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Volume 2

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Group photograph of Conference Participants at the opening ceremony

Environmental Management Conference 2011

Opening Address by the Vice- Chancellor, Prof. Oluwafemi Olaiya Balogun

It is my pleasure to welcome everyone to the University of Agriculture, Abeokuta, on this occasion of the first Environmental Management Conference to be organised by the College of Environmental Resources Management of the University.

Globally, the issue of the environment is no doubt a very serious one, and Nigeria is no exception. The reports of recent flooding in Lagos, Abeokuta and Ibadan due largely to reclamation of coastal areas, solid waste dump into water channels, lack of canals, and faulty urban planning, to mention a few, are still fresh in our memories. Also noteworthy are problems of industrial and domestic pollution of surface and groundwater, land degradation, loss of biodiversity, air and noise pollution, which are all very prominent in our environment.

Here in UNAAB, we realised quite early the need to study and assess the environment in all its ramifications. That is why UNAAB is the first University in Nigeria, right from inception, to have a College of Environmental Resources Management, where we consider issues relating to the environment, through the establishment of the Departments of Aquaculture and Fisheries Management, Forestry and Wildlife Management, Environmental Management and Toxicology and Water Resources Management and Agricultural Meteorology. It is therefore in order that the University is the host to the first edition of the Environmental Management Conference.
I have been informed that this conference is being co-sponsored by the Africa Geosciences Review, an International Journal of repute. Prof. Cornelius Kogbe, its founding Editor-in-Chief, is heartily welcome to UNAAB.

As scientists gather in this university in the next two to three days to present scholarly papers and reflect on the theme: 'Environmental Management in Coastal and Wetland Areas of Nigeria', I enjoin you to be proactive in your considerations as you formulate implementable environmental management policies. I wish you a very fruitful deliberation.

Finally, I want to seize this opportunity to urge you to take time out to look round our beautiful campus and visit Abeokuta city, taking cognisance of its historical sites like the popular Olumo rock and the traditional 'Adire' textile market at Itoku.

Thank you very much.

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LAND DEGRADATION, WATER AND AIR POLLUTION

Soil Physical Properties and Hydraulic Conductivity of Compacted Sandy Clay Loam Planted with Maize *Zea Mays*

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Abstract

Land degradation from soil compaction has a major influence on the hydraulic conductivity, total porosity (PT), micro porosity (MIC), macro porosity (MAC), roots growth and grain yield. Field experiment was conducted in a tilled and compacted sandy clay loam soil under different machinery passes to determine compaction effects on soil bulk density, total porosity (PT), micro-porosity (MIC), macro-porosity (MAC), hydraulic conductivity and growth characteristics of maize. Four plots; A, B, C and D, each of area 5 x 10 m^2 were used. Plot A was tilled with a tractor-mounted disc plough and the remaining three plots; B, C and D were subjected to 5, 10 and 15 passes, respectively of heavy duty Mercy Fergusson tractor model 4355 (3.82 Mg). Compacted plots progressively increased in bulk density between 1.63g cm^{-3} to 1.90 gcm^{-3}, while total porosity decreased from 38 to 28.3 % in plots under 5 and 15 traffic passes, respectively. Soil micro-porosity decreased from 9.6 % to 7.84 % and from 17 % to 9.17 % in the soil superficial layer (0-10 cm) and at the 10-20 cm layer, respectively while the macro porosity ranged from 28.64 % to 20.45 % and 24.3 % to 19.12 % in the 0 - 10 and 10 - 20 cm soil layers, respectively. At suction of 2 cm s^{-1}, tilled plot had the highest cumulative infiltration rate of 3.42 cm s^{-1} and hydraulic conductivity of 9.09 x 10^{-3}. Results show that different machinery passes poses different restrictions to rooting depths of maize.

Keywords: Bulk density, hydraulic conductivity, total porosity, micro porosity, macro porosity.

Introduction

As farm tractors and field equipment become larger and heavier, there is a growing concern about soil compaction. Soil compaction can be associated with a majority of field operations that are often performed when soils are wet and more susceptible to compaction. Soil structure is important and must not be damaged because it determines the ability of a soil to hold and conduct water, nutrients, and air necessary for plant root activity.

Soil compaction, as well as changes in soil physical properties, is a major factor that causes high mechanical impedance or excessive soil strength (Yamauchi, 1993; Iijima et al., 1991; Masle 2002). Soil compaction is the main form of soil degradation, which affects 11% of the land area in the surveyed countries of the world (Tamari et al., 1993; Morath et al., 1997). Compaction is caused by the use of heavy machinery, pressure from wheels, trampling by animals, frequent use of chemical fertilizers and ploughing at the same depth for many years. Agricultural processes, such as soil compaction, tillage fertilization and irrigation, have impact on soil structure, and degrade field drainage. These processes are mostly conducted near the surface, and affect topsoil structure over short time scales. Consequently, many studies have examined changes in topsoil structure (Mapa, 1986; Hill, 1990). Recently, the importance of persistence of subsoil compaction for soil structure change has been reported (Voorhees, et al., 1986; Hakansson, 1994; Horn et al., 2000; Arvidsson, 2001).

Over the years, physical properties of the soil that control water movement and retention in the soils are largely affected due to human, animal activities as well as use of machine for soil tillage purposes. Among such soil properties affected is the soil bulk density, which according to Wellings *et al.,* (1985) is the density for a volume of the soil as it exits naturally, including any air spaces and organic materials (OM) in the soil volume. Since bulk density is used to calculate the total water storage capacity per soil volume and to evaluate compaction within, which invariably determines soil layer root penetration or adequate aeration (Van Remorted and shields, 1993), the bulk density of soil depends greatly on the mineral make up of soil and degree of saturation (Buckman et al; 1960). Bulk density of soil is usually determined on core samples, which are taken by driving a metal core sampler into the soil at the desired depth and horizon. The samples are then oven-dried and weighed. A loosed soil, with an increased total pore space, will have a small weight after it is compacted. Thus, the bulk densities can be used to estimate differences in compaction of soil when subjected to different traffic machinery passes. This can be used to calculate total water storage capacity per soil volume and to evaluate soil layers with respect to the degree of compaction, allowable root penetration and air permeability (Donahue, 1990). The bulk density of soil is inversely related to the porosity of the same soil: the more pore space in a soil the lower the value for bulk density.

Another soil properties that is affect by machinery passes is the soil hydraulic conductivity, which depends on soil structure and varies in both space and time. Temporal variation of hydraulic conductivity is caused by growth and decay of plant root (Meek et al., 1992), activity of soil organism (Beven and Germann, 1982; Willoughby et al., 1996), precipitation that forms surface crusts (Messing and Jarvis, 1993), shrinking and swelling (Messing and Jarvis, 1990; Bagarello et al., 1999), freezing and thawing (Scott et al., 1994), and agricultural activities, such as tillage and wheel-traffic compaction (Ankeny et al., 1990; Logsdon and Jaynes, 1996). Hydraulic conductivity, which reflects soil structural properties such as total porosity, micro porosity, macro porosity, pore–size distribution and pore continuity, is used as an index for field drainage. When soil become compacted, changes in total porosity, micro porosity, macro porosity and pore-size distribution cause the hydraulic conductivity to decrease, and penetration resistance and bulk density to increase (Lowery and Schuler, 1994). The change in hydraulic conductivity does not always result from the changes in dry bulk density (Mc Queen and Shepherd, 2002). For instance, tillage, which is the mechanical manipulation of soil to control weeds, breaks crusts to help infiltration and seedling emergence, dispose pests or crop residues and helps to develop a desirable soil tilth for seedbeds and crop establishment (Kepner et al., 1978). It is aimed at easing soil compaction, results in soil particle re-arrangement, breakdown of aggregates and pore discontinuity, except increase in total porosity, and would thus affect hydraulic conductivity.

According to International Agricultural Engineering Conference and exhibition, (December 1990), field experiments were conducted to study the effect of soil compaction caused by tractor tyres on various soil properties as well as on maize yield in a heavy clay soil. The compaction treatments were given before sowing and after sowing with wheel passes varying from 1 to 5 at a constant tyre inflation pressure. The results were compared with the control having zero passes. It was observed that the dry bulk density and penetration resistance increased with increase in number of wheel passes while porosity showed a decreasing trend. The maize yield was highly affected due to compaction. In both treatments the average reduction in the grain yields due to compaction ranged from 1.5 to 41% compared to control plots. The limitation of this was that, the result was only compared with the plots having zero passes. Several studies have evaluated the effect of tillage on root growth (Anderson, 1987; Barber, 1971). However, there is limited information on the combined effects of tillage practices and compaction under different traffic machinery passes on sandy clay loam planted with maize. The signs of soil compaction can often be seen by observing the crops growing in a compacted soil (OSHA Part 1982.650, 1998). Slow plant emergence, thin stands, un-even early growth, small grain heads, abnormal rooting patterns, shallow or horizontal root growth and reduced nutrients concentration can be a reflection of compaction. Excessive soil compaction impedes root growth and therefore limits the amount of soil explored by roots (Van Lynden, 2000). This, in turn, can decrease the plant's ability to take up nutrients and water. From the standpoint of production, the adverse effect of soil compaction on water flow and storage may be more serious than the direct effect of soil compaction on root growth. However, the objective of this study is to determine the effect of compaction on soil physical properties, such as bulk density, total porosity, micro porosity, macro porosity, and hydraulic conductivity, of sandy clay loam soil in the humid tropical climate of Nigeria on tilled soil and under different traffic machinery passes (Compaction).

Material and Method

Site Description

The research was conducted at the Federal University of Technology, Akure (FUTA) Step B (science and Technology Education Post-Basic) Project Site located on latitude 7^0 10'N and longitude 5^0 05'East. The soil of the study area is a sandy clay loam according to USDA textural classification.

Field Experimentation

Field experiment was conducted to determine the effects of soil compaction under different machinery passes. Field experiments were carried out between the months of March and June, 2011. There were four soil treatments plots; conventional tillage (CT) – plot A, using a tractor-mounted disc plough, compacted soil under five passes - plot B, 10 passes – plot C and 15 passes – plot D. The soil was compacted using heavy duty Mercy Fergusson tractor, model 4355 (3.82 Mg). The four treatments were tested to determine their influence on maize shoot, root growth and yield considering soil properties, such as Bulk density, hydraulic conductivity, total porosity, infiltration, micro and macro–porosity, of tilled and compacted plots. The treatments were replicated three times following a randomized complete block design.

Measurements

Measurements taken included bulk density, total porosity, hydraulic conductivity and crop measurements such as leaf count, root depth, root density, stem diameter, leaf area and maize height.

Bulk Density

Soil bulk density was determined using the method described by Black and Hartge (1986). Soil samples were taken from soil core at depths 0 - 10 cm and 10 – 20 cm using ring cylinders with height 10 cm and diameter 4.8 cm. The samplers were driven vertically into the soil enough to fill the sampler, the sampler and its contents were carefully removed to preserve the natural structure and packing of the soil as best as possible. The soil extending beyond each end of the sample holder was trimmed to ensure soil is contained in exactly the volume of the cylinder. Thus, soil sample volume was established to be the same as the volume of the sampler holder. The soil cores were wrapped in polyethylene, placed in wooden box and transported to the laboratory for analysis. The soil samples were transferred to a container, placed in an oven at 105^0 C, and dried to constant weight. The weight of soil was recorded and bulk density was calculated from the relationship in equation 2.1.

$$\text{Bulk Density } (\rho) = \frac{\text{weight of oven dreid soil}}{\text{volume of the soil}} \qquad (1)$$

Total Porosity

Total porosity (% pore space) was worked out using the same soil samples collected for soil bulk density. According to Suzuki et al., (2004) total porosity of the soil was calculated from bulk density assuming a particle density of 2.65 mg/m^3 with the following formulae:

$$PT = \left[1 - \frac{DS}{DP}\right] \times 100 \qquad (2)$$

$$Mic = \left[\frac{Ww - Wd}{Vc}\right] \times 100 \qquad (3)$$

$$\text{Macro porosity (Mac)} = PT - Mic \qquad (4)$$

where PT is total porosity (%), Mac is the soil macro porosity (%), Mic is soil micro porosity (%), Ds is the bulk density (g cm-3), Dp is the particle density (g cm^{-3}), Ww and Wd are wet weight and dry weight of samples (g respectively and VC is the volume of soil in the cylinder (cm^{-3}).

Hydraulic Conductivity

The mini disk infiltrometer model was used for measuring soil hydraulic conductivity. The infiltrometer enabled the correct and accurate measurement of the hydraulic conductivity of sandy clay loam soil. The soil hydraulic conductivity was determined following the procedure described in Ale and Manuwa (2011). The process involved using mini disk infiltrometer to measure the hydraulic conductivity of soil under different machinery passes. The bubble chamber was filled up to the ¾ of its volume by running water down the suction control tube or removing the upper stopper. Immediately the upper chamber was full, the suction control tube was slided and the infiltrometer was inverted to remove the bottom elastomer and the porous disk, and the water reservoir was then filled. The position of the end of the tube with respect to the porous disk was carefully set to ensure a zero suction offset while the tube bubbles. After filling of the water reservoir, the bottom elastomer was replaced; making sure the porous disk is firmly in place. No water leaked out when the infiltrometer was held vertically.

Suction rate of 2 cm per seconds was chosen on the field for the soil infiltration measurement on tilled soil and soils under different machinery passes; 5 passes, 10 passes and 15 passes. After the adjustment of the suction rate, the starting water volume was record at time zero, the infiltrometer was then placed to a smooth spot (scraped to make a level surface) on the soil surface. Instantaneously, water begins to leave the lower chamber and infiltrate into the soil at a rate determined by the hydraulic properties of the soil. The infiltration measurements were recorded every 30 seconds for the duration of the experiment in all the plots; plot A (tilled soil), plot B (5 passes), plot C (10 passes) and plot D (15 passes). The infiltrometer was run for not less than 5 minutes on each of the plots so as to ensure the infiltration of between 15-20 mL of water needed for the accurate calculation of hydraulic conductivity. The water reservoir was refilled during the experiment. The data collected in each of the plots were used to determine the water infiltration rates of the soil. The hydraulic conductivity of soil in the entire plot was then calculated using the method of Zhang (1997). The method requires measuring cumulative infiltration vs. time and fitting the results with the function

$$I = C_1 t + C_2 \sqrt{t} \qquad (5)$$

where C_1 (m s^{-1}) and C_2 (m $s^{-1/2}$) are parameters related to hydraulic conductivity and the soil sorptivity, respectively**.**

The hydraulic conductivity of the soil (*k*) was computed from

$$K = \frac{C_1}{A} \qquad (6)$$

where C_1 is the slope of the curve of the cumulative infiltration vs. the square root of time, and A is a value relating the van Genuchten parameters for a given soil type to the suction rate and radius of the infiltrometer disk. A is computed from:

$$A = \frac{11.65\left(n^{0.1}-1\right)\exp\left[2.92(n-1.9)\alpha h_0\right]}{(\alpha r_0)^{0.91}} \qquad n \geq 1.9 \qquad (7)$$

$$A = \frac{11.65\left(n^{0.1}-1\right)\exp\left[7.5(n-1.9)\alpha h_0\right]}{(\alpha r_0)^{0.91}} \qquad n□1.9 \qquad (8)$$

where n and α are the van Genuchten parameters for the soil, r_0 is the disk radius and h_0 is the suction at the disk surface. Since the soil is sandy clay loam, the values for n and α according to van Genuchten parameters are 1.48 and 0.059, respectively which were used to calculate the hydraulic conductivity of tilled and compacted soils under different machinery passes.

Crop Measurement

Measurement of the yield components of maize plant such as leaf count, root depth, root density, stem diameter, leaf area and maize height was conducted weekly on each of the plots A, B, C and D from the 3 weeks after planting (3WAP) up to 12 WAP. The measurements were conducted on three representative plants per plot. Number of leaf (NOL) was determined by manual counting of maize leaves on representative plants. Leaf area (AOL) was determined using the equation proposed by Dwyer and Stewart, (1986). Dwyer and Stewart, (1986) reported a general equation to estimate individual leaf area of maize (Zea mays L.):

$$\text{Leaf Area} = L \times W \times A \qquad (9)$$

where LA, L, W, and A are leaf area, leaf length, leaf maximum width and a constant (A = 0.75), respectively.

Rooting depths (RL) were determined by digging of trenches around the soil profile that covers the roots of maize up to the root tip and measuring with steel rule. Maize height (HOP) and stem diameter (SD) were determined using steel rule and venier calliper, respectively. Root density (RD) was determined by sectioning the roots into 3- segment; 0 -2 (RD_1), 2 – 4 (RD_2) and 4 – root tip cm, (RD_3) the roots on each segment was counted and divided by the total number of roots and converted to percentages.

Statistical Analysis

Descriptive statistics such as mean, standard deviation (STD) and standard error (STE) were conducted on infiltration data, and ANOVA and multiple comparisons of mean infiltration and hydraulic conductivities were conducted using the statistical package for social sciences (SPSS)

Results and Discussion

Bulk density

Result obtained showed that the bulk density varied among the plots i.e. plot A (tilled plot), plot B (5 passes), plot C (10 passes) and plot D (15 passes), and depths 0 – 10 and 10 – 20 cm. The bulk density was highest (1.90 g cm^{-3}) in plots compacted under 15 to and fro passes of heavy duty equipment (Table 1). Similar observation was made by Al-Ghazal (2002), who reported that soil bulk density increased significantly with an increase in compaction depending on the number of passes of tractor wheel. The results also agreed with the findings of Meek et al. (1992) who reported an increase in soil bulk density from 1.67 - 1.92 t m^{-3} with a tire pressure of 408 kPa and wheel weight of 2724 kg at moisture contents near field capacity. Similar results were reported by Cassel et al. (1995) who found an increase in soil bulk density for tracked interrow areas of a controlled traffic area. Schuler (1994) also showed that values of bulk density of soil increased with increasing level of compaction by 8 and 10 tons of farm machinery. At tilled plot (plot A), the low bulk density was recorded due to the soil particle that has been broken into smaller aggregates.

Table 1: Mean bulk densities of sandy clay loam soil under different compaction levels

Depth (cm)	Bulk density (g/cm^3)			
	Plot A	Plot B	Plot C	Plot D
0 – 10	1.51	1.63	1.83	1.90
10 – 20	1.53	1.76	1.86	1.90

Porosity

Considerable influence of tillage and compaction on physical properties, such as total porosity, micro porosity and macro porosity of the soil was noticed as shown in Table 2. Plot A (tilled soil), on the average, has the highest total porosity of 42.5 %, which allow root growth and development in the soil and enhanced grain yield compared to the compacted plots. Plot B, on the average, has total porosity of 35.5 %, Plot C, 30.35%, and plot D, 28.3%, which resulted in poor root growth, stunted growth of maize and poor grain production. Maximum micro porosity of 14.3% was obtained at plot A, but decreased to 7.84% in plot D, which shows that micro porosity decreased in the order of soil compaction 5 < 10 < 15 passes. Similar effect was obtained for macro porosity. On the average, plot A has the highest macro porosity of 52.94% and 39.57% in plots under 15 passes of equipment. The effect of compaction was much more noticed within the 0 – 10 cm than 10 – 20 cm depth of soil in plot B, C and D which poses different restrictions to rooting depths of maize.

Table 2: Mean total porosity, micro porosity and micro porosity of soil under different compaction levels

Porosity	Depth (cm)	Plot A	Plot B	Plot C	Plot D
Total Porosity (%)	0 – 10	43	38	30.9	28.3
	10 – 20	42	33	29.8	28.3
Micro porosity (%)	0 – 10	14.3	9.6	8.93	7.84
	10 – 20	17	9.17	7.5	9.17
Macro porosity (%)	0 – 10	28.64	28.38	22.16	20.45
	10 – 20	24.3	23.82	22.22	19.12

Hydraulic Conductivity

At suction of 2 cm s^{-1}, tilled plot had the highest cumulative infiltration rate of 3.46 cm s^{-1} (Table 3), when compared with compacted plots B, C and D, where the highest infiltration rate were 0.88 (Table 4), 0.66 (Table 5) and 0.35 cm s^{-1} (Table 6) respectively. This resulted into significant reduction of soil hydraulic conductivity to 9.3×10^{-4} cm s^{-1}, 8.8×10^{-4} cm s^{-1} and 8.6×10^{-4} cm s^{-1} in plots under 5, 10 and 15 passes, respectively. The cumulative infiltration of soil in plot A, B, C and D are presented in Figures 1, 2, 3, and 4 respectively. The highest soil hydraulic conductivity (at 2 cm suction) in plot A, plot B, plot C and plot D were 9.09×10^{-3}, 9.3×10^{-4}, 8.8×10^{-4} and 8.6×10^{-4} cm s^{-1} respectively (Table 7). This observation must have been caused by the effect of tillage, which according to Bouma (1991), Kepner et al. (1978) and Van Lynden (2000), creates macropores that cause saturated and near-saturated hydraulic conductivities to increase considerably and helps to dispose pests or crop residues, which in turn help in the development of a desirable soil tilth for seedbeds and crop establishment.

Table 3: Infiltration data at suction 2cm s^{-1} on plot A (tilled soil)

Time (s)	Sqrt (t)	Volume (mL)	Infiltration (cm)
0	0	76.5	0.00
30	5.48	73	0.22
60	7.75	68	0.53
90	9.49	60.5	1.01
120	10.95	53.5	1.45
150	12.25	45.5	1.95
180	13.42	38.0	2.42
210	14.49	33.0	2.74
240	15.49	28.5	2.02
270	16.43	24.5	2.27
300	17.32	21.5	3.46

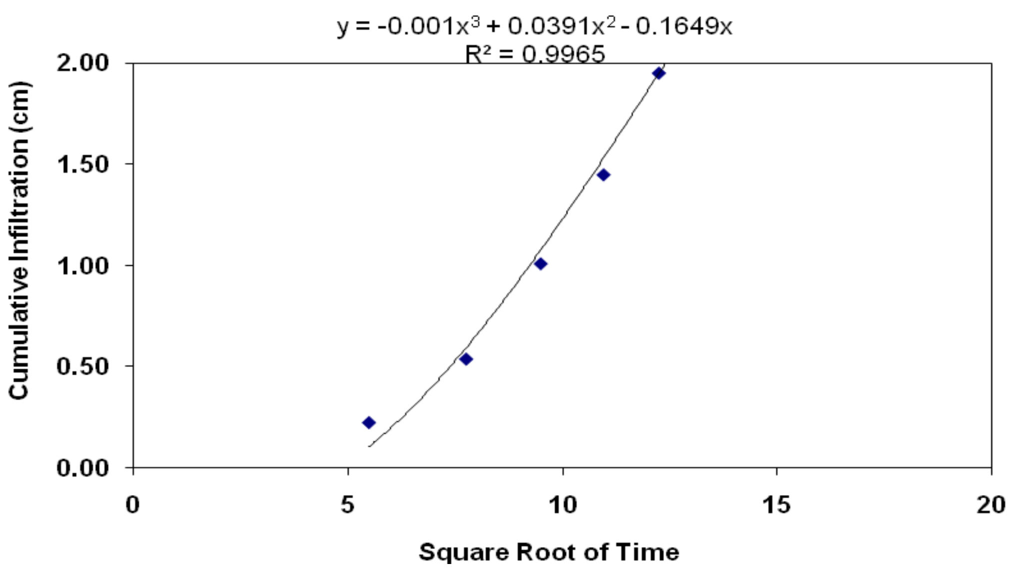

Figure 1: Cumulative infiltration against square root of time at plot A (Tilled soil)

Table 4: Infiltration data at suction 2cm s $^{-1}$ on plot B (5 passes)

Time (s)	Sqrt (t)	Volume (mL)	Infiltration (cm)
0	0	84	0.00
30	5.48	82.5	0.09
60	7.75	80	0.25
90	9.49	78.5	0.35
120	10.95	77.5	0.41
150	12.25	76	0.50
180	13.42	75	0.57
210	14.49	73.5	0.66
240	15.49	72.5	0.72
270	16.43	71.5	0.79
300	17.32	70	**0.88**

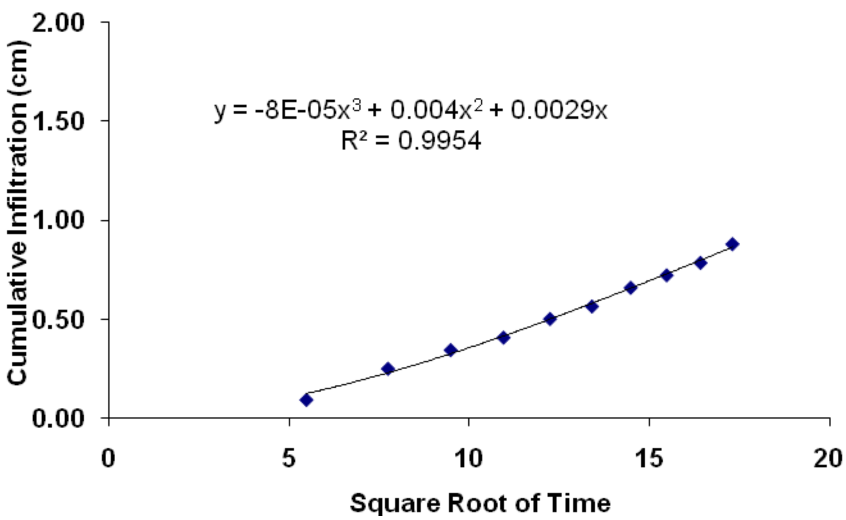

Figure 2: Cumulative infiltration against square root of time at plot B (5 passes)

Table 5: Infiltration data at suction 2cm s $^{-1}$ on plot C (10 passes)

Time (s)	Sqrt (t)	Volume (mL)	Infiltration (cm)
0	0	65	0.00
30	5.48	63.5	0.09
60	7.75	63.5	0.09
90	9.49	62.9	0.13
120	10.95	62.6	0.15
150	12.25	61.5	0.22
180	13.42	59.7	0.33
210	14.49	58.4	0.42
240	15.49	57.5	0.47
270	16.43	55	0.63
300	17.32	54.5	**0.66**

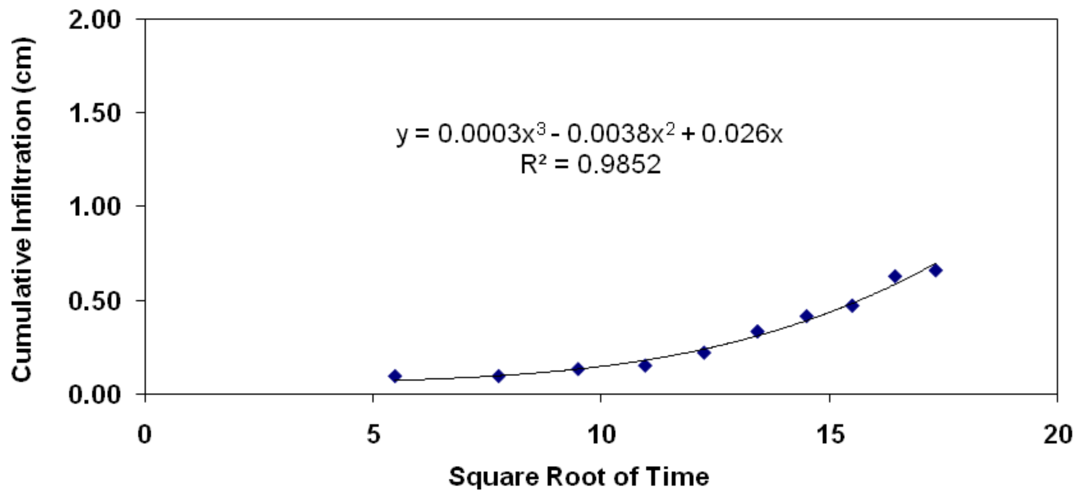

Figure 3: Cumulative infiltration against square root of time at plot C (10 passes)

Table 6: Infiltration data at suction 2cm s $^{-1}$ on plot D (15 passes)

Time (s)	**Sqrt (t)**	**Volume (mL)**	**Infiltration (cm)**
0	0	76.5	0.00
30	5.48	75	0.09
60	7.75	74.5	0.13
90	9.49	74.5	0.13
120	10.95	74	0.16
150	12.25	73.8	0.17
180	13.42	73.5	0.19
210	14.49	73	0.22
240	15.49	72.5	0.025
270	16.43	71.5	0.31
300	17.32	71	**0.35**

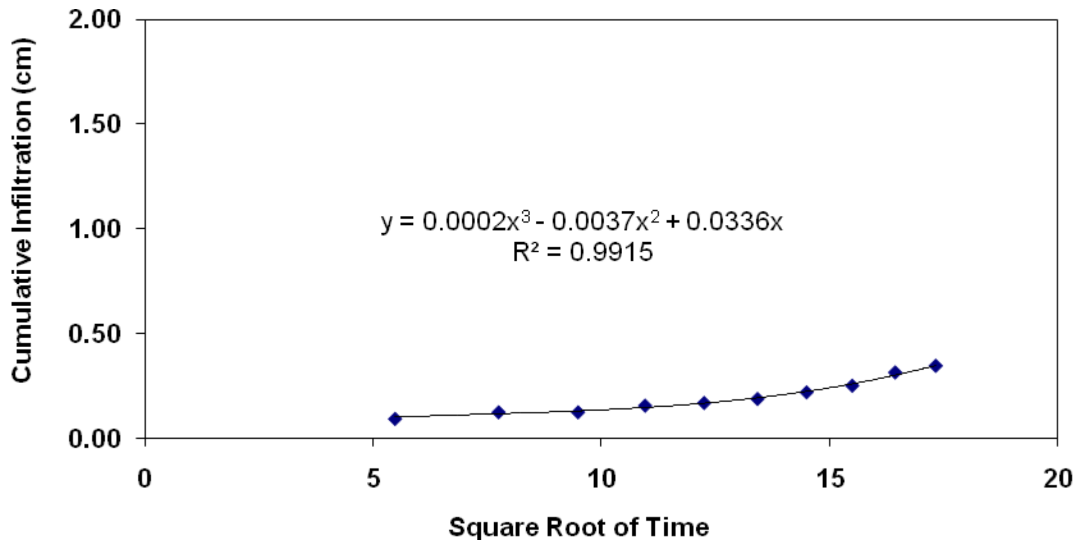

Figure 4: Cumulative infiltration against square root of time at plot D (15 passes)

Table 7: Hydraulic conductivity at suction 2cm s $^{-1}$ on all the plots

	Hydraulic conductivity (cms-1)			
	Plot A	Plot B	Plot C	Plot D
	9.09×10^{-3}	9.14×10^{-4}	8.9×10^{-4}	8.7×10^{-4}
	10.04×10^{-3}	9.46×10^{-4}	9.0×10^{-4}	8.6×10^{-4}
	8.14×10^{-3}	9.3×10^{-4}	8.5×10^{-4}	8.5×10^{-4}
Mean	9.09×10^{-3}	9.3×10^{-4}	8.8×10^{-4}	8.6×10^{-4}

Crop Measurement

At the 9th week after planting, plot A had the highest cumulative number of leaves (11) as shown in Table 8, area of leaves (854.8 cm^2), stem diameter (21.5 mm), height of plant (165.6 cm^2), length of root (21.4 cm) and root density RD_1 (29.4%), RD_2 (19.6 %) and RD_3 (50.9%) compared to the compacted plots. It was observed in plot A that, the root density at the 4 cm depth to the root tip was 50.9 %, which indicated the root potential to grow and penetrate into the soil and consequently how effective the plant make use of soil water and nutrient supplies for growth and production (Taylor and Gardner, 1960a). However, observations were different in compacted plots (Tables 9 – 11). Plot B which had 5 machinery traffic passes had number of leaves (9), area of leaves (539.5 cm^2), stem diameter (17.8 mm), height of plant (94.6 cm^2), length of root (14.7cm) and root density RD_1(45%), RD_2 (27 %) and RD_3 (27%) , At plot C (10 machinery traffic passes), the mean number of leaves was 8, area of leaves (466.62 cm^2), stem diameter (14.8 mm), height of plant (94.6 cm^2), length of root (14.cm) and root density RD_1 (55%), RD_2 (27.8 %) and RD_3 (16.7%) and at plot D 15 (traffic machinery passes), the lowest value was recorded; number of leaves (7), area of leaves (416.16 cm^2), stem diameter (13.8 mm), height of plant (82.6 cm^2), length of root (12.4cm) and root density RD_1 (50%), RD_2 (31 %) and RD_3 (18 %). The root density in plots B, C and D were higher at upper layer of the plant root just a little depth below the surface layer (0 – 2 and 2 – 4 cm) and lower from the 4 cm depth to the root tip. This was caused by soil compaction, which led to the higher concentration of roots in the upper root layers and reduced roots in the deeper layers. In strongly compacted soil, such root distribution can be partly attributed to the horizontal orientation of pores (Slowinska-Jurkiewicz and Domzal, 1999). Deeper but reduced root growth was attributed to excessive mechanical impedance, especially in dry seasons and insufficient aeration (air-filled porosity <10%) in wet seasons (Lipiec and Håkansson, 2000.) and (Medvedev et al., 2000).The crop parameters decreased with increased soil compaction (Taylor et al., 1964) and this must have resulted from root restriction caused by excessive soil strength that occur largely as a result of compaction. Better rooting was observed in loose soil of plot A (tilled soil), which can by warmer top layer compared to compacted soil early in the growing season (Lipiec et al., 1991).

Table 8: Means of crop measurement at plot A (tilled soil)

Week	NOL	AOL (cm^2)	SD (mm)	HOP (cm)	LOR (cm)	RD1 (%)	RD2 (%)	RD3 (%)
3th	7	21	6.4	21	8.6	37.5	25	25
4th	7	28.56	9.3	29	9.1	45.5	36.4	18.2
5th	8	108.3	10.8	32.8	10.4	36.8	26.3	21.1
6th	9	213.6	15.5	58.8	11.6	58.3	25	16.7
7th	9	578.5	18	95	13.4	61	22	16.7
8th	10	777.4	19.8	135	18.3	47.8	19	32.6
9th	11	854.8	21.5	165.6	21.4	29.4	19.6	50.9
10th	11	894.3	22.8	187.6	22.7	28.8	19.7	51.9
11th	11	982.8	23.1	194	23.9	34.4	17.2	48.4
12th	11	1018.64	23.5	197	24.4	33	18	48.5

NOL – number of leaves, AOL – area of leaves, SD – stem diameter, HOP – height of plant, LOR – length of root, RD – root density

Table 9: Cumulative data for crop measurement at compacted plot B (5 passes)

Week	NOL	AOL (cm^2)	SD (mm)	HOP (cm)	LOR (cm)	RD1 (%)	RD2 (%)	RD3 (%)
3th	4	19.46	5.6	14	8.2	62.5	25	12.5
4th	5	24.16	8.3	25.4	8.7	55.6	22	22
5th	5	79.36	9.8	26.8	9.2	53.8	15.3	30
6th	6	183.54	12.5	42.1	10.1	50	21.4	28.5
7th	8	383.15	14.9	62	10.8	50	25	25
8th	9	480	15.2	92.6	13.2	44	33	22
9th	9	539.5	17.8	94.6	14.7	45	27	27
10th	9	566.06	18	158.5	18.3	40	28	32
11th	9	631.9	18.9	161.5	18.8	28	20	51
12th	9	640	19	162.7	18.9	28	20	51

NOL – number of leaves, AOL – area of leaves, SD – stem diameter, HOP – height of plant, LOR – length of root, RD – root density

Table 10: Cumulative data for crop measurement at compacted plot C (10 passes)

Week	NOL	AOL (cm^2)	SD (mm)	HOP (cm)	LOR (cm)	RD1 (%)	RD2 (%)	RD3 (%)
3th	4	15.4	4.9	15	7.4	66.7	22.2	11.1
4th	5	43.94	5.7	23.9	8.4	54.5	36	9.09
5th	5	68.52	9.05	26.1	8.9	54.5	36	9.09
6th	7	148.2	11.7	41	9.1	54.5	36	9.09
7th	7	22.52	13.3	48.6	9.8	50	33	16.7
8th	8	408.25	14.5	72.5	12.1	62.5	25	12.5
9th	8	466.62	14.8	94.6	14.0	55.6	27.8	16.7
10th	9	493.75	16.2	122.6	15.7	55.6	27.8	16.7
11th	9	576.24	16.7	140.5	16.4	42.8	35.7	21.4
12th	9	585.65	16.9	142.5	16.9	42.8	35.7	21.4

NOL – number of leaves, AOL – area of leaves, SD – stem diameter, HOP – height of plant, LOR – length of root, RD – root density

Table 11: Cumulative data for crop measurement at compacted plot D (15 passes)

Week	NOL	AOL (cm^2)	SD (mm)	HOP (cm)	LOR (cm)	RD1 (%)	RD2 (%)	RD3 (%)
3th	4	12.84	4.2	14.1	6.7	62.5	25	12.5
4th	4	27	5.5	21.1	6.9	55.6	22	22
5th	5	67.2	8.53	24.6	8.2	50	30	20
6th	6	135.42	9.9	36.7	8.4	50	30	20
7th	6	226.38	12.9	45.1	9.1	45	27	27
8th	7	364.32	13	67.4	11.7	41.7	33	25
9th	7	416.16	13.2	82.6	12.4	50	31	18
10th	9	423.5	16	116.5	13.9	50	31	18
11th	9	467.2	17.2	128.6	14.9	47.6	33	19
12th	9	488.4	17.2	130	15.1	41.3	37.9	20.6

NOL – number of leaves, AOL – area of leaves, SD – stem diameter, HOP – height of plant, LOR – length of root, RD – root density

Conclusion

Plot A (tilled soil) has the lowest bulk density of (1.51g cm^{-3}) but increased from 1.63 g cm^{-3} in plot B (5 passes) to 1.90 g cm^{-3} in plot D (15 passes), which implies, the more compaction of the soil is, the greater the bulk density. Plot A (tilled soil) has the highest total porosity (The amount of "void" space within sediment) and also highest cumulative infiltration rate, which resulted to the highest hydraulic conductivity when compared to the compacted plots (B, C and D under 5, 10 and 15 traffic machinery passes, respectively). An increase in soil compactness resulted to decreased root length, higher concentration of roots in the upper soil layer, most especially within the 0 – 4 cm soil depth and increased distance between successive root layers. Crop yield increased in tilled soil (plot A) and decreased in compacted plots. Yield reduction in compacted soil accounted for smaller leaf area of maize.

References

Abu-Hamdeh, N.H., 2003. Effect of compaction and deep tillage on soil hydraulic and aeration properties and wheat yield. Comm. Soil Sci. Pl. Analysis, 34: 2277–90

Anderson, E.L., 1987. Corn root growth and distribution as influenced by tillage and nitrogen fertilization. Agron. J. 79, 544–549.

Ankeny, M.D., T.C. Kaspar, and R. Horton. 1990. Characterization of tillage and traffic effects on unconfined infiltration measurements. Soil Sci. Soc. Am. J. 54:837–840.

Arvidsson, J. 2001. Subsoil compaction caused by heavy sugarbeet harvesters in southern sweeden.Soil physical properties and crop yield in six field experiments. Soil Tillage Res. 60:67-78

Bagarello, V., M. Iovino, and W.D. Reynolds. 1999. Measuring hydraulic conductivity in a cracking clay soil using the Guelph permeameter. Trans. ASAE 42:957–964.

Barber, S.A., 1971. Effect of tillage practice on corn (Zea mays L.) root distribution and morphology. Agron. J. 63, 724–726.

Beven, K., and P. Germann. 1982. Macropores and water flow in soils. Water Resour. Res. 18:1311–1325.

Black, G.R., Hartge, K.H., (1986). Bulk density. In: A. Klute (Ed.). Methods of Soil Analysis. Part I. Physical and Mineralogical Methods. 2nd. Ed., Agronomy No. 9 (part I). ASA-SSSA. Madison, Wisconsin, USA, 363-375.

Buckman, Harry O; Brady , Nyle C . (1960) , The Nature and Property of soils. A College Text of Edapphology (6th ed), New York Macmillan Publisher, New York. Pg 50

Burgess C.P., Chapman R., Singleton P.L., Thom E.R. Shallow mechanical loosening of Soil under dairy cattle graying: Effect on soil and pasture, New Zeland Journal of Agricultural Research (2000) 43: 279-290.

Cassel, D.K., C.W. Razkowski, and H.P. Denton. 1995. Tillage effects on corn production and soil physical conditions. Soil Sci. Soc. Am. J. 59:1436-1443.

Douglass, J.T. Soil compaction effects on second harvest yields of perennial ryegrass for silage, Grass and Forage Science (1997) 52 (2): 129–133.

Drewry J.J., Littlejohn R.P., Paton R.J., Singleton P.L., Monaghan R.M., Smith L.C. Dairy pasture responses to soil physical properties, Australian journal of Soil Research (2004) 42: 99-105.

Drewry, J.J., J.A.H. Lowe and R.J. Paton, Effect of sub-soiling on soil physical properties and pasture production on a Pallic soil in Southland, New Zealand. New Zealand J. Agric. Res., (2000) 43: 269–77

Dwyer, L.M., Stewart, D.W. (1986). Leaf area development in field-grown maize. Agronomy Journal 78, 334–343.

Greenwood K.L. & McKenzie B.M. Grazing effects on soil physical properties and the consequences for pastures: a review, Australian Journal of Experimental Agriculture (2001) 41: 1231-1250.

Hankansson,, .I. 1994 Subsoil Compaction by vehicles with high axle load-extent, persistence and Crop response. Soil Till Res.29:105-306

Hill, R.L. 1990 Long term convectional and no tillage effects on selected soil physical properties. Soil Sci. Soc. AM. J. 54:161-166

Horn, R., J.J. Van den Akker and J. Arvidsson 2000. Subsoil Compaction.Catena Verl Reiskirchen

Horton R., Ankeny M.D. and Allmaras R.R., 1994. Effects of compaction on soil hydraulic properties. In B.D. Soane and C. van Ouwerker (editors) Soil compaction in crop production. Developments in agricultural engineering, n°11, Elsevier, Amsterdam, pp. 141-166.

Iijima M, Kono Y, Yamauchi A, Pardales Jr JR 1991. Effect of soil compaction on the development of rice and maize root system. Environ. Exp. Bot. 30: 333-342

Lipiec J. and Håkansson I., 2000. Influences of degree of compactness and matric water tension on some important plant growth factors. Soil Till. Res., 53, 87–94.

Lipiec J., Håkansson I., Tarkiewicz S., and Kossowski J., 1991. Soil physical properties and growth of spring barley related to the degree of compactness of two soils. Soil Till. Res., 19, 307–317.

Logsdon, S.D., and D.B. Jaynes. 1996. Spatial variability of hydraulic conductivity in a cultivated field at different times. Soil Sci. Soc. Am. J. 60:703–709.

Lowery, B. and R.T Schuler. 1994. Duration and effect of soil compaction on soli and plant-growth in Wisconsin. Soil Tillage Res. 25: 205-210

Mapa, R.B, R.E Green and L. Santo. 1986 Temporal variability of soil hydraulic properties with wetting and dry subsequent to tillage. Soil Sci. Soc. Am. J. 50:1133-1138

Meek, B.D., E.R. Rechel, L.M. Carter, W.R. De Tar, and A.L. Urie. 1992. Infiltration rate of a sandy loam soil: Effects of traffic, tillage, and plant roots. Soil Sci. Soc. Am. J. 56:908–913.

Medvedev V.V., Lyndina T.E., and Laktionova T.N., 2000. Effect of running systems agricultural engineering on soil and plants. Proc. 2nd Int. Conf. on Subsoil Compaction, 29–31 May, 2000, Gödöllo, Hungary, 91–98.

Masle J 2002 High soil strength: Mechanical forces at play on root morphogenesis and in root: shoot signalling. In: Waisel Y, Eshel A, Kafkafi U, Eds., Plant root the Hidden Half. Mercel Dekker Inc, New York, Basel, pp. 807-819.

Messing, I., and N.J. Jarvis. 1993. Temporal variation in the hydraulic conductivity of a tilled clay soil as measured by tension infiltrometers. J. Soil Sci. 44:11–24.

McIntyre S., Lavorel S., Tremont R.M., Plant life-history attributes: their relationship to Disturbance response in herbaceous vegetation. Journal of Ecology (1995) 83: 31-44

McQueen, D.J. and T.G. Shepherd. 2002. Physical changes and compaction sensitivity on a fine-texture, poor drained soil (Typic Endoaquept) under varying durations of cropping, Manawatu Region. New Zealand. Soil Tillage Res. 63:93-107

Morath D., Bruckler L., Bertuzzi P., Gaudu J.C. and Bourlet M., 1997. Error analysis of an evaporation method for determining hydrodynamic properties in insaturated soil. Soil Sci. Soc. Am. J., 61:725-735.

Mulholland B. & Fullen F.A. Cattle trampling and soil compaction on loamy sands, Soil Use and Management (1991) 7 (4): 189-193.

Scholefield D., Patto P.M., Hall D.M. Laboratory research on the compressibility of four topsoils from grasslands, Soil and Tillage Research (1985) 6: 1-16.

Scott, H.D., A. Mauromoustakos, I.P. Handayani, and D.M. Miller.1994. Temporal variability of selected properties of loessial soil as affected by cropping. Soil Sci. Soc. Am. J. 58:1531–1538.

Slowinska-Jurkiewicz A. and Domzal H., 1991. The structure of the cultivated horizon of soil compacted by wheels of agricultural tractors. Soil Till. Res., 19 (2–3), 215–226.

Suzuki, L. E. A. S., D. J. Ranert, and J. M. Reichert. 2004. Degree of compactness for no-tillage soils: reference bulk density and effects on soil physical properties and soybean yield.
Taylor, H.M., and H.R Gardner.1960a. Use of wax substrates in root penetration studies. Soil Sci. Soc. Am. Proc. 24:79-81.

Tamari S., 1994. Relations between pore space and hydraulic properties in compacted beds of silty loam aggregates. Soil Tech., 7: 57-73

Van Lynden, G.W.J., 2000. The Assessment of the Status of Human-induced Degradation. FAO Report, No. 37

van Genuchten, M.Th., F.J. Leij, and S.R. Yates. 1991. The RETC Code for Quantifying the Hydraulic Functions of Unsaturated Soils. U.S. Environmental Protection Agency, EPA/600/2–91/065, Washington, DC.

Voorhees, W.B., W.W. Nelson and G.W. Randall. 1986. Extent and persistence of subsoil compaction caused by heavy axle loads. Soil Sci. Soc. Am. J. 50:428-433

Willoughby, G.L., E.J. Kladivko, and M.R. Savabi. 1996. Seasonal variations in infiltration rate under no-till and conventional (disk) tillage systems as affected by Lumbricus terrestris activity. Soil Biol. Biochem. 29:481–484.

Willatt S.T., & Pullar D.M. Changes in Soil Physical Properties under Grazed Pastures, Aust. J. Soil Res. (1983) 22: 343-8.

Yamauchi A 1993 Significance of root system structure in relation to stress tolerance in cereal crop. In: Low-input sustainable crop production system in Asia. Korean Soc. Crop Sci., Korea, pp. 347-360.

Zhang, R. 1997. “Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer.” Soil Sci. Soc. Am. J. 61: 1024-1030

Sustainable Management of Mangrove Coastal Environments in the Niger Delta Region of Nigeria: Role of Remote Sensing and GIS

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Abstract

Wetlands, which include the coastal mangroves, are amongst the Earth's most productive ecosystems. They support millions of people and provide a wide range of direct and indirect goods and services or functions. Despite the wide range of important ecosystem goods and services provided by the wetlands they are under serious threat to extinction worldwide. Due to mainly: erratic and haphazard physical developments, externalities from users (e.g. agriculture, oil and gas industry. In Nigeria, 21,342 hectares of mangrove vegetation was reported to have been lost between 1986 and 2003 due to urbanization, dredging activities, and pollution from the oil and gas industries. Recognizing the continuous degradation of the region, mangrove (or wetland) goods and services must be given a quantitative value if their conservation is to be well appreciated. GIS and RS offer opportunities in accurate monitoring and assessment of environmental changes and effects taking place in the mangrove areas. It also helps to identify the driving forces of the environmental changes. GIS mapping will assist in assessing the spatial distribution and ecological change of the environment, identifying the baseline data of the region such as vegetation types and densities, the land use types. GIS and RS will complement many existing cases of wetland (including mangrove restoration developments) and provide government and all stakeholders involved in the development of the region with strategic framework for identifying and calculating projects and programs for the restoration of degraded mangroves and development of conservation action Plans for the sustainable management of Niger Delta mangroves.

Keywords: Coastal Mangrove, Ecosystem Services, GIS and RS, Hyper spectral, Niger Delta Region, Sustainable Management

Introduction

Mangrove forests are coastal plant communities that are part of a larger coastal ecosystem that typically includes mud flats, sea grass meadows, tidal marshes, salt barrens and even coastal upland forests and freshwater wetlands (i.e. peat lands), freshwater streams and rivers. In more tropical climates coral reefs may also be part of this ecosystem (Barbier et al., 1997; Kumar, 2000). They are critical habitat for many species of fish and wildlife, serve as coastal fish and shellfish nursery habitat, and produce large quantities of leaf material that becomes the basis for a detritus food web ((James et al., 2007; James, 2008). The important mangrove vegetation such as the sea grass beds is widely recognized. Despite their importance, mangrove vegetations are threatened all over the world by direct and indirect causes. Apart from the global climate change and its effects such as rise of temperature, sea level, atmospheric CO2 etc (their decline is mainly related to anthropogenic activities (Balmford and Bond, 2005; Saunders et al., 2006). In terms of degradation, major oil spills have occurred that have devastated rivers, killed mangroves and coastal life and affected the health and livelihoods of millions of inhabitants. They have lost farming land and their incomes from oil spills and breathe air that reeks of oil, gas and other pollutants (Amnesty International Australia, 2009). The consequences of this have been enormous financial loss, extensive habitat degradation, and poverty leading to the continuous crises in the Niger Delta region, that have recently culminated into several communal conflicts, kidnapping of oil workers, and vandalization of oil installations. This continued growth has resulted in environmental problems such as coastal wetland loss, habitat degradation, water pollution, gas flaring, and destruction of forest vegetation and host of other issues.

Nigeria with the Niger Delta region hosts the largest extent of mangroves in Africa and fifth largest mangrove nation in the world (Spalding et al., 2010) and Niger Delta is the world's third largest delta, and West/Central Africa's most extensive freshwater swamp forest (Ikwegbu, 2007). The spatial boundary of the mangrove ecosystem in Nigeria is unique because it is shielded from sea water, a characteristic that differs from that of several other African countries where the mangroves are directly exposed to sea water' (NDES., 1997). Over sixty percent of the mangrove stands in Nigeria are found in the Niger Delta coastal region located in the central part of Southern Nigeria (HRW, 1999). In the Niger Delta region the mangrove ecosystem is extensive and spreads across Ondo, Edo, Delta, Bayelsa and Rivers States (WB, 1995).

On the basis of morphological, physiological, biochemical and reproductive adaptations, 84 species of plants belonging to 39 genera in 26 families are recognized throughout the world as mangroves (Saenger, 2002) of which only six indigenous and one exotic species are found within the Atlantic Coast of West Africa (Blasco, 1998). The Niger Delta is home to three endemic families represented by five plant species and the introduced family of exotic species (James et al., 2007, James, 2008). In terms of the soil, the Niger Delta coastal mangroves ecosystem is supported by saline soil with potential of Hydrogen (pH) value of between 4 for freshly deposited soft silt low tide and 7 for transitional swamps at high tide. The other intermediate soil types include the peat – clay which constitutes about 90% of the soil formation in the ecosystem (Anderson, 1967, Adegbehin and Nwaigbo., 1990).The ecosystem is considered pioneer because aluminium and organic matter caught by mangrove roots in addition to biomass created by the trees, develop their own medium and literally extend land into the lagoons, creeks, and rivers (Ashton-Jones, 1998.) Such a regional assessment is important as the region has become a flash point of conflicts and contending view points on the adverse ecological impact of oil and gas exploration activities by transnational oil corporations operating in the region (WRM., 2003.). Thus collection of spatial temporal data of such regional assessment, will particularly contribute to mapping of mangrove ecosystem that is being encouraged at both global, regional scales and even more local scales (Spalding et al., 2010).

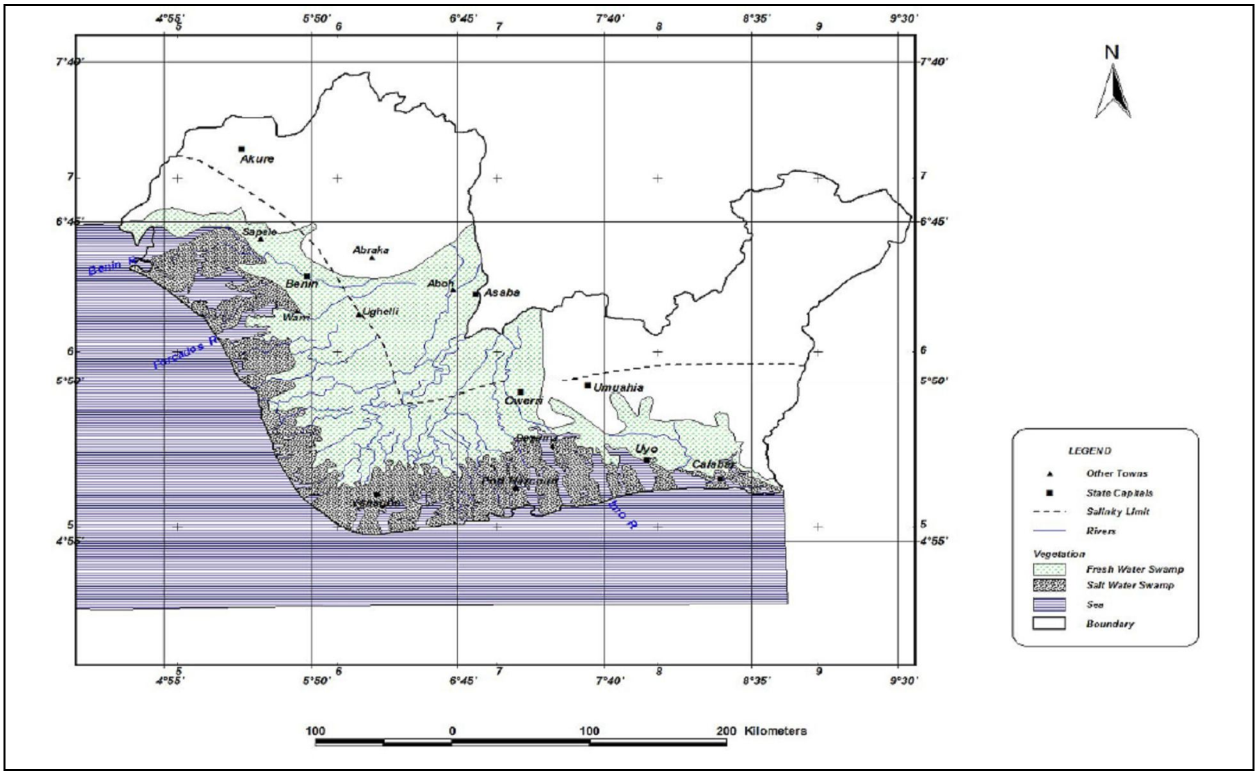

Figure 1: Niger Delta Region

Several efforts to assess the state of the environment and the environmental stewardship of economic development along the Niger Delta ecosystem of Nigeria like many other developing countries are often hindered by the lack of access to a comprehensive regional environmental information system. There is a need for concerted effort at ensuring sustainable management of Mangrove Coastal Environments in Nigeria, especially the Niger Delta Region of Nigeria. The objective of this study was therefore, to assess the utility of hyperspectral data in estimating and mapping mangrove coastal vegetation forest structural parameters.

