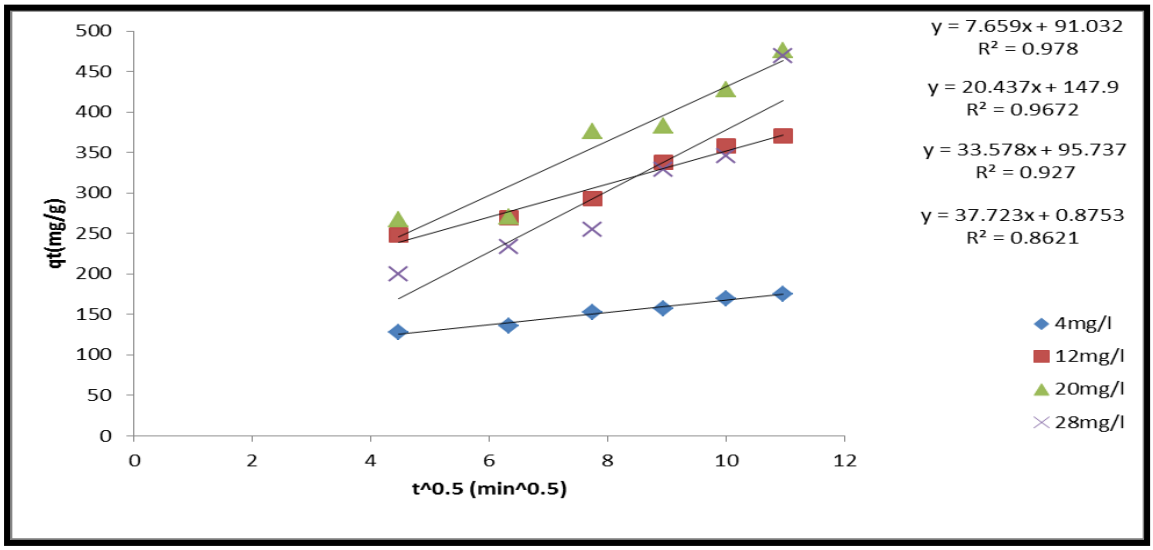

Figure 5b: Intra-particle diffusion modelling for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration

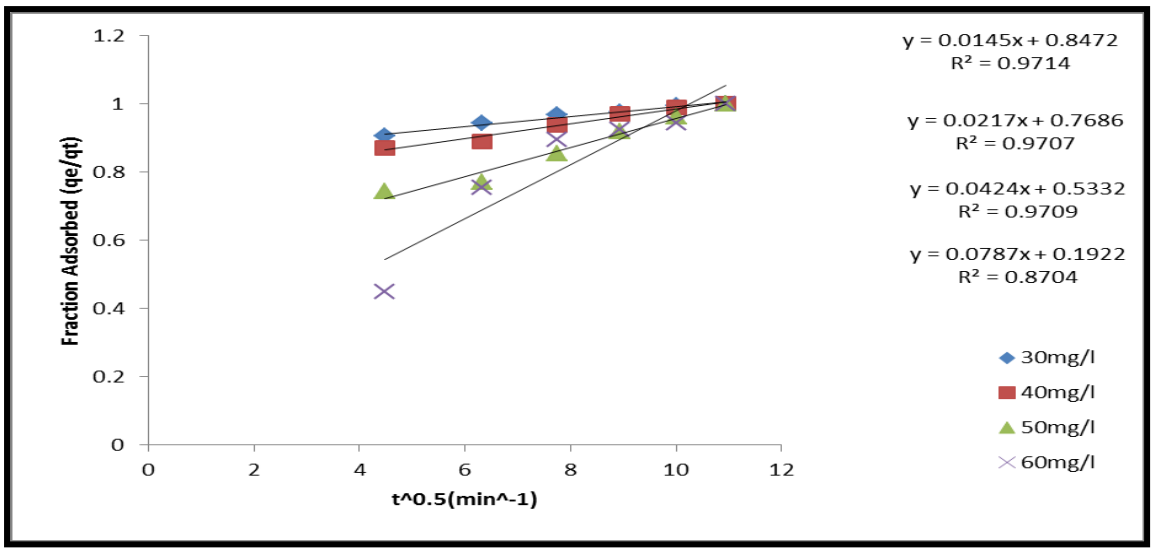

Figure 6a: Parabolic diffusion modelling for the sorption of Cr(III) ion onto acid activated shale at different initial metal ion concentration

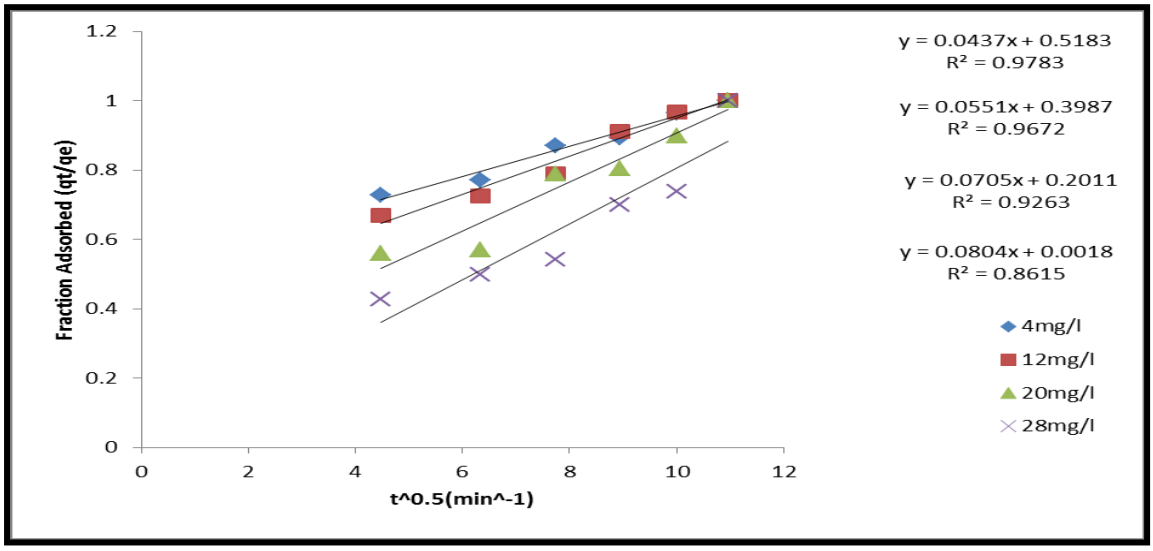

Figure 6b: Parabolic diffusion modelling for the sorption of Mn(II) ion onto acid activated shale at different initial metal ion concentration

Parabolic diffusion model was employed to varify the assumption that macropore and micropore diffusion occures in series and to test the dominance of pore diffusion step (transport of the adsorbate to the external surface of the porous solids) in the overall transport process (Taparcevska *et al*., 2010). If parabolic diffusion was found to be rate limiting, it means therefore that the transport mechanism of Cr(III) and Mn(II) ions onto acid activated shale may be controlled by pore diffusion. Intraparticle diffusion model was studied to understand the rate of internal diffusion occassioned by the transport of the adsorbate ions within the pores of the adsorbent to the active site were chemisorption takes place (Yesim and Yucel, 2000; Karthikeyan *et al*., 2010). Diffusion through the boundary layer also known as film diffusion was tested to looked at the diffusion of the adsorbate through the boundary layer.

Results of Figures 4a, 4b, 5a, 5b, 6a and 6b show that the experimental data fitted well into the selected transport model. The non-linear nature of the film diffusion plot as observed in Figure 4a and 4b suggested that the transport mechanism of Cr(III) and Mn(II) ions onto acid activated shale may not be controlled by film diffusion. For intra-particle diffusion model observed in Figures 5a and 5b, it was observed that the two plots possess identical linear nature. More also, the computed values of coefficient of determination (R^2) was observed to vary with increasing initial metal ion concentration for the two metal ions studied. The linear nature of the plots and the high R^2 values revealed that the transport mechanism of Cr(III) and Mn(II) onto acid activated shale may be controlled by intra-particle diffusion model. For parabolic diffusion model as observed in Figures 6a and 6b, it was observed that the computed cofficient of determination R^2 are equally very high. In addition, the graphical plots possesses the same linear nature as those of intra-particle diffusion model an indication that the transport mechanism of Cr(III) and Mn(II) on acid activated shale may also be controlled by the parabolic diffusion model.

The argument that the value of the coefficient of determination R^2 may be insufficient to select the kinetic model that best explained the adsorption data has also come to play in this regards as both the intra-particle and parabolic diffusion model seems to have control over the transport mechanism of Cr(III) and Mn(II) onto acid activated shale. Therefore, to select the model that best explain the transport mechanism of Cr(III) and Mn(II) onto acid activated shale, non-linear error functions were employed. Use of error functions such as error sum of square (SSE), root mean square error (RMSE) and the residual average (RA) are better and more accurate in handling non-linear model compare to R^2 since they accounts for the difference associated with each individual point fitted by the model in relation to each experimental point measured. The non-linear regression analysis based on selected error functions was done using the Solver Function in Microsoft Excel Spread Sheet and results obtained are presented in Table 3.

Table 3: Computed transport parameters for Cr(III) and Mn(II) ion adsorption onto acid activated shale at different initial metal ion concentration

	Cr(III)				Mn(II)			
	30	40	50	60mg/l	4	12	20	28mg/l
Parabolic Diffusion Model								
D_p (cm^2/sec)	13.024	14.070	13.461	13.031	4.6276	6.4729	6.6445	5.9390
qe (mg/g)	13.024	14.070	13.461	13.031	4.6276	6.4729	6.6445	5.9390
C	2.9013	3.0666	2.9702	2.9024	1.5720	1.8647	1.8143	1.7804
R^2	0.9714	0.9707	0.9709	0.8704	0.9783	0.9672	0.9263	0.8615
SSE	14.858	16.436	12.461	2.9646	1.3976	2.6830	0.8059	0.9533
RMSE	73.028	71.348	44.738	27.632	5.8570	8.4771	3.2065	0.8191
Average Residual	-5297	-5272	-3255	-3360	-424.8	-539.5	66.656	150.25
Intra-Particle Diffusion Model								
K_{ad} (mg/g min)	169.01	197.36	180.57	169.20	20.709	41.222	43.463	34.587
I	6.8232	6.9740	6.8847	6.8242	6.0343	6.1434	6.1553	6.1081
R^2	0.9704	0.9702	0.9717	0.8700	0.9780	0.9672	0.9270	0.8621
SSE	14.379	15.914	12.051	2.9409	1.2903	2.5423	0.7171	0.8605
RMSE	72.737	71.059	44.448	27.341	5.5264	8.1602	3.5281	0.4986
Average Residual	-5277	-5251	-3234	-3339	-400.9	-516.7	89.867	173.39

From the computed parameters presented in Table 3, it was observed that; for Cr(III) ion adsorption onto acid activated shale, the computed error sum of square (SSE) based on parabolic and intra-particle diffusion were: 14.858, 16.436, 12.461, 2.9646 and 14.379, 15.914, 12.051, 2.9409 at 30, 40 50 and 60mg/l respectively. For the adsorption of Mn(II) ion onto acid activated shale, the computed error sum of square (SSE) based on parabolic and intra-particle diffusion are: 1.3976, 2.6830, 0.8059, 0.9533 and 1.2903, 2.5423, 0.7171, 0.8605 at 4, 12, 20 and 28mg/l respectively. Based on the computed error sum of square (SSE), it was observed that intra-particle diffusion model had a better fit to the experimental data than parabolic diffusion model since it possesses lower error sum of square values compared to parabolic diffusion model for the two metal ions studied.

It was also observed from results of Table 3 that; for parabolic diffusion and intra-particle diffusion model, the root mean square error (RMSE) based on the adsorption of Cr(III) ion onto acid activated shale were computed to be 73.028, 71.348, 44.738, 27.632 and 72.737, 71.059, 44.448, 27.341 at 30, 40 50 and 60mg/l respectively. For Mn(II) ion adsorption on acid activated shale, the computed root mean square error (RMSE) based on parabolic and intra-particle diffusion are: 5.8570, 8.4771, 3.2065, 0.8191 and 5.5264, 8.1602, 3.5281, 0.4986 at 4, 12, 20 and 28mg/l respectively. Again we concluded based on the root mean square error that intra-particle diffusion model had the best fit to the experimental data since it has the lowest root mean square error. Evaluation of the computed kinetic parameters for both the reaction controlled and transport controlled mechanism for the adsorption of Cr(III) and Mn(II) ions onto acid activated shale revealed that pseudo-second order kinetic model possesses the lowest sum of square error (SSE) and root mean square error (RMSE) with residual average very close to zero. It means therefore, that the adsorption of Cr(III) and Mn(II) ions onto acid activated shale (AAS) was a reaction controlled mechanism. On the bases of these, it was concluded that the rate limiting step for the adsorption of Cr(III) and Mn(II) ions onto acid activated shale was chemical attachment (chemisorption) and the reaction mechanism follows the pseudo-second order kinetic model.

4.0 Conclusion

On the possible reaction mechanism that controls the adsorption of Cr^{3+} and Mn^{2+} ions onto acid activated shale, it was found that the rate limiting step for the adsorption of Cr^{3+} and Mn^{2+} ions onto acid activated shale was chemical attachment (chemisorption) and the reaction mechanism follows the pseudo-second order kinetic model. Hence, it was concluded that the sorption of Cr^{3+} and Mn^{2+} ions onto acid activated shale is a reaction controlled process. In addition, the study has further established that non-linear error function models such as error sum of square (SSE), root mean square error (RMSE) and residual average (RA) are better tools to select kinetic models compered to coefficient of determination (R^2) since the transformation of a non-linear model into its linear form explicitly alter the error variance and violates the normality assumption of a standard least square regression.

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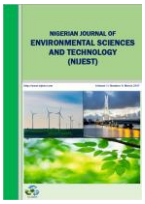

Comparative Studies on the Bioremediation of Used Engine Oil Contaminated Soil using Urea Fertilizer (UF), Goat Manure (GM), Pig Manure (PM) and Brewery Spent Grain (BSG)

Ilaboya I. R.[1,*] and Otuaro E. A.[2]

[1]Department of Civil Engineering, University of Benin, Benin City, Edo State, Nigeria

[2]Department of Civil Engineering, Delta State University, Abraka, Delta State, Nigeria

Corresponding Author: *rudolph.ilaboya@uniben.edu

ABSTRACT

The focus of the study was to evaluate and compare the performance of urea fertilizer, goat manure, pig manure and brewery spent grain for the bioremediation of used engine oil contaminated soil. Soil with no pollution history was collected and subjected to detailed laboratory analysis to determine the total heterotrophic bacterial population, pH, moisture content, total organic carbon, total nitrogen and total hydrocarbon content. Used engine oil contaminated soil was prepared by adding 250g of used engine oil into a clean dry plastic bucket containing 1kg of unpolluted soil. The mixture was properly mixed and covered with aluminium foil paper before use. The used engine oil contaminated soil was left for a period of four (4) days for stabilization before the commencement of treatment. The entire setup and its content was open throughout the period of experimentation to allow for the influence of atmospheric oxidation. The setup was monitored for twelve (12) weeks and sampling/analysis of the samples was done on a weekly basis to ascertain the progress of treatment. The residual hydrocarbon content after each treatment was determined using Atomic Absorption Spectrophotometer. Results obtained shows that pig manure is the best substrate for the clean-up of used engine oil contaminated soil with calculated removal efficiency of 64.4% followed by BSG with 51.4% removal efficiency, Goat Manure with removal efficiency of 39.9% and Urea Fertilizer with 33.7% efficiency. The kinetic modelling shows that experimental data fitted well with pseudo-first order kinetic model with calculated error sum of square (SSE) values of (0.0002, 0.0005, 0.0012 and 0.0072) and root mean square errors (RMSE) of (0.0028, 0.0073, 0.0082 and 0.0481). On the accurate prediction of the optimum remediation time, it was observed that the non-linear regression model gave higher coefficient of determination of 0.9824, 0.9812, 0.9886 and 0.9899 compared to linear regression.

Keywords: Bioremediation, Total organic carbon (TOC), Pseudo-first order model, Non-linear regression, Residual hydrocarbon content

1.0. Introduction

Bioremediation is the use of microorganism metabolism to remove pollutants from soil and water. Bioremediation can occur on its own (natural attenuation or intrinsic bioremediation) or can be spurred on via the addition of fertilizers to increase the bioavailability within the medium (bio-stimulation). Recent advancements have also proven successful via the addition of matched microbe strains to the medium to enhance the resident microbe population's ability to break down contaminants. Bioremediation can be classified as in-situ or ex-situ. When bioremediation is carried out at the site of contamination, then it is in-situ but when the contaminated soil is removed from the original site, then it became ex-situ bioremediation (Vidali, 2001). A number of technologies have been tested to remediate sites that are contaminated with hydrocarbon products such as incineration plants which have been developed to clean up hydrocarbon contaminated sites. Incineration method of hydrocarbon cleanup has the advantage of short treatment time, but the system requires huge machines and large amounts of heavy oils (Burland and Edward, 1999). Biological treatments for hydrocarbon-degradation have also been investigated and have be found to be less sophisticated

natural method of cleanup of hydrocarbon polluted sites, but the low solubility and adsorption of high molecular weight hydrocarbons limits their availability to microorganisms (Grossi *et al*., 2002). The specificity of the degradation process is related to the genetic potential of the particular microorganism to introduce molecular oxygen into hydrocarbon and to generate the intermediates that subsequently enter the general energy- yielding metabolic pathway of the cell. Positive effects of nitrogen amendment using nitrogenous fertilizer on microbial activity and petroleum hydrocarbon degradation have been widely demonstrated. However, in developing countries, inorganic chemical fertilizers are costly as well as not sufficient for agriculture, let alone for cleaning oil spills; hence, the search for cheaper and environmentally friendly options of enhancing petroleum hydrocarbon degradation. One of such options is the use of organic wastes effluents that could act as bulking agents and also as bacterial biomass suppliers. There are few literatures on the potential use of these organic wastes effluents as biostimulating and bioaugmentation agents. However, some researchers have investigated the potential use of solid organic wastes such as sugarcane bagasse (Molina-Barahona *et al*., 2004), brewery spent grain (Abioye *et al*., 2009) and animal wastes like cow dung (Akinde and Obire, 2008), poultry manure (Okiemen and Okiemen, 2005), goat manure (Agarry *et al*., 2013), and sewage sludge (Mao and Yue, 2010) as biostimulating agents in the cleanup of soil contaminated with petroleum hydrocarbons and were found to show positive influence on petroleum hydrocarbon biodegradation in a polluted environment.

However, there is need to investigate the performance of these organic waste materials as agent for the bioremediation of used engine oil contaminated soil. Furthermore, comparative evaluation of these organic waste materials has not been reported in the literature. Therefore, the focus of this study is to carry out a comparative evaluation on the potential of urea fertilizer, goat manure, pig manure and brewery spent grain in the bioremediation of used engine oil contaminated soil.

2.0. Materials and Methods

Slight modification of the method presented in Agarry *et al*. (2010) was employed in the preparation of used engine oil contaminated soil as follows; 10kg of unpolluted soil was weighed into a plastic bowl and 2.5kg of concentrated used engine oil was added gradually and was properly mixed. The moisture content of the used engine oil contaminated soil was determined immediately after mixing. The contaminated soil sample was left for 4days for stabilization before the commencement of treatment process. Prior to treatment, the physico-chemical and microbial properties of the contaminated and uncontaminated soil sample was carried out after digestion (using 1:1 ratio of 0.25M hydrochloric acid and nitric acid) to determine the effects of used engine oil contamination on the intrinsic properties of the uncontaminated soil. To commence the treatment process, 10kg used engine oil contaminated soil was shared into four (4) equal parts with each portion placed in clean plastic bucket perforated at the bottom. The clean plastic bucket and its content were placed outside and open throughout the period of experimentation to allow for the influence of atmospheric oxygen.

The details of the batch experiment are presented below:

i. To the first plastic bucket, 2000:500 (w/w) mixtures of the contaminated soil and inorganic fertilizer (urea) in addition to 20ml nutrient broth was thoroughly mixed and stored in cool dry place for further investigation.
ii. To the second plastic bucket, 2000:500 (w/w) mixtures of the contaminated soil and pig manure in addition to 20ml nutrient broth was thoroughly mixed and stored in cool dry place for further investigation.
iii. To the third plastic bucket, 2000:500 (w/w) mixtures of the contaminated soil and goat manure in addition to 20ml nutrient broth was thoroughly mixed and stored in cool dry place for further investigation.
iv. To the fourth plastic bucket, 2000:500 (w/w) mixtures of the contaminated soil and Brewery Spent Grain (BSG) in addition to 20ml nutrient broth was thoroughly mixed and stored in cool dry place for further investigation.
v. The fifth plastic bucket contains 2000g of the contaminated soil with no treatment medium. This setup was taken as the control experiment used to monitor the progress of remediation.

The treatment process commenced after 4days and samples were collected weekly for a period of twelve weeks to be tested for chemical and microbial properties, namely; pH, electrical conductivity,

total hydrocarbon content (THC), total heterotrophic bacterial (THB), total organic carbon, total nitrogen content. The progress of remediation was assessed based on changes in the concentration of these variables with treatment time. The environmental temperature was maintained within the range of 30 – 32^{o}C throughout the period of experimentation and the moisture content was kept in the range of 45 – 50% for maximum remediation. The amount of used engine oil degradation during the series of batch investigation was determined using the mass balance equation reported in Raghuvanshi *et al*. (2004) as follows:

$$q = \frac{v}{m}(C_0 - C_e) \quad (1)$$

Where: q, defines the used engine oil uptake (mg/g); C_0 and C_e: are the initial and equilibrium used engine oil concentrations in the digested soil solution [mg/l] respectively; V: is the weight of contaminated soil sample taken (g) and M: is the mass of substrate used (g). The efficiency of used engine oil degradation (%) during the series of batch experimentation was computed based on the mathematical equation reported in Eba *et al*. (2010) as follows:

$$\text{Efficiency (\%)} = \frac{100}{C_0}(C_0 - C_e) \quad (2)$$

Where: C_0 and C_e are the used engine oil concentration measured in terms of the total hydrocarbon content (mg/l) in digested soil solution before and after treatment.

To study the kinetics of used engine oil degradation, data obtained from the series of batch experimentation were analyzed using selected reaction controlled and diffusion controlled kinetic models, namely; pseudo-first order kinetic model, pseudo-second order kinetic model, film diffusion model and intra-particle diffusion model. The underlying mathematical equations and the plot parameters of the selected kinetic models are presented in Table 1.

Table 1: Definition of selected kinetic models

Kinetic Model	Kinetic Equation	Plot Parameters
Pseudo-First Order	$\ln(q_e - q_t) = \ln(q_e) - kt$ (3)	$\ln(q_e - q_t)$ against (t) (Lagergren and Svenska, 1998)
Pseudo-Second Order	$q_t = \frac{k_2 q_e^2 t}{1 + q_e k_2 t}$ (4)	$(\frac{t}{q_t})$ against (t) (Shamik and Papita, 2010)
Film Diffusion	$\ln\left(\frac{C_t}{C_0}\right) = -\left[\frac{K_f . W . S_w}{V_f}(t)\right]$ (5)	$(\frac{C_t}{C_0})$ against (t) (Van-Lier, 1989)
Intra-Particle Diffusion	$q_t = K_{ad} t^{\frac{1}{2}} + I$ (6)	(q_t) against $(t^{\frac{1}{2}})$ (Ashtoukhy *et al*., 2008)

Where;
q_e is amount of used engine oil removed at equilibrium (mg·g-1)
q_t is amount of used engine oil removed at time (t) (mg·g-1)
K_1 is rate constant of pseudo first-order adsorption ($gmg^{-1}min^{-1}$)
K_2 is rate constant of pseudo first-order adsorption ($gmg^{-1}min^{-1}$)
K_f is the mass transfer coefficient for film diffusion
S_w is the specific external surface of substrate on weight basis
W is substrate dosage
V_f is the volume of the fluid (used engine oil)
K_{ad} is intra-particle diffusion rate constant (mg/g min) and
I is the thickness of boundary layer

3.0. Results and Discussion

The physico-chemical properties of the experimental soil which include; the moisture content, pH, electrical conductivity, organic carbon, total nitrogen and total hydrocarbon content are presented in Table 2.