Need for Geospatial Technology

Nigeria as a country currently suffers from the lack or inadequacy of major geospatial scientific work that would offer an impartial evaluation of the destruction caused by oil and gas activities in the Delta area of the South (Human Rights Watch, 1999). Until recently when the nation's earth observation satellites (i.e. SAT-2 and SAT-X) were launched to replace SAT-1 allegedly lost in orbit. Majority of the existing studies (e.g. Hanley and Craig, 1991; Barbier et al., 1997; Bateman et al 1995; NDES., 1997, Ashton-Jones, 1998., James, 2008) on sustainable issues on wetlands in general and coastal mangrove ecosystem in particular, have focused largely on valuation of ecosystem goods and services to underscore the economic cost (or opportunity cost) of the degradation of these ecosystem resources. The problem facing the area has been compounded by gaps in previous research. One of the major reasons attributed to this failure is the lack of adequate information addressing the *real* needs of the region. Many studies have examined the problems of environmental degradation in the region and the need for improved understanding, monitoring, and management of the area's ecosystems. To date, there are only a few in-depth studies which employ geospatial technology studies to understand land use changes of coastal ecosystems which can help estimate the environmental impact on the livelihood of communities, and eventually help governments sustainably manage the environment.

Collecting information on the current condition and trends of ecosystem services and identifying the drivers that affect human well-being results in an understanding of *current* changes to ecosystem services Ranganathan et al., 2008). Current attempts to assess the state of the environment and the environmental stewardship of economic development along the Niger Delta ecosystem are often handicapped by the lack of complete access to a comprehensive regional environmental information system (Yaw and Merem, (2006). Furthermore, Haag and Hoagland (2002) stressed that there is limited emphasis on the assessment of change through spatial information technologies such as remote sensing and (GIS)]. Numerous studies in the literature, examining environmental risk assessment, rightly point to the need for improved understanding, of monitoring on environmental issues faced by oil and gas producing communities but without concrete allusion to the use of geospatial technologies. GIS technology as a tool used by geographers, archaeologists, geologists and other scientists in the social and natural sciences provide opportunities for storage, manipulation and mapping of data with a spatial reference (Rashmin, 2004).

Since the launch of the first Earth Resources Technology Satellite in 1972 (ERTS-1, later renamed Landsat 1), there has been significant activity related to mapping and monitoring environmental change as a function of anthropogenic pressures and natural processes. Geo-information science has presented flexible, suitable and affordable technology for data collection, information extraction, data management; routine manipulation and visualization of processes that are taking place on the earth include issues surrounding the management of mangrove coastal environments. In areas such as the Niger Delta region of Nigeria, sustainable management of resources involves a movement from a data-poor environment to data-rich environment. There is more and more need for filtering, processing, and integrating various data/information in such a way that they can be supportive to management decision. Given the rapid socio-economic and environmental changes in this region, such studies are currently in demand. The goal of this study is to use remote sensing and GIS technologies to develop an effective decision-making framework for policy makers in their assessment of the economic costs of environmental remediation or restoration projects and the formulation of conservation or management action plans for coastal mangroves of Nigeria's Niger Delta region. This research elaborates on developing a framework for planning and decision support systems, and its supporting tools for sustainable management of mangrove coastal environments. It seeks to know what opportunities remote sensing and GIS offer in accurate monitoring and assessment of environmental changes and effects taking place in Nigeria's Niger Delta coastal mangrove areas. In addition, it also proposed the use and application remote sensing and GIS technologies (e.g. Hyperspectral Remote Sensing) to monitor changes in the vegetation of the coastal mangrove environments.

A significant progress has been realised in the remote sensing of forest ecosystem in recent years linked to technological advances in sensor design, growth in information extraction techniques and increasing requirement to quantitatively describe and understand our environment (Welder & Franklin, 2003). Remote sensing instruments measure the radiation that is emitted or reflected from the earth's surface. The diversity of instruments available at present and in the future provide data with broad to fine spectral resolution, with large to small spatial resolution and other characteristics (e.g. multi-directionality) suitable for the quantitative and qualitative analysis of forests (Peterson & Running, 1989). Accurate quantitative estimation of vegetation biochemical and biophysical characteristics is necessary for a large variety of agricultural, ecological and meteorological applications (Asner, 1998).

Remote sensing science has become a critical and universal tool for natural resource managers and researchers in government agencies, conservation organizations, and industry (Philipson & Lindell, 2003; Stow et al., 2004). Information derived from remote sensing data has often been used to assist in the formulation of policies and provide insight into land-cover and land-use patterns, and multi-temporal trends. Interpretation of aerial photographs continues to be a standard tool for mapping and monitoring land-cover and land-use change (Loveland et al., 2002). The range and opportunity for remote sensing of ecosystem structure, dynamics and processes is improved with change in technology (Lunetta, 1998). Detection and characterization of change in key resource attributes allows resource managers to monitor landscape dynamics over large areas, including those areas where access is difficult or hazardous, and facilitates extrapolation of expensive ground measurements or strategic deployment of more expensive resources for monitoring or management (Li et al., 2003; Schuck et al., 2003). In addition, long-term change detection results can provide insight into the stressors and drivers of change, potentially allowing for management strategies targeted toward cause rather than simply the symptoms of the cause.

The techniques based on multi-temporal, multi-spectral, satellite-sensor-acquired data serve to detect, identify, map and monitor ecosystem changes, irrespective of their causal agents. Extracting information from a digital image begins with "spectral space" (which for our purposes includes SAR intensity or comparable LIDAR measurements). Spectral space is the data space that can be visualized by plotting measured intensity of reflected radiance in different spectral bands against each other (Lillesand & Kiefer, 2000). Remote sensing change detection studies involve a series of sequential steps that are detailed extensively elsewhere (e.g. Cihlar, 2000; Coops et al., 2007; Lunetta, 1998; Schott, 1997). For the natural resource manager, our goal here is to simplify these steps into four broad stages: data acquisition, pre-processing and/or enhancement, analysis, and evaluation. The better a manager understands how decisions in each stage affect the outcome of the study or project, the better he or she can guide those decisions.

Ecosystem services are the benefits that people derive from nature. Some benefits, such as crops, fish, and freshwater (provisioning services), are tangible. Others such as pollination, erosion regulation, climate regulation (regulating services) and aesthetic and spiritual fulfilment (cultural services) are less tangible (MA, 2005b). Ecosystem services such as provided by the mangrove can be assessed using the technologies of remote sensing and GIS, which will provide decision-makers with guidelines in making decisions and formulating policies that will affect the ecosystem generally. Remote sensing and GIS can be used for assessing mangrove ecosystem based on the Millennium Assessment as shown below.

Table 1: Methods to Assess Mangrove Ecosystem

Method	Description	Sample uses	Example
Remote Sensing	Data Obtained from satellite sensors or aerial photographs (LANDSAT, MODIS,SPOT, ASTER)	Assessment of large areas, land cover, land use and biodiversity	Assessment of mangrove vegetation and deforestation
Geographic Information Systems damage	Software that spatially maps and analyzes digitized data (ArcGIS, ArcView, IDRIS)	Analyses of spatio-Temporal changes in mangrove ecosystems, Over laying social and economic information with ecosystem information; correlating trends in ecosystem services with land use change	Niger-Delta ecosystem assessment using GIS to analyze the extent of to mangrove vegetation
Participatory Approaches and Expert Opinion	Information supplied by stakeholder groups, scientific experts, workshops, traditional knowledge	Collection of knowledge available in scientific literature, fills gaps in literature, add new perspectives, knowledge (PGIS)	Niger-Delta ecosystem assessment using (PGIS) with stakeholders

Source: Adapted from MA, 2005a

Hyperspectral Remote Sensing for Wetland Vegetation

Wetland vegetation is an important component of wetland ecosystems that plays a vital role in environmental function (Kokaly et al. 2003; Lin and Liquan 2006). It can serve as an indicator for early signs of any physical or chemical degradation and general health of the wetland environments (Dennison et al. 1993). Mapping and monitoring vegetation species distribution, quality, and quantity are important technical tasks in sustainable management of wetlands. Successful monitoring programme requires up-to-date spatial information about the magnitude and the quality of vegetation cover in order to initiate vegetation protection and restoration programme (He et al. 2005). Hyperspectral remote sensing offers a practical and economical means to discriminate and estimate the biochemical and biophysical parameters of the wetland species and it can make field sampling more focused and efficient. Hyperspectral remote sensing or imaging spectrometry refers to the recording of remote sensing data using imaging spectrometers. These instruments collect radiance values in many narrow bands forming continuous spectra. As imaging spectrometer data is characterised by a high spectral resolution compared to multispectral data it is also called hyperspectral. The concept of imaging spectrometry is shown in Figure 2.

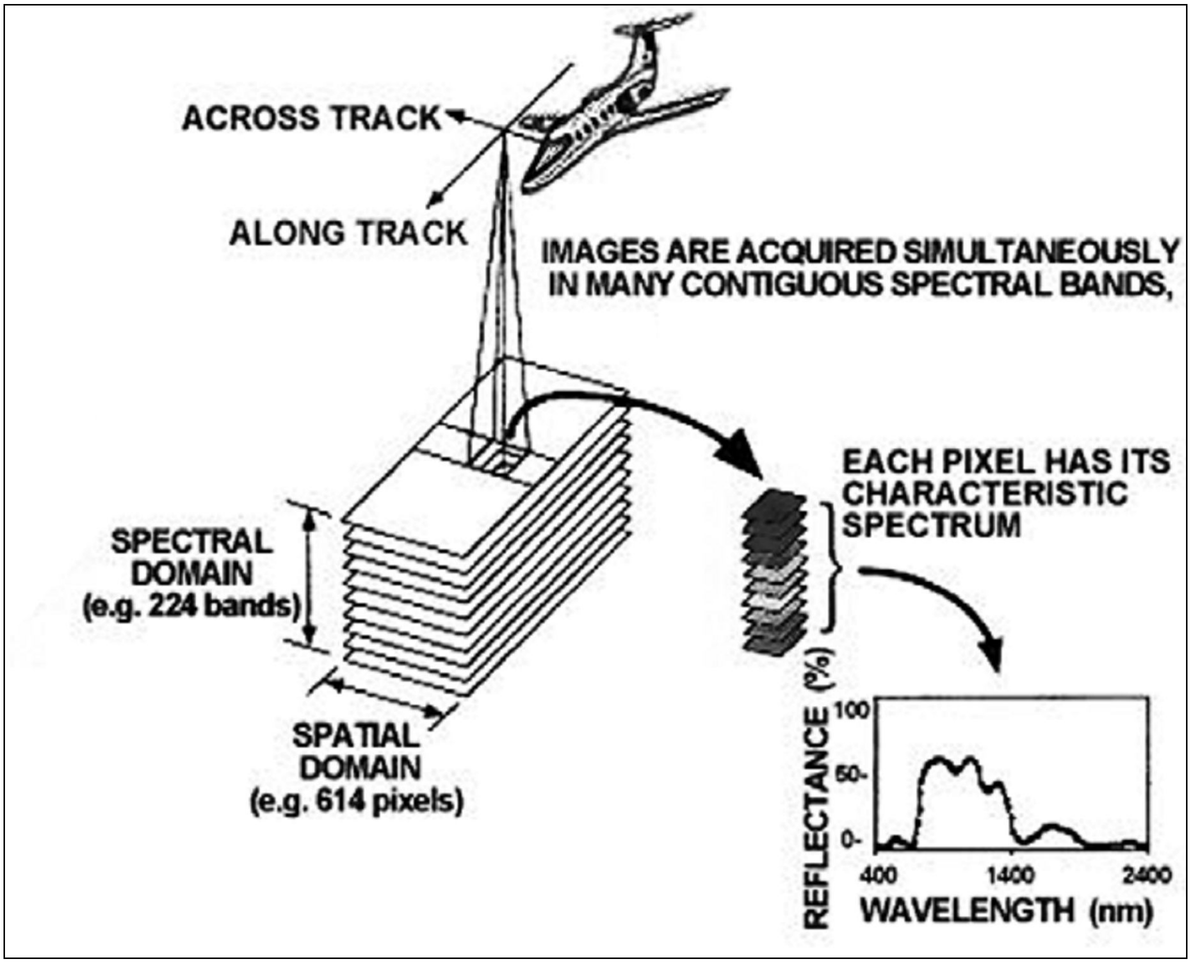

Figure 2: The concept of imaging spectrometry (after Vane & Goetz, 1988) adapted from Schlerf (2006)

The technology has been used worldwide to detect surface-water pollution discharges, map sensitive vegetation distribution, monitor agricultural plant communities, and detect vegetation health. It can easily be integrated into Geographic Information System (GIS) for more analysis because of the repeat coverage offers. Thus, changes in vegetation over time and be detected and monitored (Shaikh et al. 2001; Ozesmi and Bauer 2002). Hyperspectral sensors are the most advanced optical remote sensing systems compared to the traditionally, multispectral satellite remote sensors such as Landsat Thematic Mapper (TM), Multispectral Scanner (MSS), and Advanced Space borne Thermal Emission Radiometer (ASTER) which often lack the spatial and spectral resolution necessary to differentiate characteristics of the Earth's surface—especially when the spectral changes are very small or in a very narrow area of the electromagnetic spectrum (Jensen et al. 2004, Hardin and Jensen 2005).

Hyperspectral sensors has hundreds of narrow continuous spectral bands between 400 and 2,500 nm, throughout the visible (0.4–0.7 nm), near-infrared (0.7–1 nm), and short wave infrared (1–2.5 nm) portions of the electromagnetic spectrum (Govender et al., 2006; Vaiphasa et al. 2005). This greater spectral dimensionality of hyperspectral remote sensing allows in-depth examination and discrimination of vegetation types which would be lost with other broad band multi-spectral scanners (Cochrane 2000; Schmidt and Skidmore 2003; Mutanga et al. 2003; Govender et al. 2006). Hyperspectral remote sensing data can be acquired using a hand-held spectrometer or airborne sensors. A hand-held spectrometer is an optical instrument used for measuring the spectrum emanating from a target in one or more fixed wavelengths in the laboratory and the field (Kumar et al., 2001). Hyperspectral imagery has significant potential to aid environmental monitoring and detection efforts by providing spatially comprehensive data that can stand alone or complement existing, conventional environmental data products. Estimating wetland biomass is necessary for studying productivity, carbon cycles, and nutrient allocation (Zheng et al. 2004; Mutanga and Skidmore 2004). Many studies of field biomass have used vegetation indices based on the ratio of broadband red and near infrared (NIR) reflectance. Tan et al. (2003) used Landsat ETM bands 4, 3, and 2 false colour, and field biomass data to estimate wetland vegetation biomass in the Poyang natural wetland, China.

Studies have shown that wetland plants and their properties are not as easily detectable as terrestrial plants, which occur in large stratification (Adam and Mutanga, 2009). A major problem is that herbaceous wetland vegetation exhibits high spectral and spatial variability because of the steep environmental gradients, which produce short eco tones and sharp demarcation between the vegetation units (Zomer et al., 2008; Schmidt and Skidmore, 2003). This thus makes it difficult to identify the boundaries between vegetation community types. In addition, the reflectance spectra of wetland vegetation canopies are often very similar and are combined with reflectance spectra of the underlying soil, hydrologic regime, and atmospheric vapour (Guyot, 1990; Malthus and George, 1997; Lin and Liquan, 2006) (Figure 3). These combinations usually complicate the optical classification and results in a decrease in the spectral reflectance, especially in the near-to mid-infrared regions where water absorption is stronger (Fyfe 2003; Silva et al. 2008). However, hyperspectral narrow spectral channels offer the potential to detect and map the spatial heterogeneity of wetland vegetation (Treitz and Howarth, 1999; Jensen, 2000; Franklin, 2001; Herold et al., 2002; Hestir et al., 2008; Vaiphasa et al., 2007; Schmidt and Skidmore, 2003).

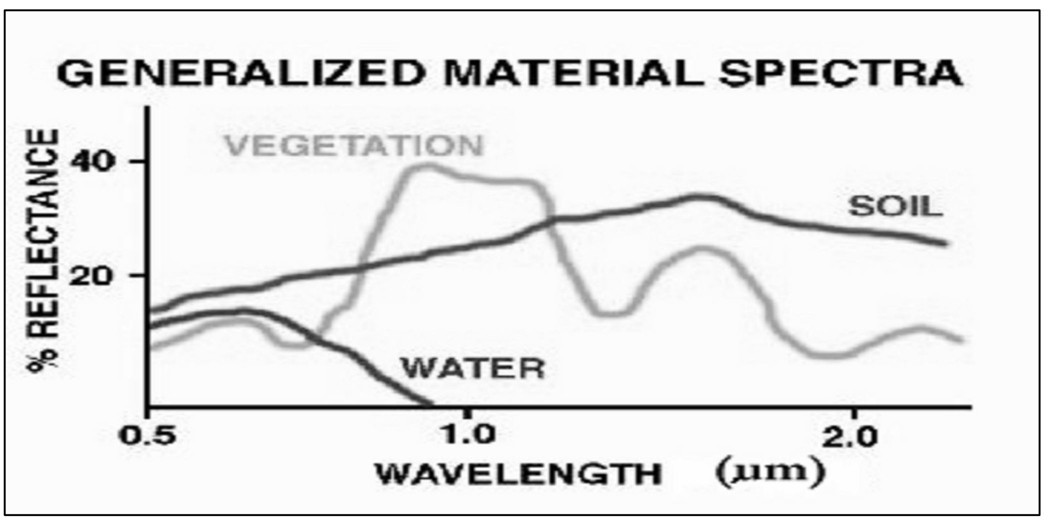

Figure 3: Spectral reflectance of soil, water and vegetation

The spectral reflectance curves of materials are used to discriminate them for identification (Figure 3). The figure shows the differences in spectral curves for vegetation, soil and water. Green plants exhibit a sharp intensity change over a short spectral distance that is formed by strong chlorophyll energy absorption near the red wavelength (0.6µm) and high reflectivity at the near-IR wavelength (0.76µm). Changes in the health status of plants are often expressed as a shift of this red-edge toward longer or shorter wavelengths. Although not detectable by the human eye, this spectral change can be indicative of senescence, water deprivation or toxic materials. Other spectral changes in vegetation detectable by hyperspectral techniques occur at wavelengths corresponding to water absorption (0.94µm) or the actual total chlorophyll absorption depth at 0.6µm. Vegetation phenology refers to the timing of different life-cycle events of the plants (such as leaf unfolding, flower first bloom, leaf fall, etc.), which are related with the change of leaf density and photosynthetic activity through the seasons (Bradley et al., 2007). These methods can be used in a quantitative assessment of change in the mangrove vegetation in the Niger Delta of Nigeria. Successful utilization of remotely sensed data for land-cover and land-use monitoring however, requires careful selection of an appropriate data set and image processing technique(s) (Lunetta, 1998).

Vegetation Indices

The most commonly used broadband remote sensing predictors of forest parameters are ratio indices (vegetation indices) computed from near infrared (NIR) and visible reflectance. The most known vegetation index is the normalised difference vegetation index (NDVI) developed by Rouse et al. (1974). NDVI is based on the contrast between the maximum absorption in the red due to chlorophyll pigments and the maximum reflectance in the NIR caused by scattering in the leaf mesophyll. For example, with increasing leaf area index (LAI) or canopy thickness, red reflectance decreases as leaf pigments absorb light, while NIR reflectance increases as more leaf layers are present to scatter the radiation (Gates et al., 1965). The use of imaging spectroscopy for forest stand structural estimation is based on the assumption that increased identification of particular spectral features associated with narrowband could improve estimation of forest attributes compared to broadband sensors (Lefsky et al., 2001; Lee et al., 2004). Narrowband two-band vegetation indices (VIs) calculated according to the principle of NDVI (see Equation below) was derived from all possible two-band combinations involving 126 bands of HyMap spectrum using the calibration data. This resulted into 15,876 (i.e. 126 x 126) VIs for each spectrum.

$$VI_{(i,j,n)} = \frac{R_{(i,n)} - R_{(j,n)}}{R_{(i,n)} + R_{(j,n)}}$$

where $R_{(i,n)}$ and $R_{(j,n)}$ are the reflectance of any two bands for each sample (n).

Linear regression analyses were performed between each VI with each forest structural parameter (mean DBH, mean height and tree density). The VIs that yielded the highest calibration coefficient of determination (R2) was subsequently selected for assessing their predictive capability on the independent data set.

One of the powerful tools to study the spatial distribution of vegetation is remote sensing (Jin, 2009). Remote sensing has traditionally been used in large-scale global assessments of vegetation distribution and land cover with the Normalized Difference Vegetation Index (NDVI) data from Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS) (Chen and Brutsaert 1997; Defries et al. 1995; Friedl et al. 2002; Loveland et al. 1999, 2000). The NDVI is an index derived from reflectance measurements in the red and infrared portions of the electromagnetic spectrum to describe the relative amount of green biomass from one area to the next (Deering 1978). This index is an indicator of photosynthetic activity of plants and has been widely used for assessing vegetation phenology and estimating landscape patterns of primary productivity (Sellers, 1985; Tucker and Sellers, 1986). The NDVI was designed to quantitatively evaluate vegetation growth: higher NDVI values imply more vegetation coverage, lower NDVI values imply less or non-vegetated coverage, and zero NDVI indicates rock or bare land. Furthermore, the MODIS NDVI data is also used for vegetation index mapping. It depicts spatial and temporal variations in vegetation activities, derived by monitoring the Earth's vegetation. These vegetation index maps are corrected for molecular scattering, ozone absorption, and aerosols. The MODIS NDVI data is based on 16-day composites and its spatial resolution is 250 m. Currently, the MODIS NDVI products have been used throughout a wide range of disciplines, such as inter- and intra-annual global vegetation monitoring, climate and hydrologic modelling, and agricultural activities and drought studies (Zhan et al. 2000; Sakamoto et al. 2005; Lunetta et al. 2006; Jin, 2009).

Conclusion

Too often, development policies have unwittingly diminished nature's capacity to provide the goods and services people depend on. Decision makers may be focused on reducing poverty, increasing food production, strengthening resilience to climate change, or producing energy. Ultimately, the developments goals are undermined as the effects of these trade-offs are felt by people who depend on nature for their livelihood and well-being. Reconciling development and nature is challenging but quite important for sustainability of the environment and its inhabitants. To fully understand changes that have already occurred in the coastal mangrove vegetation of the Niger Delta, land cover data are needed to generate scenarios of future modification of the environmental system. Land use and land cover data can be obtained using in situ field measurements or remote sensing technology. There is the need to establish integrated watershed Management. This is important considering the widespread growth and the pressure on the area's environmental indicators such as wetlands, rivers and forests cover. The states located along the Niger Delta watershed should adopt an ecosystem based integrated watershed management approach using remote sensing and GIS to quicken the periodic monitoring of the Delta's ecosystem health and the interaction between human activities and the environment in the region.

The paper demonstrates the use of hyperspectral remote sensing and GIS a practical method and technique to map wetland vegetation. It is possible to differentiate wetland vegetation using hyperspectral remote sensing, given that from afar vegetation looks homogeneous and only closer inspection reveals differences in species composition to such an extent that one can define ecologically meaningful vegetation types. Consequently hyperspectral remote sensing of vegetated surfaces in the wetland areas can be used to map species composition in considerable detail, with accuracies greater than those of conventional aerial photograph interpretation. Furthermore, vegetation mapping up to a detailed level can be improved when adding expert knowledge about the ecology of the mangrove wetland to the classification of the hyperspectral imagery.

GIS and RS offer opportunities in accurate monitoring and assessment of environmental changes and effects taking place in the mangrove areas. It also helps to identify the driving forces of the environmental changes. GIS mapping will assist in assessing the spatial distribution and ecological change of the environment, identifying the baseline data of the region such as vegetation types and densities, the land use types. GIS and RS will complement many existing cases of wetland (including mangrove restoration developments) and provide government and all stakeholders involved in the development of the region with strategic framework for identifying and calculating projects and programmes for the restoration of degraded mangroves and development of conservation action Plans for the sustainable management of Niger Delta mangroves. Extraction of information from hyperspectral measurements can enhance our understanding of vegetation biophysical and biochemical characteristics estimation and can serve as essential input to biogeochemical and climate models. In addition, efforts should be made to design a regional geo-spatial data infrastructure (GDI) because of lack of accessible regional geo-spatial information system capable of computing the interactions between humans and the environment. Such an inventory will offer the decision makers access to the appropriate temporal-spatial data for monitoring the pressures mounted on the areas ecosystem by development activities. It could act as an effective decision support system to keep development in harmony with environmental sustainability.

References

Adam, E and Mutanga, O. (2009) Spectral discrimination of papyrus vegetation (Cyperus papyrus L.) in swamp wetlands using field spectrometry. *ISPRS J Photogram Remote Sensing,* 64:612–620

Adam, E., Mutanga, O., Rugege, D. (2009). Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. Wetlands Ecol Manage DOI 10.1007/s11273-009-9169-z, also available at: uqu.edu.sa//Multispectral%20and%20hyperspectral%20remote%20sensing (Accessed 16 August 2011)

Adegbehin, J. O. and Nwaigbo., L. C. 1990. Mangrove resources in Nigeria: use and management perspectives. *Nature and Resources,* 26**,** 13-21

Amnesty International Australia, (2009) Shell in Niger Delta: The human rights cost of oil**,** 29 June http://www.amnesty.org.au/action/action/21246/

Anderson, B. (1967). Report on Soils of the Niger Delta Special Area. Portharcourt, Nigeria, NDDB

Arthurton, R.S., Kremer, H.H., Odada, E., Salomons, W. and Marshall Crossland, J.I. (2002), *African Basins: LOICZ Global Change Assessment and Synthesis of River Catchment Coastal Sea Interaction and Human Dimensions*. LOICZ Reports & Studies No. 25: ii+344 pp, LOICZ, Texel, The Netherlands

Ashton-Jones, N. J. 1998. *The Human Ecosystems of the Niger Delta. ,* Benin-Nigeria

Asner, G.P. (1998). Biophysical and biochemical sources of variability in canopy reflectance *Remote Sensing of Environment*, 64(3):234-253

Balmford, A. and Bond, W., (2005), Trends in the state of nature and their implications for human well-being, Ecology Letters 8, 1218–1234.Berger, A. R. and R. A. Hodge 1998 "Natural change in the environment: a challenge to the pressure-state-response concept." *Social Indicators Research* 44: 255 – 540

Blasco, F., M. Aizpuru, V. Caldairou, T. Gauquelin, M. Rasofoharinoro, And J. Denis (1998), Recent advances in mangrove studies using remote sensing data. *Marine and freshwater research,* 49**,** 287-296

Bradley, B. A., Jacob, R. W., Hermance, J. F., & Mustard, J. F. (2007), A curve fitting procedure to derive inter-annual phenologies from time series of noisy satellite NDVI data*. Remote Sensing of Environment*, 106, 137−145

Chen, D., Brutsaert, W., (1998). Satellite-Sensed distribution and spatial patterns of vegetation parameters over a tall grass Prairie, *Journal of the Atmospheric Sciences*, 55, 1225- 1238

Cho, M.A., Skidmore, A.K., and Sobhan I (2009).Mapping beech (Fagus sylvatica L.) forest structure with airborne hyperspectral imagery. *International Journal of Applied Earth Observation and Geo information* 11 (2009) 201–211

Cihlar, J. (2000). Land cover mapping of large areas from satellites: Status and research priorities. *International Journal of Remote Sensing*, 21, 1093−1114
Cochrane, M.A. (2000). Using vegetation reflectance variability for species level classification of Hyperspectral data, *Int. J Remote Sens* 21:2075–2087

Coops, N., Wulder, M. A., & White, J. C. (2007), Identifying and describing forest disturbance and spatial pattern: Data selection issues and methodological implications. In M. A. Wulder, & S. E. Franklin (Eds.), *Understanding forest disturbance and spatial pattern: Remote sensing and GIS approaches* Boca Raton, FL: CRC Press, Taylor and Francis Group

Danka F.S. and Klein C., (2002), Using GIS To Predict Potential Wildlife Habitat: A Case Study of Muskoxen In Northern Alaska. *International Journal of Remote Sensing,* 23(21), pp.4611-4632

Deering, D.W., (1978), Rangeland reflectance characteristics measured by aircraft and spacecraft sensor. Ph.D. Dissertation, Texas A&M University, College Station, TX, 338pp

Defries, R., Hansen, M., and Townshend, J. R. G., (1995), Global discrimination of land cover types from metrics derived from AVHRR pathfinder data. *Remote Sensing of Environment,* 54, 209-222

Evans, M. E., Hall, L. B., Samuels, P. A., Jackson, L. A. Korenaga, G. L , Hanrahan, F. E., et al. (2002). Environmental Application of Hyperspectral Remote Sensing: Managing Liability in an Age of Transparency. *Presented at the 17th World Petroleum Congress,Rio de Janieiro, Brazil, 1-5 September 2002*

FAO-(2007).The world's mangroves 1980-2005, Rome 2007
http://www.fao.org/docrep/010/a1427e/a1427e00.htm

Finlayson, C. M., Gordon, C. Ntiamoa-Baidu, Y., Tumbulto, J. and Storrs, M. (1998), *Hydrobiology of the Songor and Keta lagoons: implications for wetland management in Ghana*. Environmental Research Institute of the Supervising Scientist, Australia, 165 pp

Franklin, S.E., (2001*). Remote Sensing for Sustainable Forest Manag*ement, Lewis Publishers, Boca Raton, FL, 407 pp

Friedl, M. A., McIver, D. K., Hodges, J. C. F., Zhang, X. Y., Muchoney, D., Strahler, A. H., et al., (2002), Global land cover mapping from MODIS: Algorithms and early results, *Remote Sensing of Environment*, 83, 287-302

Fyfe, S.K. (2003). Spatial and temporal variation in spectral reflectance: are sea grasses spectrally distinct, *Limnol Oceanogr* 48:464–479

Gates, D.M., Keegan, H.J., Schleter, J.C., Weidner, V.R., (1965). Spectral properties of plants, *Applied Optics* 4 (1), 11–20

Gordon, C. (1998). The state of the coastal and marine environment of Ghana, In C. Ibe and S. G. Zabi (Eds.), *State of the Coastal and Marine Environment of the Gulf of Guinea* UNIDO/UNDP/GEF/CEDA, 158 pp

Gordon, C. (2000). Hyper-saline lagoons as conservation habitats: macro-invertebrates at Muni Lagoon, Ghana. *Biodiversity and Conservation* 9 (4): 465-478
Gordon, C. and Ibe, C. (2006), Land based sources of pollution in West Africa: current status and trends. *State of the environment on issues related to the protection of the marine environment from land based activities*, UNEP-GPA-LBA

Govender, M. Chetty, K., and Bulcock H (2006) A review of hyperspectral remote sensing and its application in vegetation and water resource studies,
http://www.wrc.org.za/downloads/watersa/2007/Apr%2007/2052.pdf. Accessed July 12 2010

Guyot, G. (1990). Optical properties of vegetation canopies, In: Steven MD, Clark JA (Eds.) *Application of Remote Sensing in Agriculture*. Butterworths, London, pp 19–44

Haag, F. and Hoagland, S (2002), The Application of Remote Sensing Techniques to Landscape Level Environmental Research: A Hybrid Approach Combining Visual and Digital Interpretation. *Norwegian J. of Geography* 56:4, 1-2

Hardin, P.J. and Jensen, R.R. (2005), Neutral network estimation of urban leaf area index, *GIScience and Remote Sensing*, 42, 251–274

He, C., Zhang, Q. and Li, Y. (2005), Zoning grassland protection area using remote sensing and cellular automata modelling—a case study in Xilingol steppe grassland in northern China. *J Arid Environ* 63:814–826

Herold, M., Gardner, M., Hadley, B., Roberts, D., (2002), T*he Spectral Dimension in Urban Land Cover Mapping from High-Resolution Optical Remote Sensing Data*, Proceedings of the 3rd Symposium on Remote Sensing of Urban Areas, 11–13 June, 2002, Istanbul, Turkey

Hestir, E.L., Khanna, S., Andrew, M.E., Santos, M.J., Viers, J.H., Greenberg, J.A., Rajapakse,S.S., Ustin, S.L. (2008). Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem, *Remote Sens Environ* 112:4034–4047

Human Rights Watch (HRW) (1999). The Price of Oil: Corporate sibility and Violations In Nigerian Oil Producing Communities Human Rights Watch NY: New York

Human Rights Watch (HRW) (1999). *The price of oil-Corporate responsibility and human rights violations in Nigeria's oil producing communities (Environment)* [Online]. New York. Available: http://www.hrw.org/reports/1999/nigeria/ [Accessed 22nd November 2010]

Ikwegbu, N. (2007). *Impact of oil Development Activities on the Physico-socio-economic Sustainability of the Niger Delta of Nigeria.*, Enugu State University of Science and Technology

James, G. K. (2008). *Assessment of Environmental Change and Its Socio-economic Impacts in the Mangrove Ecological Zone of the Niger Delta, Nigeria.* Doctor of Philosophy, University of Missouri

James, G. K., Adegoke, J. O., Saba, E., Nwilo, P. & Akinyede, J. (2007). Satellite-Based Assessment of the Extent and Changes in the Mangrove Ecosystem of the Niger Delta. *Marine Geodesy,* 30**,** 249 – 267

Jensen, J.R., (2000). *Remote Sensing of the Environment: an Earth Resource Per*spective, Prentice Hall, Saddle River, NJ, 544 pp

Jensen, R., Gatrell, J., Boulton, J. And Harper, B. (2004), Using remote sensing and geographic information systems to study urban quality of life and urban forest amenities, *Ecology and Society*, 9(5), Available also at www.ecologyandsociety.org/vol9/iss5/art5/

Jensen, R., Mausel, P., Dias, N., Gonser, R., Yang, C., Everitt, J. and Fletcher, R. (2007), Spectral analysis of coastal vegetation and land cover using AISA+ Hyperspectral data, *Geocarto International* Vol. 22, No. 1, March 2007, 17–28

Jin, Xiaomei (2009). Ecohydrology in water-limited environments using quantitative remote sensing – the Heihe River basin (China) case. Unpublished PhD Thesis, Wageningen University, Wageningen, The Netherlands

Kokaly RF, Despain DG, Clark RN, Livo KE (2003) Mapping vegetation in Yellowstone National Park using spectral feature analysis of AVIRIS data. *Remote Sens Environ* 84:437–456

Kumar, L., Schmidt, K.S., Dury, S. and Skidmore, A.K. (2001). Review of hyperspectral remote sensing and vegetation Science. In: Van Der Meer FD, De Jong SM (Eds.) *Imaging spectrometry: basic principles and prospective applications.* Kluwer, Dordrecht, The Netherlands

Kumar, R. (2000). Conservation and management of mangroves in India, with special reference to the state of Goa and the middle Andaman Islands. *Unasylva,* 51**,** 41-47

Lee, K.-S., Cohen, W.B., Kennedy, R.E., Maiersperger, T.K., Gower, S.T., 2004, Hyperspectral versus multispectral data for estimating leaf area index in four different biomes. *Remote Sensing of Environment* 91 (3–4), 508–520

Lefsky, M.A., Cohen, W.B., Spies, T.A., 2001. An evaluation of alternative remote sensing products for forest inventory, monitoring and mapping of Douglas-fir forests in Western Oregon, *Canadian Journal of Forest Research* 31 (2), 78–87

Li, L., Ustin, S.L., and Lay, M, (2005). Application of multiple end member spectral mixture analysis (MESMA) to AVIRIS imagery for coastal salt marsh mapping: a case study in China Camp, CA, USA. Int. J Remote Sens 26:5193–5207

Li, Y., Liao, Q. F., Li, X., Liao, S. D., Chi, G. B., & Peng, S. L. (2003). Towards an operational system for regional-scale rice yield estimation using a time-series of Radarsat ScanSAR images*. International Journal of Remote Sen*sing, 24, 4207−4220

Lillesand, T. M., & Kiefer, R.W. (2000), *Remote sensing and image interpretation*, New York: John Wiley & Sons, Inc.

Lin, Y and Liquan, Z. (2006), Identification of the spectral characteristics of submerged plant Vallisneria spiralis, *Acta Ecologica Sinica* 26:1005–1011

Lohr, S. L. (1999). *Sampling: Design and analysis*. New York: Duxbury Press 450 pp.

Loveland, T. R., Reed, B. C., Brown, J. F., Ohlen, D. O., Zhu, Z., Yang, L., and Merchant, J. W., (2000). Developments of a global land cover characteristics database and IGBP DISCover from 1-km AVHRR data. *International Journal of Remote Sensing*, 21, 1303- 1330

Loveland, T.R., Sohl, T.L., Stehman, S.V., Gallant, A.L., Sayler, K.L., Napton, D.E., (2002). A strategy for estimating the rates of recent United States land-cover changes, *Photogrammetric Engineering and Remote Sensing* 68, 1091–1099

Lu, D., Mausel, P., Brondizio, E., & Moran, E. (2004), Change detection techniques, *International Journal of Remote Sensing*, 25, 2365−2407

Lu, H., Raupach, M. R., McVicar, T. R., & Barrett, D. J. (2003), Decomposition of vegetation covers into woody and herbaceous components using AVHRR NDVI time series. *Remote Sensing of Environment*, 86, 1−18

Lunetta, R. S. (1998). Applications, project formulation, and analytical approach, In R. S.Lunetta, & C. D. Elvidge (Eds.), *Remote sensing change detection* (pp. 1−19). Chelsea*,* Michigan: Ann Arbor Press

Lunetta, R.S., Knight, J.F., Ediriwickrema, J., Lyon, J.G., and Worthy, L.D., 2006, Land cover change detection using multi-temporal MODIS NDVI data, *Remote Sensing of Environment,* 105, 142-154

MA (Millennium Ecosystem Assessment) (2005a), *Ecosystems and Human Well-being: Scenarios, Volume 2*. S. Carpenter, P. Pingali, E.M. Bennett and M. Zurek (Eds.), Washington DC: Island Press

MA (Millennium Ecosystem Assessment) (2005b), *Ecosystems and Human Well-being: Current State and Trends, Volume 1.* R. Hassan, R. Scholes, and N. Ash (Eds.). Washington DC: Island Press

Malthus, T.J and George, D.G. (1997), Airborne remote sensing of macrophytes in Cefni reservoir, Anglesley, UK, *Aquat Bot* 58:317–332

May, A.M.B., Pinder, J.E. and Kroh, G.C. (1997), A comparison of LANDSAT Thematic Mapper and SPOT multi-spectral imagery for the classification of shrub and meadow vegetation in Northern California, USA, *Int. J Remote Sens* 18:3719–3728

McCarthy, J., Gumbricht, T and McCarthy, T.S. (2005), Ecoregion classification in the Okavango Delta, Botswana from multitemporal remote sensing, *Int. J Remote Sens* 26:4339–4357

Mensah, A. M. (2009). The Influence of Land-use Activities on Nutrient Inputs into Upland Catchment Streams, Ghana, PhD Centre for Development Research, University of Bonn & the United Nations University Institute for Environment and Human Security 299p

Merem, E. (2005)**.** *Environmental Accounting for Changes in Farm Land Use*, *A Canadian Study,* Mellen Press, New York

Milton, E.J., Schaepman, M.E., Anderson, K, Kneubühler, M and Fox, N. (2007), Progress in field spectroscopy. *Remote Sens Environ* 113:S92–S109
Mutanga O, Skidmore, A.K and van Wieren, S. (2003), Discriminating tropical grass Cenchrus ciliaris canopies grown under different nitrogen treatments using spectroradiometry, *ISPRS J Photogramm Remote Sensing* 57:263–272

Mutanga, O., Skidmore AK (2004) Narrow band vegetation indices solve the saturation problem in biomass estimation. Int. J Remote Sens 25:3999–4014

NDES. 1997. The Niger Delta Environmental Survey (phase 1), Environmental and Socio-economic Characteristics, Lagos-Nigeria:: Environmental Resources Mangers limited

Ozesmi, S.L. and Bauer, M.E. (2002), Satellite remote sensing of wetland, *Wetl. Ecol Manage* 10:381–402

Peterson, D. L. and Running, S. W. 1989: Application in forest science and management In: Asrar, G. (Ed.): *Theory and applications of optical remote sensing.* New York. John Wiley & Sons: 429-473

Philipson, P., & Lindell, T. (2003), Can coral reefs be monitored from space *Ambio*, 32,586–593

Ranganathan, J., Raudsepp–Hearne, C., Lucas, N; Irwin, F; Zurek., M; Bennett., K Ash., N and West., P (2008), Ecosystem Services: A Guide for Decision Makers. World Resources Institute

Rashmin, G. (2004). Use of GIS for Environmental Impact Assessment: An Interdisciplinary Approach. *Interdisciplinary Science Reviews,* (March) *29:1*, 11-1

Rekolainen, S., Kaman, J. and Hiltunen, M. (2003), A conceptual framework for identifying the need and role of models in the implementation of the water framework directive, *International Journal of River Basin Management* 1(4): 347 – 352

Ringrose, S., Vanderpost, C and Matheson, W. (2003), Mapping ecological conditions in the Okavango delta, Botswana using fine and coarse resolution systems including simulated SPOT vegetation imagery. *Int. J Remote Sens* 24:1366–5901

Rouse, J.W., Haas, R.H., Schell, J.A., Deering, D.W., Harlan, J.C., (1974), *Monitoring the vernal advancement and retrogradation of natural vegetation*, NASA/GSFC, Type III Final Report, Greenbelt, MD, p. 371

Saenger, P. (2002). *Mangrove Ecology, Silviculture and Conservation,* Dordrecht:, Klumer academic

Sakamoto, T., Yokozawa, M., Toritani, H., Shibayama, M., Ishitsuka, N., and Oho, H., (2005), A crop phenology detection method using time-series MODIS data, *Remote Sensing ofEnvironment*, 96, 366-374

Saunders, C.D., Brook, A.T., Myers Jr., O.E., 2006, Using psychology to save biodiversity and human well-being. *Conservation Biology* 20, 702–705

Schlerf, Martin (2006). Determination of structural and chemical forest attributes using hyperspectral remote sensing data – Case studies in Norway spruce forests, Unpublished Ph.D. Thesis Universität Trier

Schmidt, K.S and Skidmore, A.K. (2003), Spectral discrimination of vegetation types in a coastal wetland, *Remote Sens Environ* 85:92–108

Schott, J. R. (1997). *Remote sensing: The image chain approach*. New York: Oxford University Press

Schuck, A., Paivinen, R., Hame, T., Van Brusselen, J., Kennedy, P., & Folving, S. (2003). Compilation of a European forest map from Portugal to the Ural Mountains based on earth observation data and forest statistics. *Forest Policy and Economics*, 5, 187–202

Sellers, P.J., (1985), Canopy reflectance, photosynthesis, and transpiration, *International Journal of Remote Sensing*, 6, 1335-1371

Shaikh, M., Green, D and Cross, H. (2001), A remote sensing approach to determine environmental flow for wetlands of lower Darling River, New South Wales, Australia, *Int. J Remote Sens* 22:1737–1751

Silva, T.S.F. and Costa, M.P.F., Melack, J.M and Novo, E. (2008), Remote sensing of aquatic vegetation: theory and applications. *Environ Monit Assess* 140:131–145

Spalding, M., Kainuma, M. & Collins., L. (eds.) (2010). *World Atlas of mangroves,* London: Eathscan

Stow, D. A., Hope, A., McGuire, D., Verbyla, D., Gamon, J., Huemmrich, F., et al. (2004).Remote sensing of vegetation and land-cover change in Arctic tundra ecosystems, *Remote Sensing of Environment,* 89, 281–308

Svarstad, H., L. K. Petersen, D. Rothman, H. Siepel and F. Wätzold (2008), Discursive biases of the environmental research framework DPSIR. *Land Use Policy* 23: 116 – 125

Tan, Q., Shao, Y., Yang, S and Wei, Q. (2003), Wetland vegetation biomass estimation using Landsat-7ETM data, IEEE Trans *Geosci Remote Sen* 03(4):2629–2631 IGARSS apos

Treitz, P.M., Howarth, P.J., (1999). Hyperspectral remote sensing for estimating biophysical parameters of forest ecosystems, *Progress in Physical Geography* 23, 359–390

Tucker, C. J., and Sellers, P. J., (1986), Satellite remote sensing of primary vegetation, *International Journal of Remote Sensing*, 22, 3827-3844

Vaiphasa, C.K., Skidmore, A.K., de Boer, W.F. and Vaiphasa, T. (2007), A hyperspectral band selector for plant species discrimination, *ISPRS J Photogramm Remote Sensing* 62:225– 235

WB (1995). Defining an environmental management strategy for the Niger Delta. Report prepared by Industry and Energy operations division, . *In:* JASDIP, S., D, MOFFAT, AND O LINDEN (ed.). Washington D.C.:: West African Department, World Bank

WRM. 2003. *Nigeria: Gas Corporation NLNG destroys forest in the Niger Delta.* 22nd November. Available: http://www.wrm.org.uy/bulletin/68/AF.html, Nigeria (Accessed 22nd November 2010)

Wulder, M. A. and Franklin, E. 2003: Remote sensing of forest environments - the transition from theory to information. In: Wulder, M. A., Franklin, E. (Eds.): *Remote sensing of forest environments - Concepts and case studies.* Boston, Dordrecht, London. Kluwer Academic Publishers: 3-12
Yaw A. T. and Merem, E. C. (2006a). GIS and Remote Sensing Applications in the Assessment of Change within a Coastal Environment in the Niger Delta Region of Nigeria, *Int. J.Environ. Res. Public Health* 2006, *3(1)*, 98-106, www.ijerph.org

Yaw, A. T. and Merem, E. C. (2006b), Management of watersheds with Remote Sensing and GIS: a case study of River Niger Delta region in Nigeria. ASPRS 2006 Annual Conference

Zhan, X., Defries, R., Townshend, J.R.G., Dimiceli, C., Hansen, M., Huang, C., and Sohlberg, R., (2000). The 250m global land cover change product from the Moderate Resolution Imaging Spectroradiometer of NASA's Earth Observing System. *International Journal of Remote Sensing,* 21(6&7), 1433-1460

Zheng, D., Rademacher, J., Chen, J., Crow, T., Bresee, M., Le Moine, J. and Ryu, S. (2004). Estimating aboveground biomass using Landsat 7 ETM data across a managed landscape in northern Wisconsin, USA, *Remote Sens Environ* 93:402–411

Zomer, R.J., Trabucco, A. and Ustin, S.L. (2008), Building spectral libraries for wetlands land cover classification and hyperspectral remote sensing. *J Environ Manage* 90: 2170–2177.

A Comparative Study of Portland Cement, Hydrated Lime and Lateralite as Stabilizing Agents of Quaternary Coastal Plain Sands North of Lagos Metropolis and as Road Construction Material

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Abstract

The Lagos end of the Lagos-Ibadan expressway has been constructed within a wetland terrain of South Western Nigeria. The section was constructed upon a thick deposit of relatively loose, silty and slightly clayey sand technically referred to as the Coastal Plain Sand. The formation is a major sedimentary deposit in Southern Nigeria, and it is a major road construction soil material in the northern environs of the Lagos metropolis that has been massively quarried by many road contactors as borrow materials for several years. Previous and present studies confirm the substandard geotechnical properties of the deposit as road construction material. It requires substantial improvement through stabilization by additives. This study examines the effect of three fluxes, namely Portland cement, Hydrated Lime and newly evolved "**Lateralite''** on the compaction and California Bearing Ratio (CBR) characteristics on several samples of the deposit. Lateralite offered the highest hope of stabilizing the deposit effectively for highway construction on account of its significant anti-shrinkage/swelling control and CBR enhancing effect on treated samples of Coastal Plain Sand deposit.

Keywords: Lateralite, California Bearing Ratio (CBR), Stabilization, Coastal Plain Sand

Introduction

The "Coastal Plain Sands" is a major sedimentary deposit, which extends from the Benin Republic through the northern part of Lagos metropolis to the South Eastern part of Nigeria (Jackson, 1980). The extent of the Coastal Plain Sand is shown in Fig. 1. Coastal Plain Sand has been quarried in several locations as borrow material in the construction of many important roads such as the Lagos – Ibadan expressway and the Sagamu – Ore – Benin highway. Jackson (1980) carried out considerable investigation of the deposits geotechnical properties in specific localities in Lagos and Calabar, and identified the soils as "collapsible" foundation material. Teme (1990) also investigated the deposits' engineering behaviour in the South Eastern part of the Lower Niger Delta of Nigeria and confirmed its "collapsing" nature. In practice, virtually all the important roads and highways constructed over the deposit have failed significantly. Plates 1 and 2 illustrate the occurrence of dangerous pot holes along Lagos-Ibadan Expressway. These large pot holes have a typical cross section of a clayey base course, upon which there is a compacted stone base of about 150mm thick, succeeded on top by very hard asphalt concrete of about 100mm thick. The sharp edges of the succession have constituted very dangerous vehicle tyre busters. Vehicles, which run into them un-aware at high speed are invariably thrown off balance and summersault off track. Unfortunately the illustrated phenomenon is characteristic of several stretches of the expressway.

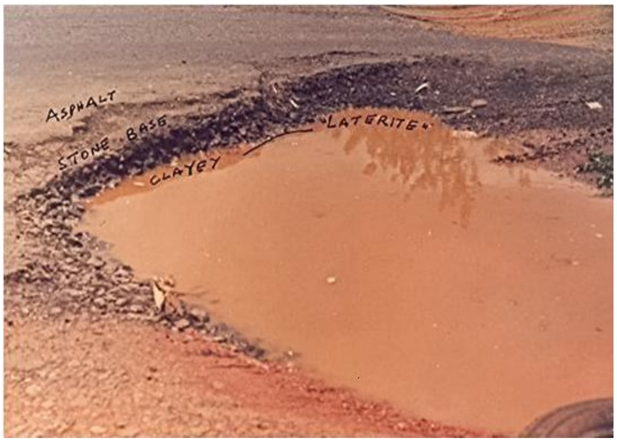

PLATE 1: Large pothole showing clayey lateritic, sub-grade, a stone base & the Asphalt wearing course on Lagos-Ibadan Expressway, Nigeria.

PLATE 2: Dangerous potholes, Lagos-Ibadan Expressway, Nigeria

Fig. 1: Map of Southern Nigeria showing the occurrence of the Coastal Plain Sands (Jackson, 1980)

Field Compaction

Several years of observation by the authors has shown that field compaction with the aid of various heavy rollers is the only form of stabilization stipulated by Consultants, and adopted by Contractors. This form of stabilization is inadequate. Under excessive heavy rollers, the soil grains break down into much finer grains, increasing the silt size content of the compacted soil. Increased silt content constitutes a further destabilizing factor for roads or highways constructed on such soil materials. Most lateritic soils, including the coastal plain sands, do not possess the degree of excellence ascribed to them by Engineers. The lateritic soils possess variable internal structures, geochemical and mineralogical properties, which derive from their geological history, and their respective geotechnical properties are as a direct response to the listed factors. Present studies show that the Coastal Plain Sands possess an "open, skeletal structure", caused by the precipitation of ferric iron oxide and alumina (sesquioxides), which occupy the interstices of medium to fine silica sand grains. Many other mineral grains are also found within the matrix. The sesquioxide precipitates form weak coatings round the silica and mineral nuclei. The bulk of the fines are silt-size, as can be observed in the Grain size distribution curve in Fig. 2. The sand content is usually fine to medium, and clay size particles are minimal. The silt-size particles seem to act as the weak binders when the soils are compacted. Although supervising engineers usually identify the compacted soils as satisfactory, the long term performance of the soils as base or sub-base course materials has shown that they are vulnerable to quick water destabilization at the onset of rainy seasons.

Stabilization

There is abundant literature to show that lateritic soils are known to respond favourably to stabilization by ordinary Portland cement and hydrated lime respectively, (Gidigasu, 1976). In practice however, the two additives have shown little success when used to stabilize fine grained lateritic soils in major road works in Nigeria. Considerable efforts and expenses have been invested on seeking a more effective additive for use in the country. The invention of 'laterilite' may be providing the needed solution. Several samples of the Coastal Plain Sands and other lateritic soils have been experimentally and successfully stabilized against water destabilization, and the treated specimens do not lose their compacted strength when soaked in water for several years.

Lateralite

Lateralite is a new mineral flux evolved experimentally by the first author over a period of about two decades. The mineral flux has been used to stabilize several samples of the Coastal Plain Sands. Lateralite is a mineral compound selected in definite proportions and pulverized to the fineness of cement to induce a pozzolanic effect on sesquioxide –rich lateritic soils in general. The treatment has been amply demonstrated practically. When one measure of the substance is mixed with ten measures of dry soil, and are both mixed with water that is equivalent to the soil's optimum moisture content, the sesquioxide minerals in the soil are noted to form a new precipitate with **lateralite,** When dry, the resulting mixture does not lose its compacted strength and does not respond to water dis-aggregation even when soaked for any length of time.

Engineering index properties of the Coastal Plain Sands

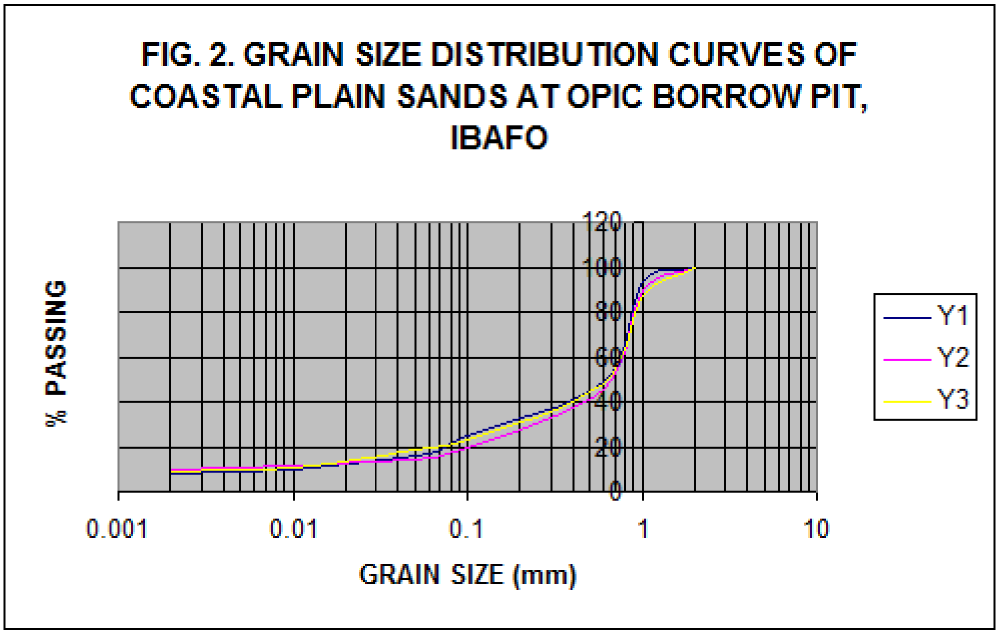

Fig. 2: Grain size distribution curves of coastal plain sands at Opic borrow pit, Ibafo

Table 1: Statistically computed values of engineering index properties of coastal plain sands from "Opic borrow pit" Lagos

Properties	No of samples	Mean values
Liquid Limit, W^L	20	35%
Plasticity Index, W^P	20	23%
Plastic Limit, W^l	20	12%
Shrinkage Limit	20	8.06%
AASHTO Classification	-	A – 7
Specific Gravity	-	2.66
Percentage fraction passing 0.075mm sieve	-	37.55%

The Stabilized Specimens

The admixture of each of the stabilizing agents to samples of the investigated soil produces an immediate reaction in the presence of water. It was rather difficult to investigate the Atterberg limits of the Mixtures, as a significant level of progressive hardening was noticed while mixing was in progress. Results became very erratic, and the tests were discontinued. Each of the stabilizers induced respective levels of hydration in the prepared specimens at the end of mixing, and by the time that the Compaction test was completed; all the specimens had developed different degrees of hardening.

Compaction

Of special interest in Table 2 are the columns showing the Degree of saturation (%) and Air voids (%). Theoretically, compacted soil specimens should have no air voids at 100% saturation. The compaction test curves shown in Figs.3 and 4 of cement and lime stabilized specimens respectively indicate that there are air voids present, since the compacted specimens were not 100% saturated. The "zero-air-voids" curves are located almost tangentially to the compacted curves.

Table 2: Compaction characteristics of treated specimens

PROPERTIES	**VALUES**						
	Untreated Soil	**Cement Stabilized**		**Lime Stabilized**		**Lateralite Stabilized**	
	0%	**8%**	**10%**	**8%**	**10%**	**8%**	**10%**
Maximum dry density (kg/m^3)	1922.2	1919.9	1921.3	1911.0	1918.2	1901.2	1913.1
Optimum moisture (m %)	12.89	13.46	13.4	13.3	14.3	13.6	15.4
Degree of saturation (%)	89.33	82.82	76.75	80.29	81.33	83.18	77.8
Air voids (%)	14.67	12.18	11.25	9.71	7.67	13.18	10.8

In contrast, lateralite treated specimens indicate a negative degree of saturation. This means that there is a significant amount of voids present in the treated specimen. This became evident as air bubbles were observed when a dried sample of the compacted soil was immersed in water. However, at the cessation of the bubbling, the immersed sample was not dissipated.

Observations during the study have also shown that treated clayey soils lose their plasticity after setting, but the soil grains remain bound together when dry, though not with a high degree of bonding like in sand/cement mix. Lateralite was found to have some pozzolanic property, although its intensity needs to be investigated. It is believed that as a result of its electrical charge, lateralite has been able to infiltrate into the open skeletal structure of fine-grained lateritic soils, surrounding and binding the larger soil grains even in the presence of water. It is inferred that soils stabilized with lateralite would hardly favour a build-up of pore water pressure when used in construction.

The "Zero-air-voids" curve of lateralite treated soils cut through the compacted curves, indicating negative values (Fig. 5). The reason for this is not yet fully understood, and it is highly essential that a detailed study of the structure of lateralite treated and compacted soil specimens be studied under the petrographic microscope, or with the electron microscope to reveal useful information on the unclear phenomenon. Lateralite treated specimens are expected to possess minimal, and the least air voids compared to those of cement and lime treated soils. It is observed that the grains of lateralite treated specimens are not dissociated when soaked in water for over nine years, and the soaked compacted specimens have also not lost their compacted strength.

Reduction in Maximum Dry Densities (MDD)

It is recognised that additives such as cement and lime do normally decrease the densities of compacted soils (Yoder, 1957; Gidigasu, 1976). The observed is consistent with the results shown in Table 3. The MDD of the untreated soil is higher than those of the stabilized soils. The values obtained from the lateralite-treated soils are the least. This can also be explained by the lighter specific gravity (SG) of lateralite, (2.45). The relative volume of the flux required for the effective stabilization of the soil is higher than those of cement (SG = 3.12) and lime (SG = 2.56) respectively. The buoyancy effect of lateralite on the soil grains is therefore higher than those of cement and lime respectively.

Table 3: Summary of the CBR Test Results.

	UNTREATED SOIL		CEMENT STABILIZED				LIME STABILIZED				LATERALITE STABILIZED			
ADMIXTURE %	0%		8%		10%		8%		10%		8%		10%	
CBR TYPE	S	U	S	U	S	U	S	U	S	U	S	U	S	U
CBR % (*80%)	16.70	35.5	96.93	54.28	129.68	59.11	63.89	52.40	74.22	51.48	64.53	45.30	142.4	51.22
WELL %	4.20	-	2./032	-	1.043	-	2.14	-	0.059	-	0.70		0.00	
MOISTURE CONTENT OF CBR SPECIMENS %	18.9	13.09	15.95	13.21	13.70	12.41	14.83	12.54	14.17	12.43	14.33	13.96	13.03	12.23

NB: S = Soaked; U = Un-soaked

California Bearing Ratio (CBR) Characteristics

The soaked CBR values obtained from unstabilized samples are less than the minimum values recommended by the Nigerian Federal Ministry of Works (i.e. 80%), for base course materials. The soaked CBR values of lime-stabilized soils do not satisfy the Ministry's recommendation either, while values of cement- and lateralite- stabilized soils are satisfactory.

Prolonged Soaking in Water

Long term observation has shown that Nigerian roads are mostly destabilized in wet weather. Sub-base and base course materials are usually compacted clayey lateritic soils, which characteristically absorb water by capillary action; and this softens the compacted soil material, no matter the degree of compaction attained during construction. It is reasonable therefore to investigate all stabilized soils meant to be used as sub-base or base course materials by **prolonged soaking in water to ascertain the possible behaviour of the soil underneath the completed pavement in wet weather**.

Compacted specimens of the soils treated with the respective stabilizing agents at the mixing ratio of 1:10 were selected in equal numbers and subjected to the immersion test. Each specimen was cured for 24 hours under wet condition, and later soaked in a bowl of water for 60 days. Continuous observation throughout the immersion period shows that the hydrated lime stabilized specimens disintegrated completely within the first six days. Cement stabilized specimens remained intact for the first four days after when rapid spalling commenced. By the tenth day, all the specimens had disintegrated. In contrast, all the lateralite stabilized specimens remained un-deformed throughout the immersion period, and up till the time of writing, all the specimens have remained intact, a period of over nine years. The observation period (9 years) practically proved that lateralite treated sub-base or base course lateritic soils are most likely to survive wet weather conditions in flexible pavements if design thicknesses and construction techniques are satisfactory.

Conclusion

The comparative effect of Portland cement, hydrated lime and lateralite as stabilizers of the Coastal Plain Sands in the northern environs of Lagos Metropolis was studied. This study showed that the performance of lateralite as soil-stabilizing agent is more effective than that of cement or hydrated lime. Results of all previous field experiments also indicated that if lateralite is used to stabilize poor quality lateritic soils such as the Coastal Plain Sands in difficult wetland environments, its performance as an adequately thick base course should lead to a positive development towards the construction of stable roads even in such areas. Engineering designs should be modified to take cognisance of the geological environment. It is also essential that the geological characteristics of the soils meant for stabilization with lateralite should be studied to confirm their suitability for lateralite action.

References

Alayaki, F. M. (2002): An examination of the engineering characteristics of lime, cement, and terralite stabilized laterite base course. Unpublished dissertation, Department of Civil & Environmental Engineering, University of Lagos, Nigeria

Akanbi, E. O. (2006): Geotechnical assessment of the coastal plain sands of south western Nigeria as highway construction material, Unpublished dissertation, Department of Civil & Environmental Engineering, University of Lagos, Nigeria, 224pp

Federal Ministry of Works & Housing Nigeria (1972) Rev. 1995: Highway Manual for Road Design Part 1

Gidigasu, M. D. (1976): Laterite Soil Engineering, Elsevier, 544pp

Jackson, J. O. (1980): The Failure of Foundations in Coastal Plain Sands of Nigeria. 7th Reg. Conf. Africa, Soil Mech. Found. Eng. Accra, pp 261-168

Meshida, E. A. (2001): The Evolution of a New Flux for Stabilizing Fine-grained Lateritic Soils. Terra Geotech. Eng. Ltd. Lagos, Research Paper No. 8, 12pp

Teme, S. C. (1990): Liquefaction Potentials of a Sandy Sub-stratum in the S. E. Lower Niger Delta of Nigeria

Yoder, E. J. (1957) in Gidigasu, (1976) Laterite Soil Engineering: "Effect of calcium chloride on the compactive effort and water retention characteristics of soils"

Aspects of the Hydrology of the Western Niger Delta Wetlands: Groundwater Conditions in the Neogene (recent) Deposits of the Ndokwa Area

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Abstract

Groundwater conditions in the thin Neogene deposits of the Sombreiro-Warri Deltaic Plain and the Freshwater Swamp physiographic environments of the Ndowa area are not well understood. Physical examination indicates that the deposits are lithologically similar to those of the Benin Formation. All deposits exhibit a fining upwards cyclical sequence of fine, medium-coarse grained and pebbly quartz and feldsphatic sands and differ from each other only in the topmost superficial cover of approximately 6-10m thickness. The configuration of the water table as deduced from measurements in dug wells show that it mirrors the general topography. Ground water movement is unidirectional from the recharge mound centered on Urhonigbe towards the south and east of the area into a major ground water sink stretching from Ogume to Aboh and beyond. The sink evidently sustains the surrounding wetlands year round. Transmissivity of the multilayered aquifer is estimated at $71m^2$ per day. Differences in the chemistry of groundwater from the three physiographic regions are reflected in elevated levels of lead and cadmium at an average concentration of 0.01mg/l and 0.13mg/l respectively in the Sombreiro-Warri Deltaic Plain terrain. Furthermore, while the order of cation abundance in Benin Formation outcrop groundwater is Ca>Mg>K>Na, it is Na>K>Ca>Mg in the Sombreiro-Warri Deltaic Plain and the Freshwater Swamps. Coliform bacteria occur in all samples tested. These findings have important implications for water and environmental management of the Ndokwa area that deserve further and closer examination.

Keywords: Groundwater, Neogene deposits, wetlands, water quality, Niger Delta

Introduction

Ndokwa is part of the western Niger Delta petroleum province and many oil and gas fields (Kwale, Ebedei, Okpai) and related installations are located in the area. Generally, the area is also endowed with an abundance of water resources. However, Emeshili (2008) estimates that less than 5% of the population has access to public water supplies. The remainder depends on untreated water from streams, ponds and groundwater, which is obtained from shallow boreholes and dug wells, as a result of which waterborne diseases are common (DSHMB, 2004). The search for clean water supply sources as well as the determination of the quality of raw water supply sources has therefore attracted much attention. Okolie et al. (2006) and Oseji et al.(2005, 2006) in attempts to facilitate successful groundwater exploitation used resistivity methods to delineate the geometry of the underlying water bearing deposits in several communities within the area. Emeshili (2008) undertook chemical and microbiological analyses of stream water and ground water pumped from boreholes and stored in overhead tanks in several communities to determine potability as did Kaizer and Osakwe (2010) for selected rivers. Iwegbue (2008) and Iwegbue et al. (2007) also sought to determine the potential effects of leached crude oil spills on the soils and groundwater.

The primary objective of this study is to build on the earlier efforts by determining and describing the groundwater conditions in the Quaternary near surface deposits that affect and to a large extent control many of the phenomena that have been observed in the previous studies. In addition, because existing studies are in general devoid of appropriate maps, the primary data collected in this study is geo-referenced and plotted on a base map of the area. The resulting map would be an essential tool and base for further studies on the wetlands and lakes that dominate the eastern part of the area.

Location and Physiography

The Ndokwa area is located between Latitude 50 15N, 5005N and Longitude 6005E, 6045E, covering a total land area of about 3000 km^2 (Figure 1). The area comprises of the Ndokwa West, Ndokwa East and Ukwani Local Government Areas of Delta State, Nigeria. Ndokwa area is part of the physiographic province that is described by Odemerho and Ejemeyovwi (2007) as the Low Deltaic Plain and Freshwater Swamps, which also coincides with Allen's (1965, Table 1) Upper floodplain and Lower floodplain respectively. In Delta state, this low province rises gradually from less than 9m above sea level in the west to about 25m above sea level at its eastern boundary.

The province is further subdivided into three distinct landform assemblages. The first is the southern lower Niger flood plain that merges with the more than 25km wide combined Ase River-Niger River flood plain to the east. The fluvial landscape of these flood plains is dominated by numerous streams and oxbow lakes. The second landform is the north-central (Sombreiro-Warri) plain that contains many freshwater swamps. The third landform type occupies the north east and is distinguished from the north-central plain by the presence of low undulating ridges and a much reduced frequency in the occurrence of swamps. All three subdivisions are represented in Ndokwa: the combined Ase River-River Niger floodplain that occupies the eastern portion and stretches from Aboh to Umuzezi; the Sombreiro-Warri that runs diagonally across the area from Abbi to Umuzezi, and the low ridged plain that extends from Obiaruku through Umuaja to Nsukwa.

Ndokwa is drained by four main river systems, namely, the Adofi River to the north, which flows south and swings northeastwards to join the dominant Ase River system whose network in combination with the River Niger drains the eastern portion of the area. The head waters of the Ethiope River and Okumeshi River (Warri River) occur here and drain the northwest portion. Secondary tropical lowland forests prevail in the area because much of the original primary forest has been lost to farming and timber exploitation. Annual ten year mean rainfall is about 2600mm while the mean daily temperature is 31.2^0C (Nigerian Meteorological Agency, 2003).

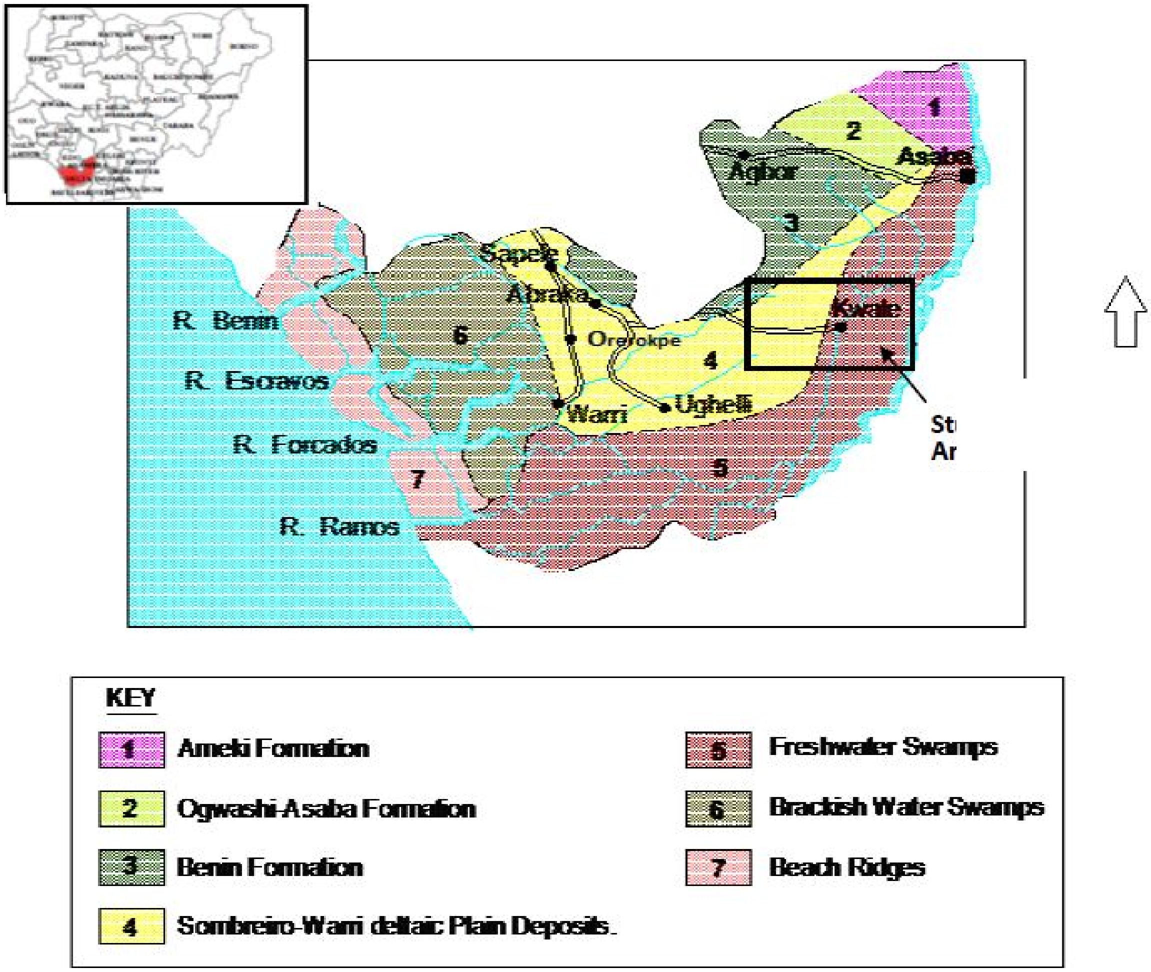

Figure 1: The study area: physiographic provinces and distribution of Recent deposits (After Akpoborie et al. 2011).

Distribution of Recent Geological Deposits

The sedimentary environments and morphological features of the Niger Delta have been described by (Short and Stauble, 1967; Allen, 1964, 1965, 1967; Oomkens, 1974; Durotoye, 1989; Odemerho and Ejemeyovwi (2007).

Specifically, the Ndokwa area is underlain by the deposits of the modern and Holocene delta top deposits that result in the various physiographic landforms described in the foregoing. The aerial distribution of the deposits thus coincides with the physiographic subdivisions and Short and Stauble's (1967, pp. 766) depositional environments. The Nigerian Geological Survey Agency retained the nomenclature in the Geological Map of Nigeria, from which Figure1 is adapted. Thus the combined Ase River/River Niger flood plain is the Freshwater Swamps, the north central plain is the Sombreiro-Warri Deltaic Plain, and both of which contain deposits that conformably overlie and mask the Benin Formation whose outcrop forms the undulating hills in the north and north east.

The deposits of the Freshwater Swamps and the Sombreiro-Warri Deltaic Plain are universally considered to be recent expressions of and a continuation of the Benin Formation. They result from the sediment laden discharges of the River Niger that is spread on the delta by its various tributaries. The sediment is generally an admixture of medium to coarse-grained sands, sandy clays, silts and clays that eventually settle in fluvial/tidal channel, tidal flat and mangrove swamp environments, a process that has been ongoing since the late Quaternary and is related to interglacial marine transgressions (Allen, 1964, Oomkens, 1974, Durotoye, 1989).

The described deposits are exploited for glass sands and quarried extensively for building purposes (Bam, 2007; Akpokodje and Etu-Efeotor, 1987; Ministry of Commerce and Industry, 2001; Atakpo and Akpoborie, 2011). Together, the deposits also constitute the shallow aquifer that is exploited by shallow (<30m) boreholes and dug wells that serve as the primary water supply source for rural as well as many semi-urban and urban communities in Ndokwa and in the Niger Delta region in general (Amajor, 1991).

The Benin Formation, the youngest of the three important formations that constitute the sedimentary fill of the Niger Delta Basin is usually described as consisting of massive continental/fluvial sands and gravels. The older formations, which are encountered only in the subsurface in Ndokwa are the Agbada Formation of paralic sands and shales and the basal Akata Formation, which consists of holomarine shales, silts and clays. The lateral equivalents at the surface as shown in Figure 1 are the Ogwashi-Asaba Formation and Ameki Formation of Eocene-Oligocene age (Short and Stauble, 1967; Asseez, 1989).

Methodology

To achieve the study objectives, the Ndokwa area was subdivided into the three geomorphic zones. Lithologs were assembled for each province from the records of Aquix Limited, a drilling company that is actively involved in private borehole construction in the area. Seventeen dug wells were selected from communities, which are evenly distributed in the area for water level monitoring in the wet and dry seasons. Five boreholes were selected for the same purpose but located in the areas where dug wells are not available due to a lower water table. Two sets of data from pump tests conducted at Kwale were analysed with the multi layer unsteady (MLU) state computer code to determine aquifer characteristics.

To understand groundwater contribution to stream flow in the area, stream flow data collected over a six- year period by the Benin-Owena River Basin Development Authority (BORBDA, 1992) at the Ossissa gauging station at Adofi, were processed with the Time Series Analysis Module of the River Analysis Package, Version 1.01 (Grayson et al. 1996; Marsh, 2003).

With respect to water quality and groundwater geochemistry, samples were collected from the selected dug wells and boreholes and screened for the major anions, cations, and some heavy metals. Replicate water samples were collected from dug wells into sterilized polyethylene bottles. Borehole water samples were collected after the boreholes have been developed, flushed clean and pumped continuously for about one hour. The set of samples designated for heavy metal analysis were immediately stabilized with acid. Electrical conductivity and Total

Dissolved Solids were measured in situ using the HACH Conductivity/TDS meter. The pH was determined by means of a Schott Gerate model pH meter and temperature was determined using mercury–in-glass thermometer calibrated in 0.2°C units from 0°C to 100°C. Nitrate was determined with the HACH Spectrophotometer using the cadmium reduction method, while the sulphate content of all the samples was determined by the turbidimetric method. Major cations and anions Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, Cl^-, NO_3^- and metals Pb^{2+}, Cd^{2+}, Zn^{2+} and Cu^{2+} were determined in the laboratory with appropriate titrimetric, flame photometric and atomic absorption spectrometric methods (APHA, 1992).

Finally, depth to water level in each of the dug wells and boreholes were measured with an electronic water level indicator. An Ertec model GPS instrument was used to determine wellhead coordinates. Existing topographic maps of the entire area are devoid of contours, averaged elevation readings from three GPS instruments at each site were used with the sparsely distributed benchmarks established for oil exploration activities to approximate the elevation of each well location. Surfer 8 (Golden Software Inc., 2002) was employed in generating the depth to water level as well as the calculated head distribution.

Results and Discussion

Lithology of the Shallow Deposits

The lithologic logs for boreholes located at Ndemili, Etua-Etiti, Ossisa, Kwale, Aboh, Abbi and Ellu are shown in Figure 2. The sediments are predominantly fine –medium grained, medium to coarse grained and coarse grained sands deposited in a fining upwards cycle. A thin clay layer (<2m) appears to consistently occur in this succession at different depths in the depositional cycle. Boreholes are screened at the lowermost coarse grained layer. At Aboh and Ossissa on the Freshwater Swamps, the topsoil contains dead vegetation while the grey gravelly sands contain fresh feldspars and angular quartz. The deposits at Abbi and Etua–Etiti exhibit a predominantly whitish coloration with depth. The logs confirm the difficulty in distinguishing the Benin Formation proper from the overlying deposits in the subsurface. The clay bands encountered at Etua-Etiti, Ndemili and Aboh apart from being too thin at less than a meter each, are characteristically discontinuous and as such do not constitute any form of confinement to the underlying sands. The deposits with the Benin Formation thus form one continuous but layered aquifer.

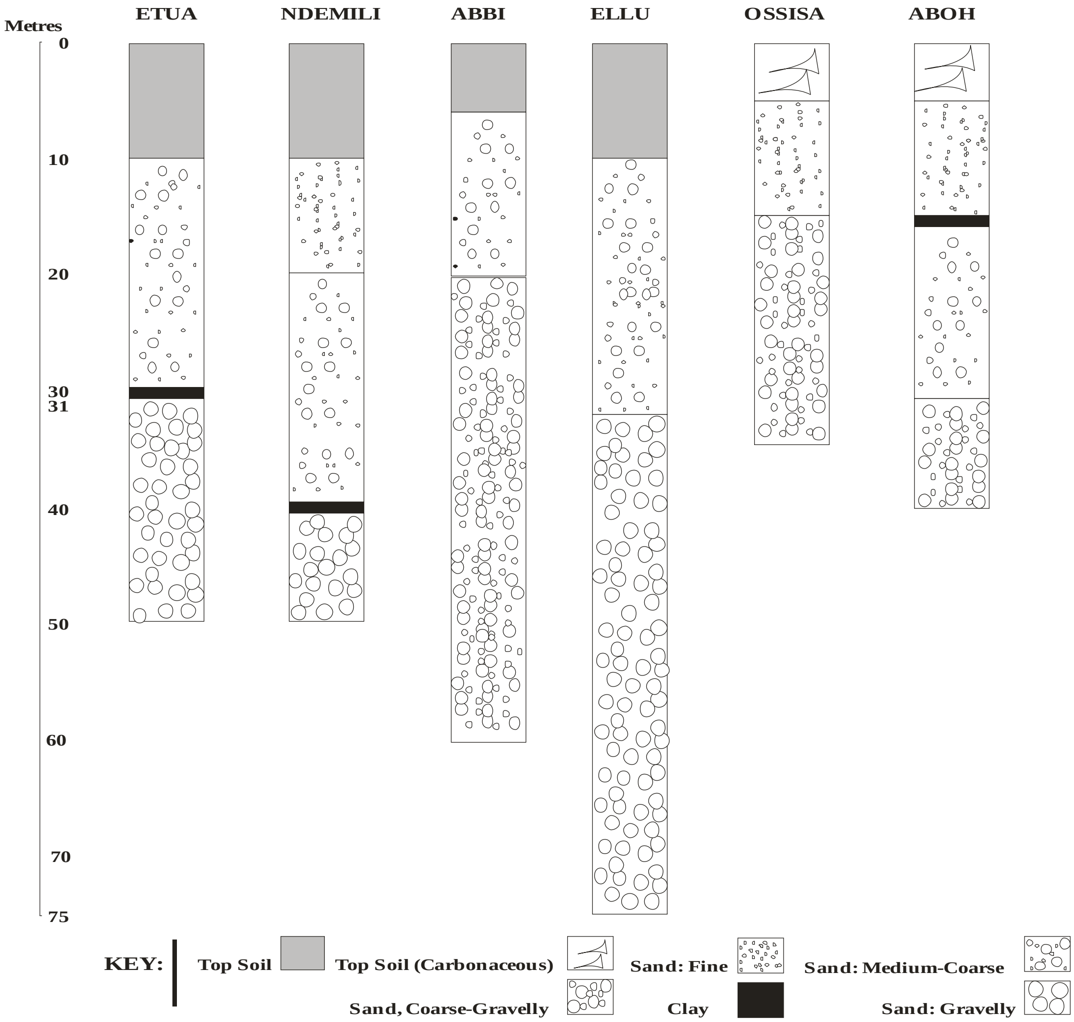

Figure 2: Lithologs from Ndokwa

Groundwater Conditions

Depth to water levels in March and July representing dry and wet seasons respectively were measured at seventeen locations in twelve communities. The results are shown in Table 1. Groundwater clearly occurs at water table conditions and seasonal water level fluctuation in 2009 was an average of 0.83m with a range of 1.61m at Ogume to 0.11m at Okpai. The configuration of the water table as contoured with the dry season data and superimposed on the geological map is shown in Figure 3.

Table 1: Groundwater Levels from Ndokwa

Locations	Latitude/ longitude	Surface elevation	Actual depth to water table for dry season	Actual depth to water table for wet season	Rise in water level within the period	Hydraulic Head for Dry Season
Ogume (Hand dug well)	N 05^{O} 45^{I} 00.4^{II} E 06^{O} 19^{I} 21.3^{II}	10	4.58	2.97	1.61	5.42
	N 05^{O} 45^{I} 18.6^{II} E 06^{O} 19^{I} 25.3^{II}	13	3.76	2.07	1.69	*9.24
Umukwata (Hand dug well)	N 05^{O} 48^{I} 17.9^{II} E 06^{O} 14^{I} 58.5^{I}	22	2.94	2.20	0.74	19.06
	N 05^{O} 48^{I} 17.4^{II} E 06^{O} 14^{I} 39.1^{II}	11	3.42	3.06	0.36	*7.58
Ebedei (Hand dug well)	N 05^{O} 49^{I} 32.0^{II} E 06^{O} 14^{I} 39.3^{II}	40	1.89	1.69	0.20	38.11
	N 05^{O} 49^{I} 34.9^{II} E 06^{O} 14^{I} 39.0^{II}	22	4.70	4.55	0.15	*17.30
Okpai (Borehole)	N05^{0} 43^{I} 33.0^{II} E06^{0} 36^{I} 02.4^{II}	18	5.36	5.29	0.11	*12.64
Aboh (Hand dug well)	N05^{O} 33^{I} 14.7^{II} E06^{0} 31^{I} 49.1^{II}	14	1.39	0.30	1.09	*12.61
Ashaka (Hand dug well)	N05^{0} 39^{I} 10.2^{II} E06^{0} 24^{I} 25.7^{II}	16	5.39	4.76	0.63	*10.61
	N05^{0} 38^{I} 50.2^{II} E06^{0} 24^{I} 14.7^{II}	23	8.35	7.74	0.61	14.65
	N05^{0} 38^{I} 44.9^{II} E06^{0} 24^{I} 07.0^{II}	12	7.33	7.00	0.33	4.67
Utagbe-Ogbe (Hand dug well)	N05^{0} 41^{I} 21.3^{II} E06^{0} 25^{I} 43.3^{II}	15	8.33	8.01	0.32	*6.67
	N05^{0} 41^{I} 25.6^{II} E06^{0} 25^{I} 46.6^{II}	17	8.04	7.68	0.36	8.96
	N05^{0} 42^{I} 07.3^{II} E06^{0} 25^{I} 58.7^{II}	16	8.01	7.70	0.34	7.99
Utagbe-Uno (Hand dug well)	N05^{0} 52^{I} 57.8^{II} E06^{0} 23^{I} 12.2^{II}	32	3.66	2.63	1.03	28.34
	N05^{0} 52^{I} 48.2^{II} E06^{0} 22^{I} 44.6^{II}	26	3.04	1.94	1.10	*22.96
	N05^{0} 53^{I} 05.7^{II} E06^{0} 23^{I} 21.4^{II}	23	2.95	2.12	0.83	20.05
	N05^{0} 53^{I} 05.0^{II} E06^{0} 23^{I} 24.3^{II}	20	2.88	2.05	0.80	17.12
Ndemilli (Borehole)	N06^{0} 01^{I} 33.0^{II} E06^{0} 17^{I} 05.3^{II}	79	23.01	-	-	*55.99
Umuaja (Borehole)	N05^{0} 56^{I} 07.6^{II} E06^{0} 14^{I} 01.9^{II}	34	15.02	14.05	0.97	*18.98
Umutu Borehole	N05^{0} 55^{I} 01.1^{II} E06^{0} 13^{I} 36.1^{II}	34	16.74	16.58	0.16	17.26
Obiaruku (Borehole)	N05^{0} 50^{I} 58.4^{II} E06^{0} 09^{I} 19.8^{II}	57	14.14	-	-	*42.86

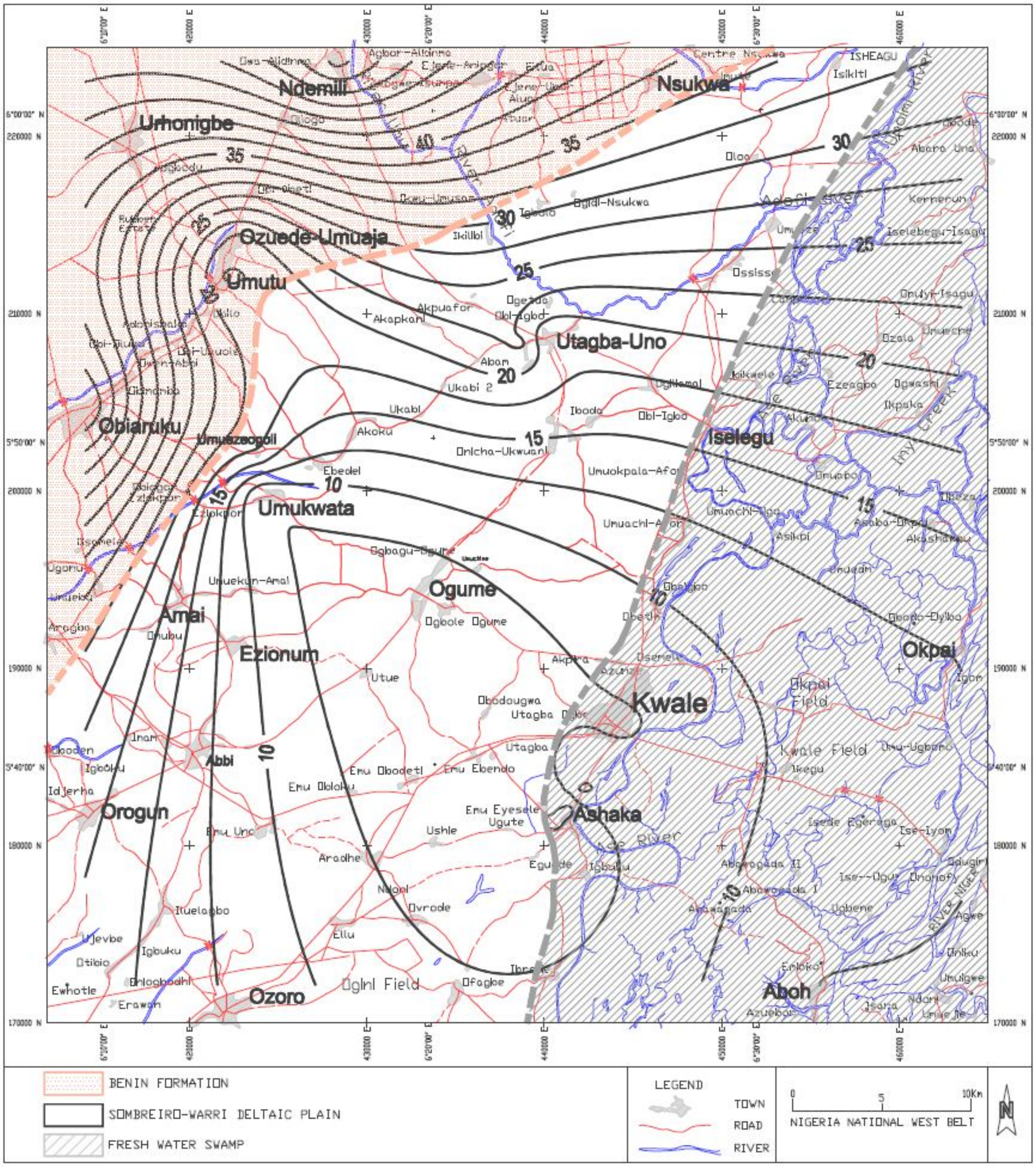

Figure 3: Physiographic terrains/recent deposits, drainage and water table contours

Ground water movement is generally from north to south. Thus recharge is more extensive at the outcrop of the Benin Formation to the north where groundwater is at a steeper gradient and from where flow is down slope, generally southwards and unidirectional. In the terrain of the overlying deposits, the ground water gradient has become virtually flat and the contours closed a characteristic of groundwater-fed wetlands. Specifically, movement is through

Urhonigbe, Ndemili and Nsukwa in the northeast, all on the Benin Formation which in this area is devoid of overlying recent deltaic deposits.

The water table contours begin to flare out in the vicinity of Umuaja-Umutu where the source of the River Ethiope is located. Movement from the recharge front is thus southeastwards towards the central area at Ogume, Kwale and Ashaka that occupy the Sombreiro-Warri Deltaic Plain. From the northwest, ground water moves south directly into the combined Ase River/ River Niger flood plain, i.e. the Freshwater Swamps. The headwater of the Adofi River that drains the northeast flank of the recharge mound is also located here. The steep ground water gradient in the recharge area flattens out on the Sombreiro-Warri Plain and flatter still on the Freshwater Swamps thus the configuration of the water table mirrors the general physiography. The resultant decrease in flow velocity would explain the dominance of perennial swamps and oxbow lakes in this wetland. Akpoborie and Osula (1999) earlier used manual hydrograph separation techniques to show that groundwater constitutes up to 72 per cent of the total annual flow of the Adofi River.

To eliminate manual errors that are naturally inherent in the manual techniques used in the earlier study, the same data from the Ossissa gauging station were reprocessed with the Time Series Analysis Module of the River Analysis Package (Grayson et al. 1996; Marsh, 2003). Figure 4 is a typical hydrograph for the 1989 year as separated by the software package. Base flow characteristics for the six years of available record are presented in Table 2. The base flow index (BFI) is the ratio of total base flow discharge for the reporting period to total discharge. The average Base flow Index for the six year period is 0.85, slightly higher than Akpoborie and Osula's (1999) estimate of 0.72.

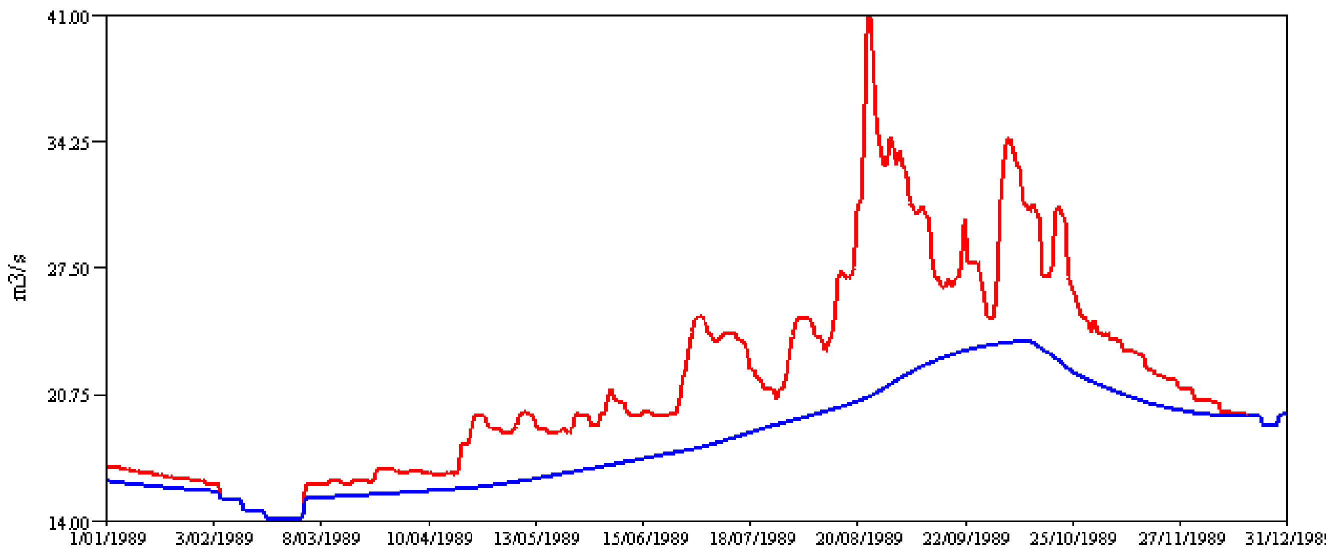

Figure 4: 1989 Stream Dischage Hydrograph for Adofi River at Ossissa, Ndokwa area with base flow indicated.

Table 2: Summary Baseflow Statistics, Adofi River at Ossissa

Statistic	1989	1990	1991	1992	1993	1994
Minimum (m^3/s)	14	16	18	15.9	24.6	25.5
Maximum (m^3/s)	41	47.5	49	46.2	53	54
Mean (m^3/s)	21.321	23.591	25.618	22.355	31.87	36.668
BFI	0.855	0.845	0.832	0.844	0.872	0.868

If the lower and more conservative estimate of 0.72 is used, it would represent an approximate annual groundwater discharge of $0.606x10^9$ m^3 and an effective annual infiltration of 1.42m spread uniformly over the effective drainage area of 425 km^2. This compares favorably with the wet season-dry season ground water level fluctuation of 1.62m measured at Ogume during the study period. Further west on the Sombreiro-Warri Deltaic plain at Okurekpo, Akpoborie et al (2000) measured annual ground water fluctuations of 5m in dug wells. Furthermore, this recharge–discharge relationship is consistent with the suggested characterization of the groundwater flow systems in the Niger Delta as one that is dominated by local alternating recharge discharge areas which when combined with low regional slopes and undulating relief make the Niger Delta region a hydrogeologically shallow watershed (Ophori, 2007; Toth, 1963) that is devoid of extensive and deep regional flow systems.

Aquifer parameters were estimated from data obtained from a pump test conducted in 1985 by Paulosa Nigeria limited in a well drilled at Kwale during the National Borehole Program. The borehole was approximately 120m deep and was completed with 170mm casing and screen. The 15m screen was placed at the bottom of the borehole. The well was pumped at 2.16m^3/hr for 15 hours. The Multilayer Unsteady state model developed by Hemke and Post (2010) was used to determine Transmissivity as 71m^2/day. Model curve matching results, Figure 5 show a good fit between observed drawdown and model predicted drawdown.

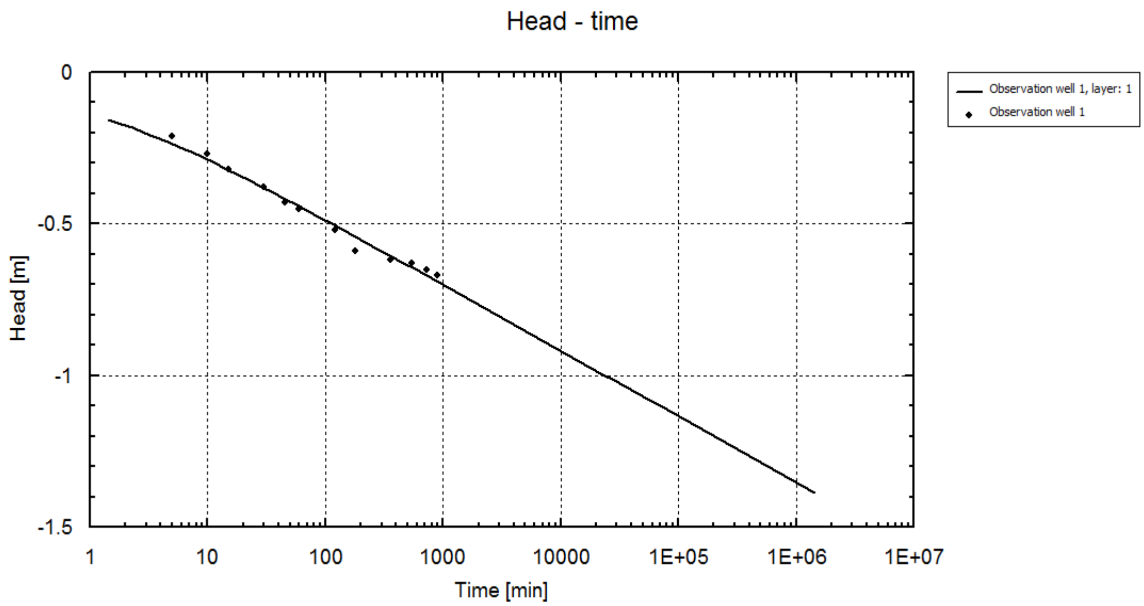

Figure 5: Time-drawdown curve from Kwale pump test.

Groundwater Chemistry

Physical and chemical characteristics of ground water in the area are summarized in Table 3. Ground water is generally soft. However, the order of abundance of the major cations in both the Sombreiro Warri- Deltaic Plain and the Freshwater Swamps is Na>K>Ca>Mg. This order is the same as that reported for shallow groundwater from Orerokpe in the Sombreiro- Deltaic Plain west of Ndokwa by Aweto and Akpoborie (2011) who suggest the dominance of water-rock interactions after recharge by rainfall in determining ground water chemistry. This would include natural softening caused by the replacement of Ca^{2+} ions by the Sodium ion. And is reinforced by the fact that in the Benin Formation outcrop and recharge area in Ndokwa where groundwater is likely more representative of pristine conditions and flow gradients are higher than at the other terrains, cation occurrence is the order Ca>Mg>K>Na (Table 3). The anions occur in the order $Cl>HCO_3>NO_3>SO_4$ in all terrains. However, the significantly higher average chloride content of 51.6mg/l appears to characterize groundwater in the Sombreiro-Warri Deltaic Plain. It is probably significant that the highest chloride content, 81mg/l was recorded from a un- ringed dug well at Utagba Uno. The only other un-ringed dug well sampled in the study at Umukwata showed an above average chloride content of 58mg/l. The observation might suggest a relationship between contamination from domestic waste and elevated chloride content (Appelo and Postma, 1993; Singh et al.2008). Aside from the higher chloride content, other contrasting differences in geochemical character appear to occur across the physiographic regions. Groundwater with lower Total Dissolved Solids (TDS) in the recharge mound to the north for example attains higher salinity at the sink in the central area where movement is significantly at lower velocity and thus longer travel time is spent in contact with the felsphatic sands. In the Ase/Niger River floodplain, dilution occurs and could be attributed to the constant flooding of the alluvial deposits and resultant recharge.

Table 3: Physical and Chemical Characteristics of Groundwater in Ndokwa

Parameters	**Physiographic Area**						
	Benin Formation		**Sombreiro-Warri**		**Freshwater Swamps**		
	Mean	**Std. Dev.±**	**Mean**	**Std Dev ±**	**Mean**	**Std Dev ±**	**SON MCL's**
pH	4.6	0.36	7.45	1.44	7.3	0.84	
TDS mg/l	18	1.42	161	48.72	109.42	16.35	
EC µs/cm	36	2.27	261.75	87.92	159	28.58	
Na^{+} mg/l	0.07	0.001	12.85	5.67	9.24	2.62	
K^{+} mg/l	0.12	0.0003	11.36	5.51	8.08	2.3	
Ca^{2+} mg/l	4.15	0.13	1.19	0.31	0.79	0.13	
Mg^{2+} mg/l	3.02	0.1	0.71	0.26	0.43	0.18	
Pb^{+} mg/l	0.00	0.00	0.01	$4x10^{-3}$	0.00	0.00	**0.01**
Cd^{+} mg/l	0.00	0.00	0.13	0.008	0.002	$2x10^{-4}$	**0.003**
Cr^{+} mg/l	0.001	0.0002	0.005	0.003	0.003	$1x10^{-4}$	**0.05**
SO_4^{2-} mg/l	0.15	0.0045	0.024	0.016	0.005	0.006	
HCO_3^{2-} mg/l	0.32	0.001	2.1	0.71	1.53	0.39	
Cl^{-} mg/l	4.51	0.32	51.63	21.53	20.57	6.79	
NO_3 mg/l	0.25	0.05	1.18	1.08	0.22	0.063	**10**
Coliform *MPN/100*	0.00	0.00	95.5	34.57	64.0	10.50	**0**

Ground water from dug wells is generally used for domestic purposes in the rural areas of Ndokwa without prior treatment and there are concerns about health implications (Emeshili, 2008.). A significant problem as the results show is the consistent presence of coliform bacteria in all screened samples in the Sombreiro-Warri Deltaic Plain and the Freshwater Swamps, at levels above WHO (2006) and SON (2007) standards. The highest counts were recorded at Umukwata and Utagba Uno, where the sampled dug wells were unlined with the standard concrete rings that are used in the construction of most dug wells in the region. Coliform counts in Benin Formation boreholes are negligible, which is consistent with the greater depths from which water is obtained as well as the better sanitary conditions that are associated with extraction of water from sealed boreholes as opposed to exposed dug wells.

The levels of occurrence in groundwater of lead, cadmium and chromium in the three physiographic terrains were compared with the maximum acceptable limits (MCL's) set by World Health Organization (WHO, 2006) which are the same as those of the Nigerian Standards Organization (SON, 2007). As shown in Table 3, chromium occurs at levels that are well below the MCL of 0.05mg/l, with the highest occurrence of 0.005mg/l recorded for groundwater in the Sombreiro-Warri Plain terrain. Similarly, Cadmium levels in the Sombreiro-Warri Plain are approximately 43 times higher than the MCL of 0.003mg/l while Lead occurrence is at the threshold MCL of 0.01mg/l. In both the Benin Formation and Fresh Water Swamps, groundwater is lead free. Cadmium also occurs in the Fresh Water Swamps at levels that are well below the MCL while it was not detected in Benin Formation water. Excessive lead intake is associated with cancer and neurological disorders while cadmium is toxic to kidneys (WHO, 2006; SON, 2007). Akpoborie et al. (2000) have indeed drawn attention to the elevated lead and cadmium in groundwater problem from other parts of the Sombreiro-Warri Plain as have Eriyamvemu et al (2005) who established the presence of high lead and cadmium levels in vegetables in the same terrain at Aladja and Ekpan, which are west of Ndokwa. The absence of lead and presence of low cadmium levels in Freshwater Swamp wetland groundwater could as before be explained by attenuation occasioned by recharge from seasonal floods.

Conclusion

The results of this study indicate that groundwater conditions in Ndokwa are controlled to a large extent by the areal and vertical distribution of the Recent deposits that overlie the Benin Formation. Thus recharge is more extensive at the outcrop of the Benin Formation to the north where groundwater is at a higher gradient and from where flow is down slope, generally southwards and unidirectional. In the terrain of the overlying deposits, the ground water gradient has become virtually flat and the contours have closed, a characteristic of groundwater- fed wetlands. A map has been presented that depicts these conditions. In the subsurface however, the available lithologs confirm the impossibility of distinguishing between the Benin Formation and the Recent deposits. The estimated Transmissivity of $71m^2$/day is representative of the combined Recent deposits and Benin Formation as a single multi-layered aquifer.

The data indicates that chemical characteristics may be used to distinguish ground water that occurs in the three physiographic terrains. Groundwater in the exposed Benin Formation recharge area for example represents more pristine conditions and exhibits higher salinity in the areas where the Benin Formation is overlain by younger deposits. In the Sombreiro/Warri Deltaic Plain, groundwater is not potable without prior treatment because it contains coliform as well as unacceptable levels of lead and cadmium. In the Freshwater Swamps, coliform was detected but it appears that dilution from perennial floods have reduced the heavy metals to an acceptable level. There are obvious implications in these results for public water supply, health management and poverty alleviation policies especially in the rural areas where there is total dependence by communities on dug well water and streams.

References

Akpoborie IA, Ekakite OA, Adaikpoh EO (2000), The Quality of Groundwater from Dug Wells in Parts of the Western Niger Delta, Knowledge Review2 (5): 72-75.

Akpoborie IA, Osula AA (2000). Aspects of the Hydrology of the Western Niger Delta: The Ethiope River and Adofi River Catchments, 13th Annual Conference of the Nigerian Association of Hydro Geologists, Benin City, November, 2000

Akpokodje EG, Etu-Efeotor JO (1987), The Occurrence and Economic Potential of Clean Sand Deposits of the Niger Delta. J. Afr. Earth Sci., 6 (1): 61-65.

Allen JRL (1970), Sediments of the modern Niger delta: A Summary and Review, In: J. P.

Morgan, (ed.) Deltaic Sedimentation: Special Publications of the Society of Economic Paleontologists and Mineralogists, Tulsa, OK, v. 15, pp.138-151

Allen JRL (1965), Late Quaternary Niger Delta and Adjacent Areas: Sedimentary Environments and Lithofacies, Bulletin American Association of Petroleum Geology 49(5): 547–600

Amajor LC (1991) Aquifers in the Benin Formation (Miocene Recent), Eastern Niger Delta, Nigeria: Lithostratigraphy, Hydraulics, and Water Quality. Environ Geol Water Sci.17 (2): 85-101.E

Appelo CAJ, Postma D (2008) Geochemistry, groundwater and pollution. AA Balkema, Rotterdam.A

APHA (1992) Standard Methods for the examination of Water and Waste water, 18th edition, American Public Health Association, Washington, D.C.

Asseez LO (1975), Review of the stratigraphy, sedimentation and structure of the Niger Delta, In: CA Kogbe (ed.) Geology of Nigeria. Rockview, Jos, 311-334

Atakpo EA, Akpoborie A I (2011), Investigation of Sand Deposit in Parts of Okpe LGA, Delta State, Nigeria, Nig. J. of Science and Environment, 10 (1, 2): 60-68

Aweto K, IA Akpoborie (2011), Geo-Electric and Hydro-geochemical Mapping of Quaternary Deposits At Orerokpe in The Western Niger Delta, J. Appl. Sci. Environ. Mgt. (In Press)

Benin-Owena River Basin Development Authority, BORBDA (1992), Hydrological Year Book, Vol.1, Obayantor, Benin City

Benin-Owena River Basin Development Authority (1995), Hydrological Year Book, Vol.II, Vol.III Obayantor, Benin City

Durotoye, B (1975), Quaternary Sediments in Nigeria, In C.A. Kogbe (ed.) Geology of Nigeria, Rockview, Jos, pp.431-444

Emeshili ME (2008), Quality Assessment of the Potability of Borehole and Surface waters in the Ndokwa area of Delta State, Nigeria. Unpublished Dissertation, Delta State University, Abraka, Nigeria, 254pp

Delta State Hospital Management Board (2004), Health Status of Rural Communities in Delta State, Health Report, Ministry of Health, Asaba

Eriyamvemu GE, Asagba SO, Akpoborie IA, Ojeaburu SI, (2005), Evaluation of Lead and Cadmium Levels in Some Commonly Consumed Vegetables in the Niger Delta Oil Area of Nigeria, Bull. Env. Contam. Toxicol. 75: 278-283

Golden Software Inc. (2002), Surfer 8. Golden Software Inc. Golden, Co. USA.

Grayson R, Argent R, Nathan R, McMahn T, Mein R (1996), Hydrological Recipes. Cooperative Research Centre for Catchment Hydrology, Melbourne Victoria

Hemke KE, Post VE (2010), MLU for Windows: Well flow modeling in multilayer aquifer systems. Amsterdam, www.microferm.com

Iwegbue CMA, GE Nwajei, FO Arimoro, (2007), Characteristic levels of Total Petroleum Hydrocarbons In Soil, Sediment And Surface Water Of An Oil Impacted Area In The Niger Delta, Pak. J. Sci. Ind. Res. 50(4): 247-250

Iwegbue CMA (2007), Distribution of Heavy metals in sediments and surface water of crude oil impacted area in the Niger delta, Nigeria, Pak. J. Sci. Ind. Res. 50(3): 178-183

Kaizer AN, Osakwe SA (2010), Physicochemical Characteristics and Heavy Metal Levels in Water Samples from Five River Systems in Delta State, Nigeria, J. Appl. Sci. environ. Manage. !4(1): 83-87

Marsh, N (2003), River Analysis Package, Software Version V1.0.1, CRC for Catchment Hydrology, Australia

Ministry of Commerce and Industry (2001), Industrial Mineral Raw Material Resources Survey in Delta State. MC&I,Asaba, 150pp

Nigerian Meteorological Agency (2003), Warri Meteorological Bulletin, In: National Meteorological Report

Nigerian Standards Organization (2007), Nigerian Standards for Drinking Water Quality, SON, Abuja

Odemerho FO, DO Ejemeyovwi (2007), The Physiographic Provinces and Drainage Systems of Delta State, Nigeria, In: F.O. Odemerho et al.(eds) Delta State in Maps, Delta State University, Abraka, pp. 9-17

Okolie EC, Ugbe FC, Osemeikhian JEA (2000), Characterization of formations and groundwater potential of Amai and Obiaruku in Delta State using resistivity and seismic refraction measurements. Jour Nig. Assoc Mathematical Physics, 10: 83-90

Oomkens E (1974), Lithofacies relations in the Late Quaternary Niger delta complex. Sedimentology 21: 195-222

Ophori DU (2007), A simulation of large scale groundwater flow in the Niger Delta, Nigeria, Env. Geosciences 14(4): 181-195

Oseji JO, EA Atakpo, EC Okolie (2005), Geoelectric investigations of the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. J. Appl. Sci. Environ. Mgt. 9(1): 157-160

Short,KC, AJ Stauble (1967), Outline of geology of Niger delta. Bull. Amer. Assoc. Petr. Geol.:54(5): 761-779

Singh AK, Mondal GC, Kumar S, Singh TB, Tewary BK, Sinha A (2008), Major ion chemistry, weathering processes and water quality assessment in the upper catchment of Damodar River Basin, India. Environ Geol, 54: 745-758

World Health Organization, (2006), Guidelines and Standards for Drinking Water, 3rd Edition, WHO, Geneva

Seasonal Mean Levels of Heavy Metals in Water and Associated Sediments from Ajawere River in Oke-Osun Farm Settlement, Osogbo, Nigeria

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Abstract

The seasonal mean variations of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn in the water and sediments of Ajawere River in Oke-Osun Farm Settlement, Osogbo, Nigeria were evaluated. Samples collected were analyzed for their heavy metal levels using Graphite Furnace Atomic Absorption Spectrophotometer (GF-AAS). Seasonal mean ranges of heavy metals in the river sediments (mg/kg) were 3.39 ± 1.34 Cd to 43.24 ± 6.15 Cr in the rainy season and 4.56 ± 1.21 Ni to 55.35 ± 4.29 As in the dry season. Seasonal mean levels of heavy metals (mg/L) in the river water ranged between 3.02 ± 0.72 As and 179.49 ± 21.45 Fe in the rainy season while the dry season mean levels ranged from 3.09 ± 1.65 Co to 278.81 ± 51.59 Fe. Wide seasonal variations were observed for Cr, Cu, Mn, Ni, V and Zn in the sediments and for all the other metals apart from As, Ni and V in the water samples. The *I*-geo values obtained indicated that the sediments were moderately polluted with respect to Cr, Cu and Pb, and was either heavily polluted or very heavily polluted with respect to As and Cd. Metal levels in the river water, in many cases, were above the specified guideline limits for natural waters. The results obtained from this study indicated that the river sediment and water samples from Oke-Osun Farm Settlement were contaminated with heavy metals in varied degrees and gave cause for concern.