Table 2: Physico-chemical properties of uncontaminated soil

S/N	Parameter	Test Result
1	Moisture Content (%)	2.6
2	pH	9.4
3	Electrical Conductivity (µs/cm)	30
4	Total Dissolved Solids (mg/l)	19.8
5	Organic Carbon (g/kg)	6.21
6	Total Nitrogen (g/kg)	7.23
7	Total Hydrocarbon Content (mg/kg)	0.00
8	Total Heterotrophic Bacterial (cfu/g)	$8*10^5$

Results of Table 2 revealed that the experimental soil is highly alkaline with a pH of 9.4, bone dry with a moisture content of 2.6% with nutritive values measured in terms of total organic carbon and total nitrogen content of 6.21 and 7.23 g/kg respectively. The soil also possesses very low concentration of dissolved solids and electrical conductivity (30 µS/cm and 19.80 mg/l respectively). It was also observed from Table 2 that the soil was completely free from crude petroleum hydrocarbon pollution as evident from the result of total hydrocarbon content. The physico-chemical properties of the used engine oil used for this study are presented in Table 3.

Table 3: Physico-chemical properties of used engine oil

S/N	Parameter	Test Result
1	Specific Gravity	2.467
2	pH	4.1
3	Dynamic Viscosity (g/cm. s)	3.567
4	Electrical Conductivity (µs/cm)	234

Addition of used engine oil to the experimental soil resulted in the contamination of the soil which invariably altered the initial physico-chemical properties of the soil. Results of changes in the soil physico-chemical properties occasioned by the addition of used engine oil are presented in Table 4.

Table 4: Effect of used engine oil contamination on the soil physico-chemical properties

S/N	Parameters	Before contamination	After contamination
1	Moisture Content (%)	2.6	40
2	pH	9.4	3.6
3	Electrical Conductivity (µs/cm)	30	80
4	Total Dissolve Solids (mg/l)	19.8	52.8
5	Organic Carbon (g/kg)	6.21	3.15
6	Total Nitrogen (g/kg)	7.23	3.78
7	Total Hydrocarbon Content (mg/kg)	0.00	9.76
8	Total Heterotrophic Bacterial (cfu/g)	$8*10^5$	$1.32*10^5$

Results of Table 4 revealed that, the addition of used engine oil to the soil invariably alter the initial properties of the soil as follows;

i. The soil became acidic as the pH changes from the initial alkaline state of 9.4 to an acidic state of 3.60
ii. High level of conductivity occasioned by the presence of high concentration of dissolved solids as observed from the results of conductivity and total dissolved solids (80 µS/cm and 52.8mg/l) was also observed.
iii. A drastic reduction in total nitrogen and total organic carbon concentration occasioned by a sudden increase in the hydrocarbon content of the soil due to contamination.
iv. It was also observed that the addition of used engine oil to the soil resulted in a drastic reduction in the total heterotrophic bacterial count from $8x10^5$ cfu/g to 1.32^x10^5 cfu/g

The effect of substrate addition (bioremediation) on the total heterotrophic bacterial growth of used engine oil contaminated soil was studied for a period of 12 weeks. The graphical relationship between

the total heterotrophic bacterial population and the remediation time for the different treatment substrate used is presented in Figure 1. The initial decrease in the bacterial count due to contamination from the used engine oil revealed the toxic effect of the used engine oil and possibly support the fact that some of the microorganisms present in the soil cannot survive in an environment contaminated with hydrocarbons emanating from used engine oil. This claim is in accordance with the reports by (Umanu and Nwachukwu, 2010).

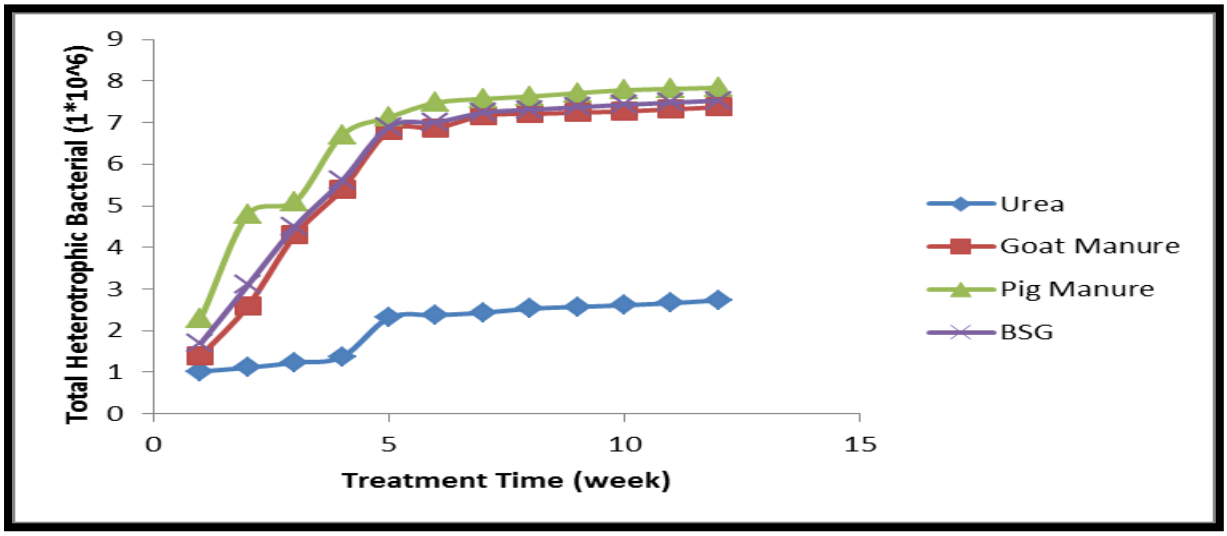

Figure 1: Variation of total heterotrophic bacterial with treatment time

Figure 1 revealed a continuous increase in the population of hydrocarbon utilizing microorganisms especially with the addition of treatment substrates, hence the higher reduction in residual used engine oil observed throughout the period of experimentation. Pig manure was observed to have the highest population of heterotrophic bacterial population followed by Brewery Spent Grain (BSG) and goat manure then urea in that order. The findings that pig manure possessed the highest population of total heterotrophic bacterial followed by BSG is in accordance with the results of Diez *et al*. (2001) which reported that pig manure is not only rich in mineral elements such as; nitrogen and phosphorous required for crude oil degradation, it also contain bacteria with varying degrees of crude oil degrading capabilities. The effect of substrate addition (Bioremediation) on the total nitrogen content was studied for a period of 12 weeks. The graphical relationship between the residual total nitrogen concentration and the remediation time with respects to all the substrate used is presented in Figure 2.

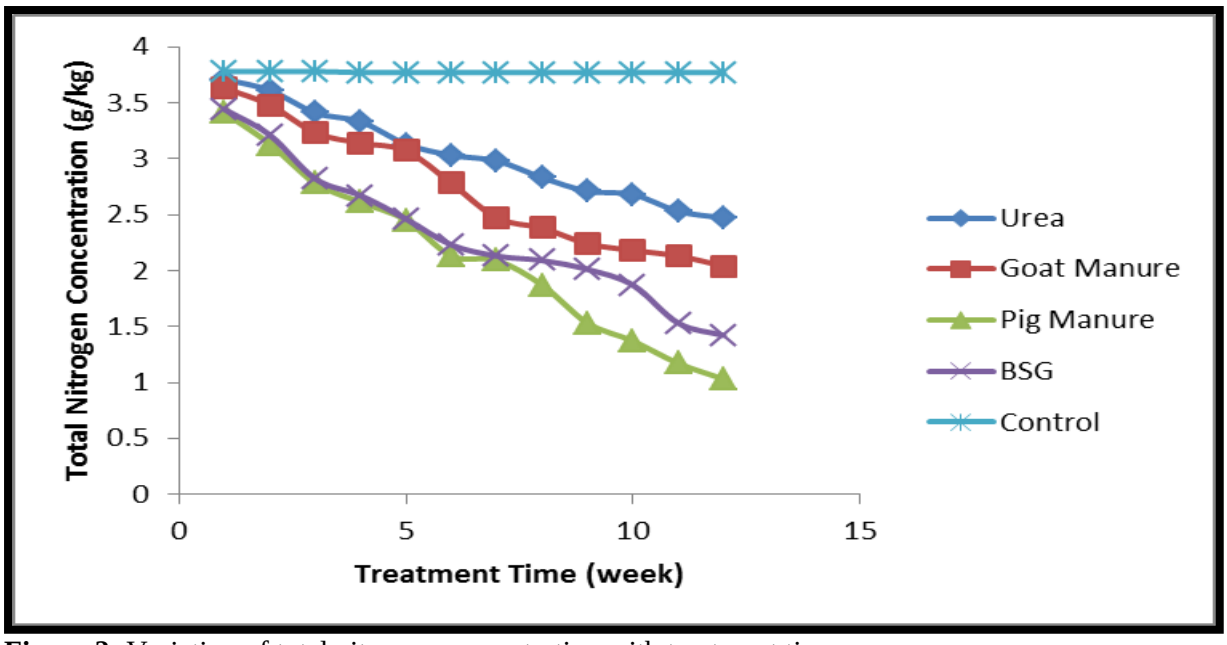

Figure 2: Variation of total nitrogen concentration with treatment time

The gradual decrease in the total nitrogen content with increase in remediation time as observed in Figure 2 could be traced to the increase in the population of total heterotrophic bacterial count occasioned by nutrient utilization. Heterotrophic bacterial normally utilized the available nutrient in the form of total nitrogen, total organic carbon and total phosphorous for their growth and cell development; consequently, leading to a drastic reduction in the nutrient level. Therefore, as the remediation time increases, there is a corresponding increase in the population of total heterotrophic bacterial present in the treatment substrate due to utilization of available nutrient resulting to decline in the concentration of these nutrients. In addition, increase in bacterial population may lead to unhealthy competition for the available nutrients since the bacterial would need the nutrient for survival. It was also observed from the result of Figure 2 that pig manure possesses the highest population of heterotrophic bacterial as seen in the available concentration of nitrogen followed by BSG and goat manure in that order. This finding agrees completely with the results of Diez *et al.* (2001). The trend that applies to total nitrogen content due to substrate addition also applies to total organic carbon content since the nutrient level of soil is measured based on the concentration of total nitrogen, total organic carbon and total phosphorous content. The variation of total organic carbon with remediation time is presented in Figure 3.

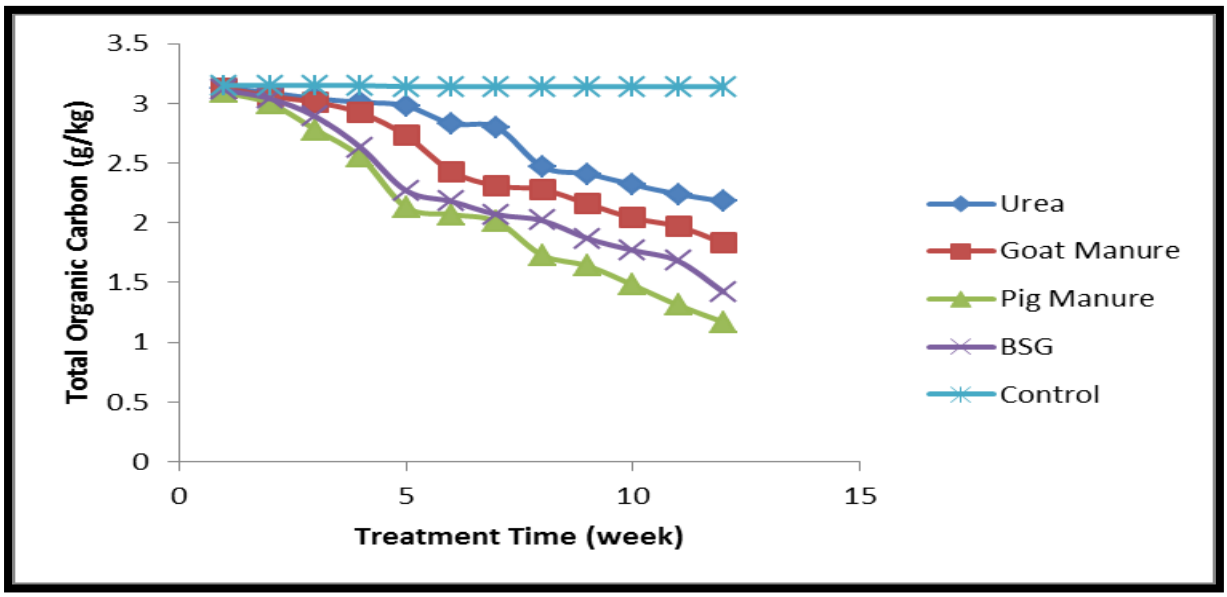

Figure 3: Variation of total organic carbon with treatment time

Like total nitrogen content, a gradual reduction in the total organic content (TOC) throughout the period of experimentation was also observed with remediation time. This reduction can also be attributed to the steady and continuous consumption of this nutrient by the microorganism for cell growth and development while also increasing in population. On the variation of total hydrocarbon content with remediation time, it was observed that the percentage reduction in total hydrocarbon content (THC) was relatively slow within the first two weeks of remediation in all the soil microcosms. The slow rate of hydrocarbon removal could be attributed to stability and adaptation of the microorganism to the hydrocarbon polluted environment. As the microorganism stabilizes and became well adapted to the environment, they tend to grow and developed based on the available nutrient while also eating up the hydrocarbon thus bringing about possible cleanup. This trend that defines the process of hydrocarbon remediation by microorganism based on substrate addition is presented in Figure 4.