Keywords: Heavy metals, sediments, water, farm settlement, Ajawere River

Introduction

The presence of heavy metals in the environment constitutes a major global source of concern to environmental scientists and engineers because heavy metals are not only harmful to humans and animals, but tend to bio-accumulate in the food chain (Yoon *et al*., 2006). According to WHO (1973; 1977), in a bid to improve their living conditions, human beings try to exploit the nature, manufacturing new products, establishing more industries, and improving on old ones. Fossil fuel combustion, agrochemical applications, metallurgical industrial activities and industrial wastes generation over the last century (Fitzgerald and Clarkson, 1991; Mason *et al*., 1994) have undoubtedly intensified the emission of various heavy metals and other pollutants into the environment thereby stressing the terrestrial, aquatic and atmospheric ecosystem beyond their natural recycling capability.

Environmental pollution from increased human activities, apart from being aesthetically offensive, can be a genuine health hazard to people as well as to plants and other biota (Onder and Dursun, 2006). The adverse effects of these pollutants on human health, agricultural productivity, natural ecosystem and total environment are significant (UNEP, 1978). It is on record that increase in heavy metal emissions has affected all environments: terrestrial (Godbold, 1994; Grigal *et al*., 1994), lacustrine (Cossa *et al*., 1994; Watras, 1994), and coastal ecosystem (Baeyens *et al*., 1998; Mason and Lawrence, 1999). Davies (1992) observed that awakening of the public conscience to environmental degradation started with events such as the observed effect of lake eutrophication following river pollution by phosphates and nitrates from detergents and fertilizers; the problems of combating photochemical smog; Minamata (methyl mercury poisoning) and *Itai-itai* (cadmium) diseases in Japan which helped to create a climate of thought in which it was acceptable to consider a role for heavy metals in human health.

By far, anthropogenic activities rather than natural geochemical activities are more responsible for the rapid chemical redistribution of free and combined lethal elements like As, Cd, Pb, Hg in the environment. Continuous exposure to heavy metal pollutants is being increasingly implicated in the etiology of a large number of ailments including cardiovascular diseases, reproductive failure, dermatitis, allergies and some cancers (Nriagu, 1979). Prasad and Oberleas (1976) maintained that a public health problem likely to remain unresolved for a long time is the fact that a large number of people are at risk of being poisoned by a persistent exposure to environmental doses of heavy metals.

Sediments in coastal systems have been found to be intense repositories of contaminants (Harvey and Luoma, 1985; Mason and Lawrence, 1999; Griscom *et al*., 2000). Direct and indirect aquatic environment contamination by toxic substances including heavy metals will affect humans as a final consumer because anthropogenic metals are either retained within the water bodies or may be taken up by organisms such as plankton, benthos or fish and finally transferred to humans (Ahmad *et al*., 2009). Unlike most organic pollutants such as organo-halides, heavy metals are non-biodegradable; heavy metals may only undergo relocation and species transformation across environmental compartments. Hence, the resident time of heavy metals in the environment is usually long. As a result, heavy metals have greater potential of constituting both short and long term serious health threat to man and other organisms as they remain persistent in the environment for years.

This paper determines the seasonal levels of heavy metals in water and associated sediments from Ajawere River in Oke-Osun Farm Settlement, Osogbo, Nigeria, to evaluate the pollution status of the aquatic environment.

Study area

Oke-Osun farm settlement is situated between longitudes 04.31 and 04.33^{o}E and latitudes 007.44 and 007.46^{o}N (Figure 1). It is located about 3.5 km South of Osun Grove in the outskirt of Osogbo metropolis. The location is a rural setting within an acquired 2,500 ha parcel of land (Oyekunle *et al.*, 2011). There is a perennial river (River Ajawere) that serves as the main drainage for the settlement and as a tributary to River Osun. River Ajawere has three existing fish ponds and a reservoir under construction across it during the period of this study. The reservoir is intended to serve as the source of potable water for people around the Osun State Government Secretariat at Abere in Osogbo.

About 90% of the total farm land consists mainly of cultivated plots allocated to farmers who plant food crops mainly while about 10% of the farm land is used for building houses by the settlers (Oyekunle *et al.*, 2011). Crops harvested from this settlement are sold to consumer intermediaries from Osogbo and its environs. The perennial nature of Ajawere River within the farm land encourages inland valley agricultural (fadama) practice, and as such, the planting of certain vegetables (e.g. *Amaranthus*) is done round the year. The farmers here actively apply agrochemicals from time to time to improve crop yields without a follow-up assessment of how much of the agrochemicals as fertilizer, herbicides and germicides affect the non-target components of the ecosystem. The choice of this river for the present study was informed primarily by the fact that it represents, to a large extent, an important aquatic habitat on the course of the only perennial river serving as the main drainage for the cultivated area. Hence, the study will give, in part, the heavy metal pollution assessment of the settlement.

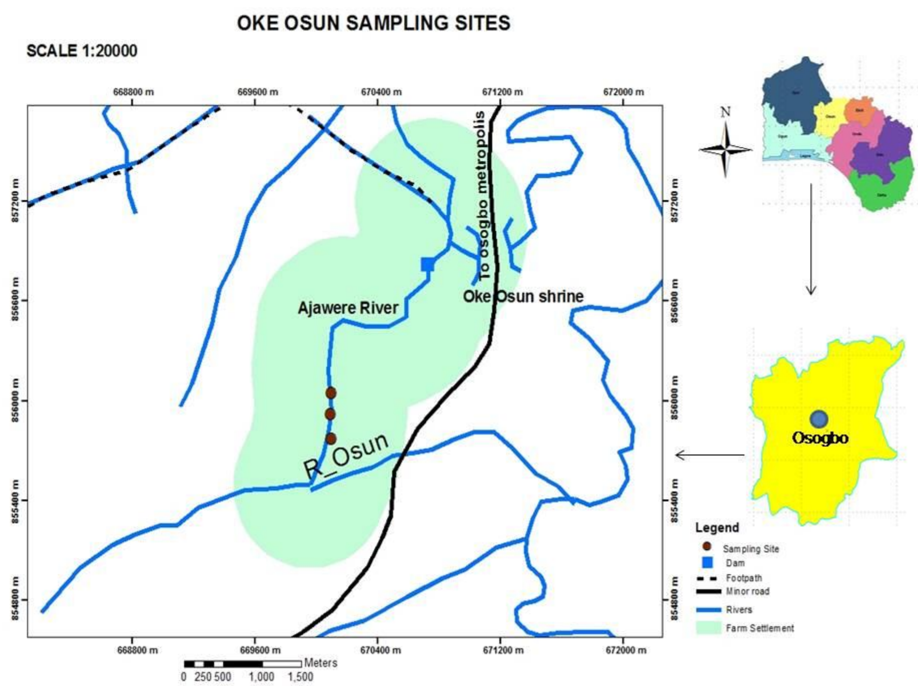

Figure 1: Map of the study area showing sampling sites

Materials and Methods

Polyethlene sample bottles and bags and Teflon beakers were washed with hot liquid detergent solution, soaked in 10% HNO_3 for 48 hours and later rinsed with triply distilled water prior to sample collection for heavy metals analysis (Ogunfowokan and Fakankun, 1998; Ogunfowokan *et al.*, 2008). The reagents used in this study were of spectra purity. They are: HNO_3 (AR) –

Riedel-deHaën, Germany; Trace metal standards (ppm) - Riedel-deHaën, Germany; HF (AR) - Rochelle Chemicals, SA; and Perchloric acid – MERCK, Germany.

Samples were collected on seasonal basis, comprising of four representative months (May, June, July and August of 2004) for the rainy season and four representative months (November and December of 2004 and January and February of 2005) for the dry season. Fine-grained surficial bed sediments were collected in polythene bags at a depth of 0 to 15cm at three sites along the river course using a hand held core sampler (Shelton and Capel, 1994). These samples were preserved in the refrigerator at about 4^oC before further analysis. The samples collected at a given site were later dried at ambient temperature and composited into a single representative sample. Final sample selection from the dried and pulverized bulk was done using coning and quartering method. Water samples from the river were collected from the same spots where sediment samples were collected using 100 mL pre-treated plastic bottles. The plastic bottles were rinsed first with the water samples at the site of collection before they were filled with the water samples to the brim and covered. Storage was done in a refrigerator at 4^0C prior to further analysis.

For the sediment samples, a modification of an earlier described method (Ogunfowokan *et al.*, 2008) was employed to secure the release of bound or free metals from the environmental matrix in their highest oxidation states. About 0.2 - 0.5 g of the selected sediment sample with particles ~ 0.5 mm in diameter was weighed into a Teflon beaker; 5mL of 70% HNO_3 was added and the beaker was covered with a watch glass. This was placed on a thermostatically controlled hot plate maintained at 120^oC for about 2 hours. Replenishing of the acid content was done at intervals to avoid bringing the content to total dryness. The beaker was allowed to cool and 5mL concentrated HNO_3 (e.g. 1.84), 2mL 60% $HClO_4$ and 5mL 40% HF were added. The beaker was replaced on the hot plate with a digestion temperature of 180 - 200^oC. When the solution became clear, the digestion was considered complete. The watch glass was now tilted sideways to volatilize most of the acid content at about 100^oC. The beaker was removed from the hot plate and cooled down after which 5mL of 6 M HNO_3 was added. Further boiling and gentle simmering for about 5 minutes was done. The watch glass was rinsed with triply distilled water into the beaker. The content of the beaker was quantitatively transferred into a 50mL volumetric flask and made up with triply distilled water to the mark. A blank determination was carried out to establish blank levels for the metals analysis.

The method of APHA et *al*. (1995) was used for water digestion. A 50mL aliquot of the collected water samples was measured and transferred into a 125mL Teflon beaker. 5mL of concentrated HNO_3 and some Hengar granules (anti bumping agents) were added. This was brought to a slow boiling on a hot plate. Evaporation was discontinued just before precipitation occurs. Replenishing of the content was done with 1:1 (v/v) HNO_3:$HClO_4$ mixture until complete digestion was ascertained i.e. when a light-coloured clear solution was shown. The digested sample was cooled down, quantitatively transferred into a 50mL volumetric flask and made up to the mark with triply distilled water. A blank determination was concurrently done.

The worked-up samples from the outlined procedures above were analyzed for their heavy metal concentrations using Graphite Furnace – Atomic Absorption Spectrophotometry (GF-AAS) available at the Department of Chemistry, University of Botswana, Gaborone, Botswana. The GF-AAS was operated as per the manufacturer's manual. In this paper, the quality control measures adopted were blank determination, calibration of instruments, and use of standard soil reference materials, determinations of percentage recovery and determination of detection limits. The purpose of carrying out a blank determination was to ascertain the extent to which the materials and reagents used contribute impurities to the overall results obtained. This was done by running a separate determination under the same experimental conditions employed in the actual analysis of the sample, but excluding the sample. The values obtained from running blank determinations were subtracted from the analyte values as applicable.

The calibration of the GF-AAS used was done to evaluate the response of the analytical procedure with respect to known quantities of the standards of the heavy metals of interest so that the response to unknown quantities in the samples could be reliably estimated. For the GF-AAS 200, 180, 160, 140, 120, 100, 80, 60, 40 and 20 µg/L concentrations of each metal solution were prepared by serial dilution for the determination of metals in the digested water and sediment samples. These solutions were run to obtain the working calibration graph. GF-AAS (SHIMADZU AA-6800, Auto Sampler ASC-6100 and Atomizer GFA-Ex 7) was used to estimate the levels of heavy metals in the samples by automatic interpolation with respect to the calibration graph.

To ascertain the sensitivity and accuracy of the GF-AAS used, certified soil reference materials of known Cu and Ni contents were digested using the exact procedures employed for the determination of heavy metals in soil and sediment samples. The certified soil reference materials and their metal contents are GBW 07406 (Cu = 390.0 ± 6.0 µg/g; Ni = 53.0 ± 1.0 µg/g) and GBW 07407 (Cu = 97.0 ± 2.0 µg/g; Ni = 276.0 ± 6.0 µg/g).

Since no certified water reference materials were available to us during the course of this study, recovery analysis was performed in order to ascertain the efficiency of the analytical procedures using standard addition method. Two equal portions (50mL each) of the water sample were measured into separate Teflon beakers. One sample was spiked with 10µg/L of mixed metal solution while the other was left un-spiked. Both samples were digested as earlier outlined and their heavy metal concentrations were determined using GF-AAS. The percentage recoveries (%R) of metals were determined using the relationship:

$$\%R = (A' - A) / B * 100$$

where A′ is the concentration of the metal in the spiked sample; A is the concentration of the metal in the un-spiked sample; and B is the amount of the metal used for spiking.

The limits of detection were calculated based on the empirical definition by Miller and Miller (2000) who consider limit of detection as the analyte concentration that gives a signal equal to the blank signal plus three standard deviations of the blank. That is:

$$y_C = y_B + 3s_B$$

where y_C = analyte signal equivalent to detection limit; y_B = blank signal; and s_B = standard deviation of the blank. From the value of y_C, the analyte concentration corresponding to the detection limit was evaluated for GF-AAS determination of metals.

Results and Discussion

Validation of Analytical Procedures Adopted

The reproducibility and reliability of the analytical procedures adopted in this study was tested in terms of sensitivity, recovery, precision and accuracy. Table 1 shows the values for measuring conditions, calibration curve, percentage recovery (% R) and limit of detection (LOD) for the heavy metals. Under the experimental conditions used, the standard calibration curves obtained showed high linearity level with r^2 values between 0.9872 and 0.9998 for Cr and Mn respectively. Recoveries of heavy metals in water ranged from 85.73 ± 6.29% Mn to 99.44 ± 6.23% V. These values were high enough to be adjudged acceptable. The percentage relative standard deviation (%RSD) values for water ranged from 2.57 to 6.99 while the values lied between 2.29 and 9.74% for sediments. These values showed that precision was even better than the generally accepted 10% RSD level. The calculated LOD values were in good agreement with the values quoted by Harris (1999). Table 2 summarizes the reliability level of the GFAAS used to reproduce specified concentration values of heavy metals in certified reference standard soil samples (GBW07406 and GBW07407). The determined percentage concentrations of Cu and Ni were 98.62 ± 1.11 and 96.70 ± 2.15%, and 99.00 ±3.13 and 90.88 ± 2.95% respectively for the two certified reference soil samples and were in close agreement with those specified by the manufacturer. This further confirms the efficiency of the described procedure and the sensitivity of the GFAAS used for the heavy metals analysis.

Table 1: Measuring Conditions, Calibration Curve, % Recovery and Limits of Detection for Heavy Metals

Heavy Metal	Current (mA)	Wavelength (nm)	Slit Width (nm)	Calibration Curve, r^2	%Recovery of Metals in Water#	Calculated LOD* (µg/L)
As	12	193.7	0.5	0.9989	98.54 ±3.46	0.231(0.2)
Cd	8	228.8	0.5	0.9992	89.99±5.52	0.004(0.003)
Cr	10	357.9	0.5	0.9872	87.15±3.60	0.023(0.02)
Co	12	240.7	0.2	0.9983	97.42±4.12	0.021(0.01)
Cu	6	324.8	0.5	0.9994	99.22±5.06	0.033(0.02)
Fe	10	248.3	0.5	0.9981	97.50±2.69	0.024(0.02)
Mn	10	279.5	0.2	0.9998	85.73±6.29	0.013(0.01)
Ni	12	232.0	0.2	0.9993	97.20±7.61	0.031(NA)
Pb	10	283.3	0.5	0.9985	89.99±2.42	0.062(0.05)
V	10	318.4	0.5	0.9907	99.44±6.23	0.024(0.02)
Zn	8	213.9	0.5	0.9890	92.38±4.57	0.003(0.002)

Values are mean of triplicate analysis ± % RSD; *Values in parenthesis are from Harris (1999); Lightening mode for all measurements was BGC-D_2; NA = not available

Table 2: Levels of Heavy Metals in Certified Reference Soil Materials.

Reference Material	GBW 07406	GBW 07407
Stated Cu content (μg/Kg)	390.0 ± 6.0	97.0 ± 2.0
Stated Ni content (μg/Kg)	53.0 ± 1.0	276.0 ± 6.0
Measured Cu content (μg/Kg)	384.63 ± 4.29	96.03 ± 3.01
Measured Ni content (μg/Kg)	51.25 ± 1.10	250.84 ± 7.39
% Measured Cu content	98.62 ± 1.11	99.00 ± 3.13
% Measured Ni content	96.70 ± 2.15	90.88 ± 2.95

Value = mean of triplicate analysis ± s.d.

Levels of Heavy Metals in Sediments

Levels of heavy metals in the river sediments from May 2004 to February 2005 are as presented in Tables 3 and 4. Arsenic monthly mean values for rainy season ranged from 11.22 ± 0.08 mg/kg in May to 14.53 ± 1.93 mg/kg in July while the values for dry season ranged from 15.79 ± 0.38 mg/kg in November to 71.45 ± 4.11 mg/kg in January. These values were much higher than the 0.32 mg/kg As mean level obtained for sediments of Ariake Bay, Japan by Tabata *et* al. (2009). The results of the dry season sediment samples compared well with the value (50 mg/kg) obtained for the estuarine sediment of the Patos Lagoon in Brazil (Mirlean *et al*., 2003). The rainy season mean of As (12.38 ± 1.59 mg/kg) was significantly lower ($p \leq 0.05$) than the dry season mean (55.35 ± 4.29 mg/kg). With background levels of As in unpolluted soils put at 5 mg/kg (Pais and Jones, 1997) it could be stated that the river sediment had suffered an increased contamination level as at the time of this study. This is probably as a result of the applications of arsenic containing herbicides in the past. Although As is a known toxin and carcinogen proven to cause human skin, lung, and bladder cancers, it is the magnitude of the dose (the amount and the route of administration) and the frequency of exposure that determines what health effects may occur. It is excreted in the urine, the sweat, and in the keratin of the skin, the hair, and the nails. Its disappearance rate from the blood is very rapid with a biological half-life of one hour and from the body into the urine with a biological half-life of four days. Because of its rapid elimination, arsenic dosages do not build up over time [Lamm, 2001]. Excessive and prolonged dependence on the water or bottom feeder fish from the river, however, may lead to arsenic related health problems.

The rainy season monthly mean levels of Cd ranged between 1.95 ± 0.58 mg/kg in July and 5.13 ± 0.86 mg/kg in May while the dry season mean levels ranged from 3.30 ± 0.87 mg/kg in December to 9.34 ± 0.53 mg/kg in November. These values were above the less than 1.0 mg/kg background value in unpolluted soils (Pais and Jones, 1997) or 0.11 mg/kg recorded by GESAMP (1982) for unpolluted sediments. Thus, there is a strong suggestion of anthropogenic inputs from such agricultural practices as the application of fertilizers. The rainy season mean level of 3.39 ± 1.34 mg/kg was significantly lower (at 0.05 levels of significance) than the mean level of 5.54 ± 2.55 mg/kg in the dry season. Cadmium is a biotoxic heavy metal regarded as an important environmental pollutant in an agricultural environment (Onweremadu and Duruigbo, 2007) because of the potential adverse effects it poses to soil, food quality and human health invariably.

Table 3: Rainy season level of heavy metals in the river sediment

Month	***Concentration of heavy metals (mg/kg)**										
	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
May 2004	11.22	5.13	6.26	45.13	14.39	36.51	14.22	5.44	24.30	11.57	17.45
	± 0.08	± 0.86	± 0.83	± 2.24	± 2.60	± 4.27	± 1.57	± 1.86	± 5.23	± 1.06	± 1.28
June 2004	11.83	3.74	7.60	38.60	17.96	36.12	15.63	3.59	31.98	10.57	14.72
	± 0.62	± 0.22	± 1.14	± 2.94	± 1.57	± 1.44	± 2.58	± 0.57	± 2.04	± 1.43	± 3.82
July 2004	14.53	1.95	7.67	45.88	15.81	37.20	14.74	3.55	24.89	12.54	13.70
	±1.93	± 0.58	± 1.04	±1.07	± 1.20	± 1.87	± 3.07	± 1.96	± 3.88	± 2.07	± 0.81
August 2004	11.94	2.73	8.16	43.34	15.89	37.79	12.83	2.42	30.69	8.33	12.64
	± 0.27	± 0.48	± 0.56	± 5.65	± 2.01	± 2.93	± 0.25	± 0.77	± 6.49	± 0.87	± 1.00
Range	11.22-	1.95 -	6.26 -	38.60-	14.39-	36.12-	12.83-	2.42-	24.30-	8.33-	12.64-
	14.53	5.13	8.16	45.88	17.96	37.79	15.63	5.44	31.98	12.54	17.45
Seasonal mean	**12.38**	**3.39**	**7.42**	**43.24**	**16.02**	**36.90**	**14.36**	**3.75**	**27.96**	**10.75**	**14.63**
± s.d.	**±1.59**	**±1.34**	**±1.08**	**±6.15**	**±2.11**	**±2.52**	**±2.12**	**±1.67**	**±5.37**	**±2.04**	**±2.60**

Values = mean of triplicate determinations **±** s.d.

Table 4: Dry season level of heavy metals in the river sediment

Month	***Concentration of heavy metals (mg/kg)**										
	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
	15.79	9.34	8.45	49.26	17.38	44.87	15.97	4.47	39.84	9.87 ±	14.86
Nov 2004	± 0.38	± 0.53	± 0.82	± 4.37	± 0.52	± 2.58	± 1.82	± 0.74	± 7.73	0.90	± 3.74
Dec 2004	70.60	3.30	12.20	33.17 ±	15.81	40.19	26.25	5.13	44.23	11.48	21.94
	± 3.35	± 0.87	± 1.97	1.72	± 2.09	± 1.00	± 4.28	± 1.21	± 1.69	± 0.98	± 0.98
Jan 2005	71.45	3.81	8.28	32.95	21.81	45.93	30.57	4.40	32.86	10.42	24.56
	± 4.11	± 0.57	± 1.36	± 2.92	± 1.82	± 5.58	± 1.16	± 0.88	± 4.04	± 0.92	± 3.26
Feb 2005	63.58	5.70	8.24	26.59 ±	22.87	46.58	24.30	4.22	42.98	10.83	23.22
	± 5.58	± 0.78	± 0.52	4.59	± 3.76	± 4.87	± 0.30	± 1.42	± 1.67	± 1.57	± 0.97
Range	15.79-	3.30-	8.24-	26.59-	15.81-	40.19-	15.97-	4.22-	32.86-	9.87-	14.86-
	71.45	9.34	12.20	49.26	22.87	46.58	30.57	5.13	44.23	11.48	24.56
Seasonal mean	**55.35**	**5.54**	**9.29**	**35.49**	**19.47**	**44.39**	**24.27**	**4.56**	**39.97**	**10.65**	**21.14**
± s.d.	**± 4.29**	**±2.55**	**±2.07**	**±1.31**	**±3.68**	**±4.27**	**±5.91**	**±1.21**	**±7.50**	**±1.14**	**±4.49**

* Values = mean of triplicate determinations **±** s.d.

Unlike most metals, Cd can be taken up by several plants such as wheat, maize, rice, spinach or tobacco (Udousoro *et al*., 2010). It can also be taken up easily by aquatic animals. Human uptake of cadmium takes place mainly through food although an exposure to significantly higher Cd levels can also occur when people smoke. Foodstuffs obtained from soils heavily polluted with Cd greatly increase its concentration in human bodies. It should therefore be stressed that in a place like Oke-Osun farm settlement where upland farming system is practiced round the year and the main drainage is Ajawere River, some caution must be exercised with respect to direct consumption of products or untreated water from the river environment to avoid Cd poison.

The monthly mean concentration of Co for the two seasons ranging from 6.26 ± 0.83 mg/kg in May to 12.20 ± 1.97 mg/kg in December showed a good agreement with the usual back ground levels of 10.0 mg/kg in unpolluted soils (Pais and Jones, 1997). Although these values were higher than the 0.102 mg/kg obtained by Awofolu *et al*. (2005) for Tyume River sediment, it can still be concluded that the river sediments in this study had not suffered serious anthropogenic input of Co. The seasonal mean values indicated a higher Co level (9.29 ± 2.07 mg/kg) for dry season than the 7.42 ± 1.08 mg/kg recorded for rainy season.

On a monthly basis, the lowest level of Cr, 26.59 ± 4.59 mg/kg, was recorded in February during the dry season while the highest level, 49.26 ± 4.37 mg/kg, was recorded in November also during the dry season. These values were generally lower than the less than 100 mg/kg level in an unpolluted soil (Pais and Jones, 1997), but significantly higher than the 20.3 mg/kg value obtained by Binning and Baird (2001) for Swartkops estuary sediments. The higher rainy season mean value of 43.24 ± 6.15 mg/kg relative to the lower dry season mean value of 35.49 ± 1.31 mg/kg observed could be attributed to leaching effects through surface runoff that probably mobilized Cr containing materials into the river sediments during the rainy season period.

For Cu, the monthly mean level ranged from 14.39 ± 2.60 mg/kg in May (rainy season) to 22.87 ± 3.76 mg/kg in February (dry season). These values were higher than the 4.7 mg/kg obtained for sediments from River Wiwi in Ghana (Biney and Beeko, 1991) or 5.1 - 21.9 mg/kg obtained in the sediments from Trinidad and Venezuela (Rojas de Astudillo *et al.*, 2005), but lower than 85.6 mg/kg recorded for River Nile Estuary in Egypt (Saad and Fahmy, 1985). The anthropogenic input could not be said to be very serious considering the fact that the background Cu concentration range in an unpolluted soil is 5-30 mg/kg (Pais and Jones, 1997) while the value in an unpolluted sediment is 33 mg/kg (GESAMP, 1982). There was no significantly difference (at $p \leq 0.05$) between dry season average concentration of Cu, 19.47 ± 3.68 mg/kg, and that of the rainy season average of 16.02 ± 2.11 mg/kg. The implication of this is that the levels of Cu in the sediments were more attributable to lithogenic effects rather than anthropogenic factors. However, future slow build up of Cu in the sediments and along the food chains in the consumers of products from this aquatic environment cannot be ignored.

The monthly mean levels of Fe in the river sediments ranged from 36.12 ± 1.44 mg/kg in June to 46.58 ± 4.87 mg/kg in February while the rainy season mean value was 36.90 ± 2.52 mg/kg and the dry season mean value was 44.39 ± 4.27 mg/kg. These values were higher than 0.46 mg/kg and 20.7 mg/kg of Fe levels in sediments obtained respectively by Saad and Fahmy (1985) and Kakulu and Osibanjo (1988) for River Nile Estuary, Egypt and Niger Delta, Nigeria respectively. The values were, however, comparable to the value (41.0 mg/kg) in unpolluted sediments (GESAMP, 1982).

Monthly mean values of Mn ranged from 12.83 ± 0.25 mg/kg in August to 30.57 ± 1.16 mg/kg in January while the mean level for rainy season was 14.36 ± 2.12 mg/kg and for dry season, the mean level was 24.27 ± 5.911 mg/kg. The values were generally higher than 0.256 - 0.389 mg/kg levels recorded for Mn in coal and sediments from River Ekulu in Enugu (Adaikpoh, 2005) but lower than the usual background levels (200 - 3000 mg/kg) in unpolluted soils and those reported elsewhere in which the Mn level for Swartkops estuary sediment was measured to be 114.9 mg/kg (Binning and Baird, 2001). Again, the sources of Mn in the sediment in this study might likely be more of geochemical than anthropogenic. In certain quantities, Mn is an essential metal in both plants and animals. The deficiency and accumulation of large concentrations of manganese can have repercussions on the central nervous system of humans (Crossgrove and Yokel, 2004), and hence, its environmental monitoring is as important as those of the other metals.

Nickel had monthly mean ranged values of 2.42 ± 0.76 mg/kg in August and 5.44 ± 1.86 mg/kg in May with rainy season mean level of 3.75 ± 1.67 mg/kg and dry season mean value of 4.56 ± 1.21 mg/kg. The values fell below the normal background range of 30 - 40 mg/kg in unpolluted soils (Pais and Jones, 1997). They were however, higher than the 0.401mg/kg obtained by Awofolu *et a*l. (2005) for River Tyume, or the 0.064 - 0.067 mg/kg Ni levels measured in coal and sediments from River Ekulu in Enugu, Nigeria (Adaikpoh *et al.*, 2005) but comparable to the 4.7 - 24.1 mg/kg Ni obtained for sediments from Trinidad and Venezuela (Rojas de Astudillo *et al.*, 2005). Agricultural fertilizers, especially phosphates, have been identified as a significant source of nickel in soil (McGrath, 1995) in addition to weathering of the parent rocks rich in Ni. Thus, the Ni levels in the sediments could be attributed to agricultural runoff from the adjacent farm lands, on one hand, and to lithogenic inputs, on the other hand. Above certain threshold levels, Ni can cause allergic skin reactions in sensitized individuals following either dermal or oral exposure (Environment Agency, 2009).

In this study, the monthly mean levels of Pb varied from 24.30 ± 5.23 mg/kg in May to 44.23 ± 1.69 mg/kg in December and the its seasonal mean level of 27.96 ± 5.37 mg/kg in rainy season was significantly lower (at $p \leq 0.05$) than its 39.97 ± 7.50 mg/kg mean level in dry season. This could be because of fewer fluxes of lead-bearing suspended particles which had settled as part of the sediments during the dry season. The Pb levels were similar to the 32.9 mg/kg value of Binning and Baird (2001), but significantly higher (at $p \leq 0.05$) than the 0.042 mg/kg value of Awofolu *et al*. (2005) or the 19 mg/kg Pb level for unpolluted sediments (GESAMP, 1982). Obviously, the Pb levels could be ascribed more to anthropogenic effects than to lithogenic factors. While soil affected or ammended by this sediment may not be harmful for planting crops such as pepper and tomatoes which are known to bioconcentrate Pb to a less extent, broad-leaf vegetables and root crops should be propagated on this soil with caution as they easily bioconcentrate Pb substantially. Pb is a highly toxic naturally occurring metal and too much of it in the human body can cause damage to the brain, kidneys, nervous system and red blood cells.

The geochemical background values of V in average shale and unpolluted soils were given as 20 mg/kg and 100-1000 mg/kg respectively (Turekian and Wadepohl, 1961; Pais and Jones, 1997). The values in this study, ranging from 8.33 ± 0.87 mg/kg in August to 12.54 ± 2.07mg/kg in July, were quite lower than the background values earlier reported. Thus, it could be presumed that the source of V in the sediment was majorly geochemical especially that the seasonal levels of 10.75 ± 2.04 mg/kg (rainy season) and 10.65 ± 1.14 mg/kg (dry season) showed no significant difference (at $p \leq 0.05$) from one another. Anthropogenic sources as secondary sources could not be ruled out altogether since there had been no earlier reports to indicate previous levels of V, vis-à-vis other metals in the sediment. Vanadium occurs naturally in fuel oils and coal and is found in many petroleum products. As a result, increases in anthropogenic vanadium emissions due to the combustion of fossil fuels, now equal natural emissions from continental dust, marine aerosols, and volcanic activity [Irwin *et al.,* 1997]. It is also a by-product of petroleum refining. Vanadium and its compounds are toxic; its toxicity depends on the valence and it increases with increasing valence, with pentavalent vanadium being most toxic [van Zinderen Bakker and Jaworski, 1980]. It has been reported that higher plants do not bioaccumulate V to any significant degree [Welch and Cary, 1975; Cary *et al*., 1983] and that on the average, plants in general have a soil bioconcentration factor (BCF) of 0.1 for vanadium [van Zinderen Bakker and Jaworski, 1980; WHO, 1988]. Hence, from the point of view of V levels in the sediments of the study area, the aquatic environment of the farmland appeared to be safe for food crop propagation.

For Zn, the monthly mean levels in the river sediment ranged from 12.64 ± 1.00 mg/kg in August to 24.56 ± 3.26 mg/kg in January. The rainy season mean level was 14.63 ± 2.60 mg/kg while the dry season mean level was 21.14 ± 4.49 mg/kg. Although these values were closely comparable with the 20 mg/kg level of Zn in average shale (Turekian and Wadepohl, 1961), they were quite lower than the 70 mg/kg reported for unpolluted sediments (GESAMP, 1982) or the 62 mg/kg value obtained for the sediments from Niger Delta, Nigeria (Kakulu and Osibanjo, 1988). The values were also lower than the 35.9 mg/kg recorded by Binning and Baird (2001) for Swartkops estuary. Despite these observations, it still could be inferred that both geochemical and anthropological factors would have contributed to Zn levels in the river sediment considering the fact that Zn level in unpolluted soils is normally between 10 mg/kg and 300 mg/kg; the values obtained being above the lower limit.

Currently, Nigeria has no established sediment quality guidelines. As a result, the US National Oceanic and Atmospheric Administration (NOAA) Effect Range-Low (ERL) and Canadian Sediment Quality (CSQ) Threshold Effects Level (TEL) guidelines stated by Rojas de Astudillo *et al*. (2005) were used as interim measures to assess whether the concentrations of heavy metals in sediments could have adverse biological impacts. The ERL and TEL for a given sediment parameter are the concentrations above which adverse biological effects are expected to occur (Long *et al*., 1995). Results of heavy metal concentrations showed that Cd at all sites sampled for both seasons occurred at concentration levels greater than the 1.2 mg/kg ERL or 0.7 mg/kg

TEL levels indicating that the existing concentrations of Cd in all the sites were sufficiently high to cause adverse biological effects to the aquatic biota. Similarly, Pb concentrations were only greater than the 30.2 mg/kg TEL value in June during the rainy season, but greater than the TEL value throughout the dry season. The existing concentrations of Pb were, however, less than the 46.7 mg/kg ERL value during both seasons.

The pollution status of the sediments was assessed using the geoaccumulation index (I-geo). The I-geo was originally used by Muller (1969) to assess the pollution status of the Rhine River sediments. It was computed from the relationship:

$$\text{I-geo} = \log_2 [C_n/1.5B_n],$$

where Cn is the measured total metal concentration in soil; B_n is the background value; and 1.5 is the background matrix correction factor due to lithogenic effects.

During the two seasons, the calculated I-geo values presented in Table 5 indicated that the river sediment was practically unpolluted with respect to CO, Fe, Mn, Ni, V and Zn; moderately polluted with respect to Cr, Cu and Pb; and heavily polluted/very heavily polluted with respect to As and Cd. Undoubtedly, the river sediment had experienced elevated heavy metals anthropogenic inputs in addition to lithogenic inputs when metals like Cr, Cu, Pb, As and Cd are considered.

In Table 6, the correlation coefficients of the metals within the river sediment are presented. Significant positive correlations existed for As and Co, As and Cu, As and Fe, As and Mn, As and Pb, As and Zn, Cd and Pb, Co and Pb, Cu and Fe, Cu and Mn, Cu and Zn, Fe and Mn, Fe and Zn, Mn and Pb, Mn and Zn, and Ni and V. The positive correlation therefore suggests common sources for these metals. It also implies that metals that are positively correlated might displace each other in their ecological functions within the environment where they existed. Also, significant negative correlations existed for As and Cr, Cr and Mn, Cr and Pb, and Cr and Zn. The negative correlations showed that there is antagonism in the association of these metals, hence the correlation in the opposite directions.

Levels of Heavy Metals in River Water

Rainy and dry seasons' levels of heavy metals in the river water are presented in Tables 7 and 8 respectively. On a monthly basis, the mean levels (μg/L) of As ranged from 2.69 ± 0.56 in July to 3.54 ± 0.38 in February. The rainy season mean was 3.02 ± 0.72μg/L while the dry season mean was 3.12 ± 0.64μg/L. These values were quite lower than the concentration levels of As with a range of between 0.70 and 5.5 mg/L in the water of a contaminated lake (Wegman and Greve, 1980). The values of As obtained in this study were below the maximum contaminant levels of As in fresh water (EEC, 1980; USEPA, 2005; SON, 2007). The future possible bioaccumulation of As in the tissues of those who use the river water for long-term domestic purposes, may however, be of concern because of bio-magnification.

Table 5: The Geo-accumulation Index (*I-geo*) Values in River Sediments

Element	**C_n**		**B_n**	**I-geo**		**Class**		**Pollution Intensity (PI)**	
	Rainy season	**Dry season**		**Rainy season**	**Dry season**	**Rainy season**	**Dry season**	**Rainy season**	**Dry season**
As	12.38	55.35	1.0	3.04	5.21	3	6	MP-HP	VHP
Cd	3.39	5.54	0.035	6.01	6.72	6	6	VHP	VHP
Co	7.42	9.27	10.0	-1.03	-6.90	0	0	PU	PU
Cr	43.24	35.49	11	1.39	1.10	2	2	MP	MP
Cu	16.01	19.47	4	1.42	1.70	2	2	MP	MP
Fe	36.91	44.39	3800	-7.27	-6.97	0	0	PU	PU
Mn	14.36	24.27	200	-4.38	-3.63	0	0	PU	PU
Ni	3.75	4.56	20	-3.00	-2.71	0	0	PU	PU
Pb	27.97	39.98	9	1.05	1.57	2	2	MP	MP
V	10.75	10.65	20	-1.47	-1.47	0	0	PU	PU
Zn	14.63	21.15	20	-1.03	-4.94	0	0	PU	PU

Table 6: Matrix of Correlation Coefficient of Metals in the River Sediments

	As	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**V**	**Zn**
As	1.00										
Cd	- 0.06	1.00									
Co	**0.54***	- 0.05	1.00								
Cr	**-0.69***	0.14	- 0.39	1.00							
Cu	**0.53***	0.11	- 0.06	- 0.40	1.00						
Fe	**0.53***	0.36	0.19	- 0.31	**0.62***	1.00					
Mn	**0.93***	- 0.02	**0.40***	**-0.53***	**0.59***	**0.51***	1.00				
Ni	0.24	0.23	0.09	0.16	0.10	0.20	0.34	1.00			
Pb	**0.54***	**0.40***	**0.54***	**-0.43***	0.22	0.35	**0.42***	0.16	1.00		
V	0.10	- 0.14	0.02	0.12	0.02	- 0.19	0.18	**0.48***	0.02	1.00	
Zn	**0.85***	0.03	0.33	**-0.59***	**0.46***	**0.62***	**0.82***	0.37	0.38	0.20	1.00

*** Correlation is significant at 0.05 level (n=24)**

Mean Cd levels (µg/L) on monthly basis ranged from 6.35 ± 2.06 in May to 23.91 ± 6.01 in February. The seasonal means were 8.08 ± 2.66µg/L for rainy season and 15.19 ± 8.73µg/L for dry season. The values far exceeded the recommended 2.0 µg/L acute contaminant level or 0.25 µg/L chronic contaminant level (USEPA, 2005) and 5 µg/L maximum contaminant level (EEC, 1980; WHO, 1993) or 3µg/L level of SON (2007). It goes without saying that the levels of Cd in the river water poses serious health problems for both the aquatic ecosystem and the humans who use the water from time to time for both domestic and agricultural purposes. For Co, the monthly mean concentration ranged from 1.30 ± 0.13 µg/L in May to 5.18 ± 1.93 µg/L in August while the rainy season mean level was 3.07 ± 1.95 µg/L and dry season mean level was 3.09 ± 1.65 µg/L. Obviously, there was no significant difference between the rainy season and dry season levels of Co in the river water indicating little or no short-term anthropogenic input. Compared with the 0.1-15.7 µg/L levels of Co obtained by FOREGS- Euro Geo Surveys for stream water (GESAMP, 1982), it can be concluded that the stream water was not so heavily

Table 7: Rainy Season Mean Levels of Heavy Metals in River Water

Month	**Concentration of Elements (mg/L)**										
	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
May 2004	2.98 ±0.43	6.35 ±0. 06	1.30 ± 0.13	36.68 ± 8.02	4.07 ± 1.50	164.00 ±27.18	83.14 ±16.68	3.74 ± 0.56	35.82 ±14.88	20.28 ±5.09	70.22 ± 1.62
June 2004	3.05 ± 0.52	7.87 ±0.81	4.09 ± 1.25	12.62 ± 2.83	4.24 ± 0.84	196.08 ± 4.34	92.02 ± 0.97	3.64 ± 0.99	16.72 ±1.46	17.28 ± 5.97	87.89 ± 14.86
July 2004	2.69 ± 0.56	8.15 ±4.41	1.72 ± 0.10	14.31 ± 4.01	12.86 ± 1.80	164.75 ±19.72	86.23 ±10.75	4.01 ± 1.37	14.24 ± 0.67	17.08 ± 3.28	108.34 ± 25.49
August 2004	3.39 ± 1.30	9.96 ± 2.18	5.18 ± 1.93	16.86 ± 3.10	14.39 ± 3.25	193.13 +2.55	96.74 ± 5.77	6.45 ± 1.00	23.43 ± 9.98	16.51 ± 3.72	93.19 ± 26.01
Range	2.69- 3.39	6.35- 9.96	1.30- 5.18	12.62- 36.68	4.07- 14.39	164.00- 196.08	83.14- 96.74	3.64- 6.45	14.24- 35.82	16.51- 20.28	70.22- 108.34
Seasonal mean ± s.d.	**3.02 ±0.72**	**8.08 ±2.66**	**3.07 ±1.95**	**20. 12 ±19.26**	**8.89 ±5.28**	**179.49 ±21.45**	**89. 53 ±13. 70**	**4.46 ±1.49**	**22. 55 ±11. 73**	**17.79 ±4.24**	**89.91 ±22. 01**

* Values = mean of triplicate determinations ± s.d.

Table 8: Dry Season Mean Levels of Heavy Metals in River Water

Month	**Concentration of Elements (mg/L)**										
	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Nov 2004	3.36 ±0.68	7.76 ±1.43	4.92 ±2.04	23.74 ±4.44	16.97 ±2.50	290.76 ±99.50	135.32 ±52.81	6.63 ±1.79	25.46 ±8.50	16.83 ±1.66	89.55 ±15.79
Dec 2004	2.83 ±0.53	7.53 ±1.27	1.83 ±0.93	27.81 ±6.43	17.11 ±2.58	275.88 ±18.71	193.20 ±5.62	5.42 ±1.02	32.49 ±15.01	12.67 ±1.78	109.00 ±6.08
Jan 2005	2.74 ±0.80	21.55 ±5.83	2.20 ±0.17	55.41 ±2.23	16.58 ±2.32	288.59 ±53.17	188.29 ±13.93	5.01 ±1.56	25.81 ±10.71	16.56 ±2.45	113.67 ±16.22
Feb 2005	3.54 ±0.38	23.91 ±6.01	3.39 ±1.08	94.61 ±3.37	16.04 ±4.49	260.41 ±24.69	164.98 ±54.44	5.92 ±2.98	31.51 ±4.62	19.40 ±1.62	124.17 ±17.45
Range	2.74- 3.54	7.53- 23.91	1.83- 4.92	23.74- 94.61	16.04- 17.11	260.41- 290.76	135.32- 193.20	5.01- 6.63	25.46- 32.49	12.67- 19.40	89.55- 124.17
Seasonal mean ± s.d.	**3.12 ±0.64**	**15.19 ±8. 73**	**3. 09 ±1.65**	**50.39 ±29.78**	**16.67 ±2.68**	**278.81 ±51. 59**	**169. 70 ±40.41**	**5.76 ±1. 84**	**29.57 ±9. 32**	**16.36 ±2. 99**	**109.10 ±18.08**

* Values = mean of triplicate determinations ± s.d.

polluted with Co. The values of Co in this study were also lower than the 0.059 mg/L (59µg/L) obtained by Awofolu *et al*. (2005) for Tyume River in South Africa.

The monthly mean levels (µg/L) of Cr ranged from 12.62 ± 2.83 in June to 94.61 ± 3.37 in February; the rainy season mean concentration was 20.12 ± 19.26µg/L while the dry season mean concentration was 50. 39 ± 29.78 µg/L. These values were higher than the 16 µg/L and 11 µg/L values stipulated by the USEPA (2005) as maximum contaminant level (MCL) for acute contaminant level (ACL) and chronic contaminant level (CCL) respectively or the SON standard level of 50 µg/L. They were also higher than the < 0.001 - 43.0 µg/L given as the range of Cr in stream water by FOREGS- Euro Geo Surveys. It is no contradictory to infer that the stream water appeared polluted with respect to Cr. Monthly variations of Cu in the river water gave a mean range of 4. 06 ± 1.50 µg/L in May to 17.11 ± 2.58µg/L in December while the seasonal variations gave a rainy season mean of 8.89 ± 5.28µg/L and a dry season mean of 16.67 ± 2.68 µg/L. These values were either comparable to or higher than the 13 µg/L or 9.0µg/L, the ACL and CCL respectively set as the MCL by USEPA (2005). The values were however, lower than 0.383 µg/L obtained for Tyume River (Awofolu *et a*l., 2005). The values were clearly lower than the MCL of 2.0µg/L in drinking water (WHO, 1993) implying that the water may be free from copper induced health problems for the humans relying on the water from this river for agricultural and domestic purposes.

The monthly mean values of Fe ranged from 164.00 ± 27.13 µg/L in May to 290.76 ± 99.50 µg//L in November. The rainy season had a mean level of 179.49 ± 21.45 µg/L of Fe while the dry season mean level was 278.81 ± 51.59 µg/L. Although these values were below the 1.0 mg/L WHO maximum permissible value of Fe for drinking water, they were higher than the 0.1mg/L WHO highest desirable level for water meant for drinking (Fatoki *et al*., 2002) but comparable with the 200 µg/L MCL in fresh water set by EEC (1980). Some levels of caution must be exercised with respect to its Fe content before the water can be considered for domestic uses. Mean values of Mn, on monthly basis, ranged from 83.14 ± 16.86 µg/L in May to 193.20 ± 5.62 µg/L in December. The seasonal mean levels were 89.53 ± 13.70 µg/L for rainy season and 169.70 ± 40.41µg/L for dry season. All the rainy season values were only slightly lower than the MCL of 100µg/L (USEPA, 1975; 1979) while all the dry season monthly values were found to be higher than the MCL. The limit of Mn in water meant for aquatic ecosystem use is 0.18mg/L (DWAF, 1996) and WHO provisional guideline value for drinking water is 0.5mg/L (WHO, 2002). These two limits were not exceeded in most cases. However, possibility of future bioaccumulation in the biota is a cause for concern as this may lead to manganese toxicity. In humans, manganese toxicity represents a serious health hazard resulting in severe pathologies of the central nervous system (CNS).

The monthly mean concentration of Ni ranged from 3.64 ± 0.99 µg/L in June to 6.63 ± 1.79 µg/L in November. The rainy season mean level was 4.46 ± 1.49 µg/L while the dry season mean level was 5.76 ± 1.8 µg/L. These values were below the 50 µg/L maximum contaminant level of Ni in fresh water (EEC, 1980) and the 20 µg/L Ni level of maximum allowable concentration in drinking water (WHO, 2002). Nevertheless, because Ni can be extremely toxic to man even at low concentrations in domestic water supply when consumed (Stoepper, 1991) and cause mutagenic, carcinogenic and tetraogenic effects (Fishbein, 1987), there is the need for its near total removal in water meant for domestic purposes. The monthly mean levels of Pb in the river water ranged between 14.24 ± 3.67 µg/L in July to 35.82 ± 14.88 µg/L in May while the rainy season mean was 22.55 ± 11.73 µg/L and the dry season mean was 29.52 ± 9.32 µg/L. These values were generally above the 10 µg/L and 15µg/L being the WHO recommend maximum allowable and maximum contaminant levels respectively (WHO, 2002). It is thus imperative to have the water properly treated before being used for domestic and agricultural purposes.

Vanadium consumption has been implicated for serious health problems including nervous depression and kidney damage (Barceloux, 1999). The monthly mean levels of V in river water in this study ranged from 12.67 ± 1.78µg/L in December to 20.28 ± 5.09 µg/L in May. For rainy season, the mean level was 17.79 ± 4.25µg/L while in the dry season the mean was 16.36 ± 2.99 µg/L. Natural sources of V release to water include wet and dry deposition, soil erosion and leaching from rocks and soils. The largest amount of V release occurs naturally through water erosion of land surfaces. It has been estimated that approximately 32 300 tons of V are dissolved and transported to the oceans by water, and an additional 306 650 tons are thought to be transported in the form of particulate and suspended sediment (Van Zinderen and Jaworski, 1980).

The monthly level of Zn in the river water ranged between 70.22 ± 1.62 µg/L in May to 124.17 ± 17.45 µg/L in February while the rainy season mean concentration was 89.91 ± 22.01µg/L and dry season mean concentration was 109.10 ± 18.08 µg/L. These values fell below the 5mg/L highest desirable level of Zn in drinking water (WHO, 1984; Ogunfowokan *et a*l., 2006) but the levels far exceeded the 20 µg/L Zn level for water meant for aquatic ecosystem (Fatoki *et al*., 2002; Ogunfowokan *et a*l., 2006). Thus, while the water from the river might not pose Zn related health problems for now, the same cannot be said of aquatic biota.

The two-tailed correlation coefficients of metals in the river water, at 0.05 level of significance (for n = 24), showed significant positive correlations for Cr/Cd, Cu/Cd, Fe/Cd, Fe/Cu, Mn/Cd, Mn/Cr, Mn/Cu, Mn/Fe, Ni/Fe, Ni/Mn, Pb/Cr, Pb/Mn, Zn/Cd, Zn/Cu, Zn/Mn and significant negative correlation for V/Cu only. The metals with high positive correlations might have been contributed to the environmental matrices via similar factors.

On a general note, the dry season mean levels of the heavy metals were higher, in most cases, than the rainy season mean levels in both the sediments and water samples of the river (Tables 3, 4, 7 and 8). This could be attributed to more gentle flow of the river during the dry season coupled with conditions of low dissolved oxygen when temperatures are slightly heightened during the dry season in which case most of the metal-bearing suspended particles had settled to form part of the sediments. Likewise, water volume had reduced during the dry season making the dissolved metals to be at higher concentration levels in the liquid phase.

Coefficient of variation (CV) is a useful statistical tool that can be employed to interpret the temporal and spatial distribution and variability patterns of pollutants in an environmental matrix. The CV values of the heavy metals in the sediment samples are given in Figure 2.

Table 9: Correlation Coefficients of Heavy Metals in River Water

	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
As	1.00										
Cd	0.16	1.00									
Co	0.06	- 0.01	1.00								
Cr	0.06	**0.71***	-0.11	1.00							
Cu	0.11	**0.41***	0.12	0.31	1.00						
Fe	0.29	**0.48***	0.16	0.32	**0.64***	1.00					
Mn	0.13	**0.53***	-0.11	**0.48***	**0.62***	**0.80***	1.00				
Ni	0.38	0.28	0.38	0.13	0.39	**0.59***	**0.45***	1.00			
Pb	-0.12	0.06	-0.09	**0.46***	0.02	0.15	**0.40***	0.05	1.00		
V	0.22	0.15	0.09	0.02	**-0.43***	- 0.21	- 0.29	0.16	-0.04	1.00	
Zn	0.05	**0.57***	-0.11	0.39	**0.60***	0.36	**0.45***	0.11	-0.15	- 0.22	1.00

*Correlation is significant at 0.05 level (n=24)

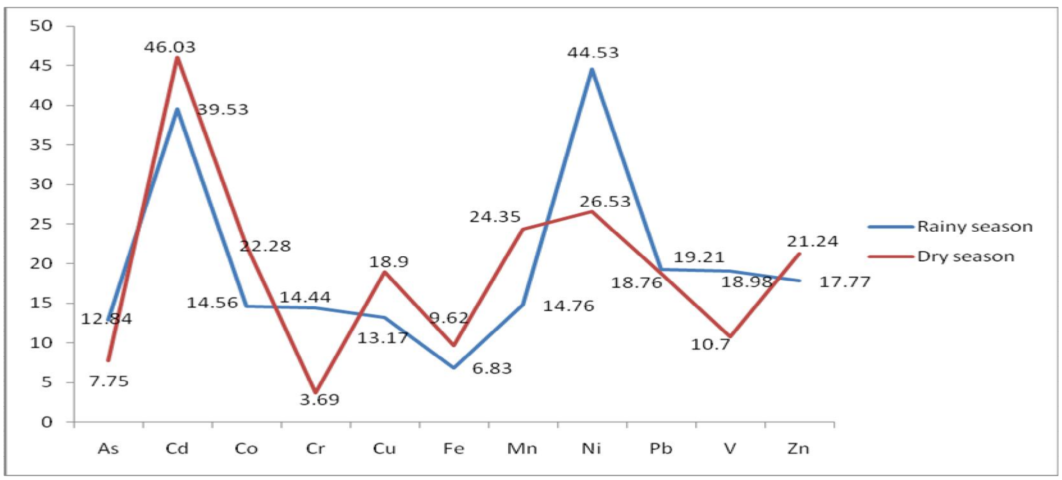

Figure 2: Coefficient of Variation of Heavy Metals in River Sediments

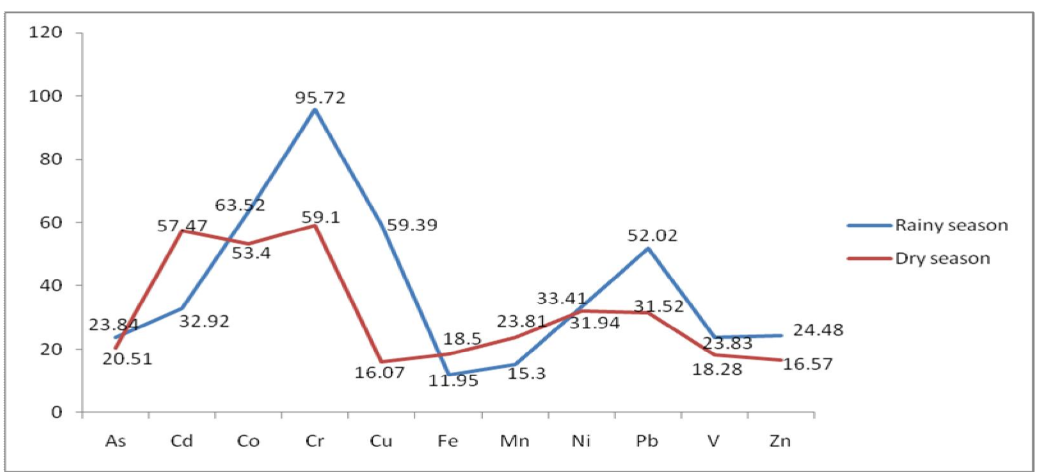

Figure 3: Coefficient of Variation of Heavy Metals in River Water

The distribution of heavy metals in the river sediment varied widely during both seasons; both the temporal and spatial distributions showed pronounced differences for Cr, Cu, Mn, Ni, V and Zn. Related trends of variability were observed for As, Cd, Co and Cr on one hand, and Fe, Mn, Ni, Pb and V on the other. The implication is that metals with related trends of variability were similarly introduced into the environmental matrix and their distributions were governed by similar factors. In the river water, the CV revealed that for both spatial and temporal distribution, only As, Ni and V had closely related patterns of distribution; the other metals were markedly differently distributed during both seasons.

Conclusion

This paper established that the river sediment was moderately polluted with respect to Cr, Cu and Pb, and was either heavily polluted or very heavily polluted with respect to As and Cd. Metal levels in the river water, in many cases, were also above the specified guideline limits for natural waters. Serious cation must therefore be exercised in using the sediments or water from this river for continuous agricultural practices as the levels of toxic heavy metals within the aquatic environment was on a high side. A follow up investigation is recommended to determine the extent to which some of the biotic species including fish and food crops from the vicinity of the study area have been affected by the status of the river.

References

Adaikpoh, E.O., Nwajei, G.E. and Ogala, J.E. 2005, Heavy metals concentration in coal and sediments from River Ekulu in Enugu, Coal City of Nigeria, *J. Appl. Sci. Environ. Mgt.* **9**(3), 5-8

Ahmad, A.K., Mushrifah, I. and Shuhaimi-Othman, M. 2009, Water quality and heavy metal concentrations in sediment of Sungai Kelantan, Kelantan, Malaysia: A baseline study, *Sains Malaysiana* **38**(4), 435-442

APHA, AWWA, WEF. 1995, Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association, Water Environment Federation, (Eds.) Greenberg A.E., Chescen, L.S. and Eaton, A.D. 1st Edition

Awofolu, O.R., Mbolekwo, Z., Mtshemia, V. and Fatoki, O.S. 2005, Levels of trace metals in water and sediments from Tyume River and its effects on an irrigated farmland, *Water SA* **31**, 87-94

Baeyens, W., Meuleman, C., Muhaya, B. and Leerinakers, M. 1998, Behaviour and Speciation of Mercury in the Scheldt Estuary (Water, Sediment and Benthic Organisms), *Hydrobiologia* **336**, 63-79

Barceloux, D.G. 1999, Vanadium. *Clin. Toxicol.* **37**, 265-278

Biney, C.A. and Beeko, C.A. 1991. Trace metal concentrations in fish and sediment from the Wiwi, a small urban river in Kumasi, Ghana. *Trop.Ecol*. **32**(2), 197–206

Binning, K. and Baird, D. 2001, Survey of heavy metals in the sediments of the Swartkops River Estuary, Port Elizabeth, South Africa, *Water SA* **27**(4), 461-466

Cary, E.E., Gilbert, M., Bache, C.A., Gutenmann, W.H. and Lisk, D.J. 1983, Elemental composition of potted vegetables and millet grown on hard coal bottom ash-amended soil, *Bull. Environ. Contam. Toxicol*. **31**, 418–423

Cossa, D., Mason, R. and Fitzgerald, W. 1994, Chemical Speciation of Mercury in a Meromictic lake, In: Watras, C. and Huckabee, J. (eds). Mercury Pollution: Integration and Synthesis. Lewis Publishers, Ann Arbor, pp. 57-67

Crossgrove, J.S. and Yokel, R.A. 2004, Manganese distribution across the blood-brain barrier III. The divalent metal transporter-1 is not the major mechanism mediating brain manganese uptake. *Neurotoxicology* **25**(3), 451-460

Davies, B.E. (1992) Trace Metals in the Environment: Retrospect and Prospect. In: Adriano, D.C. (Ed) Biogeochemistry of Trace Metals. Lewis Publishers, pp 1-17

DWAF. 1996, South African Water Quality Guidelines, Vol. 2, Recreational Water Use, 2nd Edition, Department of Water Affairs and Forestry, Pretoria, SA

EEC. 1980, Council Directives 76/464/EEC, *Official Journal of European Communities*, vol. L.229; (August 30th), 11 pp

Environment Agency. 2009, Contaminants in soil: updated collation of toxicological data and intake values for humans. Nickel. Science Report SC050021/SR TOX8. Bristol: Environment Agency

Fatoki, O.S., Luyizan, O. and Ogunfowokan, A.O. 2002, Trace Metal Pollution in Umata River, *Water S.A.* **28**(2), 183-189

Fishbein, L. 1987. Perspectives of carcinogenic and mutagenic metals in biological samples, *International Journal of Environmental Analytical Chemistry* **28**, 21 – 69

Fitzgerald, W. and Clarkson, T. 1991, Mercury and Mono-methyl-mercury: Present and Future Concerns. *Environmental Health Perspectives* **96**, 159-166

FOREGS-EuroGeoSurveys EC. 2005, Geochemical Baseline Database, http://www.gtk.fi/publ/foregsatlas/

GESAMP (IMO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP. 1982. Joint Group of Experts on the Scientific Aspects of Marine Pollution: The Health of the Oceans. *Rep. Stud., GESAMP,* (15):108p and *UNEP Reg.Seas Rep.Stud*. **16**, 108 pp

Godbold, D. 1994, Mercury in Forest Ecosystems: Risk and Research Needs. In: Watras, C. and Huckabee, J. (Eds) Mercury Pollution: Integration and Synthesis. Lewis Publishers, Ann Arbor, pp. 295-303

Grigal, D., Nater, E. and Homann, P. 1994, Spatial Distribution Patterns of Mercury in an East-Central Minnesota Landscape. In: Watras, C. and Huckabee, J. (eds) Mercury Pollution: Integration and Synthesis, Lewis Publishers, Ann Arbour, pp. 305-312

Griscom, S., Fisher, N. and Luoma, S. 2000, Geochemical Influences on Assimilation of Sediment-bound Metals in Claims and Mussels. *Environ. Sci. Technol.* **31**, 91-99

Harris, D.C. 1999. Quantitative Chemical Analysis, 5th Edition, W.H. Freeman and Company, New York

Harvey, R. and Luoma, S. 1985, Effect of Adherent Bacteria and Bacterial Extracellular Polymers upon Assimilation by *Macoma Balthica* Sediment-bound Cd, Zn and Ag. *Marine Ecology Progress Series* **22**, 189-281

Irwin, R.J., Van Mouwerik, M., Stevens, L., Seese, M.D. and Basham, W. 1997, Environmental Contaminants Encyclopedia, National Park Service, Water Resources Division, Fort Collins, Colorado

Kakulu, S.E. and Osibanjo, O. 1988, Trace heavy metal pollutional studies in sediments of the Niger delta area of Nigeria., *J.Chem.Soc.Nigeria* **13**, 9–15

Lamm, S.H. 2001, Health effects of arsenic - An information presented at the Baltimore District of the US Army Corp of Engineers to the residents of Spring Valley in Washington DC on August 7, 2001. Retrieved (12/04/2011) from the www: http://www.google.com.gh/search?hl=health+effects+of

Long, E.R., MacDonald, D.D. Smith, S.L. and Calder, F.D. 1995, Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Env. Mgmt*. **19**, 81-97

Mason, R. and Lawrence, A. 1999, Concentration, Distribution and Bioavailability of Mercury and Methyl mercury in Sediments of Baltimore Harbar and Chesapeake Bay, Maryland, USA. *Environmental Toxicology and Chemistry* **18**, 2438-2447

Mason, R., Fitzgerald, W. and Morel, M. 1994, The Biogeochemical Cycling of Elemental Mercury: Anthropogenic Influences. *Geochimica et Cosmochica Acta* **58**, 3191-3198

McGrath, S., Chaudri, A.M. and Griller, K.E. 1995, Long term effects of metals in sewage sludge soils, microorganisms and plants, *J. Ind. Microbiol.* **14**, 94-104

Miller, J.N. and Miller, J.C. 2000, Statistics and Chemometrics for Analytical Chemistry, 4th Edition, Pearson Education Limited, pp. 271.

Mirlean, N., Andrus, V.E., Baisch, P., Griep, G. and Casartelli, M.R. 2003, Arsenic pollution in Patos Lagoon estuarine sediments, Brazil, *Marine Pollution Bulletin* **46**(11), 1480 – 1484

Muller, G. 1969, Index of geo-accumulation in sediment of the Rhine River. *Geol. J.* **2**, 109-192

Nriagu, J.O. 1979, Global Inventory of Natural and anthropogenic Emissions of Trace Metals to the Atmosphere, *Nature* **279**, 409 – 411

NOAA. 1999, Sediment Quality Guidelines developed for the National Status and Trends Program. NOAA, Washington.

Ogunfowokan, A.O. and Fakankun, O.A. 1998, Physicochemical Characterization of Effluents from Beverage Processing Plants in Ibadan, Nigeria. *Intern. J. Environ. Studies* **54,** 145 - 152.

Ogunfowokan, A.O., Adenuga, A.A., Torto, N. and Okoh, E.K. 2008, Heavy metals pollution in a sewage treatment oxidation pond and the receiving stream of the Obafemi Awolowo University, Ile-Ife, Nigeria. *Environ. Monit. Assess.* **143**, 25 – 41

Ogunfowokan, A.O., Torto, N., Adenuga, A.A. and Okoh, E.K. 2006, Survey of Levels of Phthalate Ester Plasticizers in a Sewage Lagoon Effluent and a Receiving Stream *Environ. Monitor. Assess*. **118**, 457 – 480

Onder, S. and Dursun, S. 2006, Airborne heavy metal pollution of *Cedrus libani* (A. Rich.) in the city center of Konya (Turkey). *Atmospheric Environment* **40**, 1122–1133

Onweremadu, E.U. and Duruigbo, C.I. 2007, Assessment of Cd concentration of crude oil polluted arable soils. *Int. J. Environ. Sci. Tech*. **4** (3), 409 – 412

Oyekunle, J.A.O., Ogunfowokan, A.O., Torto, N. and Akanni, M.S. 2011, Determination of organochlorine pesticides in the agricultural soil of Oke-Osun farm settlement, Osogbo, Nigeria, *Environ. Monit. Asess.* **177**, 51-61

Pais, I. and Jones, J.B. Jr. 1997, The Handbook of Trace Elements, CRC Press, 90 pp

Prasad, A. S. and Oberleas, D. 1976, Trace Elements in Human Health and Disease, Vols. I & II, Academic Press, New York

Rojas de Astudillo, L., Chang Yen, I. and Bekele, I. 2005, Heavy metal in sediments, mussels and oysters from Trinidad and Venezula. *Int. J. Trop. Biol.* **53**(1), 41-53

Saad, M.A.H. and Fahmy, M.A. 1985, Occurrence of some heavy metals in surficial sediments from the Damietta estuary of the Nile. *Journ.Etud.Pollut.CIESM* **7**, 405–407

Shelton, L.R. and Capel, P.D. 1994, Guidelines for collecting and processing samples of stream bed sediment for analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program: U. S. Geological Survey, Open-File Report 94-458

SON. 2007, Standard Organization of Nigeria, Nigerian Standard for drinking water quality, pp. 15-16.

Stoepper, M. 1991, Cadmium. In: E. Merian (Ed) Metals and their compounds in the environment: Occurrence, analysis and biological relevance, New York, VCH, pp. 803 – 851

Tabata, M., Ghaffar, A. and Nishimoto, J. 2009, Accumulation of metals in sediments of Ariake Bay, Japan. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, **8**(10), 937-949

Turekian, K.K. and Wadepohl, K.H. (1961), Distribution of the elements in some major units of the Earth's crust, *Geological Society of America Bulletin* **72**, 175-192

U.S. Environmental Protection Agency. 1979, The health and environmental impacts of lead and an assessment of a need for limitation, USEPA Report 560/2-79-001. 495pp.

U.S. Environmental Protection Agency, Water Quality Criteria Fact Sheet, May 25, 2005,
U.S. Environmental Protection Agency (USEPA) 1975, Preliminary assessment of suspected carcinogens in drinking water: Report of Congress II. Office Toxic Substances, Washington, D.C

Udousoro, I.I., Umoren, I.U. and Asuquo, E.D. 2010, Survey of some heavy metal concentrations in selected soils in south eastern parts of Nigeria. *World Journal of Applied Science and Technology* **2**(2), 139 – 149

UNEP. 1978, Lead: Evaluation Techniques for one of the Priority Pollutants. UNEP/GC/Information/8. United Nations Environmental Program, Nairobi

van Zinderen Bakker, E.M. and Jaworski, J.F. 1980, Effects of vanadium in the Canadian environment. National Research Council of Canada, Associate Committee on Scientific Criteria for Environmental Quality, Subcommittee on Heavy Metals and Certain other Compounds, NRCC No. 18132

Watras, C. 1994, Sources and Fates of Mercury and Methyl mercury in Wisconsin Lakes, In: Watras, C. and Huckabee, J. (eds.) Mercury Pollution: Integration and Synthesis. Lewis Publishers, Ann Arboor, pp. 153-177

Wegman, R.L.C. and Greve, P.A. 1980, Halogenated hydrocarbons in Dutch water samples over the years 1969–77. In: B.K. Afghan and D. Mackay (Eds) Halogenated hydrocarbons in the aquatic environment, New York, Plenum Press, pp. 405–15

Welch, R.M. and Cary, E.E. 1975, Concentration of chromium, nickel, and vanadium in plant materials. *J. Agric. Food Chem.* **23**, 479

WHO 1973, WHO Technical Report Series 513 (Safe Use of Pesticides: Twentieth Report of the WHO Expert Committee on Insecticides). Geneva, pp. 43-44

WHO 1977, Lead: Environmental Health Criteria 3, World Health Organization, Geneva

WHO 1984, Guidelines for drinking water quality, vol.2: Health criteria and other supporting information, World Health Organization, Geneva

WHO 1988, Vanadium, Environmental Health Criteria 81, Geneva

WHO 1993, Guidelines for drinking water quality, vol.1: Recommendations, 2nd Edition, World Health Organization, Geneva

WHO 2002, World Health Report: Reducing risks, promoting healthy life. World Health Organization, Geneva

Yoon, J., Cao, X., Zhou, Q. and Ma, L. 2006, Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site, *Science of the Total Environment* **368** (2–3): 456–464

Soil Moisture Distribution Pattern and Yield of Jute Mallow *(corchorus olitorius)* under Three Different Soil Fertility Management

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Abstract

Field experiment was conducted to determine the soil moisture distribution pattern and yield of Jute mallow (*Corchorus olitorius)* in a sandy clay loam soil of the tropical rain forest of Akure, Nigeria, under three different soil fertility management. The treatments were: zero fertilizer application plus rain fed condition (control); 1.79 ton ha^{-1} of poultry manure plus rain fed condition; 0.54 ton ha^{-1} of urea fertilizer application plus rain fed condition. The three treatments were replicated three times in a completely randomized block design. During the period of the plant development, the moisture content of the soil increases with increase in the depth of the soil. The highest mean value for the depth of the water stored occurred in the plots under urea treatment with value 9.243 ± 2.96 cm. Measured plant parameters showed the best *Corchorus olitorius* yield components in plots under urea treatment. The mean plant height at 6 weeks after planting (WAP) was 106.13 ± 5.55 cm, mean number of leaves at 7WAP was 54.90 ± 6.71, while the mean leaf area and leaf area index at 6WAP were 572.26 ± 7.53 mm^2 and 0.16 ± 0.02, respectively. Biomass yield at 4 WAP was 1.99 ton ha^{-1} for plants in urea treated plots, 1.577 ton ha^{-1} under poultry manure and 1.445 ton ha^{-1} in the control experiment. There was no significant difference between the yields of the different treatment plots during the early stage of the plant development. The organic matter content was 2.1%, 2.15% and 2.25% in treatment plot under urea application, poultry manure and control experiment respectively. The nitrogen (N) content were 1.3%, 1.5% and 1.4% in treatment plots under urea, poultry manure plot and the control experiment respectively. Magnesium (Mg) content of treatment plots were 2.50 cmol kg^{-1}, 2.65 cmol kg^{-1} and 2.70 cmol kg^{-1} in plots under urea, poultry manure and the control experiment, respectively. At 7 WAP, the total biomass yields were 6.78 ton ha^{-1}, 5.58 ton ha^{-1} and 3.27 ton ha^{-1} for plants under urea and poultry manure application and control, respectively. The urea fertilizer and poultry manure applied, improved the chemical properties of the, soil which led to the significant increase in the biomass yield of the plant.

Keywords: *Corchorus olitorius,* soil moisture, soil fertility, urea fertilizer, biomass yield, poultry manure

Introduction

Jute Mallow (*Corchorus olitorius*) has been observed by scientists to be demulcent, emollient, diuretic, cleansing, and tonic in nature (Fasinmirin, 2009). It is a popular vegetable, grown in both dry and semi-arid regions and in the humid areas of Africa, because of its importance in giving the body good nutrients (Oladiran, 1986). *Corchorus olitorius* belongs to the Tiliaceae family and is an erect annual herb that varies from 60 cm to approximately 150 cm in height depending on the cultivar (Husselman and Sizane, 2006).

The most common of the Jute mallow family are *Corchorus capsularis* and *Corchorus olitorius* (Fasinmirin, 2001). *Corchorus olitorius* called "ayoyo" in Hausa and "ewedu" in Yoruba is a popular green vegetable plant (Musa et al, 2010). The vegetable is also known by several names in different countries, including Jews mallow or Jute mallow in English, Egyptian spinach, and bush okra in South Africa (Van Wyk and Gericke, 2000, Vorster et al, 2002). *Corchorus* seeds show a high degree of dormancy, which can be broken by means of hot water treatment (Schippers et al, 2002). The vegetable does well in acid, neutral and basic (alkaline) soils (Facciola, 1990). It tolerates soil pH of 4.5 to 8.0, but more extreme pH conditions will reduce the availability of iron in the soil and cause yellowing between leaf veins (Palada and Chang, 2003). *Corchorus* is mainly known for its fibre product, jute, and for its leafy vegetables (Schippers, 2000). The leaves are a rich source of iron, protein, calcium, thiamin, riboflavin, niacin, folate, and dietary fibre (Palada and Chang, 2003). Jute mallow responds well to added fertilizer, especially nitrogen.

A combination of both inorganic and organic fertilizers improves yield and maintains soil fertility. The rate of fertilizer application should be based on the initial soil fertility, soil type, fertilizer recovery rate, and soil organic matter (Palada and Chang, 2003). Nitrogen fertilizer application is effective in increasing the height of the plant and fibre length, thereby bringing about high fibre yield per acre (Fasinmirin, 2001).

Jute mallow is susceptible to moisture stress owing to its shallow rooting depth, which can be prevented by irrigation (Fasinmirin, 2009). Oguntunde (2004) showed that in the past, many land surface modelers do not consider the contribution of soil moisture portion of their models to be physically based but thought of the soil moisture as more of index used for evapo-transpiration and runoff calculations rather than representative of the actual mass of moisture in the soil. Sufficient knowledge of the distribution and linkage of soil moisture to evapo-transpiration is essential to predicting the land surface processes to weather and climate (Idso, 1982). Despite this importance, global measurement and analysis of soil moisture and temperature remains an outstanding scientific problem with far-reaching significance to agriculture (Wei, 1995). The objective of this paper therefore is to investigate the soil moisture distribution pattern, growth and yield in *C. olitorious* field under three different fertility treatments.

Study Area

The field experiment was carried out at the experimental farm of the Agricultural Engineering Department, Federal University of Technology, Akure (FUTA) between April and June 2011. The site is located on latitude $7^0 16^1$ N and longitude $5^0 13^1$ E. The soil on the site is sandy clay loam according to the United State Department of Agriculture (USDA) classification. Akure lies in the South western Tropical Rain forest zone of Nigeria and have a mean annual precipitation of 1300 to 1600 mm and with an average temperature of 27.5^{o}C (Fasinmirin, 2008).

Materials and Method

Field experiment was conducted between 6th April and 8th June, 2011. The field was divided into a block system. 3 blocks of system were used. A block was divided into three plots, which serves as replications for each treatment. Each block is of equal dimension of 10m x 1.4m. The land was tilled using the disc plough and further pulverized by using light implements like hoes, spade and cutlass to form seed beds. The plots were planted with Jute Mallow *(Corchorus olitorius)* with a spacing of 0.4 m inter row by 0.3 m intra row. The seed was soaked in ordinary water for three days to break its dormancy. Field plots were replicated thrice under different fertilizer application. Seeds were planted and thinning was first done two (2) weeks after planting. Fertilizer treatment was applied accordingly, after three weeks of planting. Manual weeding was carried out on weekly basis.

Irrigation was applied to compliment the rainfall during the early stage of the plant development. The water was delivered to the experimental field using hand watering can. The first treatment was application of irrigation water plus zero fertilizer (control), the second treatment was application of irrigation water plus poultry manure (1.79 ton ha^{-1}), the third treatment was application of irrigation water plus urea fertilizer (0.54 ton ha^{-1}). The three stages of the crop development which are; emergence, vegetative/flowering, and maturity were properly monitored.

Measurements of soil moisture distribution pattern and other growth parameters were carried out during the experimental period. Meteorological data such as solar radiation, Maximum and Minimum Air Temperature, Maximum and Minimum Relative Humidity, Rainfall, Wind Speed and Sunshine Hours during the growing season were obtained from a meteorology station located very close to the site of experiment. Rain gauges were installed within the experimental field to measure Precipitations during the experiment. Soil samples were collected from 0 – 15 cm depth from each of the experimental blocks to determine the soil physicochemical properties such as particle size distribution, organic matter, soil pH, bulk density, percentage composition of nitrogen, exchangeable phosphorus, extractable potassium, calcium and magnesium using standard procedures (Agyare, 2004). The Bouyoucos (1962) method was used to determine the particle size distribution on 2 – mm sieved air – dry soil. A method illustrated by Fasinmirin (2001) was used for the determination of organic carbon content. The organic carbon was oxidized by a known concentration of potassium dichromate (1.0 N or 0.166 M) solution added in excess. The percentage nitrogen content of the soil was determined using the digestion method described by Jackson (1962). Extractable potassium, calcium and magnesium were extracted using ammonium acetate as illustrated by Fasinmirin (2001) and the individual cations of Ca^{2+}, Mg^{2+}, K^{+} were measured by Atomic Absorption Spectrometer (AAS) and flame photometer. The soil pH was determined by suspending the soil in 0.01 M $CaCl_2$ solution a 1 - 2.5 soil to solution ratio. The suspension was stirred intermittently for 30 min. The pH was taken using a pH meter and a combined glass electrode (Thomas, 1996). Soil bulk density in gcm^{-3} was determined by the core method (Blake and Hartage, 1986) using a 9.0 cm long by 6.2 cm diameter cylindrical metal core. Samples were dried at 105^{o}C for 24 h in a forced air oven, while bulk density calculated as sample dry weight (g) divided by sample volume (cm^3). The soil moisture content at depths 5, 10, 15 and 20 cm from each plot was determined twice a week by using the soil moisture meter and the gravimetric method (Lascano, 2000) occasionally to serve as a regulator (control) for the soil moisture data. The collected samples were placed in different containers of known weight, with a lid on to prevent evaporation. The containers and soil are weighed and then placed in an oven at 105^{o}C, with the lid removed, until the sample dries. The containers, and dried soils were weighed again to estimate the loss in weight which is the weight of water in the original samples, and the weight of solids is final weight less the weight of the container. The formula below can be used to estimate the moisture content of the soil by using the gravimetric method:

$$\text{Soil Moisture content} = \frac{\textit{Weight of water}}{\textit{Total weight of the sample}} \qquad \text{------} \quad 1$$

$$\text{Bulk density (BD)} = \frac{\textit{Mass of oven dried soil}}{\textit{Volume of soil}} \qquad \text{------} \quad 2$$

Results and Discussion

Climatic Condition during Experiment

The mean solar radiation value was highest in May (270.17 W m^{-2}) comparatively with the months of April and June. The first modal rainfall of the study area (June – July) is usually preceded by increase in solar radiation and convectional movement of hot humid air. The highest rainfall (199.89 mm was observed in the month of June and the least (169.60 mm) occurred during the month of April. The rainfall recorded throughout the period of the plant development was enough for good seed germination and good stand establishment.

Soil Moisture Content

The soil moisture content in the various treatments from 0 – 56 DAP is presented in Figure 1, 2 and 3. The plants enjoyed good soil moisture during all the stages of its development, because the rain was abundant enough to keep the soil in a good condition. The highest mean value for the depth of the water stored occurred in the plots under urea treatment with value 9.243 ± 2.96 cm. This is in line with the Suggested Cultural Practices for Jute Mallow by Palada and Chang (2003). There was a sharp increase in volumetric soil moisture stored from 3.98 to 11.96 cm, 3.05 to 11.62 cm, and 3.44 to 13.38 cm under the control, poultry manure and urea treatments plots, respectively during crop development in May. This observation was preceded by heavy rainfall that accompanies the onset of raining season. Soil moisture content was highest in plots under urea fertilizer treatment, than in the other two treatments. This observation confirms the findings by previous researchers including Haynes and Swift (1990). The results from the Figures indicated that moisture content of the soil was highest at the 20 cm depth almost throughout the period of the plant development in all the three blocks.

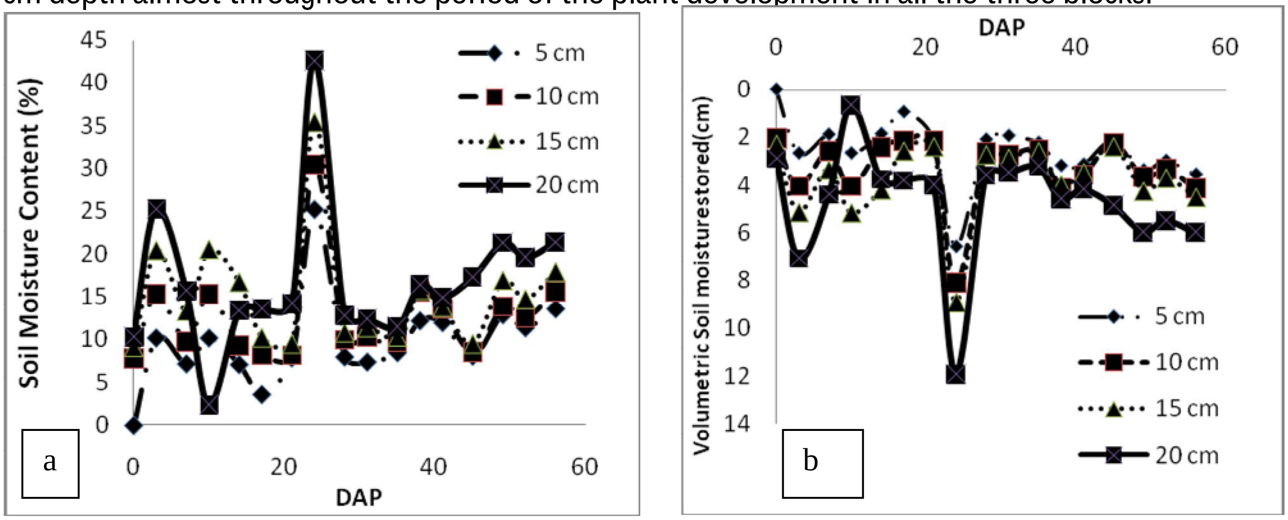

Figure 1: The moisture content and volumetric moisture stored in the soil at the control treatment (block one)

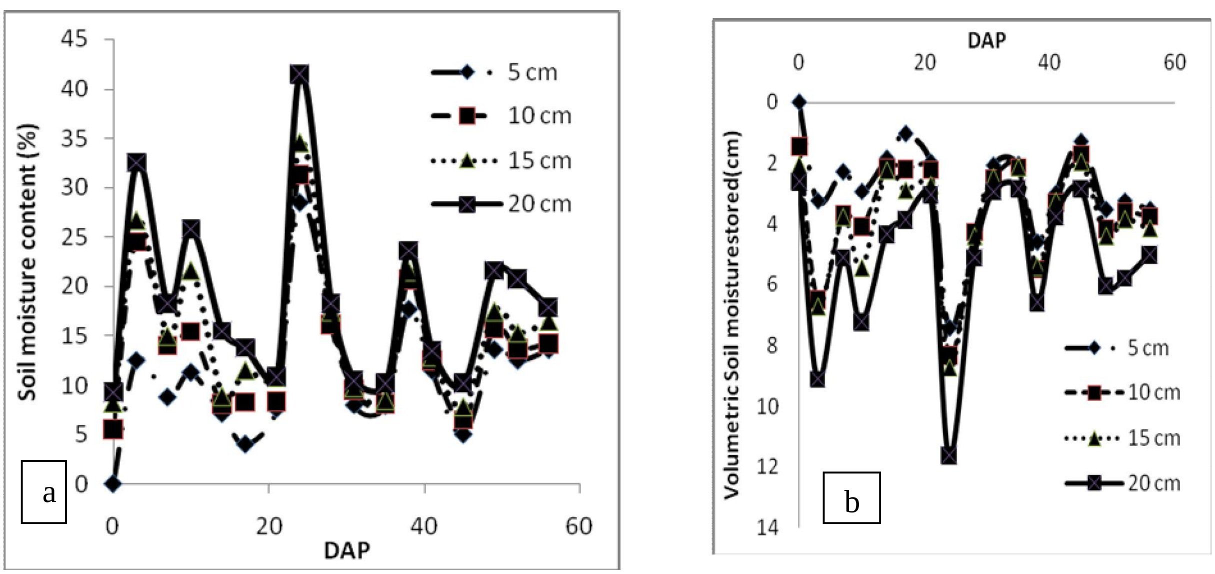

Figure 2: The moisture content and volumetric moisture stored in the soil at the poultry manure treatment (block two)

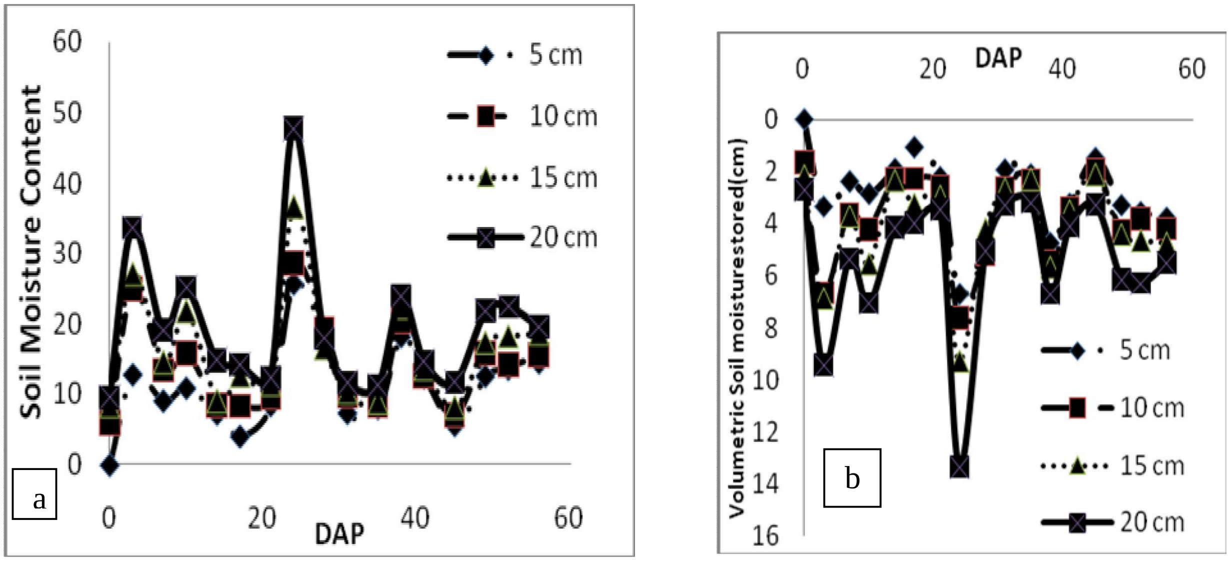

Figure 3: The moisture content and volumetric moisture stored in the soil at the urea fertilizer treatment (block three)

Plant Height

The plant height was not significantly higher in plots that received fertilizer treatments than under the control during the early stage of the plant development. The observed is because the properties of the soil were almost the same before the planting was done. Figure 3 showed the plant height at four weeks after plant (4WAP). The mean plant height under zero fertilizer (control), poultry manure and urea fertilizer treatments were 31.25 cm, 33.85 cm, and 35.68 cm at 4 WAP. Similarly, plant heights were 105.03 cm, 112.38 cm, and 113.67cm under control, poultry manure and urea fertilizer treatments respectively at the 7 WAP. There was no significant difference in the height of the crops during all the stages of its development, because, the soil fertility responsible for growth is available abundantly in the soil, and the availability of moisture in the soil is sufficient.

Number of Leaves

There are no significant differences in the number of leaves with respect to the fertilizer application as revealed in figure 4. Urea fertilizer treatment gave the highest leaf number from the 4^{th} to the 7^{th} WAP. The crop under this treatment benefited from increased soil moisture content. Plots under urea and poultry treatments produced more leaves and luxuriant growth when compared with the control treatment. The means of leaf number per sampled plot were 8.00, 8.48 and 9.15 at 4 WAP and 48.65, 50.21 and 54.90 at 7 WAP in control, poultry manure, and urea fertilizer treatments respectively. Sharma et al (1990) stated that crop growth and yield were improved when application of water can be controlled to what the plant actually need.

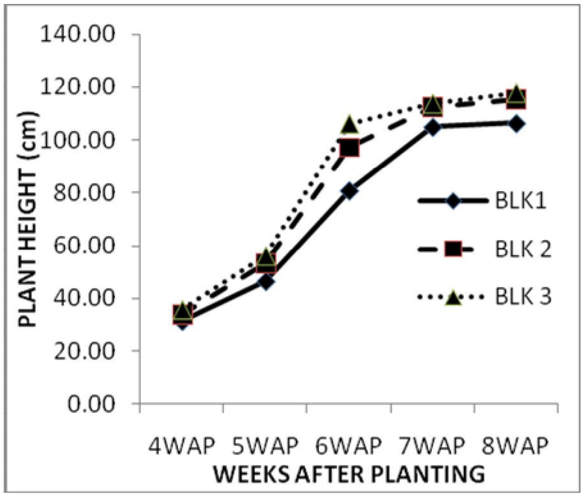

Figure 3: Mean plant height against WAP

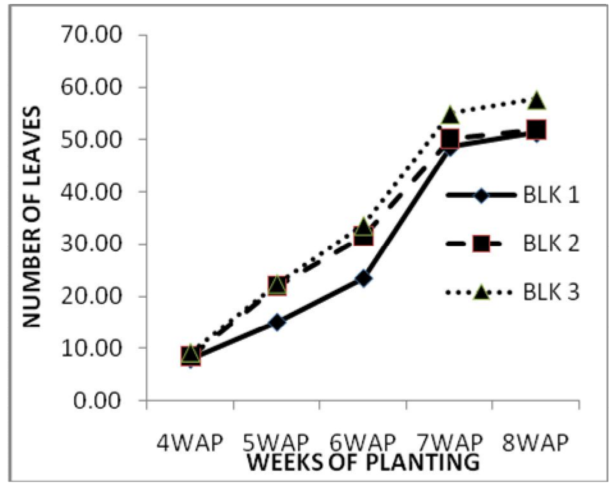

Figure 4: Mean number of leaves against WAP

Biomass Yield

The values of biomass yield in the various treatments are shown in Tables 1 and 2 for the 4th, 7th and 8th WAP. Biomass yield was increased as a result of the fertilizer applied. The total wet biomass yield for the treatments differed significantly at P = 0.05. However, no significant difference was observed between the yields of the different treatment plots during the early stage of the plant development. The total dry biomass yields at 4WAP are 0.72 ton ha^{-1} under the control treatment, 0.91 ton ha^{-1} under poultry manure treatment, and 1.05 ton ha^{-1} under urea fertilizer treatment. The total wet biomass yields at 7WAP are 5.96 ton ha^{-1}, 7.17 ton ha^{-1} and 7.98 ton ha^{-1} under the control, poultry manure and urea treatment plots respectively. At 8WAP, the total wet biomass yields are 8.04 ton ha^{-1} 10.68 ton ha^{-1} and 11.14 tonha^{-1} under the control, poultry manure, urea fertilizer treatment plots respectively. The result also revealed that the effect of the urea fertilizer and poultry dung manure was very significant to the soil fertility, despite the same application of water throughout the plant growth stages. The wet biomass yields for the 7th and 8th WAP were significantly higher under the urea and manure treated plots comparatively with the control treatment (Ansari and Ismail, 2008).

Table 1: Total biomass yield (wet) of *C. olitorius*

Treatments	Wet biomass yield in ton ha^{-1}		
	4WAP	7WAP	8WAP
Control	3.17	5.96	8.04
Poultry manure	3.73	7.17	10.68
Urea fertilizer	4.50	7.98	11.14

Table 2: Total biomass yield (dry) of *C. olitorius*

Treatments	Wet biomass yield in ton ha^{-1}		
	4WAP	7WAP	8WAP
Control	0.72	0.90	1.50
Poultry manure	0.91	1.19	1.83
Urea fertilizer	1.05	1.45	2.01

Conclusion

The performance of *C. olitorius* under three different fertility managements was evaluated. *Corchorus olitorius* was found to be very sensitive to good soil fertility condition. Total yield of *C. olitorius* (dry biomass) was highest in plots under urea treatment (2.01$tonha^{-1}$) at 8WAP. This was followed by the poultry treatment plots (1.83$tonha^{-1}$). The lowest value was recorded under the control treatment plots (1.50$tonha^{-1}$). *Corchorus olitorius* appear very sensitive to soil water and fertility treatment status because the higher the soil water content and good fertility management during the crop stages of development or growth, the greater the biomass yield observed. Excess of nitrate in the leaves of the plant can greatly affect the environment, and human health. Hence, further research is recommended to determine the influence of fertilizer quantity on nitrate accumulation in *C.olitorius*.

References

Ansari1, A. A., and Ismail S. A., (2008), Paddy cultivation in sodic soil through vermitech *int. J. Sustai, Crop prod,* 3(5):1-4

Blake G. R., and Hartage K.H., (1986), Bulk density, In: A. Klute (ed), Methods of soil analysis, Part 1, 2nd Agron. Monogr., 9, ASA,. Madison, WI. pp.363 – 375

Facciola SC (1990), A source book of edible plants, Kampony Publications. pp. 10-15

Fasinmirin J.T., (2001), Nitrogen and Water Use of Irrigated Jute Mallow, Unpublished M. Eng Thesis, Department of Agricultural Engineering, Federal University of Technology, Akure, Nigeria, pp. 4 – 63

Fasinmirin, J.T. and Oguntuase, A.M. (2008), Soil moisture distribution pattern in *Amaranthus cruentus* field under drip irrigation system. African Journal of Agricultural Research Vol. 3 (7), pp. 486-493

Fasinmirin, J.T. and Olufayo, A.A. (2009), Yield and water use efficiency of jute mallow *Corchorus olitorius* under varying soil water management strategies. Journal of Medicinal Plants Research Vol. 3(4), pp. 186-191

Haynes, R. J. and swift, R. S., (1990), Stability of soil aggregates in relation to organic constituents and soil water Content. *J. Soil sci.* 41, 73

Husselman M, Sizane N (2006), Imifino, A Guide to the use of Wild Leafy Vegetables in the Eastern Cape. ISER Monograph Two. Institute for Social and Economic Research, Rhodes University, Grahamstown, South Africa

Idso, S.B. (1982), Non-water stressed baselines: a key to measuring and interpreting plant water stress. Agric. Meteorol. Vol. 27, pp. 57-72

Jackson M.L., (1962), Soil Chemical Analysis, Prentice – Hall Inc. Englewood Cliff, New Jersey, pp. 160 – 172

Lascano R.J., (2000), A general system to measure and calculated daily crop water use. Agron. J. 92: 821-832

Musa, A., Ezenwa, M.I.S., Oladiran, J.A., Akanya, A.O. and Ogbadoyi, E.O. (2010), Effect of soil nitrogen levels on some micronutrients, anti-nutrients and toxic substances in *Corchorus olitorius* grown in Minna, Nigeria, African Journal of Agricultural Research Vol. 5(22), pp. 3075-3081

Oladiran J.A., (1986), Effect of stage of harvesting and seed treatment on germination, seedling emergence and growth in *Corchorus olitorius* 'Oniyaya'. Sci. Hortic. Pp 28: 227-233

Palada, M.C. and Chang, L.C., (2003), Suggested Cultural Practices for Jute Mallow. Asian Vegetable Research & Development Council Centre (AVRDC)

Schippers, R.R., (2000). African indigenous vegetables: An overview of the cultivated species, University Greenwich, England, pp. 193-205

Schippers R, Maundu P, Imbuni M, Obiero H (2002), How to grow and use Jew's Mallow, Horticultural Development Services, Baarn, The Netherlands. p. 10

Sharma BD, Cheema SS, Kar S (1990), Water and nitrogen uptake of wheat as related to nitrogen application rate and irrigation water regime fertilizer, News letter. 35(9): 31–35

Oguntunde P.G., (2004), Evapo-transpiration and complimentary relations in the water balance of the Volta Basin: Field measurement and GIS – based regional estimate, Ecology and Development Series No. 22. pp. 16 -91

Thomas G.W., (1996), Soil pH and Soil acidity, In: Sparks D.L. (ed.) methods of soil analysis, part 3 chemical methods, Soil Sci. Soc. of Amer., Madison, Wisconsin. pp. 475 – 490

Van Wyk B, Gericke N (2000), People's Plants, A Guide to Useful Plants of Southern Africa, Briza Publications, Pretoria, South Africa 352pp

Spatial Variation of Acid Rain and its Ecological Effect in Nigeria

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Abstract

The study is aimed at examining the spatial variation of acid rain and its ecological consequences in Nigeria. The study covers Nigeria. A total of two hundred and twenty eight rainwater samples were collected; an average of nineteen samples per month. The water samples were analysed in the laboratory and multiple regression analysis used to ascertain the level of variation and relationship with distance from the source of gas flare. Results of the Hydro chemical analysis revealed moderately low pH values of <4.99 for rainwater sources in Nigeria. The pH values however decrease from the north to the south. Also the pH value of rain water samples correlated significantly ($r = 0.97$) with latitudinal variation and is ascribed to the influence of gas flaring and other anthropogenic activities carried out in the Nigeria environment. There is the intrusion of acid rain into other sources of water, which led to mild acidity of these water sources in Nigeria. The need to extinguished gas flaring is recommended and Nigeria should embrace environmental laws and policies in order to adapt to the changing environment.

Keywords: Acid rain, gas flares, environment, degradation, Nigeria

Introduction

Human anthropogenic activities since 1800 have resulted in the emission of great volumes of gaseous materials into the atmosphere. Some of these gases - notably carbon dioxide (CO_2), methane (CH_4), and chlorofluorocarbons (CFC) nitrogen oxide – absorb earth's radiation. The radiation help to degrade the environment, leading potentially to warming of earth's surface and acid rain deposition, which in turn alter the world's climate (Intergovernmental Panel on Climate (IPCC), 2001 and 2007). At the molecular level, carbon dioxide has been emitted in greatest volume, largely from clearing forest, burning of coal, and oil and gas flaring. Carbon dioxide has the longest life span in the atmosphere, thus accumulating over time (Cooper, 2000). The accumulation has been observed in eastern United State of America (United States General Accounting Office (USGAO) 2000). For instance GAO (2000) opined that the combustion of coal and other fossil fuels produces, as by-products, a wide variety of chemicals, including gases like sulfur dioxide and nitrogen oxides. These gases, which are emitted into the atmosphere may be carried up to hundreds of miles by air currents, and are often transformed into acidic compounds, which are then returned to the earth. When the compounds are delivered by precipitation, such as rain and snow, the process is called wet deposition. When they are delivered as gases, aerosols, and particles, the process is called dry deposition. In addition, in high-elevation and coastal areas, they may be delivered through cloud or fog water, called cloud deposition.

However the concept of acid rain was first referred to by Robert Augus in 1872 during the industrial revolution to mean any acidic precipitation (such as rain and fog among others) or depositions that occur downwind of areas where major emission of SO_2, CO_2, and NO_x from human activities takes place (Oden, 1976; Botkin and Keller, 1998 and Efe, 2010b). Figure 1 shows the various atmospheric processes through which pollutants from gaseous emission react with water in the atmosphere to produce acid rain. It is evident that gaseous emissions of SO_2, CO_2, NO_x, and NH_3, from burning fossil fuels, and other anthropogenic activities form the major source of acid deposition in the region. Once airborne, these pollutants can travel for several thousand kilometres and this long atmospheric lifetime enables their oxidation into acidic species (Pickering and Owen, 1994 and Tripathy and Panda, 1999). Subsequent deposition of the acids onto land, leads to widespread soil and surface water acidification. Through infiltration processes, acid rain also leaches various heavy metals from the soil into subsurface water, which impacts aquatic life. Acid rain also affects the flora and fauna on land as well as causing damage to sculptures and buildings (Pickering and Owen, 1994 and Tripathy and Panda, 1999).

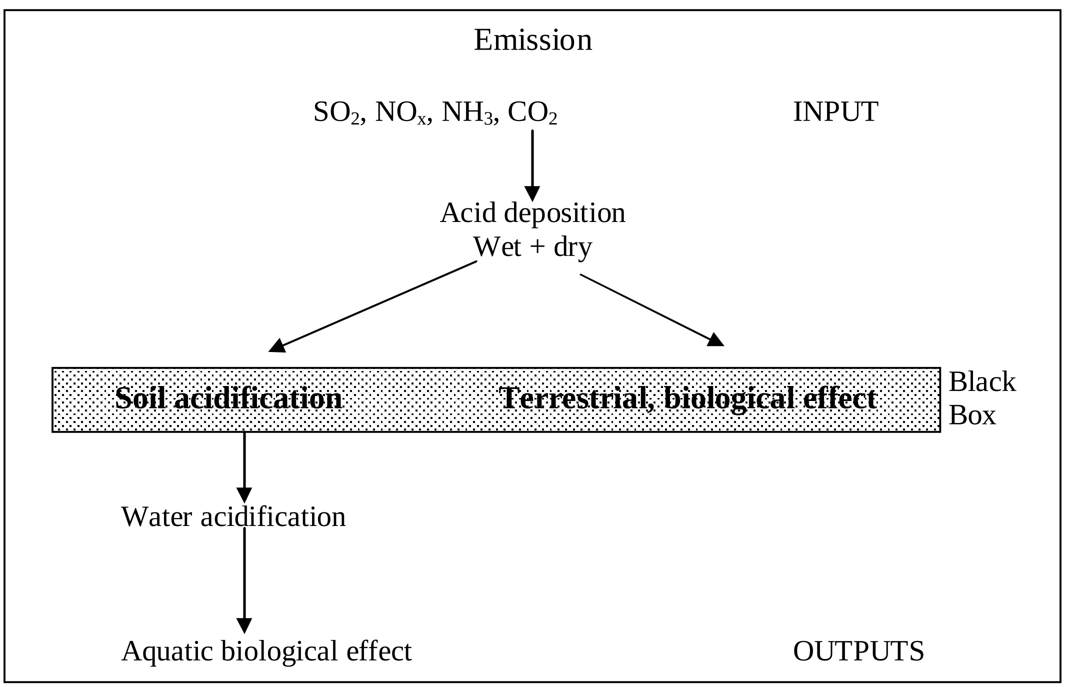

Figure 1: The chain linking some emitted gases (SO_2, NO_x and NH3) to soil and water acidification (modified after Last and Whathing, 1991; Efe, 2010b)

Similarly Likens, Bormann and Johnson (1972) give discussions of acid rain effects in North America, and Seip (2001) noted that around 1900 there were reports of fish deaths that could have been caused by poor water quality. In 1959 the Norwegian biologist Alf Dannevig suggested that long-range transported sulphur pollutants could cause acidification and kill fish in Norwegian bodies of water. Odén (1968, 1976) has earlier described the possible effects of acid deposition on soils and water in Norway, and opined that increasing number of lakes and streams in Norway were reported to be acidic in the 1960s, and there was concern about possible effects on forests. This resulted in a large interdisciplinary Norwegian research project, *Acid Deposition – Effects on Forest and Fish* (Sur nedbørs virkning på skog og fisk, SNSF) that lasted from 1972 to 1980. Originally the intention was to focus on effects on forests, but soon the interest in water acidification and the accompanying biological impacts was at least as great (Seip 2001). The occurrence of acid rain has also been reported in rains in Bangkok, Thailand (Somboon, 1997).

In Nigeria, acid rain has been observed in Warri, the rural areas of Delta State, Nigeria and the Niger Delta region of Nigeria (Efe, 2005, 2006, 2010b). There is however the need for the examination of its spread over the country. Efe (2006, 2010b) opined that gas flaring, waste incineration, bush burning, flumes from fairly used cars and other anthropogenic activities are the major causes of acid rain in Nigeria. Similarly the increased atmospheric concentration of carbon dioxide in recent years has also resulted in increased carbonic acid, which has been linked to the occurrence of acid rain in Nigeria (Efe, 2011).

However, studies on acid rain in Nigeria have been limited to the Niger Delta region of Nigeria, to the neglect of other part of Nigeria (Onianwa et al, 2002; Omoleomo et al; 2008 and Efe, 2010b). The reason for this perhaps, is that the Niger Delta area formed the foci of gas flares, and scholars felt that its ecological impact should be limited to the area (Efe, 2011). In recent times, the need for the extension of the investigation to the entire country is advocated. For instance Shell Petroleum Development Company SPDC (1995) argued that though there is the occurrence of acid rain in the Niger Delta region, acid rain is not restricted to the vicinity of the gas flares, but there is no evidence that gas flaring is the major factor. However Alakpodia (2000) asserted that gas flaring is the major cause of acid rain in the Niger Delta region of Nigeria and called for more studies to regularly assess the issue of acid rain and its causes not only in the region but over the Nigerian landscapes.

Leading credence to the above call, Efe (2006) further confirm the occurrence of acid rain in 18 rural coastal communities of Delta State. He observed a mean pH value of 6.4 in the open atmosphere, whereas lower pH values of 5.0 – 5.3 were seen in roof catchments of buildings in some coastal communities of Delta State, which he attributed to the proximity of the buildings to gas flare sites. Omoleomo et al (2008) also attributed the acidification of surface and ground water by acid rain in the Western Niger Delta to the flare rates, though he failed to correlate the gas flares with the pH values of the water sources. At the International Conference on Natural Resource, Security and Development in the Niger Delta held on March 8-11, 2010 at Niger Delta Wetlands Centre, Yenagoa, Bayelsa State, Nigeria, participants called for the examination of the spatial distribution of acid rain over Nigerian landscape as an impact of oil exploitation (Efe, 2010a). This study therefore addresses the identified gap by examining the spatial variation of acid rain and its ecological effects in Nigeria.

Methodology and Conceptual Issues

The data used for this study were collected through direct field survey that last from January to December for fourteen years (1997 – 2010). A total of 19 sterilized plastic rain gauges were randomly distributed on the basis of 19 rainwater samples a month, and the choice of these years is based on the time the researcher was able to secure the services of research assistants to undertake the collection of rainwater samples at the various sites. The spatial distribution of the 19 rainwater sample sites was determined with 2 by 2 latitudinal and longitudinal intersection (Figure 2). The rain gauges were positioned at the designated study sites at 1.5metres above the ground. To avoid dry precipitate on the gauges, they were removed immediately after the rain and returned to the sites when rain bearing cloud was observed. The rainwater samples were collected in line with Efe (2010b), where rainwater samples were collected from the first rain events for every month and for time lapse, experiment samples were taken at 5min, 10min, 15min and 20minutes from the start of the rain event with a final sample for any subsequent rain. All the rain events studied were collected as time lapse samples.

The volume of rain in each time interval was recorded and the samples were analysed for their physico-chemical parameters, the average values of the time lapse samples for each rain event were utilized for this study. This technique has been used by Somboon (1997) and Efe (2005, 2006, 2010b). A sub sample of the rain was used to measure pH and temperature immediately upon collection using a Teledo MC236 pH meter and digital mercury thermometer. The remaining rainwater collected was poured into sterilized plastic containers with and kept in a cooler containing ice to reduce the degradation of samples before analysis. Upon arrival at the laboratory, turbidity was estimated with a turbidity meter (APHA 214A). Nitrate-NO_3^- was determined by colorimetric spectro-photometry and SO_4^{2-} was determined with spectrometry via precipitation with $BaCl_2$. A digital MC 226 conductivity meter was used to determine the electrical conductivity and Total Dissolved Solid (TDS) of the water sample. Sodium ion (Na^+) and K^+ were determined with a flame Emission Analyser. Lead, cadmium, magnesium and iron were analyzed with an Atomic Absorption Spectrophotometer (AAS) 3200 Metler model. ANOVA and simple regression analysis were used to determine the latitudinal variation in pH and the effect of distance on acid rain intrusion on rainwater sample in Nigeria

The study adopts the concept of distance decay, which states that the quality and quantity of information decrease as distance increase from the source of information (Tobler 1970 and Alber et al 1971). Distance decay is a geographical term, which describes the effect of distance on cultural or spatial interactions. The distance decay effect states that the interaction between two locales declines as the distance between them increases. Once the distance is outside of the two locales' activity space, their interactions begin to decrease. This model has been used extensively in human geography and ecology for several decades. For instance many ecological phenomena incorporate the pattern of decreasing community similarity with geographical distance (Nekola and White 1999). The above concept can be applied to this study because as distance increases from gas flares areas, the intensity of its influence decreases. That is, the intensity has inverse relationship with distance. In this study, the intensity of the occurrence of acid rain decreases as distance increases from gas flare areas, which could be ascribed to gas emission like ,So_2, and No_2 among others from the selected areas (Efe 2010b).

Results and Discussion

The spatial distributions of pH values of rainwater samples were generally lower than the WHO (2010) threshold of 6.5 for potable water. Apart from stations in the northern Nigeria (Potiskum, Maiduguri, Kano, Sokoto and others) that had higher pH values above 5.6 threshold of normal rainwater, the other rainwater samples collected from the coastal area (Port Harcourt, Warri, and Lagos among others) down to the middle belt area of Bida, Abuja, Lokoja, and Kaduna- Jos plateau areas had pH values that were generally lower than the 5.6 pH values for normal rainwater (Figure 2). During the period of investigation, Nigeria had 5.36 mean pH value, this however span 4.96 in the Niger Delta region to 5.69 in Sokoto - Nguru area (Figure 2 and Table 1). The result showed a reduction of 0.73 in acid rain from the coast to the northern extremities. Thus, indicating widespread acid rain over the entire country where rainwater samples were harvested for this study (Figure 2). The 5.69 mean pH recorded in northern Nigeria indicate that these area had pH that conform to 5.60 of a normal rainwater, but however did not conform to 6.5 pH threshold of World Health Organization (WHO 2010) for potable water. The result is corroborated by Somboon (1997), Onianwa (2002), Omoleomo *et al* (2008) and Efe (2010) who opined that the widespread acid rain experienced in Nigeria most especially in the Niger Delta region could be ascribed to the rate of gas flare in the coastal belt of Nigeria. Other factors are the increased anthropogenic activities, industrial and fumes from increased fairly used cars and motor cycles among others in Kano, Sokoto, Maiduguri, Abuja, Lokoja, Lagos, Warri, Benin city and Port Harcourt.

The distribution of pH in rainwater indicate 5.36 mean pH value, and an increase of 0.5 pH values from the coast to the northern extremities of Nigeria (Table 1). The observed indicates about 10% reduction in acid rain from latitude 4^0N to latitude 14^0N of the equator. The given result corroborated Somboon (1997) and Efe (2010b) who confirmed the spatial distribution pattern of acid rain in Bangkok and Nigeria respectively.

The spatial pH distribution in Nigeria also corroborated the concept of acid rain, which state that acid rain depositions occurs downwind of areas where major emission of SO_2, CO_2, and NO_x from human activities take place (Oden, 1976; Botkin and Keller, 1998 and Efe, 2010b). And the distance decay concept, which state that the spread of activities decreases with increasing distance from the centre of activities. Thus the level of rainwater acidity increases from northern extremities to the coastal belt of Nigeria (Figure 2).