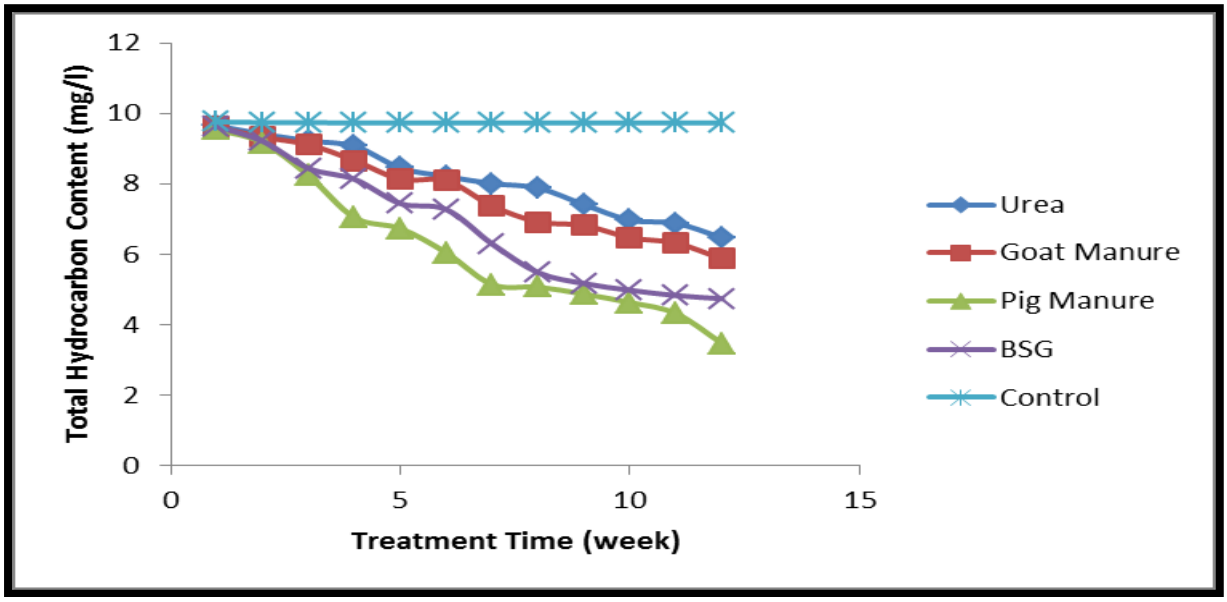

Figure 4: Variation of total hydrocarbon content with treatment time

Result of Figure 4 shows that pig manure is the best substrate for the cleanup of used engine oil polluted soil followed by BSG and goat manure in that order. At the end of the remediation time of 12 weeks it was observed that pig manure was able to reduce the concentration of the used engine oil hydrocarbon from the initial 9.76mg/l to 3.47mg/l while BSG reduces the concentration from 9.76mg/l to 4.74mg/l. That of goat manure reduces from 9.76mg/l to 5.87mg/l while inorganic fertilizer (urea) reduces it from 9.76mg/l to 6.47mg/l respectively. The breakdown of petroleum hydrocarbon by the available microorganism resulted in the formation of carbonzylic acid as by product which in turn will have effect on the pH of the system. When the effects of substrate addition (Bioremediation) on the total pH of used engine oil contaminated soil was studied for a period of 12 weeks, results obtained is presented in Figure 5.

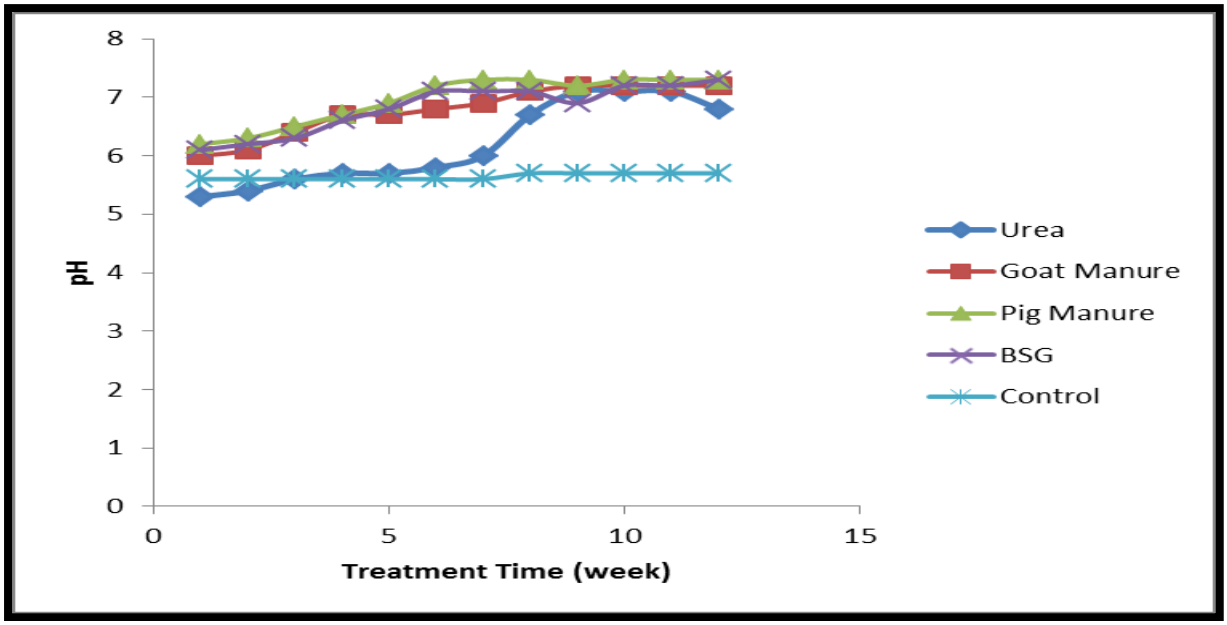

Figure 5: Variation of pH with Treatment Time

It was observed from the result of Figure 5 that pig manure raised the pH of the soil to a range between 6.2 and 7.3, which is ideal for crude oil utilizing bacteria as reported in (Vidali, 2001). This indicates that pig manure has a buffering effect on the soil which would have contributed to the enhanced hydrocarbon degradation since high level of acidity is a challenge in biodegradation. The use of pig manure to stimulate used engine oil biodegradation could be one of the severally sought environmentally friendly ways of eliminating petroleum hydrocarbon pollution problems in the

natural ecosystem. More also BSG shows a substantial performance as another reliable material for the biodegradation of used engine oil contaminated soil. An initial reduction in pH value was observed for all the substrate used due to breakdown of hydrocarbon to acid fractions. The pH value of a soil sample is the most frequently determined parameter in soil analysis. It is the characteristic value of what is known as "soil reaction," and allows soils to be classified according to their acidity and alkalinity. The effect of substrate addition (bioremediation) on the electrical conductivity of used engine oil contaminated soil was also studied for a period of 12 weeks and result obtained is presented in Figure 6.

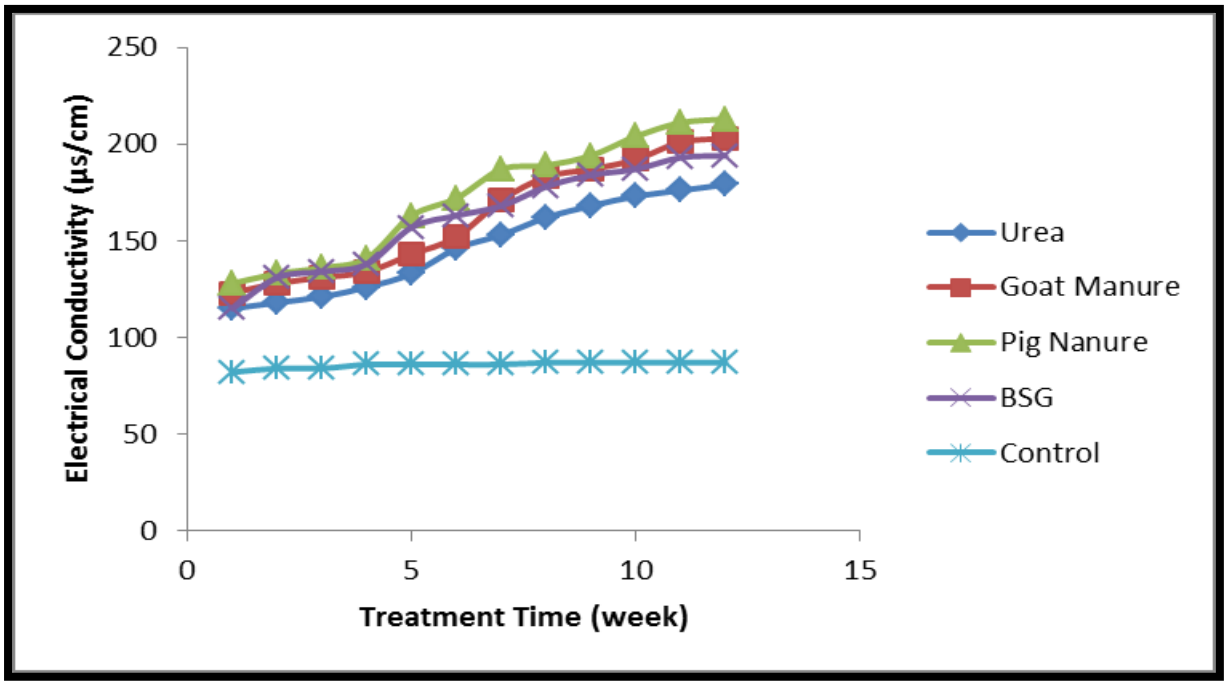

Figure 6: Variation of electrical conductivity with treatment time

The trend observed in Figure 6 was attributed to the presence of high level of dissolved ions occasioned by the breakdown of the hydrocarbon by the heterotrophic bacterial present in the substrate used. The linear trend of the control setup as observed in all the Figures indicate the complete absence of microorganisms due to lack of substrate addition. The graphical variation between the amount of used engine oil degradation and the efficiency of bioremediation with treatment time for all the substrate used is presented in Figures 7 and 8 respectively.