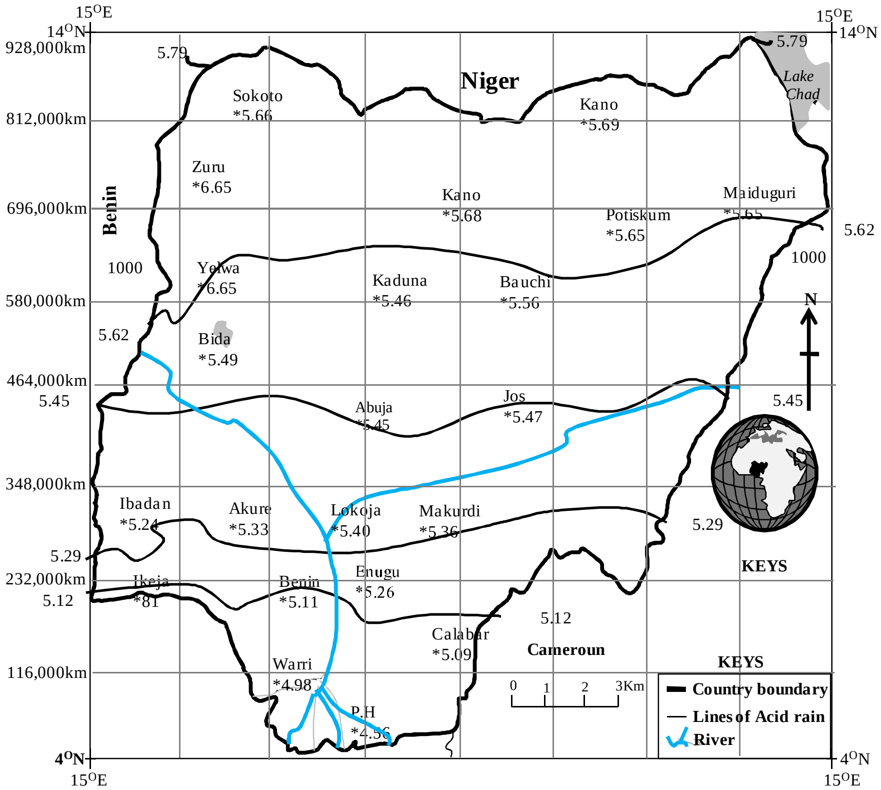

Figure 2: Map of Nigeria indicating rainwater collection points with corresponding recorded pH values

Table 1: Mean seasonal distribution of pH over latitudinal locations from flare sites

Months	Lat 5.4	Lat 6.8	Lat 8.2	Lat 9.6	Lat 11	Lat 12.4	Lat 13.8	Mean
January	4.95	4.97	5.23	5.45	5.49	5.65	5.46	5.31
February	5.01	5.09	5.56	5.46	5.49	5.65	5.54	5.4
March	4.98	5.06	5.33	5.4	5.56	5.65	5.34	5.33
April	4.98	5.09	5.36	5.36	5.53	5.68	5.5	5.36
May	5	5.11	5.47	5.46	5.47	5.47	5.67	5.38
June	5.08	5.14	5.5	5.51	5.5	5.6	5.6	5.42
July	5.12	5.19	5.22	5.23	5.22	5.22	5.62	5.26
August	5.06	5.16	5.32	5.35	5.36	5.36	5.56	5.31
September	5.33	5.39	5.4	5.4	5.42	5.46	5.69	5.44
October	5.25	5.33	5.35	5.4	5.41	5.35	5.64	5.39
November	4.99	5	5.08	5.35	5.55	5.65	5.6	5.32
December	4.9	4.91	5.02	5.31	5.52	5.67	5.46	5.26
Mean	5.05	5.12	5.32	5.39	5.46	5.53	5.55	5.35

Source: Fieldwork, 2011

The multiple regression analysis performed on latitudinal variation and pH level in rainwater samples revealed a standardized beta correlation (r) value of 0.97 (Table 2), indicating that latitudinal increase contributed 95% to the concentration of pH in rainwater. Such that as latitudes (distance) increases, pH concentration in rainwater increases, showing that acid rain decline with latitudinal increase in Nigeria, thus further confirming the concept of distance decay discussed earlier. The analysis of variance (F) value 914.975, which is greater than the critical F value 6.09 in Table 3, showed that acid concentration in rainwater resources from the coast to the north, varied significantly with latitudinal variation.

The seasonal variation of acid rain in Nigeria showed that the months of December had the lowest mean pH (5.29), while September had 5.44 pH values, indicating that rainwater in the months of December and September generally record the highest and lowest concentration of acid rain in Nigeria respectively (Table 1). The above corroborated (Efe 2006 and 2010) who observed higher pH values in rainwater samples collected during the wet months of September and July in the Niger Delta area of Nigeria.

Table 2: Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta	B	Std. Error
1	(Constant)	4.757	0.066		72.415	0.000
	Lat	0.062	0.007	0.973	9.397	0.000

a, Dependent Variable: pH

Similarly, the acidic concentration in rainwater harvested also varied with the duration of rainfall. Higher acidic concentrations were generally recorded in the first 5 minutes of rainfall and lowest at the end of the rain (Table 4 and Figure 3). The observation showed a mean pH values of 5.13>5.24>5.33>5.42>5.46 for rainwater at 5minutes, 10 minutes, 15 minutes, 20 minutes and >20 minutes of rainfall (Table 4). The increase in rain pH throughout a rain event was reported previously in rains in Bangkok, Thailand and in Warri and rural areas of Delta State, Nigeria (Somboon, 1997; Efe, 2005, 2006, 2010b). Decrease in acidity is attributed to acidic species being washed out of the atmosphere during rain events (Efe 2010b).

Table 3: ANOVA explaining the Variation in acid rain over latitude

Model	Sum of Squares	Df	Mean Square	F	Critical F	Remark
Between	.032	7	.005	914.975	6.09	Significant variation exist
Within	.000	4	.000			
Total	.032	11				

a Predictors: (Constant), lat13.8, lat9.6, lat8.2, lat5.4, lat12.4, lat11, lat6.8; b Dependent Variable: Mean

Table 4: Temporal variation in mean acid rain and estimated gas flares rate (BCM)

Years	**5mins**	**10mins**	**15mins**	**20mins**	**>20mins**	**Mean**	***Gas Flare rates (BCM)**
1997	4.99	5.01	5.25	5.39	5.48	5.224	29.41
1998	4.99	5.14	5.29	5.38	5.49	5.258	26.18
1999	5.01	5.15	5.29	5.38	5.43	5.252	24.61
2000	4.99	5.15	5.29	5.38	5.43	5.248	26.76
2001	5.03	5.18	5.31	5.37	5.45	5.268	27.01
2002	4.99	5.19	5.32	5.4	5.44	5.268	21.05
2003	5.12	5.19	5.35	5.4	5.45	5.302	24.26
2004	5.14	5.19	5.38	5.41	5.43	5.31	22.9
2005	5.16	5.22	5.38	5.42	5.43	5.322	21.56
2006	5.21	5.35	5.41	5.47	5.46	5.38	18.94
2007	5.21	5.36	5.41	5.43	5.46	5.374	18.6
2008	5.2	5.35	5.43	5.43	5.45	5.372	
2009	5.22	5.35	5.44	5.45	5.48	5.388	
2010	5.28	5.37	5.44	5.45	5.52	5.412	
2011	5.33	5.35	5.45	5.47	5.52	5.424	
Mean	**5.124667**	**5.236667**	**5.362667**	**5.415333**	**5.461333**	**5.320133**	

*The lower the pH value, the higher the acidity; Source: Authors' Fieldwork

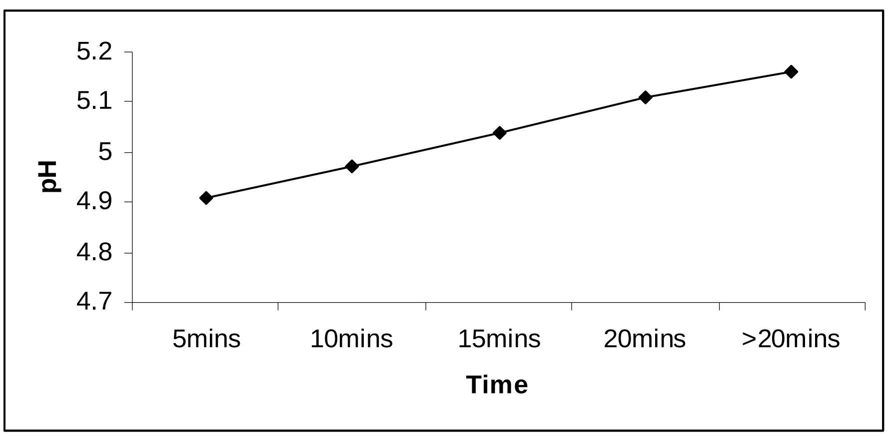

Figure 3: Temporal variation in acid rain, Nigeria

From Table 1 and Figure 4, the seasonal distribution of pH revealed a gradual decrease in acid rain from dry season to the peak of the wet season (September). This is evidence from mean pH values of 5.31 in January and 5.44 in September.

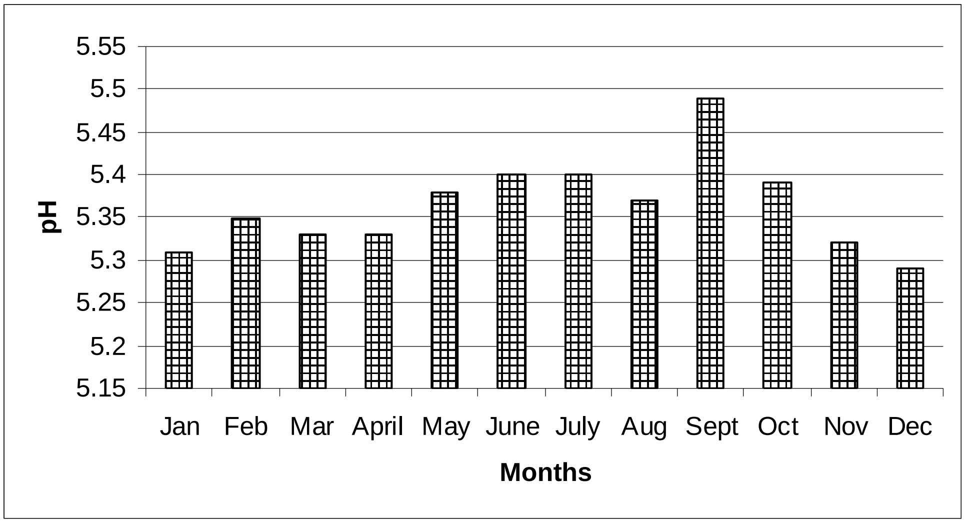

Figure 4: Seasonal variation in pH concentration in rainwater over Nigeria

The high level of acidity in rainwater could be ascribed to the influence of gas flares in Nigeria. This is because the years with high rate of flares had the lowest pH concentration in rainwater (Figure 5). For instance the highest gas flare (29.41BCM) was recorded in 1997, which also had the lowest pH 4.98 during the period of study. However with decline in flare rate over the years, there is a corresponding increase in pH over the country.

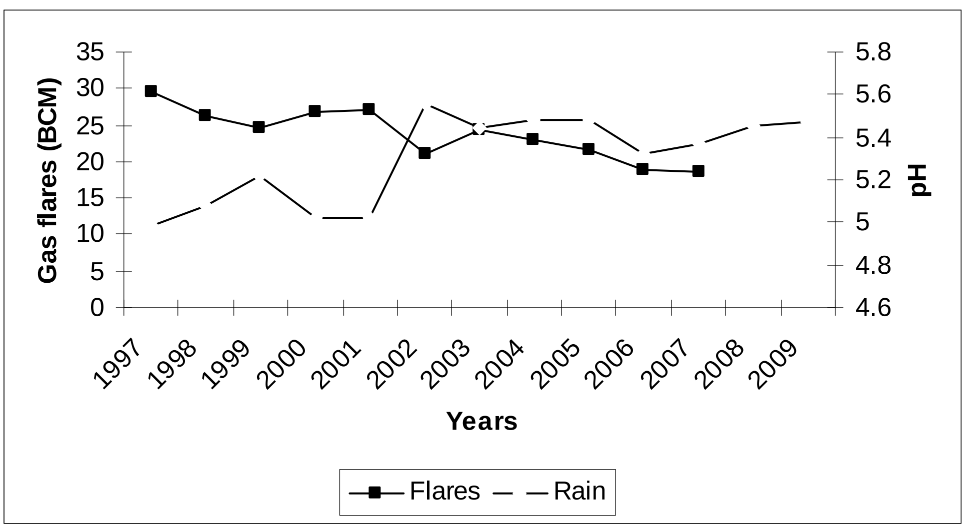

Figure 5: Mean distribution of gas flare and pH concentration in rainwater *BCM Billion cubic metres

Table 5 showed that acid rain has a strong inverse correlation with gas flaring (-0.80), indicating that as gas flaring increases, pH value decreases. And since lower pH indicate higher acid rain values, it showed that gas flaring is responsible for the occurrence of acid rain in Nigeria. Hence the higher the gas flare rate, the higher the occurrence of acid rain in Nigeria. This corroborated Somboon (1997) and Efe (2006, 2010b).

Table 5: Standardized Beta Coefficients (a) Explaining the relationship between acid rain and gas flares

	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations		
	B	Std. Error	Beta	Zero-order	Partial	Part	B	Std. Error
(Constant)	5.227	.044		117.674	.000			
Gas flares	-.007	.002	-.801	-4.007	.003	-.801	-.801	-.801

a Dependent Variable: pH

Ecological Implication of Acid Rain in Nigeria

The occurrence of acid rain in Nigeria has some implication on domestic water sources, vegetation and properties in Nigeria. The effects of acid rain on domestic water sources has been documented in Nigeria (Ogunkoya and Efi, 2003; Olobaniyi et al, 2007 and Efe and Mogborukor, 2008). For instance Efe and Mogborukor (2008) asserted that pH in rain, river, and open well water sources in Nigeria are generally low and there is low solute content in the region. Figure 6 showed the pH values in rain, river and open well water sources. The study revealed that pH values of rainwater, river water and open well water sources are 4.98 > 5.12 > 5.23, indicating mildly acidic rainwater, river water and open well water over Nigeria environment. And over 83% of 228 water samples for rain, well and river respectively had pH values below the lowest pH thresholds of 5.6 for rain water. It should be noted that The Target Water Quality Range (TWQR) for pH in water for domestic use is 6.5 (Efe and Mogborukor, 2008 and Efe, 2011). This made these water sources available to the residents of Niger Delta of Nigeria of low quality.

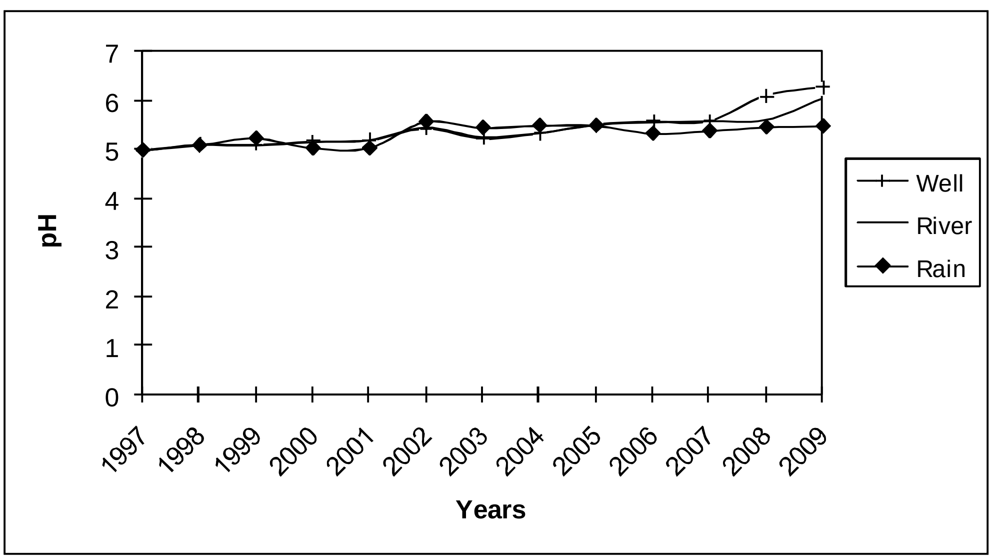

Figure 6: Mean distribution of pH in rain, hand dug wells and rivers in Nigeria

Similarly Ogunkoya and Efi (2003) and Olobaniyi et al (2007) opined that the acidic nature of rain, river and open well water sources in Nigeria causes corrosion of storage bowls, fetching bucket, tanks, borehole casing and plumbing fixtures in water distribution system. The acidic nature has also been associated with short life span of surface and submersible pumps used in the Niger Delta region. This corroborated the preliminary observation where over 75% of pumping equipment and hydro pneumatic tanks failed after 5 - 6 years of installation, thus reducing their useful age by 4 years (EPA, 2004), as well as failure of water distributing system i.e. pipes line, and hydro pneumatic tank valves. Also roofs are easily corroded, thereby impinging on the low quality of rainwater harvested in the region. As a result, demand for water is far greater than the supply. Similarly in spite of the alternative source of water supply via provision of boreholes made available by the oil companies in the oil rich Niger Delta, there is still acute shortage. The boreholes cannot go round the communities and apart, most of the boreholes and other water schemes are not functional and sustainable because of high level of acid, NO_4, Mg and Pb.

Similarly the acidification of the water sources led to productive failure in aquatic life. The eggs of fish species such as gold fish, salamonide, roach, and tilapia have reportedly been killed by high acidity. Amphibians that spawn in streams in the early wet season are unable to reproduce. Similarly, reduced Ca and increased Cd and Pb concentration in surface water as a result of acidification, result in deformed bone structures and poor growth in fish (Efe and Mogborukor, 2008 and Efe, 2010b). Consequently birds such as loons and osprey that predominate in the area and feed on fish are no longer found.

At the leaf surface, chlorosis and yellowing of leaves, wilting of the leaf tips, abscission of leaves and accelerated senescence was observed and, over the past thirteen years, more than 40% of tree and other plant species have been lost. The effects were most pronounced closest to the gas flaring sites where rain pH was lowest (pH 3.39) in most of the flare sites, Deleterious effects of acid rain on plants were reported previously (Jacobson, 1984, Neufeld et al 1985, Efe 2010b). Acid also damages roots and stems in addition to the leaves of plant. Such damage to plants is also an indirect threat to the microorganisms which decompose them, and subsequently the rest of the ecosystem. Jeffrey et al (1981) found application of simulated sulphuric acid to a number of crops resulted in decreased yield and growth and foliar injury. A decrease in the growth and yield of crops like cassava, sweet potatoes, maize, melon, plantain, rubber amongst others has also been reported in the area potentially due to effects from acid rain. The impact has invariably affected the socio economic life of the inhabitants of the oil producing communities in the agrarian communities (Jagtap, 2007). Acid rain has also affected soils by removal of essential nutrients leading to soil infertility in the region.

The cornea and mucous layer of the respiratory tracts are very sensitive to acid rain. Rates of acidosis, irritation of eye, conjunctivitis, bronchitis and prolonged coughing, and lung disease have been found around the gas flare sites, higher than in non oil producing regions of Nigeria (Asonye et al, 2004; Efe and Mogborokor, 2008). Health problems were previously linked to exposure to airborne acidity (Lippmannm 1985) and Keratoconjunctivitis was reported in a previous study among children in oil-producing industrial areas of Delta State, Nigeria where it was attributed to pollution in the area (Asonye et al., 2004). The high level of toxic heavy metals in fresh waters can also impact human health via consumption of birds and fish contaminated by exposure to the polluted waters.

According to Efe (2010b) the buildings and structures in Nigeria according to the residents have been decoloured and disfigured. Most landlords in the region asserted that they have to carry out routine repainting of their houses every two years because of decolouration by acid rain. Similarly, because of corrosion of the roofs most buildings in most of the area suffer leakages. Recent surveys found over 40% of houses in the region (especially those at the foci of the flare sites), leaking and roof repairs or replacement was carried out every three years (Alakpodia, 2000, and Efe, 2005). However, in the non oil producing region such repairs were required much less frequently. In addition most car owners in the region reported that their cars were regularly decoloured that they had to re-spray once every three to four years. The bottom plate and body of the car are usually affected by corrosion, leading to rust age, requiring annual body work on the car.

Based on the above environmental impacts of acid rain the study therefore recommends immediate enactment of legislation extinguishing gas flaring; alternatively it should be converted to industrial raw material for the production of domestic gases. There should be reduction of emission of acid gases. Acidified dug wells, rivers and other water bodies should be treated with lime to restore the pH to a level at which fish and other organism can survive. Rainwater harvested for domestic uses should be purified. All environmental laws for the protection of the environment should be implemented and periodic environmental impact assessment by both the oil company and the federal government of Nigeria should be carried out. The gas flaring operators should plough back part of their profits for the provision of social infrastructures in the region.

Conclusion

The study revealed a declining concentration in acid rain distribution from the coastal areas to northern Nigeria, with a mean pH of 5.36 in Nigeria. However 4.96 pH values were observed in the Niger Delta region where gases are being flared. Other southern states like Lagos, and Akure among others had pH of 5.06 in rainwater and northern areas recorded pH of 5.56, which confirmed the presence of acid rain. The level of rainwater acidity increases from the northern extremities to the coastal belt of Nigeria. This has not only affected other water sources, but also impacted negatively on plant and animals, as well as buildings.

References

Alber, R; J.S. Adams and P.R.Gould (1971), *Spatial Organisation: The Geographer's views of the World*. Englewood Cliff N.J.

Alakpodia I. J. (2000), The Environment of the Niger Delta in B.C. Uweru and J.O. Ubrurhe (ed) *Readings in General Studies, Nigerian People and Culture*, Warri, About Research Publisher. pp. 190-203

Asonye, C. C and E. R. Bello (2004), The blight of pollution keratoconjunctivitis among children in oil-producing industrial areas of Delta State, Nigeria. *Ecotoxicology and Environmental Safety*, Vol., 59(2), pp244-248

Cooper, R.N. (2000), International Approaches to Global Climate Change. *The World Bank Research Observer,* pp 145-170

Efe, S.I. (2005), Urban effects on precipitation amount, distribution and rainwater quality in Warri metrololis, Ph. D. Thesis Department of Geography and Regional Planning, Delsu – Abraka, pp. 10-103

Efe, S.I. (2006), Quality of rainwater harvesting for rural communities of Delta State, Nigeria. *Environmentalist* 26; pp 175-181

Efe, S. I. (2009), Climate Change and Food Security in African: Delta State Nigeria Experience, In Anyadike, R. N. C., Madu, L.A. & Ajaero (ed.) Proceedings on Climate Change and the Nigerian Environment Conference, 29 June – 2nd , July, 2009, University of Nigeria, Nsukka, Nigeria, pp 105-126

Efe, S. I. (2010a), Environment and Sustainable Development: the case of Climate Change and Flood hazards in The Niger Delta Region of Nigeria, Proceedings, International Conference on Natural Resource, Security and Development in the Niger Delta, March 8-11, 2010, Niger Delta Wetlands Center, Yenagoa, Bayelsa State, Nigeria

Efe, S. I. (2010b), Spatial variation in acid and some heavy metal composition of rainwater harvesting in the oil producing region of Nigeria. *Natural* Hazard, DOI10.1007/s11069-010-9526-2

Efe, S. I. (2011), Climate Change and Environmental Degradation: The Case of Acid Rain in Nigeria, Proceedings, The 52nd annual conference of the Association of Nigerian Geographers, 14-17th February, 2011, Usmanu Danfodiyo University, Sokoto, Nigeria

Efe, S. I. and Mogborukor J.O.A. (2008), Acid rain in the Niger Delta region: Implication on Water Resource Crises, Proceedings, International Conference on the Nigerian State, Oil industry and the Niger Delta, 11-13th March, 2008, Glory land Cultural Centre, Yenagoa, Bayelsa State, Nigeria

Botkin, D.B. and Keller, E.A. (1998), *Environmental Science*, *Earth as a Living Planet* (2nd ed.), John Wiley and Son Inc., New York

Intergovernmental Panel on Climate (IPCC) 2001, The report of working Group 1 of the Intergovernmental Panel on Climate Change, Survey for policymakers

Intergovernmental Panel on Climate (IPCC) 2007, *Climate change 2007: The fourth assessment report (AR4). Synthesis report for policy makers*, http: www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf. (Accessed September 23, 2010)

Jacobson, J. S. (1984), Effect of Acidic Aerosol, fog, Mist and Rain on Crops and Trees, *Phill. Trans. Roy. Soc. Lond*. B 49: pp. 327-338

Jagtap S 2007, Managing vulnerability to extreme weather and climate events: Implications for agriculture and food security in Africa, *Proceedings of the International Conference on Climate Change and Economic Sustainability,* 12-14 June 2007, Nnamdi Azikiwe University, Enugu, Nigeria

Jeffrey J. Lee, Grady E. Neely, Shelton C. Perrigan and Louis C. Grothaus (1981), Effect of simulated sulfuric acid rain on yield, growth and foliar injury of several crops. *Environmental and Experimental Botany* Vol. 21(2), p 171-185

Last, F.T. and Whathing, R. (1991), *Acidic Deposition: Its Nature and Impacts*. Edindurgh, the Royal Society of Edindurgh

Likens, G.E., Bormann, F.H. and Johnson, N.M., 1972, Acid rain, Environment, 14, pp 33-40

Lippmann, M (1985), Airborne acidity: estimates of exposure and human health effects. *Environ . Health, Perspect*, 63, pp. 63-70

Neufeld, H. S.; J. A. Jernstedt and B. L. Haines (1985), Direct Foliar Effects of Simulated Acid Rain, I. Damage, Growth and Gas Exchange *New Phytologist,* Vol. 99, No. 3 pp.389-405

Nekola, J. C. and White, P. S. 1999, The distance decay of similarity in biogeography and ecology, J. Biogeogr. 26: pp 867-878

Odén, S., 1968, The acidification of air and precipitation and its consequences in the natural environment. *Ecology Committee Bulletin*, No. 1, Swedish National Science Research Council, Stockholm

Oden, S. (1976), The Acidity Problem – An Outline of Concepts *Water, Air and Soil Pollution*. 6: pp 137-166

Ogunkoya, O.O. and Efi, E.J. (2003), Rainfall quality and sources of rainwater acidity in Warri area of the Niger Delta, Nigeria, *Journal of Mining and Geology*, 39 (2), pp 125-130

Olobaniyi, S.B.; Ogban, F.E.; Ejechi, B.O. and Ugbe, F.C. (2007), Quality of Groundwater in Delta State, Nigeria *Journal of environmental Hydrology* 15: pp 1-9

Omoleomo O. Omo-Irabor, Samuel B. Olobaniyi, Kehinde Oduyemi, Joseph Akunna (2008), Surface and groundwater water quality assessment using multivariate analytical methods: A case study of the Western Niger Delta, Nigeria. *Physics and Chemistry of the Earth* 33 (2008), pp 666-673)

Onianwa P.C, Odukoya OO, Alabi H. A. (2002), Chemical composition of wet precipitation in Madan, Nigeria. , *Bulletin of the Chemical Society of Ethiopia.* 16(2), pp 41-147

Pickering, K.T. and Owen, L.A (1994), *An Introduction to Global Environmental Issues,* Butter and Tanner Ltd., Great Britain

Seip, H. M. (2001), Acid rain and climate change – Do these environmental problems have anything in common? *Cicerone 6:2*

Somboon, W. (1997), *Acid and some Heavy Metal Composition of Rain in Bangkok Thailand:* Research in the Faculty of Science, King Mongkut Institute of Technology. Thomburi Bangkok, Thailand

Shell Petroleum Development Corporation (SPDC) (1995), *Nigeria Brief note on the Environment and Community Relatio*n, May 1995

Spore 2008, *Climate change*, Special Issue August: 23

Tripatly, S.N. and Panda, S. (1999), *Fundamental of Environmental Studies*, Dech, New A.S. Offset

Tobler, W. R. 1970, A computer movie simulating urban growth in the Detroit region, Econ. Geogr. 46, pp 234-240

United States General Accounting Office (USGAO) (2000), Acid Rain Emissions: Trends and Effects in the Eastern United States a Report to Congressional Requesters *GAO/RCED-00-47* March 2000

World Health Organization (WHO) (2010), International Standard for Drinking Water and Guidelines for Water Quality, Geneva

Hydraulic Conductivity and Infiltration of Soils of Tropical Rain Forest Climate of Nigeria

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Abstract

Hydraulic conductivity (K_θ) is the single most important hydraulic parameter for flow and transport-related phenomena in soil. In this study, the effects of soil moisture contents, soil bulk density (BD), total porosity (PT), soil water holding capacity (WHC), organic matter content, and cation exchange capacity (CEC) on hydraulic conductivity of various sized aggregates of horizon A (0 – 20 cm soil layer) in five major cities (Ibadan, Ife, Akure, Owo and Ado-Ekiti) of the tropical rain forest zone of Nigeria was investigated. Hydraulic conductivity was determined by a steady-state flow using an infiltration device (mini-disk infiltrometer). Suction rates of 2 cm s^{-1}, 3 cm s^{-1}, and 4 cm s^{-1} were chosen at different locations on the fields for the infiltration measurement and subsequent estimation of soil hydraulic conductivity. At 2 cm s^{-1} suction rate, the mean value of K_θ ranged from 0.0022 ± 0.001 cm s^{-1} to 0.00071 ± 0.0004 cm s^{-1}. The highest and lowest mean bulk densities 1.5 g cm^{-3} and 1.33 g cm^{-3} were observed in soils of Ife and Akure, respectively. Similarly, mean total porosity values ranged between 0.44 cm^3 cm^{-3} and 0.5 cm^3 cm^{-3}. Statistical relationship between the total porosity and hydraulic conductivity gave a high correlation coefficient, r = 0.94 at $p < 0.05$. The correlation coefficient (r) between water holding capacity and hydraulic conductivity was 0.95. Results shows that Soil physical properties such as bulk density, total porosity and water holding capacity affect water infiltration characteristics of soils of the study area.

Keywords: Hydraulic conductivity, Infiltration, Total porosity, Bulk density, Nigeria

Introduction

Hydraulic conductivity (K_θ) is defined as "the metres per day of water seeping into the soil under the pull of gravity or under a unit hydraulic gradient" (Kirkham, 2005). It is governed by two forces, gravity, and capillary action (Kostiakov 1932). Cumulative Infiltration (I) is the total amount of water that enters into soil (Angelaki et al., 2004). Hydraulic conductivity and Cumulative infiltration of water are two interrelated parameters. Knowledge of hydraulic conductivity is very important in solving environmental problems because it is one of the most important soil physical properties for determining infiltration rate, irrigation and drainage practices, and other hydrological processes (Gulser and Candemir, 2008). It is an important soil property when evaluating the potential use of soil for many agricultural and non agricultural uses (Chakravorty et al., 1998-99). Hydraulic Conductivity is also useful in controlling water infiltration and surface runoff, leaching of Pesticides from agricultural lands and migration of Pollutants from contaminated sites to the groundwater (Bagarello and Sgroi, 2007).

Infiltration on the other hand is extremely important, because it determines not only the amount of water that will enter a soil, but also the entrainment of the "passenger" chemicals (nutrients, pollutants) dissolved in it (Kirkham, 2005). It also controls leaching, runoff, and crop water availability (Franzluebbers, 2002). Infiltration and evaporation are the most significant processes determining soil water storage (Lampurlanés and Cantero-Martínez, 2005). In saturated soils, the hydraulic conductivity is represented as K_{sat} and is the ease or ability in which water moves through a soil column when all pores are full of water, or conducting water (Reynolds, 1993; Lal and Shukla, 2004) while in unsaturated soils, the hydraulic conductivity is represented as K_{θ}. Under saturated conditions, continuous water phase and maximum conductivity is allowed because all of the pores are water-filled and conducting water (Hillel, 1998). Flow through an unsaturated soil is more complicated than flow through continuously saturated pore spaces. Macropores which are defined as soil pores greater than 1.0 mm (Luxmoore, 1981) are filled with air, leaving only finer pores to accommodate water movement. The movement of water in unsaturated soils is dictated by differences in matric potential, not gravity. The matric potential gradient is the difference in the matric potential of the moist soil areas (high matric potential) and nearby drier areas (low matric potential) into which the water is moving (Brady and Weil, 1999). Coarse-textured and well-aggregated soils are more conductive than clayey soils because of the large pore spaces (Halfmann, 2005). However, movement of the soil from a saturated state to an unsaturated state sharply decreases the hydraulic conductivity. As suction develops, the largest pores (the most conductive pores) are the first to empty, thus transferring flow to the smaller pores (Hillel, 1998). Water could be found along pore walls and may not have a continuous path; therefore, disrupting flow by causing "air" barriers. Water will flow as film creep along the walls of wide pores or as tube flow through narrow waterfilled pores (Hillel, 1998). The hydraulic conductivity of coarse-textured soils and/or well-aggregated soils will decrease more rapidly than fine-textured soils (Lal and Shukla, 2004).

Hydraulic conductivity depends on physical characteristics of soil such as the intrinsic permeability (soil or fractures), the degree of saturation, the type of soil, bulk density, total porosity and the configuration of the soil pores. It is influenced by the properties of the fluid being transmitted (such as viscosity) as well as the porous medium. The interpretation of these physical characteristics of soil and the management of agricultural practices requires assessment of the hydraulic properties of soil, such as infiltration and sorptivity (Green et al., 2003). Pore size and continuity are also important to the hydraulic conductivity of soils. Pore continuity or better-connected pores help increase infiltration (Ankeny et al., 1990). If soil moisture increases, soil pores may expand in soils with high organic matter content (Tsuboyama et al., 1994). It is well known that infiltration of water and chemicals in many field soils is enhanced by macropores (Logsdon and Jaynes, 1996; Mohanty et al., 1997, 1998; Shouse and Mohanty, 1998). Thus, the spatial variation, size, and interconnectedness of biological and structural macropores would play a key role in determining the rate of influx through soils (Das Gupta et al., 2006). Furthermore, Macropores and earthworm and decaying root channels vastly increase the amount of water that will infiltrate the soil (Fuentes et al., 2004). Hydraulic conductivity generally decreases according to soil textural class as follows; sandy soil > loamy soil > clay soil (Ozdemir, 1998). Increases sand and silt content in soil texture generally increase soil bulk density (Hillel, 1982) and decreases total porosity, but increases ratio of macro porosity in total porosity (Gulser and Candemir, 2008).

Hydraulic conductivity may change as water permeates and flows in a soil due to various chemical, physical and biological processes (Gulser and Candemir, 2008). Some soil physical characteristics which affect hydraulic conductivity are the total porosity, the distribution of pore sizes, and the pore geometry of the soil (Hillel, 1982). Several studies have been conducted in the past to study the spatial and temporal variations of saturated hydraulic conductivities, with contrasting results. Cassel and Nelson (1985) demonstrated a large temporal variation in saturated hydraulic conductivities at different depths in a laboratory soil column. Few independent spatial (Mohanty et al., 1994) or temporal (Lin et al., 1998) variability studies have been conducted for unsaturated hydraulic conductivity parameters. Messing and Jarvis (1993) and Logsdon and Jaynes (1996) investigated the temporal variations in unsaturated hydraulic properties due to agricultural operations (Das Gupta et al., 2006). According to Messing and Jarvis (1993) studies to monitor the spatiotemporal variations of both saturated and unsaturated hydraulic parameters in a plowed and unplowed plots in a clay soil, strong temporal trends in unsaturated hydraulic conductivity values that resulted from changes in the climatic conditions as well as tillage practices were observed (Das Gupta et al., 2006). Logsdon and Jaynes (1996), states that unsaturated hydraulic conductivity variability reflected the evolution in micropores with tillage. The saturated hydraulic conductivity values did not show consistent temporal variations, but were more spatially correlated. They attributed this phenomenon to the influence of macropores, which were unstable due to tillage, shrink– swell phenomena, and root activities (Das Gupta et al., 2006). Lin et al. (1998) observed that the spatial variability of unsaturated hydraulic conductivity at low soil water tension could be related to soil macropore distribution in Vertisols and vertic intergrades (Das Gupta et al., 2006). They also noticed marked temporal variations of unsaturated hydraulic conductivity and saturated hydraulic conductivity values during a 3-month period between August and October 1997. They attributed this behavior to the shrink–swell characteristics of the clay due to the variations in precipitation during the measurement period (Das Gupta et al., 2006). Hydraulic conductivity can be influenced by seasonal changes. As the growing season progresses, hydraulic conductivity can decrease because of increased root growth clogging pores, soil slaking, and a breakdown of structure in tilled soils (Lampurlanés and Cantero-Martínez, 2005).

Because of its high natural spatial and temporal variability, hydraulic conductivity is often a poor indicator of soil hydraulic response to management practices because natural variability often obfuscates treatment variability therefore robust estimates of soil hydraulic parameters are needed to differentiate management effects and spatial variability with statistical significance (Strudley et al, 2008) and also to properly characterize the spatial variability of soil parameters. Considering these importance of hydraulic conductivity, the research was aimed at to determining infiltration, water retention characteristic and hydraulic conductivity of soils in the tropical rainforest of Nigeria.

Materials and Methods

Description of Study Areas

The study was conducted in the Humid Sub-tropical Climate of Nigeria. This climate is influenced by the monsoons originating from the South Atlantic Ocean, which is brought into the country by the (maritime tropical) MT airmass. The Tropical rainforest has a very small temperature range; the temperature ranges are almost constant throughout the year. The southern part of Nigeria experiences heavy and abundant rainfall. The storms are usually conventional in making, due to the region proximity, to the equatorial belt. The annual rainfall received in this region, is very high, usually above the 2000 millimeters rainfall giving for tropical rainforest climates worldwide. More than half of humid zone of Nigeria is covered by pre-cambrian basement complex. Five locations were chosen within the southwestern part of Nigeria for the experiment and they include Akure (Ondo state), Ibadan (Oyo state), Ife (Osun state), Owo (Ondo state), and Ado (Ekiti state).

Akure, (latitude $7^0$14'N and longitude $5^0$08'E) is located within the humid region of Nigeria. Akure lies in the rain forest zone with a mean annual rainfall of between 1300 – 1600 mm and with an average temperature of 27^0C. The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. Akure is about 351 m above the sea level. Akure is an area of about 2,303 km^2, situated within the western upland area (Fasinmirin and Oguntuase, 2008). Ibadan, (latitude $7^0$23'47'N and longitude $3^0$55'0'E) is 1,189.2 sq mi (3, 080 km^2) in area with a density of 2, 144.5/sq mi (250/km^2). Ibadan has a tropical wet and dry climate, with a lengthy wet season and relatively constant temperature throughout the course of the year. The wet season runs from April through October, though August sees somewhat of a lull in precipitation. The remaining months forms the dry season. Ibadan experiences the Harmattan between the months of November and February. It has an average temperature of 26.5^0C and relative humidity of 81%. The average rainfall is about 1,316 mm. the city ranges in elevation from 150 m in the valley area to 275 m above sea level on the major north-south ridge which crosses the central part of the city. Ile-Ife is also located within the humid region of Nigeria. Total annual rainfall of Ile-Ife is about 1350 mm. The average daily minimum temperature ranged between 20 ^{0}C and 22 ^{0}C, and the average maximum temperature between 27 ^{0}C and 35 ^{0}C (Osunbitan et al., 2005). Ife lies at the intersection of roads from Ibadan (40 miles [64 kilometer] west), Ilesha, and Ondo. Owo lies within latitude 7˚11'N and longitude 5˚35 'E. Mean annual rainfall is between 1000 mm and 1400 mm, most of this being recorded in the months of April to September. The heaviest rains in Owo come in May/June and September/October. Owo is in southwestern Nigeria, at the southern edge of the Yoruba Hills, and at the intersection of the roads from Akure, Kabba, Benin city and Siluko. Ado Ekiti, (latitude $7^0$37'N and longitude $5^0$15'E) is the capital of Ekiti state in the southwest Nigeria. The mean annual rainfall is about 1600 mm with a temperature range of 23^0C to 34^0C and the relative humidity ranges between 48 and 100%.

Field Experimentation and Soil Sampling

Field experiments were conducted from February to May, 2011. It includes the determination of the soil's infiltration rates, moisture content, soil temperature, air temperature and relative humidity of the sites. Soil samples were collected from soil profiles at three different points, approximately 200 m apart within the 0 - 20 cm soil layer (horizon A). The soil sampling was conducted at the five different locations in the tropical rainforest zone of Nigeria. The samples were packed in plastic bags, and transferred to the laboratory and allowed to dry in the open air until reaching friability.

Physical-chemical Characterization of Soils

The chemical characterization of the various soil sample collected from all the locations includes the analysis of organic matter content, Cation Exchange Capacity (CEC) at pH 7.0, soil pH and base saturation whereas the physical characterization consisted of particle size analysis, water holding capacity, particle density, bulk density and total porosity determination. The percentage Nitrogen, extractable Phosphorus and exchangeable Potassium (K^+) was extracted with HCl solution and their levels determined by flame photometry. The cation exchange capacity (CEC) at pH 7.0 with Ammonium Acetate was determined following the procedure described by Chapman (1965). Soil particle sizes were determined by the pipette method using the ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils. Textural classification was carried out using the USDA classification system. The bulk density (BD) was obtained by the gravimetric soil core method described by (Blake and Hartage, 1986) using a 5.0 cm long by 7.1 cm diameter cylindrical metal core and the particle density (PD) was assumed to be 2.65 g cm^{-3}. The total porosity (PT) was calculated from BD and PD using the equation and relationship developed by Danielson and Sutherland (1986).

$$\text{Total Porosity} = \frac{1 - \text{Bulk density (g cm}-3)}{2.65 \text{ g cm}-3} \tag{1}$$

The organic matter content (OMC) was determined using the ASTM D 2974 – Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Organic Soils.

Soil moisture content (MC) was recorded during infiltration using a hand-held digital soil moisture meter - Lutron PMS-714; IP- 65 water resistance, heavy duty ranging from 0-50% moisture content with a 7.9" SS probe supplied by Lutron Electronic Enterprise Co., Ltd. Measurement were taken at 5cm, 10cm, 15cm, and 20cm depth respectively at the experimental sites. Soil temperature (ST) was measured using the Soil digital thermometer DTM-307 supplied by Tecpel Co., Ltd., Taiwan. Tecpel soil digital thermometer has temperature sensors that make measurement precise. Soil temperature is measured by inserting the two sensors into the soil and recording the corresponding temperature values. The relative humidity (RH) and air temperature (AT) of the experimental sites during this research was measured using the Lutron LM-8000 pocket environment anemometer.

The Hydraulic conductivity test was carried out using the mini–disk infiltrometer made by Decagon Devices (Pullman, Washington). It consists of a plastic tube, 22.5 cm long and 3.1 cm in outside diameter, marked with milliliter gradation (0 to 100 mL), a rubber stopper placed in the top, and a styrofoam-looking base that holds the tension. One-half centimeter above the base is an air-inlet tube. The infiltrometer is constructed of a polycarbonate tube with a semi-permeable stainless steel sintered disk (4.5 cm diameter, 3 mm thick) at set suctions of 0.5 cm and 7.0 cm with a radius of 1.55 cm. Suction rates of 2cm, 3cm, and 4cm per seconds were chosen at different points on the field for the infiltration measurement, which was recorded every 30 seconds for the duration of the experiment. The different suction rates were chosen for better accommodation of infiltration measurement for the different soil types. Data collected were used to calculate the water infiltration rates of the soil.

The hydraulic conductivity of soil was calculated using the method of Zhang (1997), which works well for measurements of infiltration into dry soil. The method requires measuring cumulative infiltration against time and fitting the results with the function:

$$I = C_1 t + C_2 \sqrt{t} \qquad (2)$$

where C_1 (m s^{-1}) and C_2 (m $s^{-1/2}$) are parameters. C_1 is related to hydraulic conductivity, and C_2 is the soil sorptivity.

The hydraulic conductivity of the soil (K_θ) was computed using the relationship

$$K_\theta = \frac{C_1}{A} \qquad (3)$$

where C_1 is the slope of the curve of the cumulative infiltration vs. the square root of time, and A is a value relating the van Genuchten parameters for a given soil type to the suction rate and radius of the infiltrometer disk. A is computed from:

$$A = \frac{11.65\left(n^{0.1}-1\right)\exp[2.92(n-1.9)\alpha h_0]}{(\alpha r_0)^{0.91}} \qquad n \geq 1.9 \qquad (4a)$$

$$A = \frac{11.65\left(n^{0.1}-1\right)\exp[7.5(n-1.9)\alpha h_0]}{(\alpha r_0)^{0.91}} \qquad n□1.9 \qquad (4b)$$

where n and α are the van Genuchten parameters for the soil, r_0 is the disk radius, and h_0 is the suction at the disk surface.

Statistical Analysis

The slope of the curve of the cumulative infiltration vs. the square root of time was determined using a Basic Microsoft Excel spreadsheet macro created by Decagon (Decagon Devices, 2007). Soil properties for the different locations were compared using a one way analysis of variance ANOVA and the existence of inter-relationships between data set was tested by linear correlation and the correlation coefficients using statistical package for social sciences (SPSS). Hydraulic conductivity was subjected to statistical analysis to determine the mean, standard deviation, coefficient of variation among soil samples from different locations.

Results and Discussion

Weather Conditions of the Project Locations

The mean maximum soil temperature during the period of the experiment was recorded in Ado (41.9°C), while Ibadan site has the mean minimum soil temperature (29.1°C). The mean soil temperature of Ife is equally high. This might have contributed to the cycle of wetting and drying of the soil and indirect increases in soil bulk density with time. The mean air temperature ranged from 39.2°C to 28.5°C with Ife and Akure having the highest and the lowest values respectively. Ibadan has the maximum relative humidity (66.8%) while Ado has the minimum relative humidity (41.8%). The relative humidity influences the rate of evapotranspiration which in turn affect the soil moisture content. Ambient relative humidity (RH) or the water potential is one of the most important factors that affect the water content and the wettability in surface soil (Doerr et al. 2002; Goebel et al. 2004).

Table 1: Mean maximum and minimum soil temperature (Ts), air temperature (Ta), and relative humidity (RH) of horizon A of the experimental sites.

Location	Ts (°C)		Ta (°C)	RH (%)	
	Max	Min		Max	Min
Ado	41.9 ± 4.24	39.6 ± 3.59	37.5 ± 6.84	41.9 ± 13.52	41.8 ± 13.54
Akure	30.5 ± 6.09	29.8 ± 5.69	28.5 ± 2.89	72.6 ± 8.63	72.3 ± 8.71
Ibadan	29.9 ± 2.49	29.1 ± 2.41	29.9 ± 2.38	66.8 ± 10.15	66.6 ± 10.18
Ife	38.6 ± 3.62	37.8 ± 4.04	39.2 ± 10.47	50.3 ± 22.54	50.2 ± 22.53
Owo	33.4 ± 5.89	33.1 ± 5.89	33.4 ± 3.82	55.2 ± 15.06	55.0 ± 15.06

Physical and Chemical Properties of Sampled Soils

Table 2 shows the result of particle size composition of the collected soil samples. There was little variation in the percentages of sand, silt, and clay among the collected soil samples. According to the USDA classification system, the soil samples collected at the Akure, Ibadan, and Owo sites are predominantly Sandy clay loam while those of Ado and Ife are loam and Sandy loam respectively. Akure has a slightly higher sand content (68.16%) than the others, as well as the lowest silt (10.35%) content. Ado has the lowest sand content (53.68%) and the highest silt (28.32%) content respectively. Ado and Ibadan have the highest clay content (24.33% and 24.32%) while Ife has the lowest clay (14%) content.

Table 2.Textural classifications of soil of the experimental sites.

Location	Sand %	Silt %	Clay %	USDA Textural Class
Ado	53.68	28.32	18	Loam
Akure	68.16	10.35	21.49	Sandy clay loam
Ibadan	59.68	16	24.32	Sandy clay loam
Ife	59.68	26.32	14	Sandy loam
Owo	55.67	20	24.33	Sandy clay loam

The mean percentage organic matter content (OMC) of sites of experiment are 1.45 (±0.08), 1.12(±0.17), 0.58(±0.33), 1.51(±0.48) and 3.29 (±0.38) for Ado, Akure, Ibadan, Ife and Owo, respectively (Table 3). The organic matter content (OMC) was above 3% in Owo with a value of 3.22%, which is the highest value recorded. Ibadan has the least OMC value of 0.58%. Least significant difference (LSD) test conducted on the mean OMC between Ado and Akure soils, Ado and Ife soils, Akure and Ibadan soils, and Akure and Ife soils showed no significant difference at p = 0.05 (Table 4). However, the difference in OMC between Ado and Ibadan soils, Ado and Owo soils, Akure and Owo soils, Ibadan and Ife soils, and Ife and Owo soils is significant at p = 0.05. The differences in mean OMC observed between the different locations may have been caused by both the slightly different textural classes of soils and the levels of residue cover on sampled soils. The highest soil pH value of 6 was observed in Owo and the lowest pH of 5.2 was obtained in Ado. Generally, the CEC at pH 7.0 for all the sites ranged from 3.22 to 0.63 $cmol_c\ kg^{-1}$. Owo which has the highest organic matter content was found to have the highest soil pH and CEC (Table 3). This agrees with the works of Bayer and Bertol (1999) and Vogelmann et al., (2010) who reported that soil samples with higher values of CEC were found to have high levels of organic matter and pH. The high organic matter content of Owo soil might also be due to the high clay content of the sampled soils at Owo and this conforms to the findings that as clay contents increases soil organic matter increases (FAO, 2005). The exception observed in soil samples at Ibadan might have occurred due to the low value of CEC.

Sampled soils collected at Ife equally agree with Bayer and Bertol (1999) and Vogelmann et al., (2010) with CEC and organic matter content of 1.96 $cmol_c\ kg^{-1}$ and 1.51%, respectively. Soil samples from Ibadan exhibited the least CEC and organic matter content, the least percentage nitrogen (0.63%) and exchangeable potassium (0.1 $cmol_c\ kg^{-1}$) but the highest extractable phosphorus (85.61mg kg^{-1}). Ado which has the lowest soil pH also has the lowest extractable phosphorus of 6.71 mg kg^{-1}; this is because Phosphorus availability is strongly influenced by soil pH as reported by Mullen (2009). Availability of Phosphorus is maximized when soil pH is between 5.5 and 7.5 (Mullen, 2009).

Table 3: Means of organic matter content, soil pH, CEC at pH, percentage nitrogen, extractable phosphorus and exchangeable potassium.

Location	OMC (%)	pH	CEC ($cmol_c kg^{-1}$)	N (%)	P (mg kg^{-1})	K ($cmol_c\ kg^{-1}$)
Ado	1.45(±0.08)	5.20(±0.56)	1.47(±0.11)	0.13(±0.03)	6.71(±0.18)	0.15(±0.11)
Akure	1.12(±0.17)	5.34(±0.88	1.71(±0.19)	1.40(±0.14)	16.93(±0.25)	0.58(±0.06)
Ibadan	0.58(±0.33)	5.60(±0.58)	0.63(±0.18)	0.11(±0.03)	85.61(±0.15)	0.10(±0.18)
Ife	1.51(±0.48)	5.80(±0.30)	1.96(±0.24)	0.14(±0.02)	32.31(±0.07)	1.36(±0.47)
Owo	3.29(±0.38)	6.00(±0.21)	3.22(±0.24)	0.18(±0.03)	31.47(±0.13)	0.26(±0.65)

Table 4: Multiple comparisons of mean OMC of the study areas (LSD test at p = 0.05)

Locations		OMC mean difference	Std. Error	Sig.
I	j	i – j		
Ado	Akure	0.33	0.263	0.24^{ns}
	Ibadan	0.87	0.263	0.01*
	Ife	0.06	0.263	0.82^{ns}
	Owo	1.84	0.263	0*
Akure	Ibadan	0.54	0.263	0.07^{ns}
	Ife	0.39	0.263	0.17^{ns}
	Owo	2.17	0.263	0*
Ibadan	Ife	0.93	0.263	0.01*
	Owo	2.71	0.263	0*
Ife	Owo	1.78	0.263	0*

* The mean difference is significant at the 0.05 level
ns – Not significant.

The mean values of soil moisture content at different soil depths and the trend showing their variations from one location to another is presented in Table 5 and Fig. 1 , respectively. The 0 - 5 cm depth had the lowest soil moisture, while the 15 - 20 cm depth has the highest soil moisture. It shows that the soil moisture content increase with depths. This is in agreement with work of Halfmann, (2005) who also noted that soil moisture increases with depth and that there was a significant increase in soil moisture at the 5-10 cm depth. Soil moisture of all the sites varied according to the seasonal distribution of both rainfall and air temperature and this influenced the hydraulic conductivity as high values were obtained in drier soils than in the wetter soils (Bagarello and Sgroi, 2007). The effects of initial water content on infiltration are also well known qualitatively (Philip 1957a, 1969).

Table 5: Means of soil moisture contents at different depths.

Mean moisture contents (%)				
	Depths (cm)			
Location	0 - 5	5 - 10.	10 - 15.	15 - 20.
Ado	5 ± 2.24	8.7 ± 1.02	10 ± 1.52	10.3 ± 2.37
Akure	2.6 ± 3.61	6.3 ± 4.36	8.1 ± 5.43	10 ± 6.17
Ibadan	4.2 ± 2.71	6.2 ± 2.91	8.1 ± 1.56	10 ± 2.4
Ife	4.7 ± 3.08	6.2 ± 3.37	7.6 ± 1.8	8.5 ± 1.43
Owo	3.3 ± 1.87	5.6 ± 2.84	7.3 ± 2.42	9.2 ± 2.58

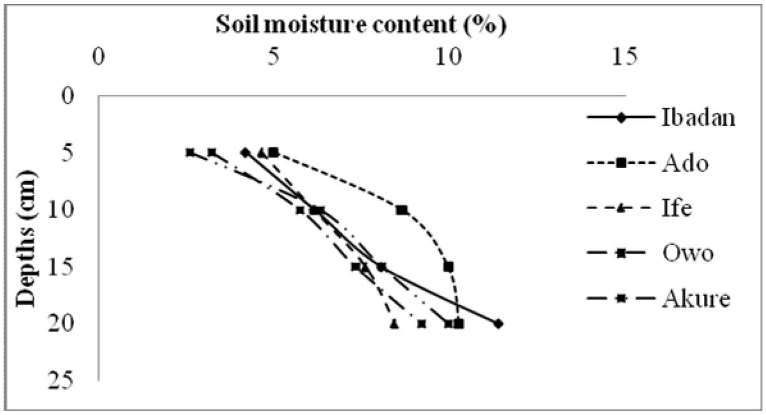

Fig. 1: Soil moisture variation with depths at the sites of experiment

The results of bulk density, total porosity, water holding capacity and soil moisture content are shown in Table 6. The bulk density ranges between 1.5 g cm^{-3} to 1.33 g cm^{-3}. Ife with a sandy loam texture has the highest mean bulk density; this must have been due to the successive rainfall observed towards the final stage of the experiment. This is in conformation with the findings of Fohrer et al. (1999) who reported that soils with low antecedent moisture content were more susceptible to compaction under rainfall. Osunbitan et al. (2005) suggested that high rainfall in combination with cycles of wetting and drying of soil may be responsible for the general increase in soil bulk density with time. The high bulk density values at Ife and Ado could also be due to increase in sand and silt contents of their soil, which according to Hillel, (1982) generally increase soil bulk density.

The total porosity varies from 0.44 cm cm^{-3} to 0.5 cm cm^{-3} with Ife having the lowest while Ibadan and Owo have the highest values. This shows an inverse relationship between the bulk density and the total porosity of soils of the various experimental sites as shown in Fig. 2 (a) and (b). This observation agrees with the works of Vogelmann et al., (2010), Kay and Angers (2002), Gantzer and Anderson (2002) and Ringrose-Voase (1996). The water holding capacity ranged from 25.15% to 36.69% for all soil samples but the highest was recorded in Owo while the lowest occurred in Ife. Owo soils had the highest water holding capacity values (Table 6) probably because it had the highest clay content while Ife with the lowest clay content had the lowest water holding capacity values. This agrees with the findings of Leelamanie (2010), who states that water content of soil samples increased with increasing clay content. According to Hillel (1998), “a sandy soil will absorb water more rapidly during infiltration, but clay can sustain the evaporation process longer”. The result shows that if clay contents increase, water holding capacity of the soil which has a high correlation with the hydraulic conductivity (k) also increase as shown in Fig. 2(c). Also, the high soil temperature observed in Ife (Table 1) site and the consequent drying of the soils might have been responsible for the low water holding capacity. This finding agrees with the observation of Doerr et al., (2006), who stated that the “greater drying of soils is making them less able to retain water”.