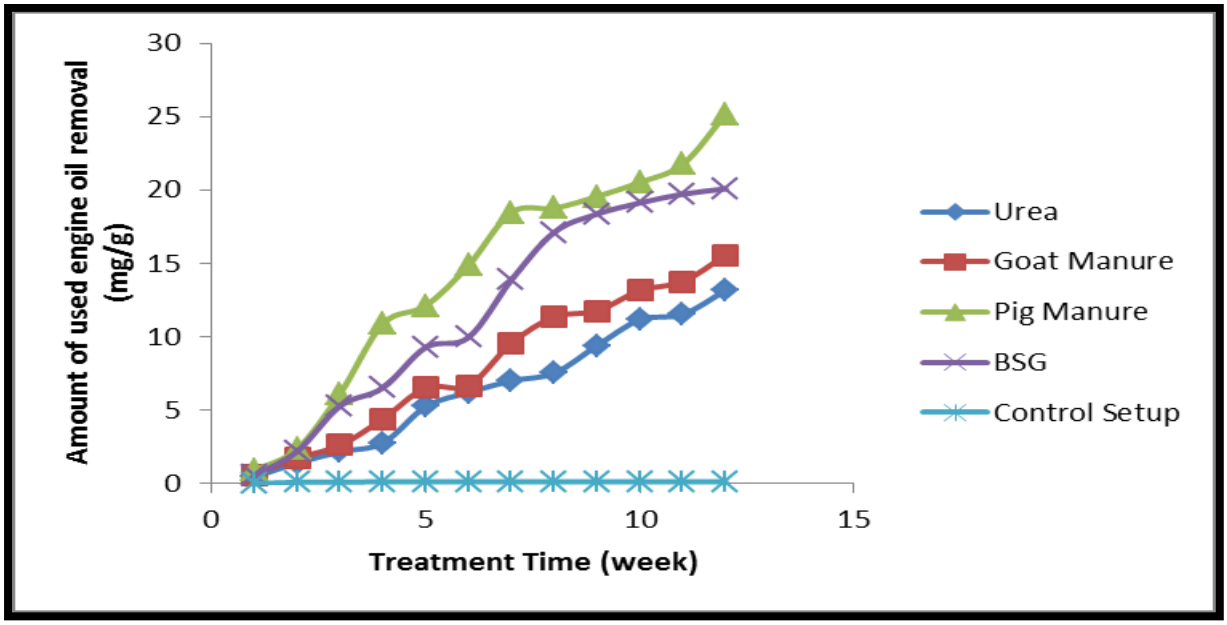

Figure 7: Amount of used engine oil removed with time

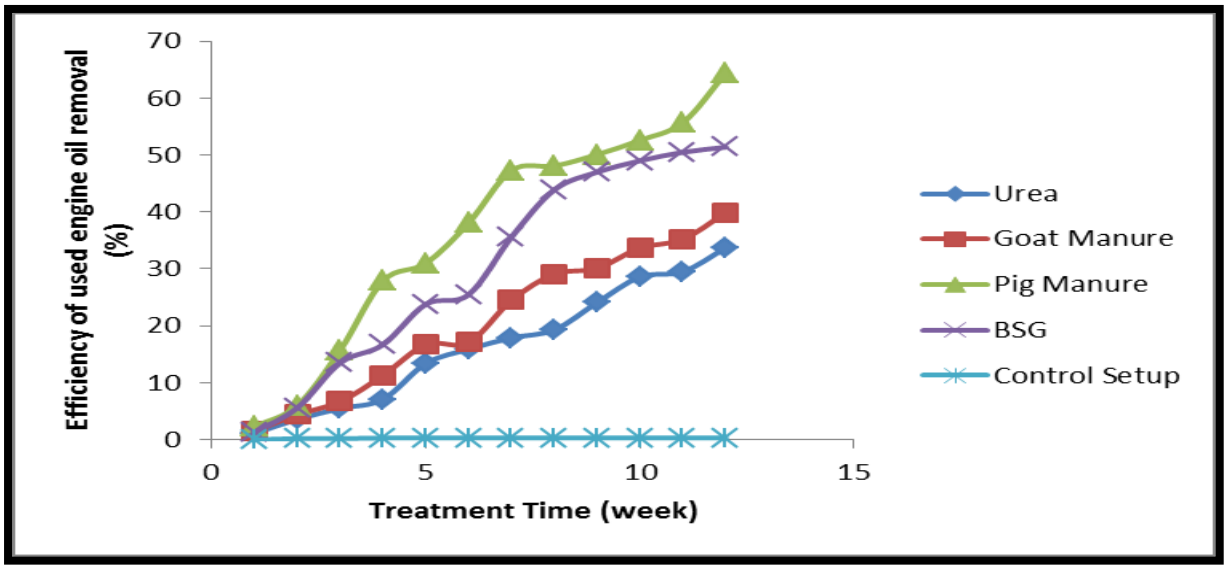

Figure 8: Efficiency of used engine oil removal with time

It can be deduced from the result of Figures 7 and 8 that, the efficiency of remediation increases with treatment time. Increase in the efficiency of remediation with treatment time can be traced to the increase in the population of the heterotrophic bacteria resulting from the gradual depletion of the available nutrients such as total organic carbon and total nitrogen. To determine the mathematical relationship between the efficiency of used engine oil degradation and remediation time, linear and non-linear regression modelling was done. To select the model that best explain this relationship, coefficient of determination (r^2) which measures the corresponding change in the dependent variable occasioned by change in independent variable was employed. Results of the linear and non-linear regression modelling are presented in Table 5. Based on the result of Table 5, the non-linear regression model was acclaimed the best model and can be employed to predict the maximum time required for complete remediation of used engine oil contaminated soil using any of the selected substrate.

Table 5: Parameters of linear and non-linear regression model

S/N	Model	Substrate	Model Equation	R^2
1	Linear Regression	Pig Manure	Y = 1.141 + 5.455X	0.950
		BSG	Y = -1.326 + 4.897X	0.956
		Goat Manure	Y = -2.495 + 3.592X	0.947
		Urea Fertilizer	Y = -2.861 + 3.000X	0.939
2	Non-Linear Regression	Pig Manure	$F(x) = -0.3321X^2 + 9.772X - 8.932$	0.9824
		BSG	$F(x) = -0.2051X^2 + 7.651X - 8.305$	0.9812
		Goat Manure	$F(x) = -0.0451X^2 + 4.178X - 3.864$	0.9886
		Urea Fertilizer	$F(x) = 0.02845X^2 + 2.631X - 1.998$	0.9899

Kinetic analyses allow estimation of bioremediation rates as well as determination of the appropriate rate equation characteristic of possible reaction mechanisms. Based on kinetic classification, bioremediation mechanism can be described by reaction-controlled or transport-controlled. Pseudo-first order and pseudo-second order kinetic models were applied in this study to describe the reaction-controlled mechanism for the bioremediation of used engine oil contaminated soil using pig manure, brewery spent grain, goat manure and urea fertilizer. Film diffusion, and intra-particle diffusion models were applied to satisfactorily describe the transport or diffusion controlled mechanism. The graphical variation between the remediation time (t) and Log (q_e–q_t) based on pseudo-first order kinetic model is presented in Figure 9 while the variation between the remediation time (t) and (t/q_t) based on pseudo-second order kinetic model is presented in Figure 10. When the time dependent batch remediation data were analyzed using the film diffusion and intra-particle diffusion models, the results obtained are presented in Figures 11 and 12 respectively.

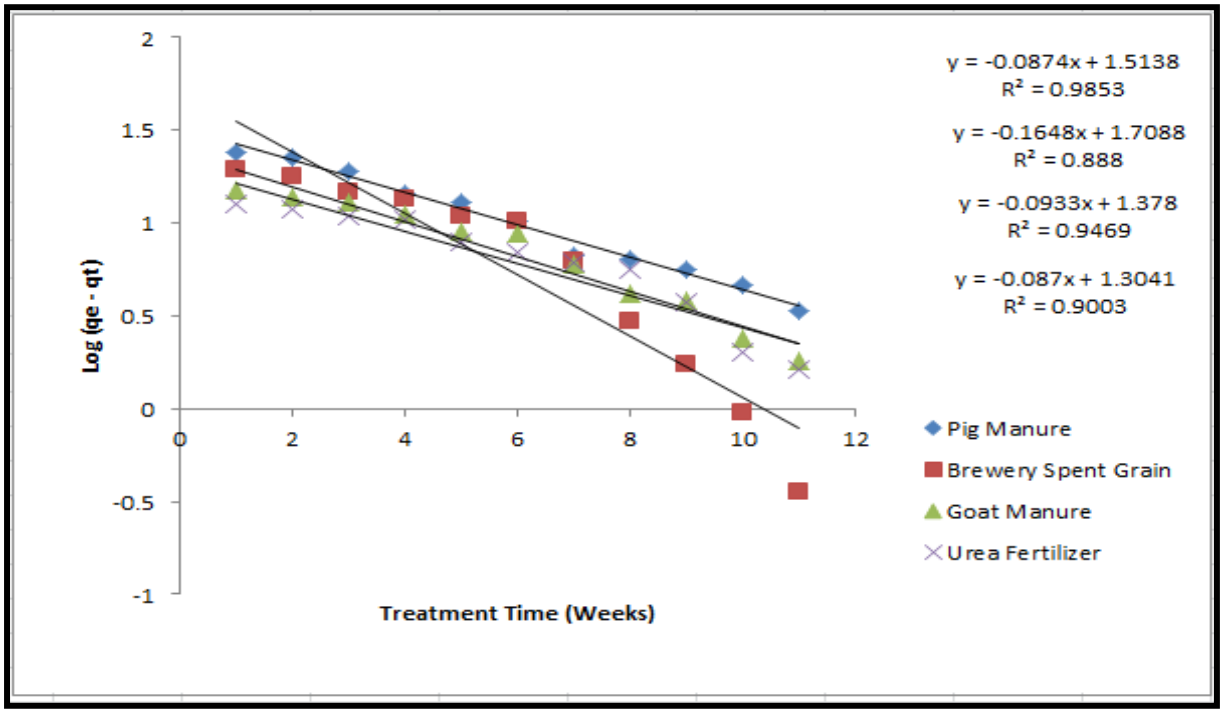

Figure 9: Pseudo-first order kinetic model for the bioremediation of used engine oil contaminated soil

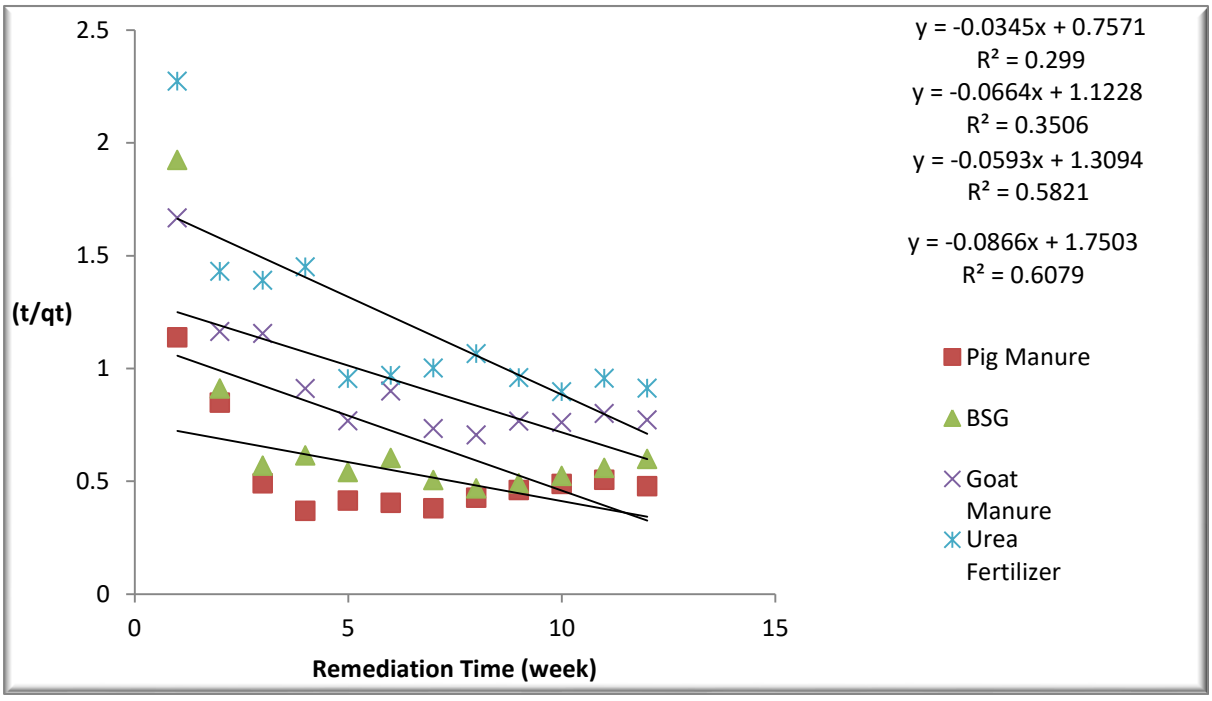

Figure 10: Pseudo-second order kinetic model for the bioremediation of used engine oil contaminated soil

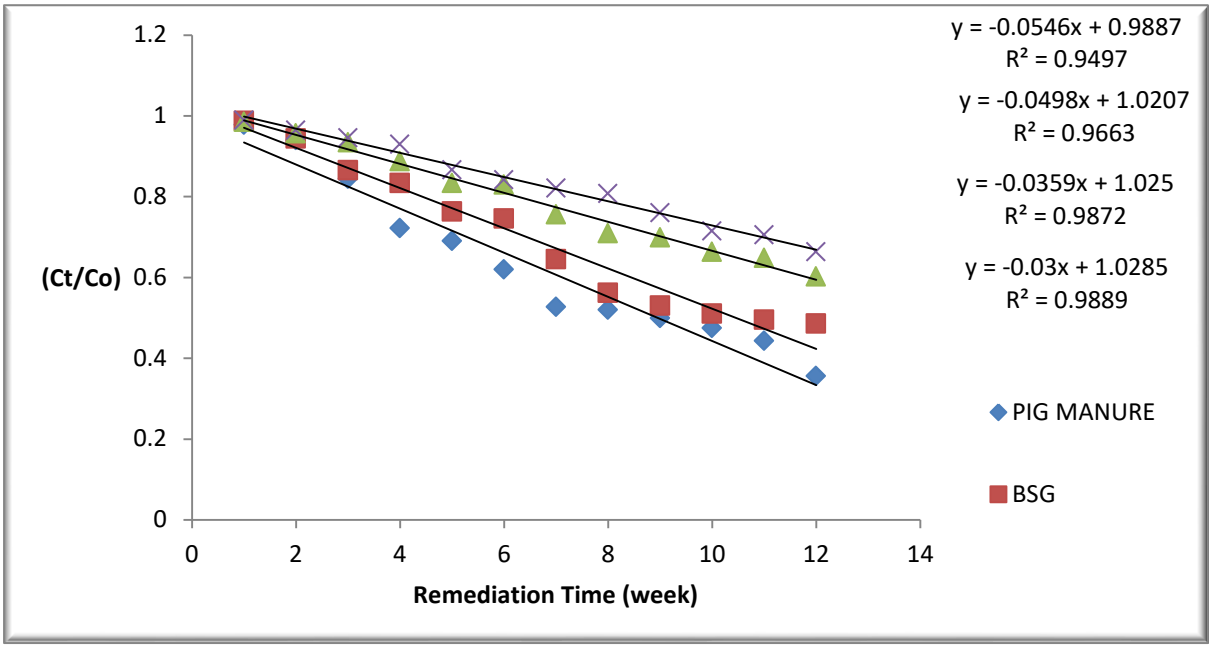

Figure 11: Film diffusion model for the bioremediation of used engine oil contaminated soil

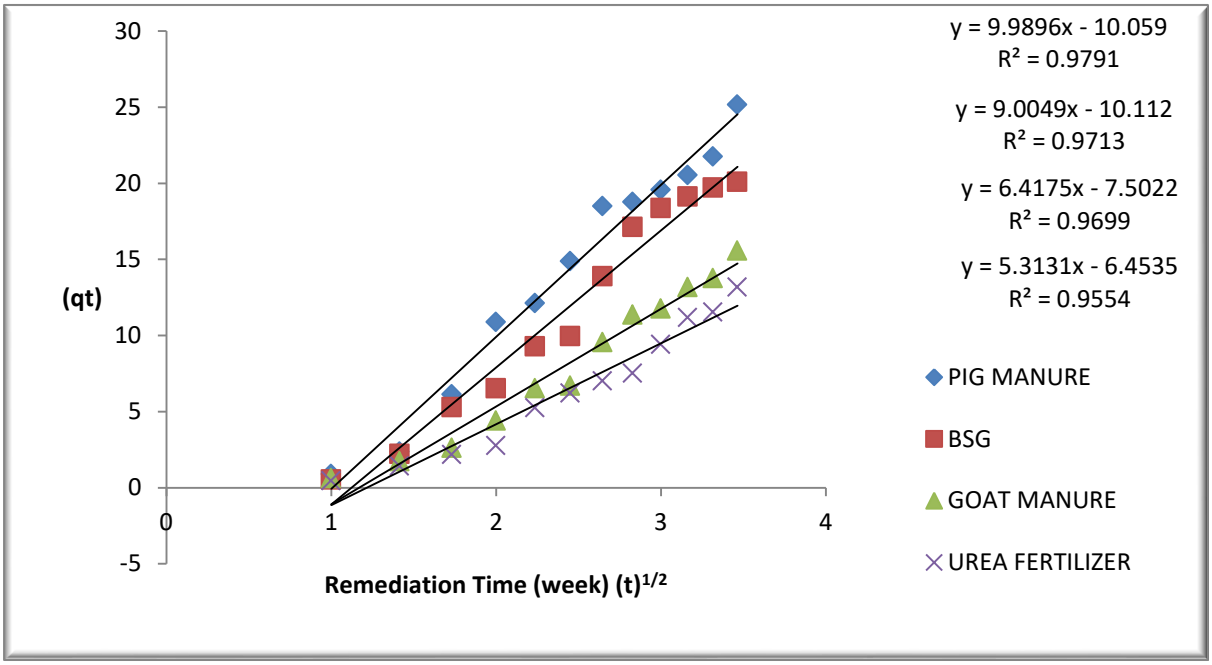

Figure 12: Intra-particle diffusion model for the bioremediation of used engine oil contaminated soil

Pseudo-first order kinetic model and pseudo-second order kinetic model were tested to study the reaction mechanism involved in the bioremediation of used engine oil contaminated soil using some selected substrate. Film diffusion was tested to study the diffusion of the particles of used engine oil after degradation through the boundary layer (film) while Intraparticle diffusion model was studied to understand the rate of internal diffusion occassioned by the transport of the particles of used engine oil after degradation within the pores of the substrate. If chemical reaction becomes the rate limiting step in the bioremediation process, then the bioremediation process will be a reaction controlled process. Conversely, if diffusion step is rate limiting, then the bioremediation process will be a diffusion controlled process. On the kinetics that best explains the experimental data, linear coefficient of determination was first employed as bases for judgment and result of Table 6 shows the computed values of r^2 for pig manure, brewery spent grain, goat manures and urea fertilizer based on the different kinetic models.

Table 6: Computed coefficient of determination (R^2)

Kinetic Models	Pig Manure	BSG	Goat Manure	Urea Fertilizer
Pseudo-first order	0.9853	0.8880	0.9469	0.9003
Pseudo-second order	0.2990	0.3506	0.5821	0.6079
Film diffusion	0.9497	0.9663	0.9872	0.9889
Intra-particle diffusion	0.9791	0.9713	0.9699	0.9554

Based on the result of Table 6, the bioremediation of used engine oil contaminated soil using pig manure can best be described by using the pseudo-first order kinetic model. When brewery spent grain (BSG) was employed as the substrate, the remediation process can best be described by using intra-particle diffusion model. When goat manure was employed as the substrate, the remediation process can best be described by using film diffusion model. Finally, when urea fertilizer was employed as the substrate, the remediation process can best be described by using film diffusion model. Determination of r^2 value and its subsequent application in the selection of best fit kinetic model is not satisfactory owing to the alteration in the error structure associated with the transformation of non-linear kinetic equation to its linear form. In addition, r^2 value only account for the difference associated with each individual point fitted by the model in relation to the overall average of the fitted curve. Therefore, to have an accurate judgement in the selection of best fit kinetic model, non-linear error functions were employed. Error functions such as sum of error square (SSE), root mean square error (RMSE) and the residual average (RA) unlike r^2 accounts for the difference associated with each individual point fitted by the model in relation to each experimental point measured. Results of the computed kinetic parameters using the selected non-linear error functions are presented in Table 7.

Table 7: Computed error functions for selected kinetic models

Model Parameters	Pig Manure	BSG	Goat Manure	Urea Fertilizer
Pseudo-First Order				
q_e(mg/g)	102.92	148.54	270.28	280.94
K(min^{-1})	0.0018	0.0011	0.0014	4.5E-03
R^2	0.9853	0.8880	0.9469	0.9003
SSE	0.0002	0.0005	0.0012	0.0072
RMSE	0.0028	0.0073	0.0082	0.0481
Average Residual	-0.412	-0.556	-0.798	-0.884
Pseudo-Second Order				
q_e(mg/g)	45.713	12.233	7.1322	14.711
K_2(g/mg/min)	0.3355	0.3314	0.3376	0.3388
R^2	0.2990	0.3506	0.5821	0.6079
SSE	0.1432	0.2343	0.4467	0.8839
RMSE	0.0457	0.0567	0.0844	0.1269
Average Residual	-2.221	-4.416	-5.029	-7.106
Film Diffusion Model				
K_f (kg/s)	16.262	21.061	12.135	11.654
W (g)	2.1066	1.3591	2.3443	3.7812
Sw (kg)	0.2345	0.4561	0.9923	0.6534
Vf (m^3)	1.0345	2.1309	1.0034	1.3042
R^2	0.9497	0.9663	0.9872	0.9889
SSE	1.8394	1.3900	1.1471	2.0102
RMSE	0.2562	1.0492	0.7972	0.3170
Average Residual	-1.044	-1.645	-1.4060	-1.2650
Intra-Particle Diffusion				
K_{ad} (mg/g min)	23.262	45.061	26.133	31.602
I	4.1013	3.3583	4.3256	6.1400
R^2	0.9791	0.9713	0.9699	0.9554
SSE	0.8367	0.3973	0.1498	0.8662
RMSE	1.2567	2.4923	1.7909	2.0708
Average Residual	-1.078	-1.886	-1.065	-1.642

From the result of Table 7, it was observed that pseudo-first order kinetic model had the lowest calculated error sum of square and root mean square error with computed residuals almost close to zero. The calculated error sum of square (SSE) are (0.0002, 0.0005, 0.0012 and 0.0072) while the computed root mean square errors (RMSE) are (0.0028, 0.0073, 0.0082 and 0.0481). Based on the calculated error values, it was concluded that the bioremediation of used engine oil contaminated soil

using pig manure, brewery spent grain, goat manure and urea fertilizer is a reaction controlled process for which the reaction mechanism follows a pseudo-first order kinetic model.

4.0 Conclusion

Bioremediation is emerging as alternative technology for removing pollutants from the environment, restoring contaminated sites and preventing further pollution. Result of the study revealed that pig manure, Brewery Spent Grain (BSG), Urea Fertilizer and goat manure are effective for the biodegradation of used engine oil contaminated soil since they can facilitate the rate of breakdown of the hydrocarbon component of the used engine oil. In addition, pig manure was observed to have the highest population of heterotrophic bacterial followed by Brewery Spent Grain (BSG) and goat manure then urea fertilizer in that order. At the end of remediation time of 12 weeks' pig manure was acclaimed the best substrate for the clean-up of used engine oil contaminated soil with calculated removal efficiency of 64.4% followed by BSG with 51.4% removal efficiency, Goat Manure with removal efficiency of 39.9% and Urea Fertilizer with 33.7% efficiency.

Linear and non-linear regression analysis of the experimental data revealed that the non-linear regression analysis best explains the experimental data and can be employed to predict the maximum remediation time of used engine oil degradation. Results of the kinetic modelling based on the calculated error functions revealed that pseudo-first order kinetic model had a better fit to the experimental data. Finally, it was observed that for the entire period of experimentation (12 weeks), there was a gradual decrease in the total nitrogen content (TNC), total organic carbon (TOC) and total hydrocarbon content (THC) with remediation time. The use of pig manure, goat manure, brewery spent grain and urea fertilizer to enhance the degradation of used engine oil contaminated soil could be one of the severally sought bioremediation strategies of remediating natural ecosystem that is contaminated with petroleum hydrocarbons.

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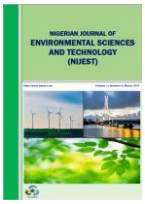

Position Paper

The Need for Inclusion of Geomatics Engineering as a Programme in Nigerian Universities and Registrable by Council for the Regulation of Engineering in Nigeria (COREN)

Okonofua E. S.[1], Oladosu O. S.[1] and Ehigiator –Irughe R.[1,*]

[1]Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Benin City, Nigeria

Corresponding Author: *raphael.ehigiator@uniben.edu

ABSTRACT

This paper presents the field of Geomatics as an evolving field, its relevance to other fields of engineering in general as well as other countries who have been practicing it. The rationale for teaching Geomatics Engineering courses in Nigerian Universities as well as making it COREN registrable is borne out of good intention to put it where it rightly belongs. In this work, previous researches on the relevance of Geomatics Engineering in other engineering practices and the advantages the profession has offered other fields of Engineering due to proper placement were reviewed. Geomatics Engineering has metamorphosed over the years and many countries have taken advantages of this development as a welcome idea and Nigeria cannot be exception. This article also revealed the need for the Council for the Regulation of Engineering in Nigeria (COREN), to urgently incorporate Geomatics Engineering into its structure as a field of engineering practice in Nigeria similar to what is obtainable in other advanced counties. This will help in harnessing the full advantage of the profession in the field of Engineering practices where the knowledge of Geomatics is required.