Table 6: Means of bulk density (BD), total porosity (PT), and water holding capacity (WHC) horizon A of the experimental sites.

Location	BD (kg cm^{-3})	PT(cm^3 cm^{-3})	WHC (%)
Ado	1.44 ± 0.03	0.46 ± 0.01	31.98
Akure	1.33 ± 0.03	0.5 ± 0.01	34.86
Ibadan	1.41 ± 0.19	0.47 ± 0.08	33.57
Ife	1.5 ± 0.06	0.44 ± 0.02	25.15
Owo	1.41 ± 0.03	0.47 ± 0.02	36.69

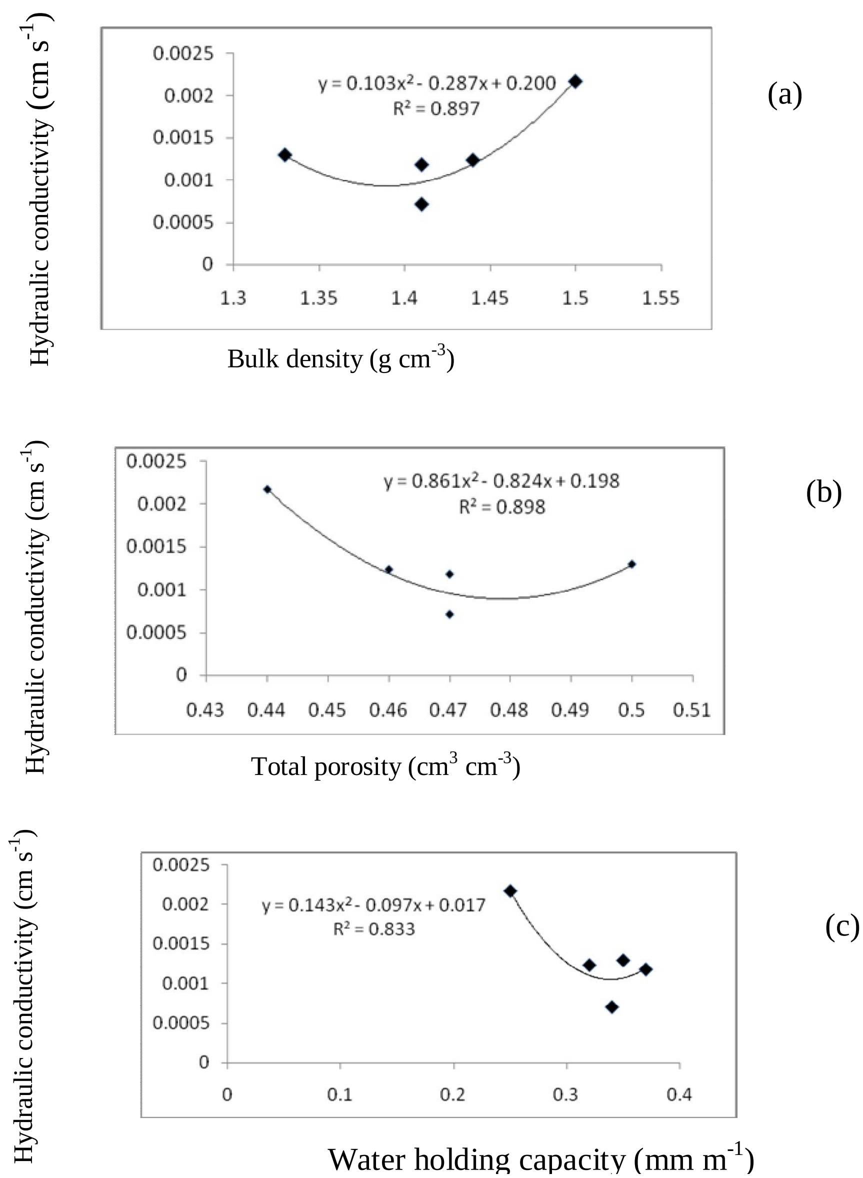

Fig. 2: Relationship between the hydraulic conductivity and bulk density (a), total porosity (b), and water holding capacity (c).

Hydraulic Conductivity and Infiltration of Sampled Soils

The hydraulic conductivity (K_θ) increases with increasing organic matter content. At 2 cm and 4 cm suction, sample soils collected at Ife, which has the highest K_θ value (2.17 x 10^{-3} cm s^{-1} and 1.08 x 10^{-3}cm s^{-1}) has OMC value of 1.51% while at 3 cm suction, Owo soil samples, which has the highest K_θ value (1.47 x 10^{-3} cm s^{-1}) also has the highest OMC value of 3.29%. The organic matter content as reported by Bayer and Bertol (1999) and Vogelmann et al., (2010) is influenced by the CEC as soil samples with high CEC have high OMC and pH. The soil moisture of all the sites varies with times as influenced by the weather conditions such as rainfall, air temperature and relative humidity and in turn affects the infiltration rates and hydraulic conductivity. If the soil profile is initially wetter, then the initial rate of infiltration is generally lower, corresponding to reduced absorption (Furman et al., 2006) and vice versa. The soils bulk density, total porosity and water holding capacity relationship with hydraulic conductivity was shown in Figure 2. Statistical relationship between the total porosity and hydraulic conductivity gave a high correlation coefficient, $r = 0.94$ at $p < 0.05$. Increasing macro porosity or decreasing micro porosity in soil structure causes increases in soil hydraulic conductivity (Ahuja et al., 1984). Similarly, bulk density and hydraulic conductivity gave a high correlation coefficient, $r = 0.94$ at $p < 0.05$. The correlation coefficient (r) between water holding capacity and hydraulic conductivity was 0.95. K_θ of Ife at 2 cm suction was 51.1%, 200.8%, and 80.3% higher over the K_θ of Akure, Ibadan, and Owo soils respectively. The difference of mean of K_θ among all soils at the experimental sites are not significantly different at $p = 0.05$.

Table 7: Means of soil hydraulic conductivity of sampled soils at different suction rates.

	Mean hydraulic conductivity x 10^{-3} (cm s^{-1})		
	Suction rates (cm s^{-1})		
Location	2	3	4
Ado	1.24 ± 0.91	0.69 ± 0.38	0.53 ± 0.29
Akure	1.3 ± 1.05	0.42 ± 0.39	0.48 ± 0.23
Ibadan	0.71 ± 0.39	0.54 ± 0.19	0.37 ± 0.2
Ife	2.17 ± 0.53	1.27 ± 0.21	1.08 ± 0.56
Owo	1.18 ± 1.02	1.47 ± 0.47	0.69 ± 0.41

Table 8: Pearson correlation coefficient (r) among various soil properties

	OMC	PT	BD	MC
OMC	-	0.50 *	-0.50 *	-0.09 ns
PT	0.50 *	-	-0.99**	-0.56*
BD	-0.50 *	-0.99**	-	0.54*
MC	-0.09 ns	-0.56*	0.54*	-

** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level.

Correlation coefficients among some soil physical properties are presented in Table 8. Organic matter content significantly correlated with total porosity and bulk density at $p = 0.01$. Total porosity correlated significantly with organic matter content, bulk density and moisture content, while the correlation between bulk density and organic matter, total porosity and moisture content were significant at p = 0.05. In this study, increased soil OMC increases the PT and decreases the BD. The inverse relationship between PT and BD was shown (Table 8) as PT significantly increases with decrease in BD and vice versa.

Conclusion

In this research, variations in soil bulk density, total porosity, water holding capacity, and moisture content in five different locations within the south western part of Nigeria were investigated. Also the variability of hydraulic conductivity of soils specifically from horizon A was determined. Total porosity and bulk density shows inverse relationship. Soils hydraulic conductivity increased with increase in organic matter content depending on CEC and soil pH. Soil hydraulic conductivity is highly dependent on soil bulk density, total porosity, and water holding capacity. Results shows that soil physical and chemical properties such as bulk density, total porosity, water holding capacity, organic matter content, and aggregation affect water retention characteristic, infiltration and hydraulic conductivity of soils of the study areas.

References

Ahuja I.R., Namey J.W., Green R.E. and Nielsen D.R. (1984). Macroporosity to characterizespatial variability of hydraulic conductivity and effects of land management. *Soil Sci.Soc. Am. J.*, 48 pp. 699–702.

Angelaki, A., Sakellariou – Makrantonaki, M., Tzimopoulos, C., Yannopoulos, S. 20Estimation of Sorptivity at a Sandy Soil Sample. proc. int. conf. Protection and Restoration of the Environment VII , mykonos, Greece.

Ankeny, M.D., T.C. Kaspar, and R. Horton. 1990. Characterization of tillage and traffic effectson unconfined infiltration measurements. Soil Sci. Soc. Am. J. 54:837–840

ASTM D 2974 – Standard Test Methods for Moisture, Ash, and Organic Matter of Peat andOrganic Soils

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

Bagarello, V., Iovino, M., Reynolds,W.D., 1999. Measuring hydraulic conductivity in a cracking clay soil using the Guelph permeameter. Trans. ASAE 42 (4), 957–964.

Bagarello, V., Sgroi, A., 2007. Using the simplified falling head technique to detect temporal changes in field-saturated hydraulic conductivity at the surface of a sandy loam soil. Soil & Tillage Research 94, 283–294

Bayer, C., Bertol, I., 1999. Chemical characteristics of a humic cambisol affected by tillage systems, with emphasis on organic material. R. Bras. Ci. Solo 23, 687–694.

Blake, G.R., Hartge, K.H., 1986. Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis: Physical and Mineralogical Methods, vol. 1. American Society of Agronomy, Madison, pp. 363–375.

Brady, N.C., and R.R. Weil. 1999. The Nature and Properties of Soils. Prentice Hall, Upper Saddle River, New Jersey.

Cassel, D.K., Nelson, L.A., 1985. Spatial and temporal variability of soil physical properties of Norfolk loamy sand as affected by tillage. Soil Till. Res. 5 (1), 5–17.

Chakravorty, B., Pandey, N. G., Sivadas, A. K., 1998-99, Determination of Hydraulic conductivity of soils in central bihar, NIH, Roorkee.

Chapman, H.D. 1965. Cation-exchange capacity. *In:* C. A. Black (ed.) Methods of soil analysis Chemical and microbiological properties. Agronomy 9: 891-901.

Danielson, R.E., and P.L. Sutherland. 1986. Porosity. p. 443–461. *In* A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison WI

Das Gupta, S., Mohanty, B. P., Kohne, J. M. 2006. Soil Hydraulic Conductivities and their Spatial and Temporal Variations in a Vertisol. Soil Sci. Soc. Am. J. 70:1872–188 Decagon Devices User's Manual, Version 9, Pullman, WA, USA.

Doerr SH, Dekker LW, Ritsema CJ, Shakesby RA and Bryant R 2002 Water repellency of soils: The influence of ambient relative humidity. Soil Sci. Soc. Am. J., 66: 401- 405.

Doerr, S.H., Shakesby, R.A., Dekker, L.W., Ritsema, C.J., 2006. Occurrence, prediction and hydrological effects of water repellency amongst major soil and land use types in a humidtemperate climate. Eur. J. Soil Sci. 57 (5), 741–754

FAO. 2005. The importance of soil organic matter. FAO soils bulletin No. 80. Rome

Fasinmirin J. T., Oguntuase, A. M. 2008. Soil moisture distribution pattern in *Amaranthus cruentus* field under drip irrigation system. African Journal of Agricultural Research Vol. 3 (7), pp. 486-493

Franzluebbers, A.J. 2002. Water infiltration and soil structure related to organic matter and its stratification with depth. *Soil Til. Res.* 66:197-205.

Fohrer, N., Berkenhagen, J., Heckler, J.M., Rudolph, A., 1999. Changing soil and surfaceconditions during rainfall—single rainstorm/subsequent rainstorms. Catena 355–375.

Fuentes, J.P., Flury, M., Bezdicek, D.F., 2004. Hydraulic properties in a silt loam soil undernatural prairie, conventional tillage and ontill. Soil Sci. Soc. Am. J. 68, 1679–1688.

Furman, A., Warrick, A. W., Zerihun, D., Sanchez, C. A. 2006. “Modified Kostiakov InfiltrationFunction: Accounting for Initial and Boundary Conditions”. *J. Irrig. Drain. Eng.*, 132(2), 588.

Gantzer, C.J., Anderson, S.H., 2002. Computed tomographic measurement of macroporosity in chisel-disk and no-tillage seedbeds. Soil Till. Res. 64 (1–2), 101–111.
Goebel M-O, Bachmann J, Woche SK, Fischer WR and Horton R 2004 Water potential andaggregate size effects on contact angle and sur-face energy. Soil Sci. Soc. Am. J., 68: 383-393.

Green, T.R., Ahuja, L.R., Benjamin, J.G., 2003. Advances and challenges in predicting agricultural management effects on soil hydraulic properties. Geoderma 116, 3–27.

Gulser, C., Candemir, F., 2008. Prediction of Saturated Hydraulic Conductivity Using Some Moisture Constants and Soil Physical Properties. Samsun 55139

Halfmann, D. M., 2005. Management system effects on water infiltration and soil physical properties. M. Sc Thesis. Texas Tech University, Faculty of Soil science. Texas (Unpubl.) pp 9-11, 35, 85, 92

Hillel, D. (1982). Introduction to soil physics. Academic Press, Inc. San Dieoga, California

Kay, B.D., Angers, D.A., 2002. Soil structure. In: Warrick, A.W. (Ed.), Soil Physics Companion. CRC Press, Boca Raton, FL, pp. 249–295.

Kirkham, M.B. (2005) *Principles of Soil and Plant Water Relations.* Elsevier Academic Press: Burlington, MA. pp. 145-172.

Kostiakov, A. N. 1932. “On the dynamics of the coefficients of water percolation in soils and on the necessity of studying it from a dynamic point of view for purpose of amelioration.” *Transactions of the 6th Communication of the Int. Society of Soil Sciences*, Part A: 17–21

Lal, R. and M. K. Shukla, eds. 2004. *Principles of Soil Physics*. Marcel Dekker, Inc., New York.

Lampurlanés, J. and C. Cantero-Martínez. 2005. Hydraulic conductivity, residue cover and soil surface roughness under different tillage systems in semiarid conditions. *Soil Til. Res.* In Press.

Leelamanie DAL. 2010. Changes in soil water content with ambient relative humidity in relation to the organic matter and clay. Trop. Agric. Res & Ext. 13(1).

Lin, H.S., K.J. McInnes, L.P. Wilding, and C.T. Hallmark. 1998. Macroporosity and initial moisture effects on infiltration rates in Vertisols and vertic intergrades. Soil Sci. 163:2–8.
Logsdon, S.D., and D.B. Jaynes. 1996. Spatial variability of hydraulic conductivity in a

cultivated field at different times. Soil Sci. Soc. Am. J. 60:703–709.

Luxmoore, R.J., 1981. Micro-, meso-, and macroporosity of soil. Soil Sci. Soc. Am. J. 45, 671-672.

Meek, B.D., E.R. Rechel, L.M. Carter, W.R. DeTar, and A.L. Urie. 1992. Infiltration rate of a sandy loam soil: Effects of traffic, tillage, and plant roots. Soil Sci. Soc. Am. J. 56:908 913.

Messing, I., and N.J. Jarvis. 1993. Temporal variation in the hydraulic conductivity of a tilled clay soil as measured by tension infiltrometers. J. Soil Sci. 44:11–24

Messing, I., and N.J. Jarvis. 1990. Seasonal variation in field-saturated hydraulic conductivity in two swelling clay soils in Sweden. J. SoilSci. 41:229–237

Mohanty, B.P., Ankeny, M.D., Horton, R., Kanwar, R.S., 1994. Spatial variability of hydraulic conductivity measured by disc . Water Resource. Res. 30, 2489–2498.

Mohanty, B.P., R.S. Bowman, J.M.H. Hendrickx, and M.Th. van Genuchten. 1997. New piecewise-continuous hydraulic functions for modeling preferential flow in an intermittent flood-irrigated field. Water Resour. Res. 33:2049–2063

Mohanty, B.P., T.H. Skaggs, and M.Th. van Genuchten. 1998. Impact of saturated hydraulic conductivity on the prediction of tile flow. Soil Sci. Soc. Am. J. 62:1522–1529.

Mullen, R., 2009. Soil PH and Nutrient Availability. Sparky Boy Enterprises. Ohio.

Osunbitan, J.A., Oyedele, D.J., Adekalu, K.O., 2005. Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. Soil Till. Res. 82, 57–64

Ozdemir, N. (1998). Toprak Fizigi. OMÜ Ziraat Fak. Ders Kitabı, No:30, Samsun.

Philip, J. R. 1957a. “The theory of infiltration: 5. The influence of the initial moisture content.” *Soil Sci.*, 84, 329–339.

Philip, J. R. 1969. “Theory of infiltration.” *Adv. Hydrosci.*, 5, 215–305

Reynolds, W.D. 1993. Saturated hydraulic conductivity: laboratory measurement. p. 589-598. *In* Carter, M.R., ed. Soil sampling and methods of analysis. Lewis Publ., Boca Raton, Florida.

Ringrose-Voase, A.J., 1996. Measurement of soil macropore geometry by image analysis of sections through impregnated soil. Plant Soil 183 (1), 27–47.

Shouse, P.J., Mohanty, B.P., 1998. Scaling of near-saturated hydraulic conductivity measured using disc infiltrometers. Water Resour. Res. 34, 1195-1205.

Starr, J.L., 1990. Spatial and temporal variation of ponded infiltration. Soil Sci. Soc. Am. J. 54 (3), 629–636

Strudley, M.W., Green, T.R., Ascough II, J.C., 2008. Tillage effects on soil hydraulic properties in space and time: state of the science. Soil Till. Res. 99, 4–48.

Tsuboyama, Y., R.C. Sidle, S. Noguchi, and I. Hosoda. 1994. Flow and solute transport through the soil matrix and macropores of a hillslope segment. Water Resour. Res. 30:879–890

Vogelmann, E. S., Reichert, J.M., Reinert, D. J. Mentges, M.I., Vieira, D. A., Peixoto de Barros, C. A., Fasinmirin, J. T., 2010. Water repellency in soils of humid subtropical climate of Rio Grande do Sul, Brazil. Soil Till. Res. 110, 126–133

Zhang, R. 1997. “Determination of soil sorptivity and hydraulic conductivity from the disk infiltrometer.” *Soil Sci. Soc. Am. J.* 61: 1024-1030.

Interpretation of Observed Surface Ponds Water Quality using Principal Components Analysis and Cluster Analysis

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Abstract

Varieties of approaches are being used to interpret the concealed variables that determine the variance of observed water quality of various sources. A considerable proportion of these approaches are statistical methods, multivariate statistical techniques in particular. The use of multivariate statistical techniques is required when the number of variables is large and greater than two for easy and robust evaluation. By means of multivariate statistics of principal components analysis (PCA) and cluster analysis (CA), this study attempted to determine major factors responsible for the variations in the quality of 30 surface ponds used for domestic purposes in the 6 selected communities of Akoko Northeast LGA, Ondo State, Nigeria. It classifies the samples' location into mutually exclusive unknown groups that share similar characteristics/properties. The laboratory results of 20 parameters comprising 6 physicals, 8 chemicals, 4 heavy metals and 2 microbial from the sampled ponds were subjected to PCA and CA for further interpretation. The result shows that 5 components account for 97.52% of total variance of the surface pond quality while 2 cluster groups were identified for the locations. Based on the parameters concentrations and the land uses impacts, it was concluded that domestic and agricultural waste strongly influenced the variation and the quality of ponds in the area.

Key Words: Multivariate statistics, ponds, water quality, variance and interpretation

Introduction

The complexity of water quality as a subject is reflected in various types of measurements. These measurements include simple (in situ), basic and more complex parameters (Laboratory). For instance, pH, temperature and DO could be measured with a portable in-situ pH meter, a mercury thermometer and M90 Mettler Toledo AG DO meter, respectively (USGS 2006). BOD, TSS, Cu, Fe, Total bacterial counts, Total coliforms etc could be analyzed in the laboratory using standard methods for water samples examination (Ayoade, 1988; APHA, 1998, WHO 2006 and USGS 2006).

The surface water quality assessment is a matter of serious concern today due to its role in servicing domestic water needs of water stress areas (Yerel, 2010 and Ayeni *et al*, 2011). The surface water (ponds) quality is principally influenced by the natural and the anthropogenic processes particularly in the urban areas and agricultural activities around the rural areas (Ayeni, 2010 and Ayeni *et al*, 2011). The level of water quality is relatively determined by the content of physical, chemical and biological parameters present in it. Relationship between two parameters may also lead increases or decrease in the concentration of others. This relationship or association is usually achieved using multivariate statistical techniques (Ifabiyi, 1997; Mazlum *et al*, 1999; Jaji *et al* 2007). This is because some analysis is primarily concerned with relationships between samples, while others trepidation are largely with relationships between variables. According to Mazlum *et al*, (1999) and Yerel, (2010), many multivariate statistical techniques have the capacity to summarize a large data by means of relatively few parameters. Nonetheless, the choice of using any of the multivariate statistical techniques lies on the nature of the data, problem, and objectives of the study. In view of the fact that the daily drinking and domestic water needs of the majority of residents in the area are met by unsafe surface water, in particular surface ponds (Ayeni, 2010), there is the need to understand the variables that control their quality variation. Principal Component Analysis (PCA) and Cluster Analysis (CA) of multivariate techniques are therefore adopted for the study. According Praus, (2005), PCA is used to search new abstract orthogonal eigenvalues which explain most of the data variations in a new harmonize structure. Each principal component (PC) is a linear combination of the original variables and describes different source of information by eigen-value based on the decomposition of the covariance/correlation matrix (Geladi and Kowalski, 1986). PCA is designed to modify the observe variables into uncorrelated variables of linear combinations of the original variables called "principal components" (Praus, 2005 and Yerel, 2010) as well as to investigate the factors which caused variations in the observed datasets (Mazlum *et al*, 1999). The principal component therefore provides information for interpretation and better understanding of the most meaningful parameters, which describes the whole data set through data reduction with a minimum loss of the original information. Cluster analysis (CA) is an exploratory analysis technique for classifying a set of observations into two or more mutually exclusive unknown groups based on combinations of interval variables (Stockburger, 1997; Trochim, (2006): Murali-Krishna *et al* 2008 and Yerel, 2010). According to Yerel (2010), CA organizes sampling entities into discrete clusters, such that within-group similarity is maximized and among-group similarity is minimized according to some objective criteria Its purpose is to discover a system of organizing observations and sort them into groups so that it is statistically easier to predict behavior of such observations based on group membership that share similar identities/properties. In this study observation, sampling location classification was done by the use of Hierarchical Cluster Analysis (HCA) procedure. HCA identify relatively homogeneous groups of variables (cases) through dendrogram based on selected characteristics. Dendrogram clearly distinguished locations bahaviours and interprets the description of the hierarchical clustering in a graphical format (Hastie et al, 2001 and Ryberg, 2006).

Study Area and Sampling Locations

The study area lies between longitude 5°38' and 6°04'E, and latitude 7°26' and 7°42'N in the northern senatorial part of Ondo State, SW – Nigeria (Fig. 1). It is bounded by Akoko North West LGA to the north, Edo State to the east, Akoko South East and West LGAs to the south, and Ekiti State to the west. It is primarily characterized with undulating relief ranges between 149 and 671m above sea level and located on basement complex rock formation (Ayeni, 2010). The complex composed mainly of granite, mischist, gneisses and metasediment (Barbour *et al*, 1982 and Adekunle *et al,* 2007). The area falls within sub-tropical climate with average rainfall over 1500mm per annum. The temperature ranging from about 30^{0}C to 38^{0}C while the vegetation cover is dominated by derived secondary rain forest. The soil is classified as Ferric Acrisols with relatively higher cation profiles (Fasona *et al,* 2007; Nwachokor and Uzu, 2008).

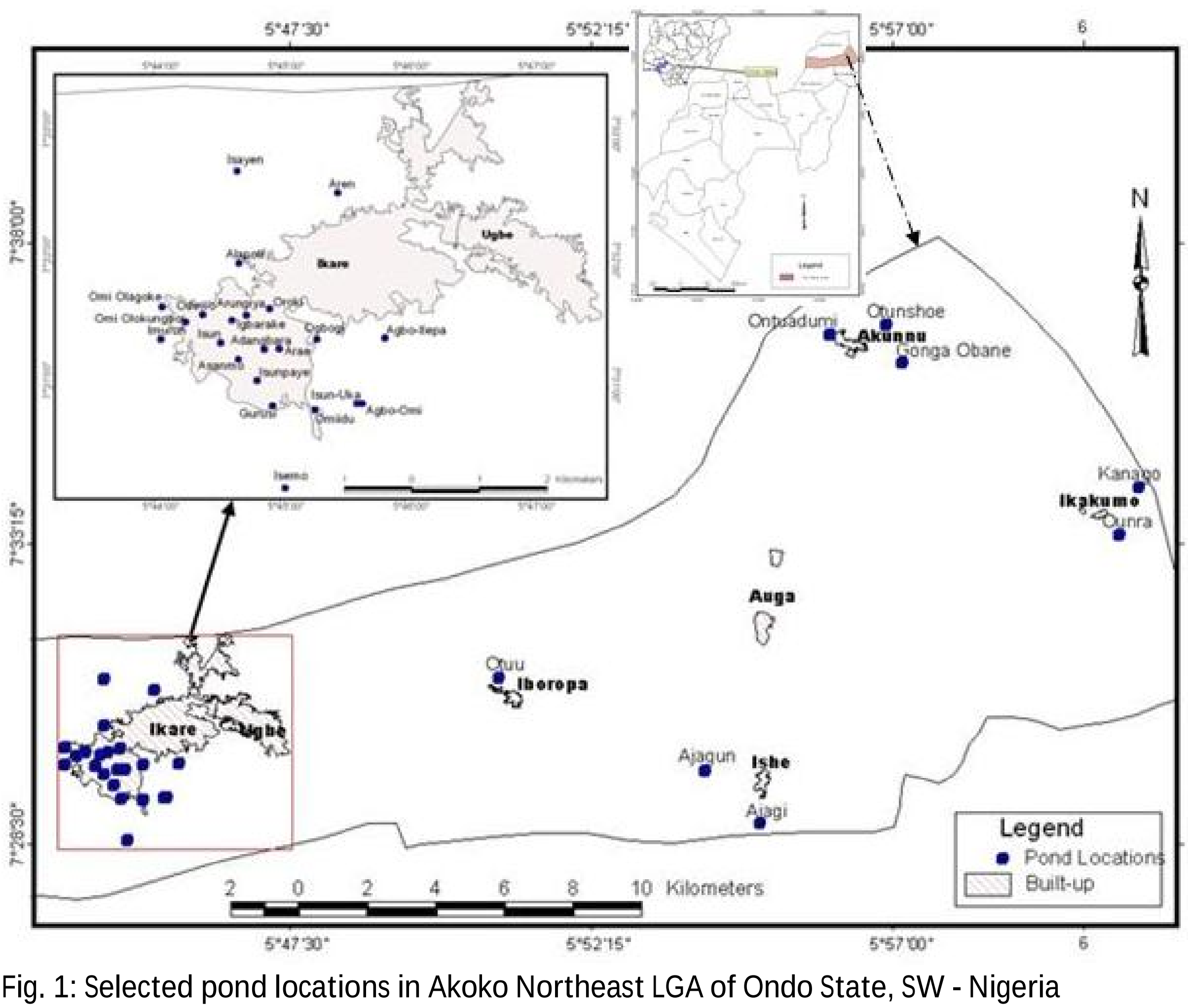

Fig. 1: Selected pond locations in Akoko Northeast LGA of Ondo State, SW - Nigeria

Methods

Twenty (20) water quality parameters from 30 surface ponds were monitored for 12 months. For each month, water sample from selected ponds are collected and analysed in the laboratory using APHA (2005) standard methods for the examination of water and wastewater.

The coordinates of sampled ponds are interpolated on geo-rectified map of the study area (Fig. 1). The selected surface water quality parameters for the study are pH, temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspends Solid (TSS), Total Dissolved Solid (TDS), Turbidity, Total Hardness (TH), Calcium Hardness (Ca^{+}), Magnesium Hardness (Ma^{2+}), Chloride (Cl^{-}), Nitrate (NO_3^{-}), Phosphate (PO_4^{3-}), Oil & grease, Cupper (Cu), Iron (Fe), Manganese (Mn), Zink (Zn), Total bacterial counts (TBC) and Total coliforms (TC).

The laboratory results were evaluated using multivariate statistical techniques of PCA for selected parameters and CA for sample locations. The principal component is thus given by the formula:

$$Z_{ij} = a_{i1}X_{ij} + a_{i2}X_{2j} + a_{i3}X_{i3} + ...+ a_{in}X_{nj} \qquad (1)$$

where,

z = component score,
a = component loading,
x = measured value of variable,
i = component number,
j = sample number, and
n = the total number of variables.

In the case of cluster analysis, the formula is given thus:

$$d_{ij}^2 = \sum_{k=1}^{m} (z_{ik} - z_{jk})^2 \qquad (2)$$

where

d^2ij = the Euclidean distance,
z_{ik} = the values of variable k for object i
z_{jk} = the values of variable k for object j
m = the number of variables.

Results and Discussion

The result of principal components analysis in Table 1 shows that of the 20 components, only 5 had extracted eignvalues over 1. This is based on Chatfield & Collin (1980) assumption which started that components with an eigenvalue of less than 1 should be eliminated. The extracted 5 components were subsequently rotated according to varimax rotation in order to make interpretation easier and fundamental significance of extracted components to the water quality status of the selected ponds. The result of rotation revealed that the percentages of the total variances of the 5 extracted components when added account for 97.52% (i.e. their cumulative variance) of the total variance of the observed variables. This indicates that the variance of the observed variables had been accounted for by these 5 extracted components. The calculated components loadings, eigenvalues, total variance and cumulative variance is shown in Table 2 while the scree plot of the eignvalues of observed components is depicted shown in Fig. 2.

Table 1: Principal Component Matrix of eignvalues less than 1 (5 components extracted)

	Component				
	1	2	3	4	5
pH	.838	.001	-.195	.379	.171
Temp	-.290	.273	-.589	.649	-.067
Do	.687	-.349	-.592	.150	.115
BOD	-.535	.334	.581	.450	-.243
TSS	.641	-.361	.378	.484	.200
TDS	.688	.715	.050	-.008	.092
Turbidity	.755	-.399	-.380	.324	-.042
TH	.734	.654	.145	-.004	-.097
Ca	.825	.476	.258	.116	.035
Mg^{2+}	.576	.776	.017	-.126	-.222
Cl^-	.449	.871	.018	-.152	.104
NO_3^-	-.361	.451	-.520	-.083	.578
PO_4^{3-}	.928	-.022	.045	.020	-.221
Oil & grease	-.273	.408	.312	.427	.663
Zn	.621	-.641	-.224	.379	-.084
Fe	-.513	.230	.428	.701	.069
Mn	-.353	.209	.096	.517	-.744
Cu	-.026	-.449	.822	-.309	.161
TBC	.462	-.439	.596	.304	.324
TC	-.770	.126	-.490	.346	.173

Table 2: Rotated Component loading matrix, eignvalues, total variance and cumulative variance

Variables	Component				
	1	2	3	4	5
TH	.983				
Mg^{2+}	.979				
TDS	.979				
Cl^{-}	.954				
Ca^{+}	.900				
Zn	.	.959			
Turbidity		.947			
Do		.840			
pH		.818			
TSS		.779			
PO_4^{3-}		.621			
Cu			-.943	.	
Temp			.872		
TC			.766		
TBC			-.699		
NO_3^{-}			.661		
Oil & grease				.953	
Fe				.745	
Mn					.952
BOD					.773
Eigenvalue	7.399	4.412	3.335	2.581	1.776
Total variance %	36.996	22.058	16.674	12.908	8.882
Cumulative variance %	36.996	59.054	75.728	88.634	97.517

Rotation Method: Varimax with Kaiser Normalization

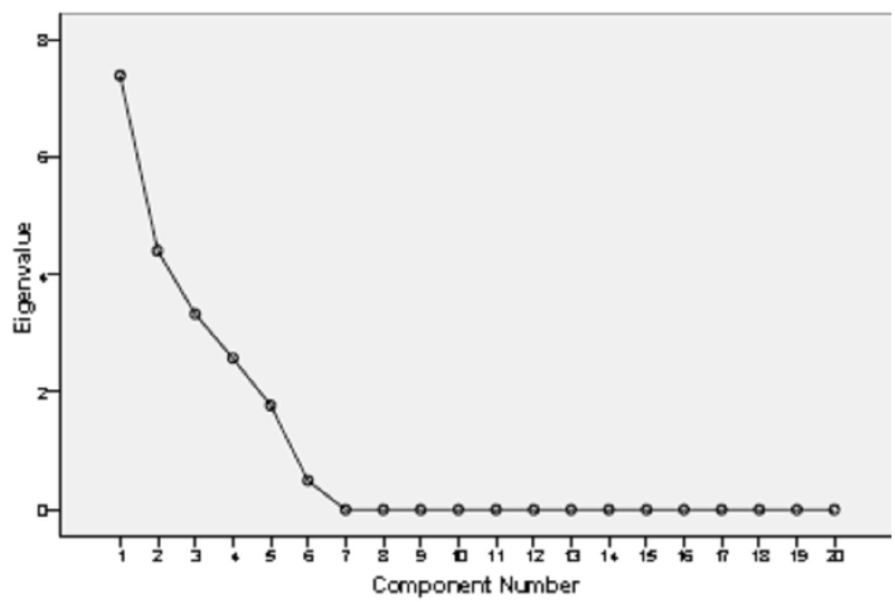

Fig. 2: The scree plot of the eignvalues

Based on the component loadings, the variables are grouped accordingly with their designated components as follows:

Component 1 TH, Mg^{2+}, TDS, Cl^- and Ca^+,
Component 2: Zn, Turbidity, DO, pH, TSS and PO_4^{3-}
Component 3: Cu, temperature, TC, TBC and NO_3^-
Component 4: Oil & grease and Fe
Component 5: Mn and BOD

Component 1, component 2, component 3, component 4 and component 5 explained 36.996%, 22.058%, 16.674%, 12.908% and 8.882% of the variance respectively. Classifying the component loading according to Liu *et al* (2003), the loading values greater 0.75 signifies "strong", the loading with absolute value between 0.75 and 0.50 indicate "moderate" while loading values between 0.50 and 0.30 denote as "weak"., respectively. Using this classification, all variable in component 1 and component 2 had strong positive loading except PO_4^{3-} with moderate positive. Amongst the 5 variables in component 3, two (2) had strong positive loading (Temperature and TC), NO_3^- had moderate positive loading while Cu and TBC were signified with strong and moderate loading respectively. All variables in components 4 and 5 explained strong positive loading.

An interpretation of the rotated 5 principal components is made by examining the component loadings noting the relationship to the original variables. Component 1 gives information about the variation in TH, Mg^{2+}, TDS, Cl^- and Ca^+. In this component, loading indicates that organic matter and organic acids which could be attributed to various anthropogenic activities and geological formation and/or composition of the area greatly influence the quality of selected ponds. The same also interpreted for component 2 but considers its eignvalue and total variance, it is quite lower compared with component 1.

Components 3 explained information about Cu, temperature, TC, TBC and NO_3^-. This component represents pollution from domestic and agricultural waste as well as geological composition of the area. However, the significance of NO_3^- in the component 3, indicates that nitrification takes place in the vicinity of the ponds. In the component 4, it can be understood that dissolved or emulsified oil and grease extracted from water especially unsaturated fats and fatty acids and Fe extracted from the parent rock of the area are of the significance in that component. In the component 5, Mn presence is an indication of the parent rock influence while BOD claimed that there is a high level of organic pollution, caused usually by poorly treated waste water.

The dendrogram of observed locations dataset was generated using Euclidean distance of HCA for CA result (Fig. 3 and Table 3). Based on Euclidean distance, two major clustering groups (cluster 1 and cluster 2) were observed. Cluster 1 characterized with low Euclidean distance correspond to locations 6, 9, 7, 3, 13, 19, 17, 22, 10, 30, 4, 5, 2, 12, 23, 27, 18, 26, 29, 21, 25, 28 and 24. Cluster 2 which has high Euclidean distance is coherent to locations 15, 16, 1, 20, 8, 11 and 14. Sub group clusters were also clarified within the major cluster 1 and vary with significance Euclidean distance.

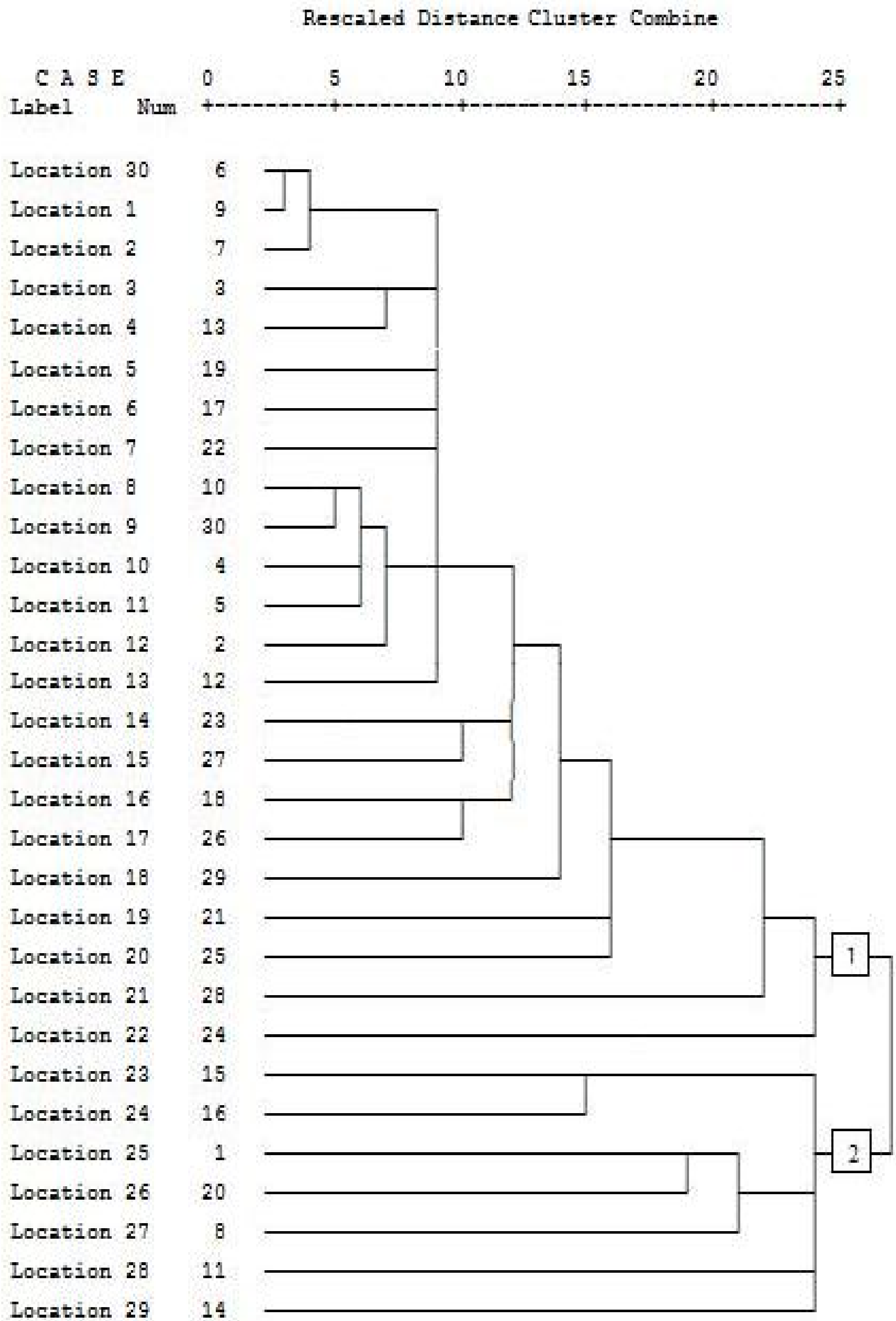

Fig. 3: Dendrogram of hierarchical cluster analysis

Table 3: Pond names and their cluster membership

Identification	Ponds' names	Clusters	Identification	Ponds' names	Clusters
Location 1	Omiidu	1	Location 16	Otunadumi	1
Location 2	Agboomi	2	Location 17	Gonga Obane	2
Location 3	Isun-uka	2	Location 18	Isun	2
Location 4	Isemo	2	Location 19	Imurun	2
Location 5	Gurusi	2	Location 20	Arungiya	1
Location 6	Alapoti	2	Location 21	Igbarake	2
Location 7	Isayen	2	Location 22	Omi-Alagoke	2
Location 8	Aren	1	Location 23	Omi-Olokungboye	2
Location 9	Agbo Ilepa	2	Location 24	Odewo	2
Location 10	Ajagi	2	Location 25	Oroki	2
Location 11	Ajagun	1	Location 26	Asanmo	2
Location 12	Ootu	2	Location 27	Ogbogi	2
Location 13	Ounra	2	Location 28	Arae	2
Location 14	Kanago	1	Location 29	Adangbara	2
Location 15	Otunshoe	1	Location 30	Isunpaye	2

The dendrogram clarifies cluster 1 as the abnormality observation which had high variation in the concentration of the surface water quality parameters compared to cluster 2 surface water samples concentration. The variation in cluster 1 might be due to low polluted effluents from non-point sources (agricultural and urban activities). Cluster 2 shows a high pollution from agricultural area which encompasses the ponds.

Conclusion

This study presents the usefulness of multivariate statistical techniques of large and complex dataset in order to obtain better information and interpretation concerning surface water quality. Principal component analyses helped in identify the factors responsible for surface water quality variations in 6 selected communities. The result revealed that the percentages of the total variances of the 5 extracted components when added account for 97.52% (i.e. their cumulative variance) of the total variance of the observed variables. The variation in components 1 and 2 loading indicate that organic matter and organic acids could greatly influence the quality of selected ponds. Components 3 ascribed mainly to domestic and agricultural waste of the ponds environment while component 4 and 5 respectively attributed to dissolved/emulsified poorly treated waste water. On the other hand, the result of cluster analysis revealed 2 major clustering groups resulting from influence of agricultural and urban activities around the samples' location. Cluster 1 characterized with low Euclidean distance corresponds to 23 locations and clarifies with sub groups that varies with significance Euclidean distance while cluster 2 coherent to 7 locations and observed high Euclidean distance with sub group of insignificance Euclidean distance. Therefore, it is worthwhile to conclude that PCA and CA are better tools for better understanding of the concealed information about parameters variance and datasets discrete information in water quality assessment studies.

References

APHA (2005): "Standard methods for examination of water and wastewater". American Public Health Association, 21th Edition, Washington DC, Pg 4 - 144

Ayeni, A. O. (2010) "Spatial Access to Domestic Water In Akoko Northeast LGA, Ondo State, Nigeria" Unpublished Ph.D. Thesis, University of Lagos, Lagos, Nigeria

Ayeni, A.O., I.I. Balogun and A.S.O. Soneye (2011) "Seasonal Assessment of Physico-chemical Concentration of Polluted Urban River: A Case of Ala River in South-western Nigeria", *Res. J. Environ. Sciences, 5(1): 21-35*

Ayoade, J. O. (1988): "Tropical Hydrology and Water Resources", London, Macmillan Publishers Ltd

Barbour, J. S. Oguntoyinbo, J. O. C. Onyemelukwe and J. C. Nwafor (1982): Nigeria in Maps, London, Hodder and Stoughton.

Chatfield, C. & Collin, A.J. (1980): Introduction to Multivariate Analysis". Published in the USA by Chapman and Hall in Association with Methuen, Inc. New York, USA. Cited in

Mazlum, N., A. Ozer and S. Mazlum (1999): Interpretation of Water Quality Data by Principal Components Analysis, *Tr. J. of Engineering and Environmental Science 23, 19 - 26.*

Fasona, A.S., F.O. Omolayo, A.A. Falodun and O.S. Ajayi (2007): Granite Derived Soils in Humid Forest of Southwestern Nigeria - Genesis, Classification and Sustainable Management, *America – Eurasian J. Agric & Environ. Sc. 2(2): 189 - 195*

Geladi P. and B. R. Kowalski (1986): Partial least square regression: A tutorial. *Anal. Chim. Acta 185**:** 1-17.*

Hastie, T., Tibshirani, R., and Friedman, J., (2001), The elements of statistical learning—data mining, inference, and prediction: New York, Springer Science+Business Media, Inc., 533 p.

Ifabiyi, I.P. (1997): "Variation in Water Gravity with Rainfall Incidences: A Case Study of Ogbe Stream Ile-Ife, Ife" *Research Publications in Geography*, *Vol. 6 No. 1 and 2 pp 139-144.*

Jaji, M.O, O. Bamgbose, O.O. Odukoya and T.A. Arowolo (2007): Water Quality Assessment of Ogun River, South West Nigeria, *Environmental Monitoring Assessment*, *133: 473-482* Springer Science and Business Media

Mazlum, N., A. Ozer and S. Mazlum (1999): Interpretation of Water Quality Data by Principal Components Analysis, *Tr. J. of Engineering and Environmental Science 23, 19 - 26.*

Murali Krishna P.S. M., S. G. Moses and V.S.G. K. Murali Krishna (2008): Application cluster analysis, discriminate analysis and principal component analysis for water quality evaluation for the river Godavari at Rajahmundry region, *International Journal of Applied Environmental Sciences 2(3): 195-209*

Nwachokor, M.A. and F.O. Uzu (2008): Updated Classification of Some Soil Series in Southwestern Nigeria *Journal of Agronomy 7(1): 76-81*

Praus, P (2005): Water quality assessment using SVD-based principal component analysis of hydrological data, *Water SA 31 (4): 417 - 422*

Ryberg, K. R (2006): Cluster Analysis of Water-Quality Data for Lake Sakakawea, Audubon Lake, and McClusky Canal, Central North Dakota, 1990-2003, Prepared in cooperation with the Bureau of Reclamation, U.S. Department of the Interior Scientific Investigations Report 2006–5202, U.S. Geological Survey, Reston, Virginia, 47p

Stockburger, D. W (1997): *Multivariate Statistics: Concepts, Models, and Applications,* www Version 1.0 http://www.psychstat.missouristate.edu/multibook/mlt04.htm accessed on the 29/06/2011

USGS (2006): Common water measurements Page Last Modified: Monday, 28-Aug-2006 14:56:21 EDT http://ga.water.usgs.gov/edu/characteristics.html Accessed on the 14/02/2009

WHO (2006): *Guidelines for Drinking-Water Quality,* Volume 1, Recommendations 1st Addendum to 3rd edition, World Health Organization, Geneva (Electronic version).http://www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.ht_mlAccesse d on the 14/02/2009

Yerel, S. (2010): Water Quality Assessment of Porsuk River, *Turkey E-Journal of Chemistry, http://www.e-journals.net 2010, 7(2), 593-59.9*

Multivariate Statistical Analysis for the Assessment of Hydrogeochemistry of Groundwater in Agbabu Area, S.W. Nigeria.

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Abstract

Investigation into the hydrogeochemistry of groundwater in Agbabu Area in S.W Nigeria using physical and chemical parameters has been carried out. Samples were collected from eighty water points, comprising fifty two samples in the dry season and twenty eight water samples in the rainy season. The physical parameters measured in the field were pH, temperature, electrical conductivity and total dissolved solids. Chemical constituents analyzed for includes, bicarbonate, chloride, sulphate, nitrate, phosphate, calcium, magnesium, sodium, potassium, iron, zinc, copper, chromium, cadmium, lead, arsenic, nickel, total hardness, calcium hardness, manganese, turbidity, alkalinity, oil and grease for groundwater and were determined using established standard method. Descriptive statistics, correlation matrices, factor analysis, together with cluster analysis were used to gain an understanding of the hydrogeochemical processes in the study area. Factor analysis identify six main processes influencing groundwater chemistry which are sea water intrusion, mineral precipitation and dissolution, seasonal changes, cation exchange processes, human activity and decay organic matter. These six factors accounted for 74.6% of total variance of the groundwater.

Keywords: Groundwater, multivariate statistical analysis, hydrogeochemistry

Introduction

The chemistry of water is an important factor determining its uses for domestic, irrigation or industrial purposes. Groundwater is one of the earth's most important resources for human life. Groundwater quality depends upon the geological environment, human activity, natural movement, recovery and utilization (Reghunanth et al 2002, Senthikumar et al, 2008). Groundwater is gaining increasing importance in the supply of water to rural communities in Agbabu and its environs since surface water are easily polluted. The need for water has greatly increased due to over abstraction of groundwater from the coastal aquifer resulting into seawater intrusion and deterioration of the groundwater quality in the study area. Hydrogeochemistry of Agbabu area remain poorly understood, despite the lack of alternative water sources. Saltwater intrusion and deterioration of groundwater quality in the study area demand for comprehensive understanding of groundwater chemical evolution for optimum management of the groundwater resource. In this study, multivariate statistical analyses such as correlation coefficient, descriptive statistics, factor and cluster analyses were used for interpreting the hydrogeochemical data set obtained in the study area.

Multivariate analyses were employed because of its usefulness as a tool to reduce and organize large hydrogeochemical data sets into groups with similar characteristics and then relating them to specific changes in hydrological process. Multivariate statistical techniques have become widely accepted and used in groundwater quality assessment over the last decades (Ako et al, 2010, Reghunath et al 2002, Elueze et al. 2004).

Location and Geology of the Study Area

The study area lies within the latitudes 6^0 28^1 N and 6^0 37^1 N and longitudes 4^0 32^1 E and 4^0 5^1 E of the Greenwinch Meridian (Fig 1). The Elevation ranges between 50 and 250 m above the sea level. The study area has a tropical climate. There are 2 distinct seasons, the wet season and the dry season. Wet season normally commences from April to October while the dry season commences from November and ends in March.The annual rainfall ranges between 1000 mm and 1500 mm.

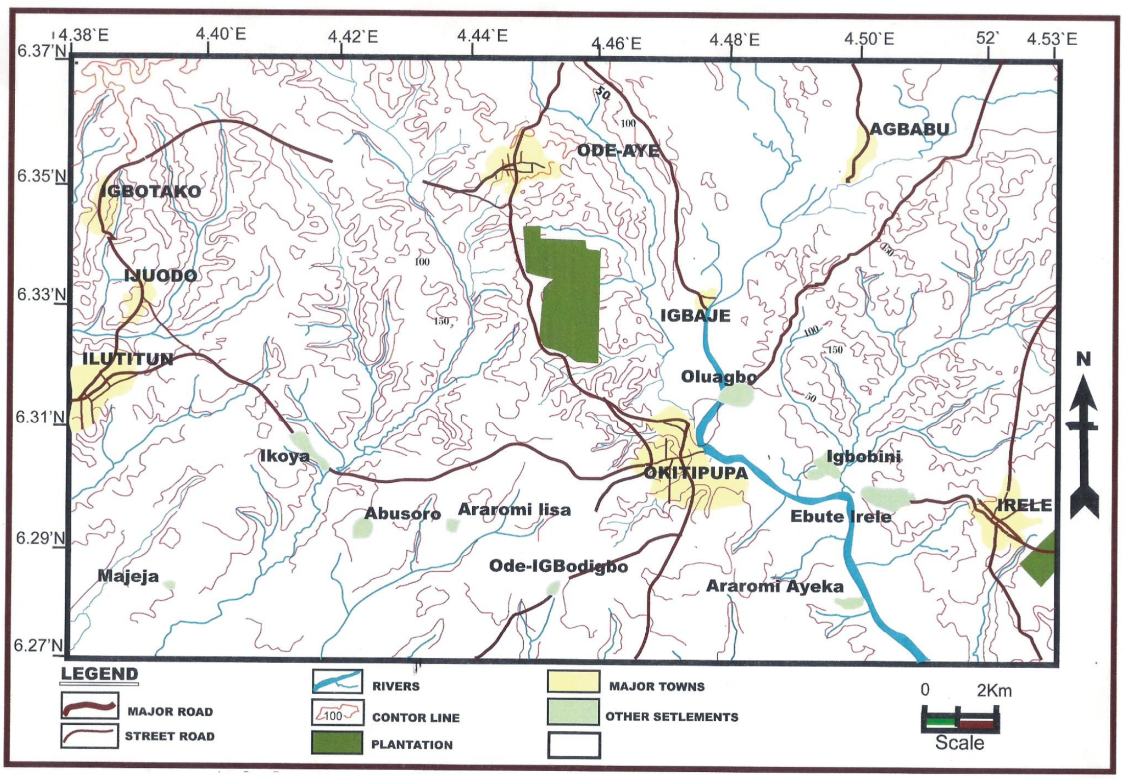

Fig. 1: Map of the Study Area

The study area lies on the central part of the Dahomey sedimentary basin and is underlain by clastic sediments which rest unconformably on the crystalline basement complex. Omosuyi

(2001) identified the predominant rock types as shales and sandstones and minor rocks as limestones and unconsolidated sediments with age range of Albian to recent. Omatsola and Adegoke (1981) proposed that Dahomey basin comprises of horst and graben and are filled with Ise, Afowo and Araromi formation gently dipping cretaceous formation. Stratigraphic sequence is shown in Table 1.

Groundwater in the coastal aquifers suffers from seawater intrusion due to over abstraction and water quality degradation as a result of urbanization and agricultural practices (Liu et al, 2003; Gurugnanam et al, 2009; Aris et al, 2007; Farooq et al, 2010; Belkhiri et al, 2010; Akoteyon et al, 2010)

Table 1: Summary of the Stratigraphy in Dahomey Basin

Age	Stratigraphy	Lithology
Recent	Alluvial deposit Benin formation	Sands, Clay lenses, Lignite, Shale
Oligocene	Ijebu/Ogwashi-Asaba formation	Sands, Limestone, Bituminous sands
Eocene	Ilaro formation	Sandstone
	Ofosun formation/ Ameku formation	Sandstone, Mudstones, Glauconites, Glauconites and Phosphates
Paleocene	Akinbo formation	Shales, Fossilliferous Shales
		Limestone, Quartzs, Glauconites
Maestrictian	Araromi formation	Sand, Shales, Siltstone Limestone, Bituminous sands
Turorian	Afowo formation	Sandstones, Shales, Siltstones, Clay
Barrenian	Ise formation	Sands, Guts, Siltstone
Precambrian	Basement complex	

Sources: Omatsola and Adegoke (1981)

The aims this paper are to:

(a) Use multivariate statistical techniques to explain the hydrogeochemistry of the groundwater in the study area.

(b) Identify the geochemical evolution of groundwater in Agbabu area and delineate the saline water intrusion in the coastal aquifers.

Materials and Methods

A total of eighty water samples were collected from hand dug wells and boreholes from the study area (fifty two water samples in the dry season and twenty eight in the rainy season). Two litres of water samples were collected using polythene bottles in the month of March, the end of dry season, and October, the end of rainy season. Water sampling points were located using Global Positioning System (GPS). Twenty seven physico-chemical analyses were determined using the established method of analyses (APHA1992). pH, EC, TDS, and temperature were measured in the field using PH 2603. Bicarbonate, SO_4, Cl, PO_4 NO_3, total hardness, alkalinity, turbidity, calcium, oil and grease and Mg were determined by wet analyses.

Cd, Pb, Cr, Cu, Fe, Zn, Mn, were determined by Atomic Absorption Spectrophotometer while Na and K were determined by flame Photometric methods.