Keywords: COREN, Geomatics Engineering, Technological Advancement, Professional

1.0. Introduction

Geomatics a new paradigm comes from the French word “géomatique”. (Its roots are “geo” (Earth) and “informatics” (information + automation + “ics”) which is the accepted form for the name of sciences). Another description of Geomatics was derived from two words Geodesy + Geoinformatics. In the Latin language, the Geomatics correspond to Geomatica (Adeoye, 2010; Nwilo, 1999; Nwilo et al., 2000), and Russia is called Геоматика (Geomatika). Geomatics Engineering is the application of the knowledge of mathematics and sciences leading to the acquisition, processing (arrangement), and interpretations of ground and spatial data which is used for Engineering designs for the benefit of mankind (Junnilainen, 2006).

Junnilainen, (2006) describes terrestrial surveys with a much older history as being the fundamentals for determining size and shape of the earth, and of establishing country and continent-wide reference Networks. He also noted that in ancient time, the surveyor was called a person who uses geometry and primitive tools such as surveying rope, chain or tape in order to define the cadastral edge. A lot of words have been used in order to express Geomatics engineering from ancient time to today such as Geometrist, Surveyor, Survey Engineer, Geodesist, Photogrammetrist, Cartographer, Geoinformatiker, Geomatician etc. As the parallel to the technological development, surveying and mapping sector has improved itself and adapted to the new phenomena. This phenomenon has been synchronized into military and security architecture for the production of maps used in defense and combat. On a global scale, within the Last two centuries, the most affected engineering due to the revolution in computer and space technology is Geomatics Engineering. This is as a result of the sophistication of real time equipment in data capturing, preserving, analysis and presentation (Junnilainen, 2006).

Also, Geomatics as a department in Engineering that deals with all kinds of position-dependent measurement, calculation, analysis and visualization studies; has the advantage of sharing processed acquired data for engineering designs in Civil/Structural Engineering, electrical Engineering, Water resources and Environmental Engineering. Spatial information for hydrological and hydraulic designs are also acquired by Geomaticians for the design of hydraulic structures. The first beneficiary of acquired data are the Engineers, hence relocating Geomatics to Engineering is an added advantage to the college of Engineering as it is in most advanced countries. Geomatics Engineering is one of the vast engineering branches that are open to technological developments and best practices in contemporary technology (Cerba, 2012).

Geomatics, as a modern discipline, which integrates acquisition, modeling, analysis, and management of spatially referenced data, i.e. data identified according to their locations; its full advantage can be fully harnessed when it is domiciled in the faculty of Engineering for the purpose of share technical facility and ease of access to acquired data (Junnilainen, 2006).Based on the scientific framework of geodesy, it uses terrestrial, marine, airborne, and satellite-based sensors to acquire spatial and other data. It includes the process of transforming spatially referenced data from different sources into common information systems with well-defined accuracy characteristics (URL-1). Besides, Geomatics like other Engineering disciplines involves intersection of the physical, biological, business and social sciences with respect to mathematical and logical relationships as illuminated Fig 1 (URL-2).

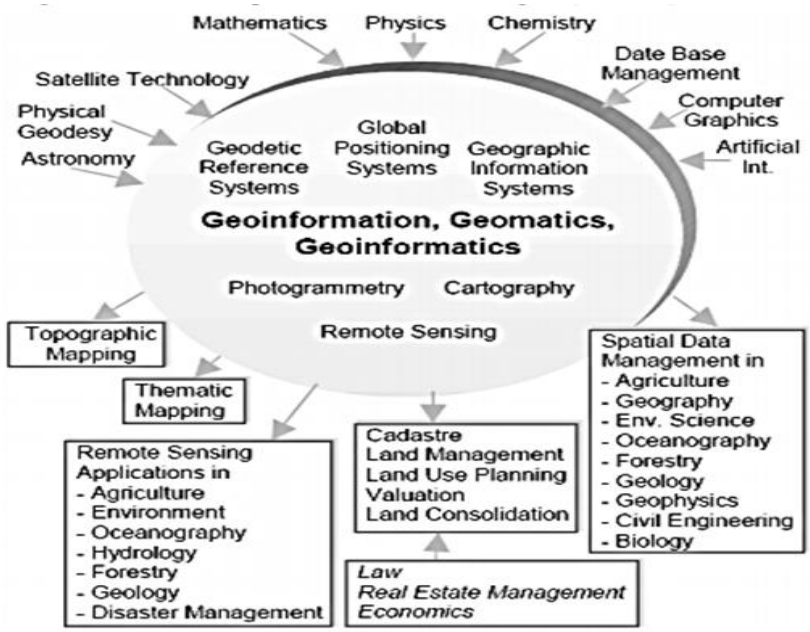

Figure 1: Geomatics at glance. Source: (Grun, 2008)

The aim of geomatics engineering according to Cerba, (2012) involves the development and use of various spatial techniques based on modern technology to better understand, plan, organize, monitor and manage the earth we live in, the production of various maps and spatial data /information for the needs of the country (planning, property, defense etc.) and determining precise position (horizontal and vertical) of any kind of space or land related to the earth. These are the basic details needed for the design of Engineering infrastructure hence to need to bring Geomatics closer to where the outputs are put applied.

1.1. Aim and Objectives

The aim of this paper is to unravel the need to teach Geomatics Engineering in Nigerian University, acceptable by Nigerian Society of Engineer (NSE) and to become registrable by Council for the Registration of Engineering in Nigeria (COREN). While the objectives are but not limited to:

a. present the overview of Geomatics engineering at a glance.

b. showcase the interdependency of major engineering fields with Geomatics Engineering.
c. emphasize the application of Geo-data acquired by Geomatics Engineering to various engineering fields for solving societal problems.
d. disabuse biasness and mediocrity against Geomatics engineering among Nigerians.

2.0. Justification for the inclusion of Geomatics Engineering in the Faculty of Engineering in Nigerian Universities

For the past years the polytechnics and universities in Nigeria, have been focused on producing cadastral surveyors and technicians. This was so because of the historical background of the country during the precolonial, colonial and postcolonial eras. The focus was on cadastral and boundary surveying as if it was the only discipline of surveying gave the profession a narrow perception in the eye of the public and making the practicing Surveyor the worse advertiser of their products. Emphasis was more on boundary delineation. The recent advancement in Technology has revolutionized the profession.

Over the last decade the Department of Surveying in most Nigerian University have transformed to the Department of Surveying and Geomatics. In University of Benin, the department was named GEOMATICS in conformity with international standard of nomenclature and because the department is domicile in the Faculty of Environmental Sciences. Most international Universities adopted the name GEOMATICS ENGINEERING or GEOSPATIAL ENGINEERING etc., depending on the Faculty housing the programme. Geomatics at the University of Benin was approved as a department to transform from the traditional surveying programme to one concerned with not just only ground survey data acquisition but also train students in processing the acquired data to produce designs of Engineering infrastructure. Courses in this program covers, highway geometrics, water resources and environmental Engineering, geotechnical engineering and fluid mechanics (Brimicombe, 2008). Increasingly, Geomatics is playing a central role in designing, building and managing the spatial information systems underpinning a modern society. The discipline builds on a strong measurement science base which is closely linked to its traditional land administration focus. The discipline has built on this strategic advantage to focus increasingly on the science, Engineering and management of spatial information.

The introduction of the B.Eng. programme in Geomatics Engineering is justified at this time in Nigeria because in spite of the huge potential for geomatics engineers to provide the needed engineering mapping services for all phases of environmental engineering and management, there are currently few universities offering this programme in Nigeria. The surveying education currently being offered in Nigeria is aimed at practicing as land surveyors and being largely skill and rule based, it does not meet the knowledge-based requirement for Geomatics Technology.

The new geomatics engineer will provide all mapping and engineering surveying services for engineering, scientific and military applications which include: mining and underground engineering works, highway engineering, tunnel engineering, deformation studies, water supply engineering, feasibility studies, erosion modelling & remediation, flood prediction, refuse evacuation engineering, irrigation & precision agriculture, navigation and tracking of moving vehicles or objects, Geotechnical Engineering, land surveying for cadastral, mapping for the production of township maps, establishment of geodetic control networks for establishment of national or state plane coordinate systems, establishment of national geodetic datums and linkage with international datums, precise positioning of scientific structures, space exploration, study of earth dynamics, measurements and predictions of earth tremors and quakes, rocket launching, military engineering and intelligence gathering, pipeline engineering, power line engineering, optimal route selection, environmental systems modelling, automated mapping and facilities mapping (AM/FM), contextual analysis of spatial features, etc. (Brimicombe, 2008). The table below show list of some selected leading Universities in the world offering Geomatics Engineering and the equivalent degree certificate compared to B.Eng. certificate issued in Nigerian Universities offering Engineering, accredited and registrable by (COREN). The

advantages enjoyed by these institutions include; shared facilities, ease of access to acquired data, robust knowledge in data (point and spatial) acquisition and design using the acquired data etc. The Nigerian University Geomatics Engineering graduates also stand the chance of benefiting from the above listed advantages and in addition be acquitted with the type of data details to acquire for specific projects. Table 1 is list of Universities oversea offering Geomatics Engineering.

Table 1: Some Universities offering Geomatics Engineering Programme

S/N	University	Degree Offered	Faculty	Location
1	Imperial College of Science, Technology and Medicine	B.Eng. Geomatics Engineering	Engineering	UK
2	University College, London	B.Eng. Geomatics Engineering	Engineering	UK
3	De Montfort University, Leicester	B.Eng. Geomatics Engineering	Engineering	UK
4	Moscow State University of Geodesy and Cartography	M.Sc. Engineering Geodesy and Geomatics	Engineering and management	Russia, Moscow
5	Siberian State University of Geosystems and Technology	M.Sc. Geodesy and Geomatics Engineering	Engineering	Russia, Novosibirsk
6	University of Melbourne	B.Eng. Geomatics Engineering	Engineering	Australia
7	University of New South Wales (UNSW)	B.Eng. Geomatics Engineering	Engineering	Australia
8	University of Queensland	B.Eng. Geomatics Engineering	Engineering	Australia
9	University of South Australia	B.Eng. Geomatics Engineering	Engineering	Australia
10	Ohio State University	B.Eng. Geomatics Engineering	Engineering	Columbus, USA
11	University of Wisconsin	B.Eng. Geomatics Engineering	Engineering	Wisconsin USA
12	University of Maine	B.Eng. Spatial Information Engineering	Engineering	Orono, USA
13	California State University, Fresno	B.Eng. Geomatics Engineering Department	Engineering	California
14	University of Tehran,	B.Eng. Department of Surveying and Geomatics Engineering	Engineering.	Iran
15	British Columbia Institute of Technology.	B.Eng. Department of Geomatics Engineering Technology.	School of Construction and the Environment	British Columbia, Canada.
16	University of Calgary	B.Eng. Geomatics Engineering	Engineering	Canada
17	University of New Brunswick, Fredericton	B.Eng. Geodesy and Geomatics Engineering	Engineering	Canada
18	University of Toronto	B.Eng. Geomatics Engineering	Engineering	Canada
19	Dublin Institute of Technology	B.Eng. Geospatial Engineering	Engineering	Republic of Ireland
20	Purdue University	B.S. (LSE) and B.S. (LSE & BSCE)	Engineering	West – Lafayette, USA
21	Kwame Nkrumah University of Science and Tech. Kumasi	B.Sc. (Geodetic Engineering)	Engineering	Ghana
22	University of Mines and Technology, Tarkwa	B.Sc. Geomatics Engineering	Mineral Resources Technology	Ghana
23	University of Nairobi	B.Sc. (Geospatial Engineering)	Engineering	Kenya
24	University of Stuttgart	B.Eng. Geomatics Engineering	Engineering	Germany
25	University of Twente	M.Sc. Spatial Engineering	GeoInformation Science and Earth Observation (ITC)	Netherlands

2.1. Some Equipment Used in Geo-Data Acquisitions in Geomatics

Some of the equipment used in Geomatics shows that some professionally trained persons can understand and handle them successfully. These devices are used to acquire data which form the basis of Engineering designs. Various data such as: one dimensional, two dimensional, three dimensional, even four dimensional are products from Geomatics engineering work which are needed for various engineering design purposes.

Figure 2: Some modern Geomatics Engineering Equipment

Fajemirokun et al., (2002) affirmed that with the enlarged tasks of surveying, the need for new or modified curricula in the tertiary institutions in Nigeria has become paramount. In view of this, the curriculum of Geomatics department, University of Benin and that of other institutions like University of Lagos have been revisited and review severally as occasion demands by many capable hands to reflect the internationally accepted best practices. Geomatics as identified by most engineering professionals as also the case observed in Nigeria is closely related to the disciplines listed in Table 2.

Table 2: Closely related disciplines to Geomatics Engineering

1	Computer Science	9	Geotechnical Engineering
2	Information Science	10	Metrology
3	Civil Engineering	11	Coastal Engineering
4	Geophysics	12	Disaster/hazard Engineering
5	Environmental and Natural Resource Management	13	Applied mathematics
6	Instrumentation Engineering	14	Space Engineering
7	Hydrology	15	Navigation Engineering
8	Glaciology and Sea Level	16	Railway Engineering

As in all disciplines of the engineering profession, Geomatics Engineering is influenced by: Global trends, Regional needs and trends, National needs and trends, State needs and trends as well as Ethical concerns, Social responsibilities and Independence. In Figure 3, Laser scanner and Total station equipment can be seen at glance in industrial application work. Starting from inventory survey to capture and update, the plant inventory as the solid basis for planning and the subsequent creation of plans, factory information systems and 3D models, setting-out and control measurements are carried out during the alterations and new constructions. Post construction surveys, deformation monitoring

and as-built surveys carried out by Geomaticians have saved a lot of damages to engineering infrastructure in recent times (Kufoniyi, 1999).

Figure 3: Laser Scanner and Total station in industrial application (Source: GEODATA, 2015).

Thereafter, machines and tools are positioned and accurately aligned and calibrated and inspected to ensure the quality of the finished product as well as all the necessary control and monitoring measurements during ongoing operations; for instance, on crane tracks, rolling mill frames, etc. Measurement data with high precision for accurate information on the size, shape and position of objects on site with pinpoint accuracy using the advantage of the latest technology are now possible Figure 3 shows a total station being used for alignment in an industrial setup (Kufoniyi, 1999).

Figure 4: Application of laser scanner on bridge and pipeline (Source: Mills et al., 2004)

2.2. Geomatics View of Societal Needs

What the society needs from the perspective of a Geomatics Engineers are specified as follows.

a. The need to have a place to live and work;

b. The need to manage our cities with this being an increasing requirement;

c. The need to manage the land and marine environment which is on the increase;

d. The need to continue to build and increasingly maintain our physical infrastructure.

All these activities are central to the role of a Geomatics Engineer. As a result of the above, there will be increasing needs within society for the management of spatial information (Mills *et al.,* 2004). Specifically, society will require Geomatics Engineers to among other things to engage in the following services.

- Design, build and manage spatial data infrastructures such as the geodetic framework, the various base mapping systems, the new spatial data collection technologies such as high-resolution satellites and spatial data measuring systems such as the global positioning system.

- Society will increasingly need to design, build and manage the spatial business systems concerned with the natural and built environment which build on this spatial data infrastructure. This will include all the systems to manage utilities and services, geographic information systems (GIS), land administration systems and all the natural resource information systems including the marine environment.
- Society will continue to require Geomatics Engineers to design, build and manage the urban and rural habitation which has been a traditional function of survey engineers. This includes the development of residential, commercial and industrial land developments.
- Finally, within this more complex society, Geomatics Engineers will increasingly be required to design and apply the measurement systems which will control much of the construction and management of the above development and management of the environment for the benefits of mankind.

From the list above, it can be concluded that society will have an increasing requirement for an engineering profession which is responsible for ground data acquisition, spatial information acquisition, post construction survey, infrastructure deformation monitoring and managing 3D Geospatial dimensional space of our natural and built environment.

3.0. Geomatics Engineering Curriculum Design

The design of curriculum for Geomatics engineering in Nigeria has been advocated by renowned academician and professional stake holders. The training initially offered in the institutions discussed by Fajemirokun, et al., (2002) on Geomatics education in Nigeria was geared towards training in the field of surveying from where students may be exposed to the basic rudiments of computer hardware and software, and taught some of the programming languages. Courses on the various divisions of surveying were offered. Such divisions include Plane Surveying, Engineering Surveying, Geodetic Surveying, Photogrammetry, Remote Sensing and Hydrographic Surveying.

The activities of geomatics are included in, but not limited to, Surveying and Mapping, Cartography, Digital mapping, Geodesy, GIS, Land Information Management, Digital Photogrammetry and Remote Sensing. Geomatics can also be regarded as the integration of the traditional survey techniques and applications with the modern methods of Global Navigation Satellite System (GNSS), Remote Sensing and Geographic Information System Fajemirokun, et al., (2002).

Due to the change of emphasis from Surveying to Geomatics, the training of surveyors in Nigeria is being modified to meet the training needs of geomatics education. Many institutions at the University and Polytechnic levels are now modifying their curricula so as meet the training needs for the geomatics education. It has indeed become very important for every higher institution in the country to change or modify their curricula in order to produce the needed man power to meet the current needs in the private and public sectors.

Many professionals in allied fields like engineering, sciences, health and social sciences and even in education and business administration are now embracing Geomatics. The higher institutions offering surveying are now saddled with the task of developing new curricula to train Geomatics Engineer and professionals from other fields of study (Fajemirokun, et al., 2002). In the light of this, several institutions of higher learning previously offering Geomatics as surveying, or surveying and Geoinformatics have seen need to upgrade to the internationally acceptable best practices of upgrading to full Geomatics training. Table 3, is a sample of the designed curriculum currently being run in the Department of Geomatics, University of Benin (UNIBEN).

Table 3: Sample of curriculum design and courses taken by Geomatics students UNIBEN

COURSE CODE	COURSE TITLE 100 Level	COURSE CODE	COURSE TITLE 200 Level
CHM 111	General Chemistry I	GEM 221	Introduction to Geomatics Engineering
CHM 113	Organic Chemistry I	EMA 281	Engineering Mathematics I
MTH 111	Algebra and Trigonometry	GEM 231	Introduction to Computer Programming
MTH 112	Calculus and Real Analysis	MEE 211	Applied Mechanics I
PHY 111	Mechanics, Thermal Physics & Properties of Matter	MEE 221	Engineering Drawing, I
PHY 113	Vibrations, Waves and Optics	EEE 211	Electrical Engineering, I
GST 111	Use of English I	GEM 211	Basic Environmental Geomatics I
GST 112	Philosophy and logic	CVE 211	Strength of Materials
CHM 122	General Chemistry II	LAB 201	Laboratory/ Field Work I
CHM 124	Organic Chemistry II	EMA 282	Engineering Mathematics II
MTH 123	Vectors, Geometry and Statistics	GEM 212	Basic Environmental Geomatics II
MTH 125	Differential Equation and Dynamics	GEM 232	Engineering Computer Graphics& CADD
PHY 109	Practical Physics	GEM 252	Computer Application to Geomatics Engineering
PHY 124	Electromagnetism & Modern physics	MEE 212	Engineering Mechanics II
GST 121	Peace Studies and Conflict Resolution	GEM 222	Mathematical Cartography
GST 122	Nigerian Peoples and Culture	CVE 212	Element of Architecture I
GST 123	History and Philosophy of Science	EEE 212	Electrical Engineering II
	300 Level 1st Semester	LAB 202	Laboratory/Field Work II
EMA 381	Engineering Mathematics III		**500 Level 1st Semester**
MEE 351	Thermos Dynamics	PRE 571	Engineering Management, Economics and Administration
CVE 341	Engineering Geology I	GEM 531	Engineering Geodesy I
GEM 331	Geomatics Engineering Networks	GEM 521	Space Geodesy
GEM 311	Cadastral and Land Information Management	GEM 531	Digital Image Processing
GEM 341	Engineering Statistics	GEM 541	Digital Terrain Model
GEM 361	Geospatial Information System I	GEM 501	Project
GEM 351	Photogrammetry & Remote Sensing I	CVE 521	Civil Engineering Hydraulics
MEE 361	Fluid Mechanics I	GEM 511	Geo-Environmental Engineering
GST 300	Entrepreneurship	GEM 581	Lab/ Field work V
	300 Level 2nd Semester		**OPTIONAL COURSES (Choose two Courses only)**
EMA 382	Engineering Mathematics IV	GEM 551	Applied Building Information Modelling
GEM 317	Engineering Geophysics	CVE 523	Engineering Hydrology I
GEM 312	Operation Research in Engineering	CVE 553	Non-Topographic Photogrammetry
GEM 322	Hydrology and Water Resources Engineering	CVE 555	Positioning, Navigation and Wireless location
GEM 362	Photogrammetry and Remote Sensing II	CVE 541	Geotechnical Engineering
GEM 392	Hydroinformatics Engineering I		
GEM 332	Mining and Special Geomatics Engineering		**500 Level 2nd Semester**
GEM 352	Geometric Geodesy	GEM 528	Water Resources and Environmental Engineering
GEM 372	Adjustment and Least Squares	GEM 516	Mapping Laws and Code of Professional Practice for Civil and Geomatics Engineering
ELA 302	Swimming/Field Camping	GEM 514	Marine Geodesy
	OPTIONAL COURSES (Choose one Course only)	GEM 522	Physical Geodesy
GEM 342	Geodetic Astronomical Methods	GEM 532	Engineering Geodesy II
GEM 342	Engineering Geology	GEM 524	Adjustment & Mathematical analysis
MEE 362	Fluid mechanics II	GEM 552	Health, Safety and Environmental Management system
	400 Level 1st Semester	GEM 502	Final Year Project
EMA 481	Applied Engineering Mathematics		**OPTIONAL COURSES (Choose two Courses only)**
CVE 441	Soil Mechanics	GEM 592	Sensor Web and Internet of Things
GEM 421	Engineering Surveying	GEM 562	Environmental Remote Sensing and GIS
GEM 461	Geospatial Information System II	GEM 572	Environmental modeling
GEM 451	Advanced Remote Sensing and GIS	GEM 556	Environmental Monitoring and Management
GEM 411	Hydroinformatics Engineering II	CVE 522	Engineering Hydrology II
CVE 423	Environmental Engineering		
GEM 471	Potential Theorem and Spherical Harmonic		
GEM431	Geodetic Engineering		
CVE 431	Introduction to Transportation Engineering		
LAB 401	Laboratory/field work IV		
	OPTIONAL COURSES (Choose one Course only)		
CVE 421	Hydraulic and Hydrology		
CPE 481	Numerical Computation		
	400 Level 2ndSemester		
	SIWES (Industrial Training)		

Table 3 reflects the summation of courses offered in the department of Geomatics, university of Benin. The programme contains 53% Engineering courses covering Civil and Mechanical Engineering; and 47% Surveying courses. The more than 50% Engineering courses give the students leverage in Engineering practices and profession. We therefore recommend Table 3 to National University Commission (NUC) and COREN as the minimum requirements by students offering Geomatics engineering to pass before graduating from Nigeria Universities. It is a reflection of the evolvement and revolution of the discipline of Geomatics over time and over the world.

5.0. Conclusion

Geomatics Engineering in higher education around the world used to be in a perilous condition because of student low turnout and lack of proper awareness of what the programme entails. Recently, this narrative is changing globally as there is a holistic marketing approach in ensuring that the advantages of geomatics engineering is appreciated in nearly all fields of engineering and Nigerian universities cannot be exception. The change in the discipline has been dramatic and exciting and here is a great deal of demand for the graduates and very good support for sponsored-research in the Geomatics Engineering discipline. Therefore, this study has added immensely to the clarion call of geomatics engineers for the inclusion of geomatics into Nigerian Universities curriculum and also a division in Nigeria Society of Engineers which is registrable by the Council for the Regulation of Engineering in Nigeria, COREN.

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iv) Sample journal article citation:

Izinyon, O.C. and Ehiorobo, J.O., (2014). L-moments approach for flood frequency analysis of river Okhuwan in Benin-Owena River basin in Nigeria. *Nigerian Journal of Technology*, 33(1), pp.10-19

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