Results and Discussion

Descriptive Statistical Analysis

Statistics of the hydrogeochemical data of the groundwater samples are presented in Tables 2. Groundwater in the study area have pH values ranging from 4.1 to 7.1 in the dry season and 6.73 and 8.70 in the raining season, indicating that the groundwater is changing from acidic to alkaline due to influx of HCO_3 ions as a result of percolation of rainwater through soils in the rainy season . Electrical conductivity ranges between 10 micros/cm and 300 micros/cm at 25^oC in the dry season and between 10 micros/cm and 870 micros/cm at 25^oC in the rainy season. The concentration of cations is in the order of Na >K > Ca> Mg. Sodium concentration varies from 2.98 mg/l to 21.07 mg/l, potassium from 1.26 mg/l to 19.86 mg/l, calcium from 0.80 mg/l to 18.82 mg/l and Mg from 0.01 mg/l to 11.18 mg/l in dry season. For the rainy season, the order is Mg > Ca > Na > k. The concentration of Nitrate is between 0.01 mg/l and 0.26 mg/l for dry season and between 0.01 and 0.70 mg/l for rainy season. The increase in the concentration of nitrate in the rainy season over the dry season period may be attributed to application of agricultural chemicals and atmosphere precipitation.

Table 2: Descriptive statistics of groundwater in dry season

S/N	Parameter	Minimum	Maximum	Mean	Std dev	Std error
1	HCO_3	1.83	112.85	39.45	24.91	3.49
2	Cl	1.00	63.81	37.54	15.42	2.16
3	NO_3	0.01	0.26	0.06	0.06	0.01
4	PO_4	0.12	0.82	0.33	0.15	0.02
5	SO_4	0.01	0.55	0.19	0.12	0.02
6	Ca	0.80	18.82	4.67	3.67	0.51
7	Ca hard	2.00	47.00	11.65	9.17	1.28
8	Total hard	4.02	69.95	17.79	12.14	1.70
9	Mg	0.01	11.18	2.26	2.21	0.31
10	Oil and grease	0.10	176.65	6.65	26.03	3.65
11	Na	2.98	21.07	11.05	4.04	0.57
12	K	1.26	19.86	7.04	4.00	0.56
13	PH	4.10	7.10	5.41	0.70	0.10
14	EC	10.00	300	95.29	73.74	10.33
15	TDS	2.00	220.00	65.22	54.70	7.66
16	Temp	24.00	36.90	29.99	3.24	0.45

Cluster Analysis

Cluster analysis was used here to determine if the samples could be grouped into statistically hydrogeochemical groups that may be significant in the geology context. In the study area, the clustering resulted into four major water groups (Fig. 2). Group 1 is composed of the wells 36, 38, 27, 25, 33, 42, 44, 46, 48, 40, 41, 43, 3, and 49 and this account for 29.4% of the total groundwater samples. This type of water is relatively fresh with a mean EC of 65.3 microsiemens/cm at 25^oC. This group is basically chloride dominated.

Group 2 is represented by the well 24, 26, 34, 35, 28, 29, 21, 15, 7, 9, 8, and 4 and this represents 23.5 % of the groundwater samples. The mean electrical conductivity of this group is 27.4 microsiemens/cm at 25^oC. This water type is bicarbonate dominated and has low concentration of sulphate. This water type can be interpreted as the first step of water-rock interactions occuring in dilute solutions because of the abundance of bicarbonate in the aquifers.

Group 3 include samples from well 30, 31, 6, 20, 16, 45, 12, 50, 2, 22, 23, 19, and 1. Chloride content is also high with respect to bicarbonate concentration. The mean electrical conductivity is 107.5 microsiemens/cm at 25^oC.

Group 4 comprises wells in stations 37, 39, 11, 5, 17, 18, 32, 13, 14, 51, and 10. The mean electrical conductivity is 227.8 microsiemens/cm at 25^oC and the dominant ion is chloride. Based on the geological and geographical position, the source of high concentration can be traced to sea water intrusion. Group four water samples have the greatest contamination.

Correlation Coefficient

The correlation coefficient is presented in Table 3. There is a positive correlation between Mg and Cl in the groundwater samples. Mg also shows positive and significant correlation with all the analyzed parameters except SO_4. The Mg-Cl positive correlation shows the influence of seawater and groundwater in mixing. The correlation coefficient between Mg and Cl is around 0.96 in this study. In general, anthropogenic factor due to over-abtraction of fresh water is responsible for the saltwater intrusion. There is also a high correlation coefficient between TDS and EC. Mg and Cl ions present in the water sample gave rise to the high TDS values.

Factor Analysis for Groundwater

The analysis generated six factors which together account for 74.6 % of variance. The rotated loading, eigen values, percentage of variance and cumulative percentage of variance of all the six factors are given in Table 4 and their screen plot in Figure 3. The first eigen value is 4.45 which account for 27.82 % of the total variance and this constitutes the first and main factor. The second eigen value is 1.91 and this account for 11.98 %. The third, fourth, fifth and sixth eigen values are 1.50, 1.43, 1.33 and 1.31 and accounts for 9.40 %, 8.93 %, 8.31 % and 8.18 % of the total variance respectively.

Factor 1 exhibit 27.82 % of the total variance of 74.6 % with positive loading on Ca, Ca hardness, total hardness, Mg, EC and TDS. This factor indicates strong association (r =0.6 – 0.9) between Ca, calcium hardness, total hardness, Mg, EC and TDS in groundwater. This factor is attributed to geogenic influence of these chemical constituents on groundwater as a result of water – rock interaction and this account for the temporary hardness of the water. The dissolution of carbonates and substitution of sodium with magnesium in the transient of water flow may be identified with this factor. The highest EC in the groundwater was 300 µS/cm at 25^oC and minimum was 10 µS/cm 25^oC. This is showing a high total mineralization, calcium and magnesium are major ions in the water and relatively related to the natural condition.

Therefore, this factor is related mainly to the dissolution process of carbonate minerals such as calcite and aragonite due to the fact that Mg and Ca are abundant and mobile.

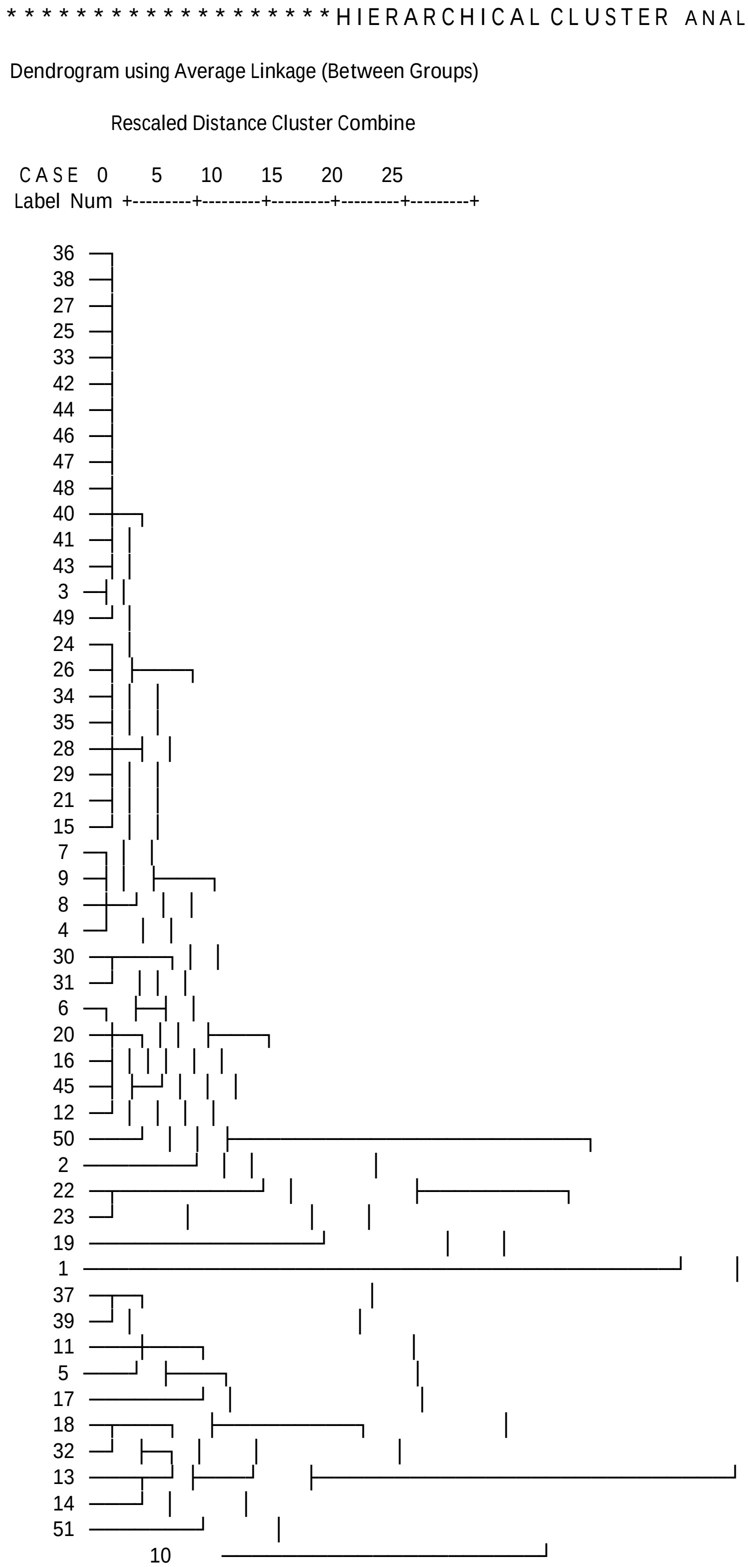

Fig. 2: Dendrogram for groundwater in dry season

Table 3: Correlation Matrix of Groundwater in Dry Season

		TABLE:														
Paras	Hco3	Cl	No3	PO4	So4	Ca	Ca Ha	TH	Mg	Oil/G	Na	K	PH	EC	TDS	TEM
Hco3	1															
Cl	0.28	1														
No3	0.05	0.33	1													
Po4	0.13	0.1	-0.04	1												
So4	0.18	0.05	0.09	0.33	1											
Ca	-0.05	0.15	0.08	0.05	-0.01	1										
Ca Hard	-0.05	0.15	0.08	0.05	-0.01	1	1									
TH	0	0.12	-0.04	0.08	-0.01	0.91	0.91	1								
Mg	0.05	0.3	0.14	0.1	-0.01	0.33	0.33	0.41	1							
Oil/G	-0.21	-0.24	-0.1	-0.11	0.11	0.27	0.27	0.27	-0.15	1						
Na	-0.2	0.05	-0.09	0.14	0.05	0.24	0.24	0.22	-0.03	0.28	1					
K	0.9	0.15	0.12	0.12	-0.05	0.11	0.11	0.12	0.23	0.02	-0.07	1				
PH	-0.13	0.24	-0.04	0.01	-0.22	0.14	0.14	0.12	0.17	0.09	0.2	0	1			
EC	0.08	0.4	0.08	-0.06	-0.04	0.65	0.65	0.67	0.61	-0.13	-0.03	0.13	0.16	1		
TDS	0.07	0.34	0.05	-0.04	-0.03	0.68	0.68	0.69	0.58	-0.11	0.02	0.07	0.16	0.95	1	
Temp	0.23	-0.07	-0.01	0.16	0.09	0.19	0.19	0.25	0.18	0.12	0.07	0.27	-0.05	-0.05	-0.02	1

Factor 2, which explains 11.96 % of the total variance, includes the high loading of oil and grease, Na, Ca hard and Mg. The high loading of oil and grease suggest pollution through spillage or through wastes from oil industries or may be as a result of decomposition of some forms of aquatic life, since the concentration of oil and grease increases toward the seashore in the study area. The presence of Na may be due to cation exchange process by which calcium and magnesium are replaced by the sodium ions. This can be link with the high loading of oil and grease which indicate the alkaline nature and this represent the role of dissolved CO_2 in the groundwater system as a result of the interaction between the groundwater and oil and grease.

Table 4: Rotated varimax matrix for groundwater in dry season

S/N	Parameters	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
1	HCO_3	0.03	-0.50	0.37	0.27	-0.22	0.00
2	Cl	0.25	-0.42	0.20	0.00	0.36	0.54
3	NO_3	0.02	0.02	-0.01	0.06	-0.08	0.91
4	PO_4	-0.02	-0.07	0.77	0.15	0.21	-0.10
5	SO_4	0.00	0.08	0.75	-0.10	-0.32	0.20
6	Ca	0.90	0.31	0.06	0.10	0.02	0.04
7	Ca Hard	0.90	0.31	0.06	0.10	0.02	0.04
8	Total hard	0.90	0.24	0.08	0.16	0.02	-0.10
9	MG	0.55	-0.35	-0.07	0.25	0.20	0.14
10	Oil & Grease	0.09	0.79	-0.02	0.11	-0.06	-0.02
11	Na	0.11	0.55	0.29	-0.06	0.44	-0.09
12	K	0.07	-0.08	-0.09	0.76	0.08	0.22
13	PH	0.11	0.05	-0.09	-0.01	0.85	0.01
14	EC	0.89	-0.30	-0.08	-0.07	0.10	0.11
15	TDS	0.90	-0.26	-0.05	-0.09	0.09	0.05
16	Temp	0.10	0.10	0.21	0.78	-0.11	-0.16
	Total	4.45	1.91	1.50	1.43	1.33	1.31
	% Of variance	27.82	11.96	9.40	8.93	8.31	8.18
	Cumulative	27.82	39.78	49.18	58.11	66.42	74.60

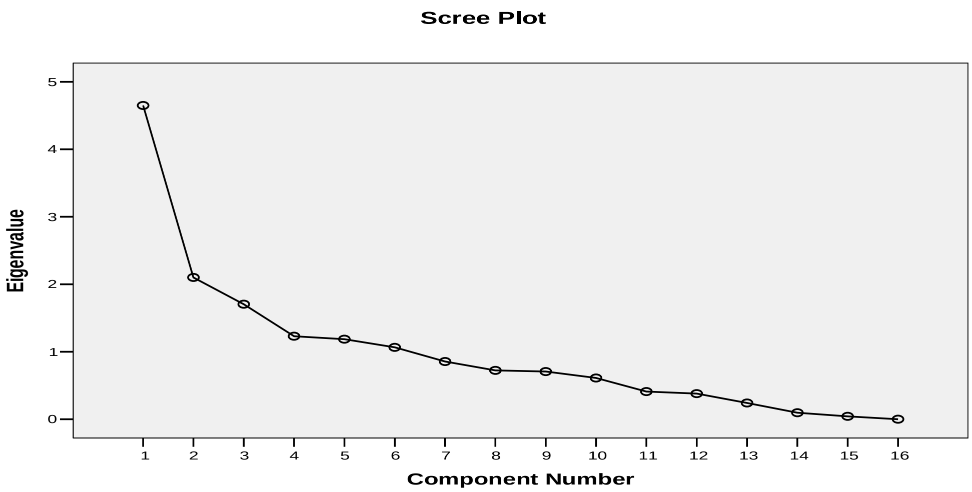

Fig. 3: Scree plot for Groundwater for dry season

Calcium and magnesium may be released into the water as a result of weathering of feldspars, amphiboles and pyroxenes. The lower concentration of Mg and Ca compared to Na is a result from the cation exchange process that occurs naturally when seawater intrudes into the aquifer system.

Factor 3 represent 9.4 % of the total rotated variance matrix of 74.6 % with positive loading of PO_4, SO_4, and weak loading of HCO_3. The presence of phosphate may be traced to agricultural activities in this area, which is the application of phosphate fertilizer. Although SO_4 concentration is more enhanced in seawater than freshwater, but SO_4 shows poor correlation with sodium (r = 0.05), Ca (r = 0.01) and Cl (r = 0.05) in this study. This indicates that the derivation of SO_4 is more related to other processes than extraction from seawater (Olobaniyi and Owoyemi, 2006). The source of SO_4 may be associated with precipitation and evapo - transpiration. Bicarbonate concentration may be due to seasonal changes associated with chemical reactions during rainstorm.

Factor 4 is associated with high loading of K and temperature. The high loading of K suggests pollution from application of potash fertilizer to the agricultural lands. The fourth eigen value is 1.43 and this account for 8.93 % of the total variance. The mean temperature of 30.0 ^{o}C was recorded in the study area during the dry season. It is known that the water temperature is controlled by the intensity of solar radiation, which reflects the temperature during the dry season, when the sampling was done. Temperature here plays an important role in the weathering process of the groundwater. The association of temperature and potassium indicates also the influence of temperature resulting into the hydrolysis of K – feldspar and plagioclase feldspar due to the fact that the contact time is long enough for significant dissolution of silicate minerals. Good examples of this process was observed in well 8 (19.86 mg/l), well 21 (17.48 mg/l) and well 16 (15.53 mg/l) where relatively high concentration of K is associated with higher temperature.

Factor 5 has a positive loading of pH, Na and Cl. Factor 5 account for 8.31 % of the total variance. The association of Na and Cl suggest salinity and it is an indication that the seawater mixes with the freshwater system.

Factor 6 accounted for 8.18 % of the variance with positive loading of NO_3 and Cl. The presence of chloride may be associated with environmental and atmospheric precipitation. The high loading of NO_3 in the groundwater samples may be attributed to atmospheric influence, plant remains, agricultural practices as well as sewage disposal at the recharge area of the groundwater. Nitrogen is a large component of both synthetic and organic fertilizer. Nitrate is a highly soluble compound and thus is extremely mobile in the environment. After fertilizer application, all nitrogen that are not absorb by the crops migrates into the groundwater.

Conclusion

Hydrogeochemical and contaminants studies of the groundwater in Agbabu and its environs were carried out through comprehensive interpretation of multivariate analysis of the chemical and physical data obtained. It can be concluded from the study that

The quality of the groundwater in the study area has been degraded by anthropogenic factors.

There are saltwater intrusion into the coastal aquifer leading to increase in the concentration of some ions, particularly chloride and magnesium, at the deeper depth.

Majority of the dissolved constituents found in the groundwater are as a result of weathering of minerals from the host rock. The sources of some of the constituents may be linked to the effluent water discharge, decay of organic matter, agricultural practices, as well as oil spillage.

Cluster analysis confirmed the existence of four types of water quality: low, medium high and very high polluted surface and groundwater. From factor analysis, the overall hydrochemical characters of the samples from surface and groundwater does not show evidence of mixing but are affected by cation exchange processes. Some of the groundwater is of good quality based on their physical chemical properties. Therefore, they are good for domestic purposes but those that are contaminated should be discarded or treated before use.

References

Ako, B.D., Adeniyi, F.I. and Adepoju, J.F. (1990): Statistical Test and Chemical Quality of Shallow Groundwater from a Metamorphic Terrain, Ile-Ife/Modakeke, SW Nigeria Jour. African Earth Sciences, Vol. 10 No 4 Pp 603 - 613.

Akoyeton, I.S, Ogundele, F.O and Soladoye, O (2010): Characterisation by factor analysis of chemical facies water in the coastal plain sand aquifers of Lagos, S.W, Nigeria. Int. Jour. Acad. Res. Vol. 2, No. 5, pp 256 -260.

Aris , A.Z, Abdullah, M.H and Woong, K.K (2007): Hydrochemistry of groundwater in Manukan island, Sabah. The Malaysian jour. of Analytic sci. , Vol. 11, no. 2, pp 407 -413.

Belkhiri, L., Boudoukha, A, Mouni, L. and Baouz T. (2010): Multivariate Statistical Characterization of Groundwater Quality in Ain Azel Plan, Algeria. African Journal of Environmental Science and Technology, Vol. 4 (8), Pp 526 – 534.

Elueze, A.A., Omidiran, J.O. and Nton, M.E. (2004): Hydrogeochemical Investigation of Surface Water and Groundwater around Ibokun, Ilesha Areas, South Western. Nigeria – Journal of Mining and Geology. Vol. 40 (1): Pp 57 – 64.

Farooq, M.A., Malikm M.A., Abbasi, H.N. (2010): Multivariate Statistical Approach for the Assessment of Salinity in the Periphery of Karachi, Pakistan. World Applied Sciences journal. Vol.11 (4). Pp 379 – 387.

Gurugnannam, B, Sures, M, Vinoth, M, Prabhakaran, N and Kumarevel, S (2009): GIS based microlevel approach for hydrogeochemical studies in upper Manimuktha sub basin , vella, South India. Inadian J. Sci. Technol. Vol. 2, No. 11, pp 5 – 10.

Liu, Chen- Wuing, Lin, Kao- Hung and Kuo, Yi-Ming (2003): Application of Factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. The science of total environment, Vol. 313, pp 77-89.

Olobaniyi, S.B. and Owoyemi, F.B. (2006): Characterization by Factor Analysis of the Chemical facies of Groundwater in the Deltaic Plain Sands Aquifer of Warri, Western Niger Delta. African Journal of Science and Technology. Science and Engineering Series. Vol. 7, No. 1, Pp 73 – 81.

Omosuyi, G.O. (2001): Geophysical and Hydrogeological Investigation of Groundwater Prospects in Southern Part of Ondo State. Unpublished PhD Thesis. FUTA.

Omatsola, M.E. and Adegoke, O.S. (1981): Tectonic Evolution and Cretaceous Stratigraphy of Dahomey Basin. Jour. Min. and Geology. Vol. 18 No. 1, Pp 130 – 137.

Reghunath, R., Sreedhara Murthy, T.R., Ragharan, B.R. (2002): The Utility of Multivariate Statistical Techniques in Hydrogeochemical Studies: An Example from Karnataka, India. Water Research. Vol. 36. Pp 2437 – 2442.

Senthikumar , G, Ramanathan, A.L, Nainwal , H.C and Chidambaram, S (2008) : Evaluation of the hydrogeochemistry of Groundwater using factor analysis in the Cuddalore coastal region, Tamilnadu, India. Indian Journal of marine sciences Vol. 37(2), pp 181 – 185.

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Impact of Urbanization on Wetland Degradation: A Case Study of Eleyele Wetland, Ibadan, South West, Nigeria

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Abstract

Nigeria is richly endowed with both coastal and inland wetlands, many of which are being threatened by anthropogenic drivers such as land use activities, urbanization, agricultural activities in addition to the emerging threats of climate change. Therefore, this study highlights the environmental assessment of urbanization land-use impacts on degradation of Eleyele Wetland in Ibadan SW-Nigeria. For the study, a GIS-based remote sensing assessment was employed to characterize the temporal changes in land-use dynamics within the catchment areas of the Eleyele Wetland. In addition, about 40 water samples (from both the main Lake and feeding streams) and 25 bottom sediments samples were collected and subjected to chemical analyses of the major cations and trace metals using inductively coupled plasma mass spectrometer and atomic Emission spectrometer (ICP-MS /-AES) methods respectively. The GIS-based assessment revealed a reduction in the riparian wetland forest of 1.25 km^2 as at 1984 to 0.70km^2 by 2004 with a projected decline of 0.42 km^2 by 2014. These clearly signify considerable impact of human activities with loss of 45-70% of the wetland riparian and light forests due to about 70% increase in build-up areas between 1998 and 2004. The measured physico-chemical parameters of the water revealed relatively higher values in the feeder streams compare to that of the main wetland Lake with pH values of 6.5 to 8.8 and 6.7 to 10.1 and EC of 141 to 1252µS/cm and 142 to 424µS/cm respectively. The average Ca, Mg Na and K concentrations in the lake revealed values of 29.1, 9.3, 29.6 and 13.0 mg/l respectively while those of the feeder streams are 43.9, 9.9, 39.7 and 13.49mg/l respectively. The results of the trace metals such as Cr, Cd, Co, Cu, Pb, Ni, Fe, Al, Mn and Zn also show the similar trend of higher values in the feeder streams over those of the lake samples, a situation which could be attributed to impacts of urban waste water and effluent discharges to the feeder streams. However, the lower concentration in the main lake can be attributed to the dilution effect. The overall results highlight the negative impacts of the human-induced influence on the Wetland ecosystem through land-use and waste effluent discharges with attendant degradation / loss; hence, the need for Integrated Water Resources and Environmental Management in order to safeguard the overall quality of the wetland ecosystem.

Keywords: Urbanization, Wetland degradation, Eleyele Wetland, Ibadan-Nigeria.

Introduction

Wetlands are among the Earth's most productive ecosystems. The significance of wetlands lie in their roles in the hydrological cycle, for flood and biomass production, as refuge for wildlife, biogeochemical functions, as nutrient and pollution filters for water quality improvement among others. However, it had been reported that a large percentage of wetlands have been lost in the last century, apparently due to drainage and land clearance as consequence of agricultural, urban and industrial development activities (Frenken, 2002; Williams et al., 2009). Coupled with these anthropogenic impacts, the degradation of wetlands is being compounded by the emerging reality of climate change and associated impacts.

Wetlands are generally flat-floored, relatively shallow and occupy the lower reaches of watersheds of large rivers, which are either located near the coast and generally do not have large flood plains (Windmeijer and Andriesse, 1993). They comprise of valley bottoms and flood plains, which may be submerged for greater parts of the year. The hydromorphic fringes and contiguous upland slopes contribute water to the valley bottom through runoff and groundwater flow. Wetland ecosystems, including rivers, lakes, floodplains and marshes, provide many services that contribute to human well-being and poverty alleviation (Millennium Ecosystem Assessment, 2005). However, they are increasingly subject to intense pressure from multiple human activities such as water diversion, pollution, over-exploitation of natural resources, and reclamation.

Wetlands are significant ecosystems for two principal reasons: they could be used in a sustainable way and would relieve current pressures on the upland agro-ecoystems, which is being threatened by increasing population pressures as well as desertification. Secondly, physical conditions for cropping within wetland/inland valley are more favorable than uplands since there is more water in this ecosystem. In addition, during the dry season, valley bottom and fringes are almost the only location in most agro-ecological zone where crops can be grown outside irrigated areas. The principal problem posed by these agro-ecoystsems is that for reasons, which are unclear, the potentials of wetlands have remained relatively untapped. According to Brerton, 1988), only 10 and 25 % of these are currently used for agricultural production, although a trend toward a greater use of wetlands is apparent in many areas of Nigeria and West Africa.

Nigeria is a country richly endowed with both coastal and inland wetlands and these wetlands are of ecological, economic, socio-cultural, scientific and recreational significance. Wetlands provide critical functions that are essential for sustainable development in many areas. Wetlands are hugely diverse and these could be ponds, marshes, coral reefs, peat lands, lakes or mangroves. These wetland types share one fundamental feature which is the complex interaction between soil, water, animals and plants.

Furthermore, it should be pointed out that the greatest increases in food production (both during the raining and dry seasons) in Nigeria could come from the wetlands and associated hydromorphic lands. However, with urban populations increasing in Nigeria, food production from the uplands cannot meet increasing population food demand; thus, wetlands may be the most logical environment in which to close this gap. For example, due to their hydrological characteristics, wetlands are favorable ecosystems for rice production during the rainy season and for the cultivation of various arable crops and vegetables during the dry seasons when the water levels have receded. Thus such wetland environment can be described as a small-scale irrigation sites developed through exploitation of shallow groundwater by private farmers, who take responsibility for the investment and management of the farms. It is an alternative to large-scale irrigation system, which failed to meet the food self-sufficiency and security of Nigeria (Baba, 1993). In other words, wetlands cropping afforded peoples some opportunities utilizing the surplus labor during the dry seasons unlike in the rainy seasons when there is labor constraint. However, it should be noted that due to poor land use management soil quality has degenerated resulting in low organic matter content, declining nutrients, fragile topsoil structure and reduced soil moisture coupled with uncontrolled crop cultivation and over grazing. In addition to this, the Nigeria's wetland resources are currently being threatened by some anthropogenic and bio-geophysical factors which are increased population pressure, rapid urbanization, mining and pollution among others. Therefore, at present and for the foreseeable future, human activities will continue to adversely affect wetland ecosystems. The rate at which wetlands are being lost is affecting water supply and water resources management in various parts of Nigeria and especially with the case of Eleyele Wetland in Ibadan metropolis. Hence, there is no gainsaying that the degradation of wetland ecosystems will increase the task and challenges of water resources management in Nigeria.

Climate, topography and soils interact to determine major hydrological processes of the inland valleys and this in turn determine the availability of surface or ground water. Water from the uplands flows towards the valley bottom as surface runoff and just below the soil surface (interflow), or well below the soil surface (groundwater flow). Usually, three hydrological processes characterize wetlands viz: seepage, runoff and vertical fluctuations in the water table (Carsky and Masajo, 1992; Raunet, 1985). These processes are however, determined by indices such as rainfall, soil texture, soil depth, and catchments area as well as valley morphology. Therefore the variability of indices across any section of the wetland ecosystem will in turn affects the hydrologic characteristics of the wetlands. In view of the ecological and hydrological significance of wetlands the negative impacts of such climate change and human-induced degradation on the features of wetlands system (i.e. *components, attributes* and *functions*) will have serious consequences in terms of environmental sustainability. Usually, the *components* of wetlands system are the biotic and non-biotic features such as soil, water, plants and animals, while the *attributes* relate to the variability and diversity of these components e.g. diversity of species. However, the, influence of agricultural land-use and other human activities alongside with climate change-induced hydrological modifications (affecting a biotic factor) are said to affects the attributes and functions of wetlands ecosystem (Gosselink, and Tuner, 1978). These are reflected in terms of storage of runoff water, reduction of peak runoff rates, improvement in the quality of water flowing over and through the lands, provision of habitat for birds and wildlife and the maintenance of biodiversity of plant and animal species.

Nonetheless, there are several drivers for wetlands degradation, notable among these lies in the need to expand agriculture to feed growing population, especially in the developing regions of the world, leading to the conversion of wetlands into farmlands. Agricultural activities have been recognized as affecting ground and surface water quality adversely from both point and non-point sources (William et al., 2009). In tropical savanna region wetlands are called *fadamas,* which apart from serving as refuge for wildlife, are primarily utilize to sustain agricultural activities at the local communities. In such tropical region, as in most of the developing countries of Africa, apart from population increase and the attendant competing water needs for agricultural, domestic, and industrial purposes, the surface water regimes are vulnerable to rainfall variability and/or river regulation and abstraction activities. Therefore, ensuring the successful delivery of allocated water to a wetland will require integrated management of associated surface and groundwater resources, at the same time there is the need for better understanding of the agriculture water management in wetland ecosystem.

In summary, there is no doubt as to the increasing impacts of agricultural land-use and other urban human activities on the wetland ecosystem functions on one hand. On the other hand, there is a consensus that climate change is an ongoing phenomenon which will impact negatively on wetland hydrology. Therefore, knowledge of climate variations in space and time as well as knowledge of impacts of land-use activities within the catchment of wetland is vital for adequate assessment of wetland loss and degradation.

Based on the above background, the overall aim of this investigation is to highlight the environmental assessment of land-use impacts and degradation of Eleyele Wetland in Ibadan SW-Nigeria, with specific objectives of:

a) Assessing the effect of the land-use activities on the the wetland ecosystems and
b) Assessing the geochemical characters and contamination of bottom sediments and soils of the Eleyele wetland.

Study Area

Eleyele Wetland

The study location Eleyele Wetland is located in north-eastern part of Ibadan, southwestern Nigeria within longitude N07^{0}25'00" and N07^{0}27'00" and Latitude E03^{0}50'00" and E03^{0}53'00" (Figure 1). The study site is surrounded by Eleyele neighborhood in the south, Apete in the east and Awotan in the north. Eleyele wetland is a modified natural riverine wetland type with area of about 100 km^2 including the catchment area. The elevation is relatively low ranging between 100-150m above sea level and surrounded by quartz-ridge hills toward the downstream section where the Eleyele dam barrage is located. A number of stream channels serve as feeding / recharge streams to the Eleyele wetland basin. In 1942, the quest to create a modern water supply system to meet the challenge of water scarcity for the emerging Ibadan metropolis led to the construction of Eleyele Dam on the main River Ona with a reservoir storage capacity of 29.5 million litres.

Climatic Setting and Vegetation

The study area, Ibadan fall under Tropical Hinterland Climate Zone (about 150–240km northwards from the coast) with 1000 to 1500mm annual rainfall, temperature range of 21–25°C and relative humidity range of 50–80%. The dry season range from 4–5 months between November to March, with December-January characterized by NE-SW dry, cold and dusty harmattan trade wind, from the Sahara Desert. For the study Eleyele Wetland, the adjoining hilly quartzite ridges are covered by forests, while the wetland lowland areas are dominated by light forest, riparian wetland forest most of which had been impacted by human activities.

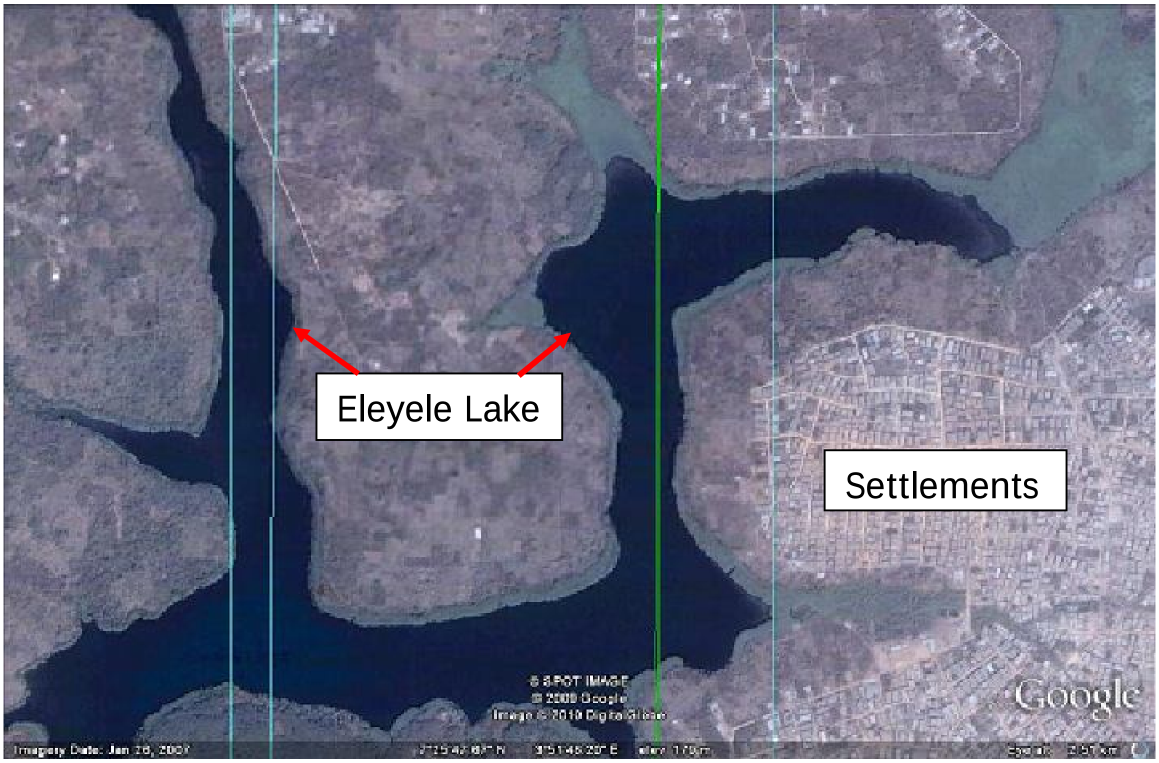

Figure 1: Aerial Photo of Eleyele Wetland catchment showing the agricultural land-use and encroaching settlements (Source; Google Earth).

Geology and Drainage System

Geology of Ibadan and environs, including the catchment of Eleyele Wetland, falls within the Pre-Cambrian rocks of Southwestern Nigeria which is part of the Nigerian Basement Complex. The major rock types are schist-quartzites, granite-gneiss, banded gneiss, augen-gneiss, and migmatites (Jones and Hockey, 1964; Olayinka et al., 1999), while minor rock types such as pegmatite, aplites, quartz veins, and dolerite dykes intruded the main rocks in places (Figure 2). Gneisses are migmatized in places, and characterized by predominantly medium-sized grains while schist-quartzites occur as elongated ridges striking NW-SE (Olayinka et al., 1999).

The drainage system is controlled by the bedrock geology, with characteristic dendritic pattern of the streams and rivulets being structurally controlled. Flash overland flow and drainage discharge is common during the wet season from May through October aided by the hilly nature of the surrounding terrain. The Eleyele Wetland and the associated dam at Eleyele receive water from River Alapata and the headstream of River Ona (see Figure 2). The catchment of the Eleyele Wetland is relatively well drained with network of River Ona and its tributaries (such as Ogbere, Alapata and Ogunpa). River Ona flows roughly in north - south direction.

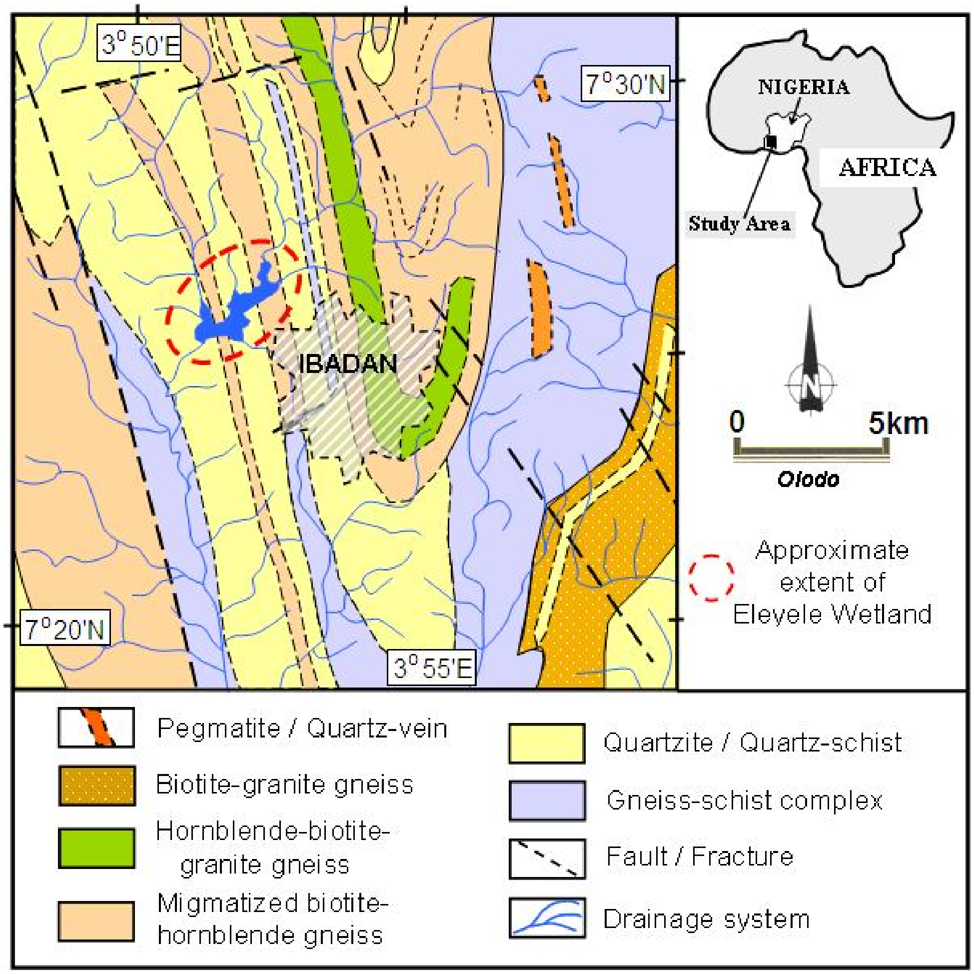

Figure 2: Geological map of the Ibadan showing the location of Eleyele Wetland

Methodology (Sample Collections and Analyses)

Methods employed in this study involved a number of activities, both field and laboratory based, were undertaken in order to generate the necessary data. Initial desk study involved a GIS-based assessment of the sptial and temporal changes in the areal extent of the different land-use in order to assess land use changes and possible attendant impacts of human activities on the Eleyele Wetland ecosystem. Subsequent field in-situ measurements of field physico-chemical properties of water samples from both the main wetland reservoirs and the feeding streams as well as sampling of water and bottom sediment samples along the feeding tributaries and within the wetland reservoir were also undertaken. In addition soil samples from the buffer zones were also collected.

Physico-chemical parameters measured or determined in the field are electrical conductivity (EC), Total dissolved solid (TDS), pH and temperature of the water with the aid of portable pH/Conductivity/Temperature meter (model PC Testre meter). For the field sampling operation, a local boat was used in moving from locations to locations within the make lake while water samples were collected in two separate 50cl polyethelene sampling bottles for cations (acidified) and anions analyses. In addition, the buffer zones soils as well as bottom sediment samples within the lakes and feeding streams were also collected with the aid of hand auger with polythene bags. Figure 3 presents the sampling locations of the different media within the catchment of Eleyele Wetland.

Water samples were preserved after collection before chemical analyses under refrigeration, while bottom sediment samples were air-dried and sieved with sieve of 0.2µm mesh size to obtain the clay portions. Subsequently, cations and trace elements in the water and bottom sediments samples were analyzed at the ACME Analytical Laboratory, Vancouver, Canada, using ICP-MS and ICP-AES method respectively. However, the buffer soil samples were aired dried and subjected to chemical analyses at the soil laboratory of the Agronomy Department at the University of Ibadan, Ibadan, Nigeria.

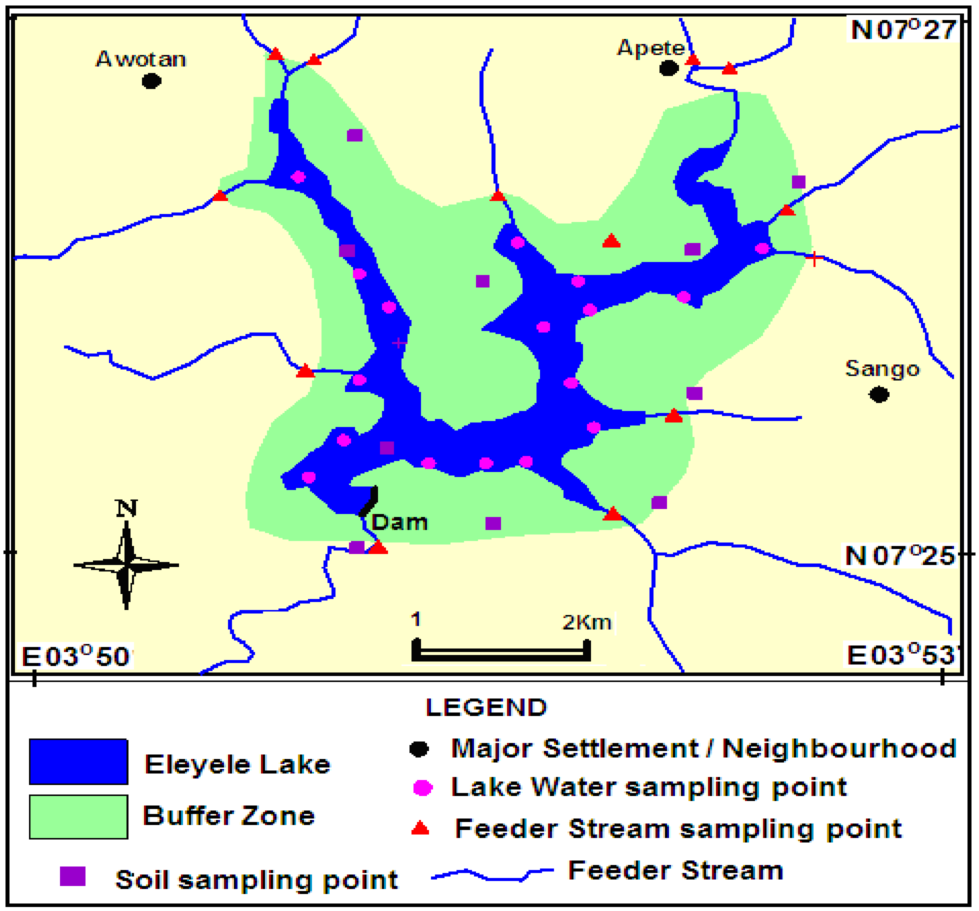

Figure 3: Location map of the Eleyele Wetland Catchment showing the water, soil and bottom sediments sampling points

Finally, as part of data evaluation, the results of the in-situ physico-chemical measurements and laboratory geochemical analyses of the water samples, bottom sediments and soil samples were subjected to statistical evaluation involving statistical summary and correlation to ascertain the interdependence or otherwise of the different parameters. For the assessment and quantification of the level of wetland contamination / degradation with respect to the various media sampled (water, bottom sediments, and buffer soils), some quantitative and qualitative indices were used to describe the concentration trends and also to allow for easy comparison between the measured parameters and a number of standards.

Results and Discussion

GIS-based Mapping of Land Use Changes

The GIS-based assessment of the temporal changes in the areal extent of the different land-use type involved evaluation of remotely sensed satellite imagery for the period of 1984 and 2004, while the resulting evaluation were used to obtain scenario for the intervening period of 1994 and the future projection for the period of 2014. The composite map of the spatial didtribution and areal coverage of the different land use types for the periods of 1984 and 2004 are presented in Figure 4a and b, while the evaluated results is presented in Table 1.

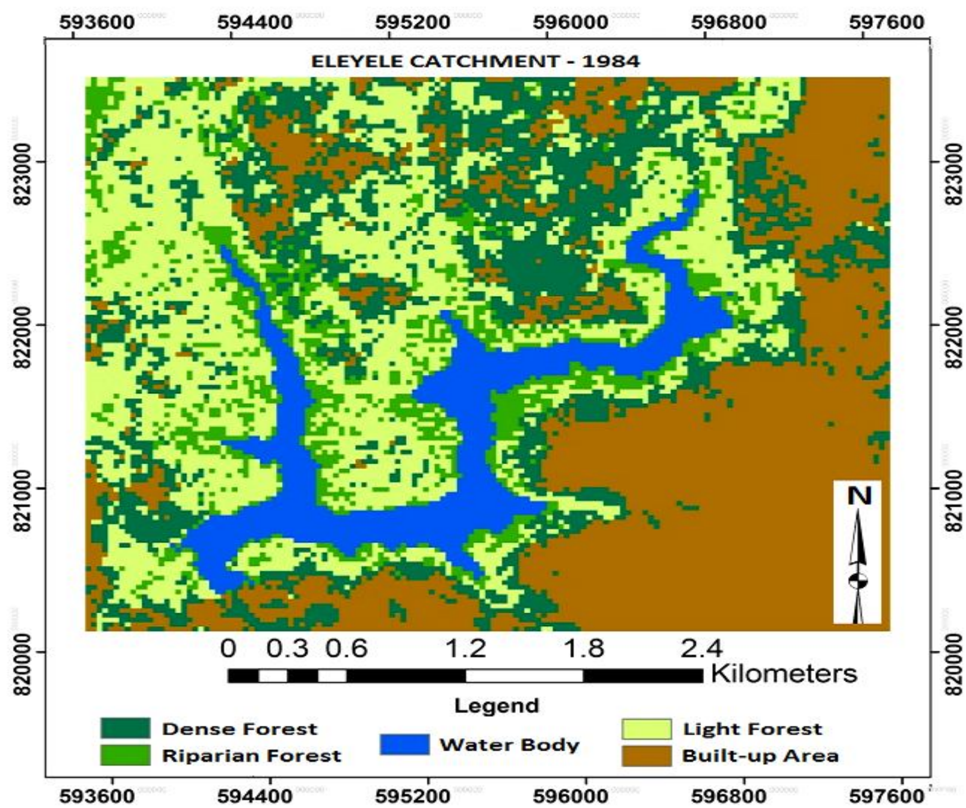

Figure 4a: GIS-based imagery map of spatial distribution of the land-use type as at 1984.

As presented in Table 1, a critical interpretation and evaluation of the imageries revealed that the dense forest within the catchment area had reduced in extent from 3.38km^2 in 1984 to 3.01km^2 by 2004 with a projected decrease to 2.52km^2 by 2014. Similarly, the riparian wetland forest of 1.25 km^2 as at 1984 was reduced to 0.70km^2 by 2004 and also projected to decline to 0.42 km^2 by 2014. The water body, however, experience comparatively little change with an areal extent of 1.25 km^2 as at 1984 and 1.14 by 2004.

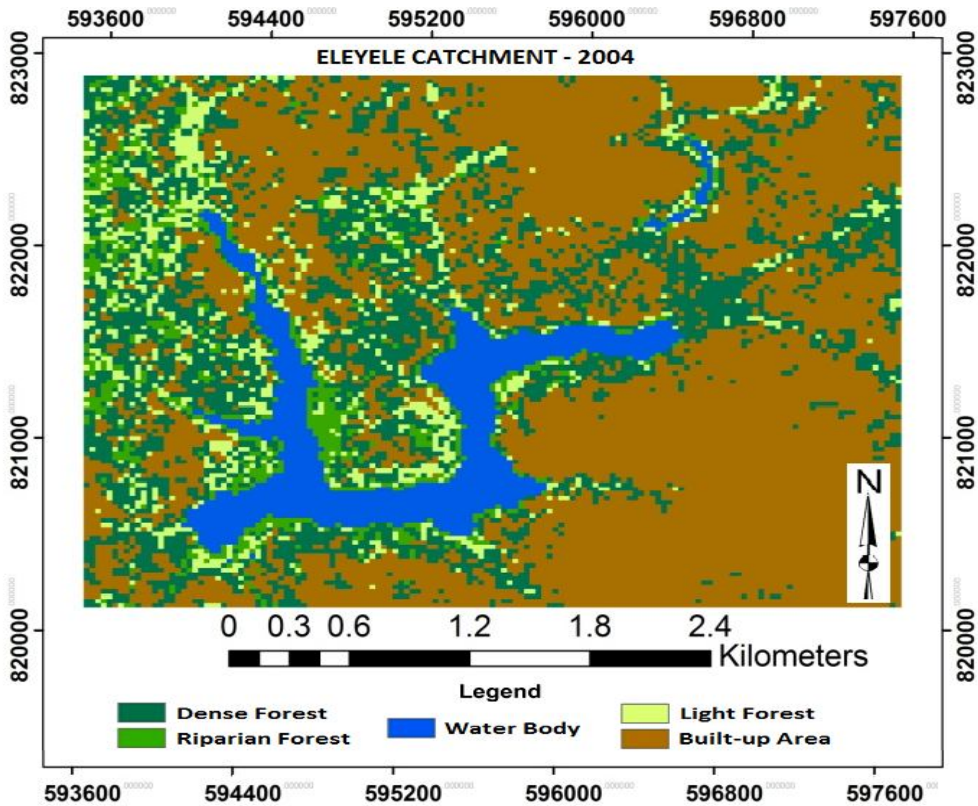

Figure 4b: GIS-based imagery map of spatial distribution of the land-use type as at 2004.

Nonetheless, considerable impact of human activities within the Eleyele catchment is reflected in the considerable decline in areal extent of the light forest from 3.84 km^2 in 1984 to 1.09 km^2 by 2004 apparently giving way for the built-up area which had expanded from 4.47 km^2 in 1984 to 7.52 km^2 by 2004 (see Table 1).

Table 1: GIS-based estimated and projected temporal changes in the spatial extent of land use types (in km^2) within the Catchment of Eleyele Wetland

Land Use Type (km^2)	1984^+	1994*	2004^+	2014*
Dense forest	3.38	3.20	3.01	2.52
Riparian (wetland) forest	1.25	0.98	0.70	0.42
Light forest	3.84	2.46	1.09	0.01
Water body (River)	1.25	1.19	1.14	1.09
Built-up Area	4.47	5.99	7.52	9.04

+ = Estimated * = Projected

Furthermore, the temporal and spatial changes in land use pattern are clearly evident as highlighted in Fig. 5. The riparian wetland forest and the surrounding light forest witnessed significant loss or degradation (of 45-70%), due to urban development activities resulting in increase of about 70% in build-up areas as at 2004 compared the situation in 1984. This is no doubt a clear indication of anthropogenic activities or impact of urbanized activities within the catchment of Eleyele Wetland with attendant degradation and loss. However, unlike the riparian wetland forest and the light forest, the Eleyele wetland water body and surrounding dense forest are less affected with about 10% loss as at 2004.

This may be attributed to the fact that most of the so-called dense forests are located on the surrounding hilly quartzite ridges with poor accessible for development compared to the light forest area at the low lying plains, in addition to the fact that some are planted forest reserves. Nonetheless, the observed minimal change in the extent of the wetland water body despite the obvious encroachment implies that the feeding channels are still kept open and that water, as usual, do find its level.

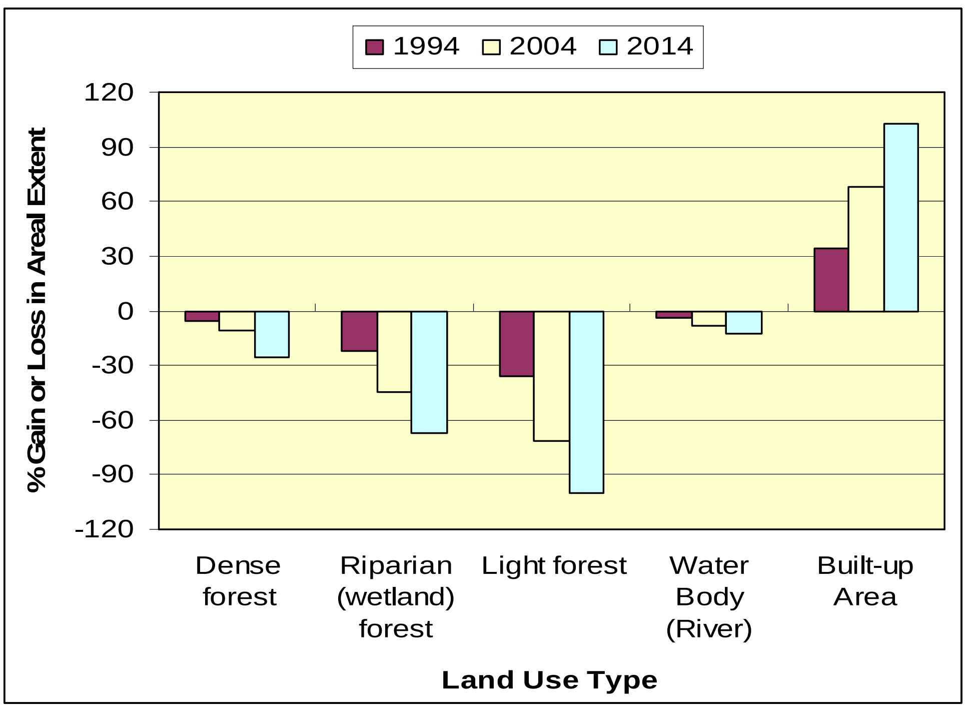

Figure 5: Temporal variation in the estimated percentage loss / gain in the extent of the different land use within Eleyele Wetland with reference to 1984 situation.

Physical and Chemical Characteristics of the Wetland Waters

The summary of results of field physico-chemical data and chemical analyses of the water samples from the Eleyele wetland lake and feeding streams within the catchment of Eleyele wetland are presented in Tables 2.

The results revealed water pH range of 6.7 – 10.1 for the main wetland lake indicating neutral to alkaline in nature compared the values of 6.5 – 8.8 for the feeding streams. Also the water temperature of 28.6 – 32.7°C (av. 31.0°C) for the main lake reflects a tropical lake setting influenced by solar heat exchange compared to the cooler temperature of the riparian feeding steam (25 – 30.9°C). Also the distribution of the electrical conductivity (EC) varies between 250 – 344µS/cm (av. 316µS/cm) with corresponding TDS values of 213–334mg/l (av. 242mgl) within the main Lake indicating low variability. However, as graphically presented in Figure 6, the observed higher values and variability of EC (141 – 1,252µS/cm) and the corresponding TDS (106 – 9,39mg/l) in the feeder streams can be attributed to anthropogenic point sources discharges of untreated waste effluents within the catchment area. The trend is consistent with the results of Tijani et al., 2007 as well as that of Tijani and Onodera, 2009.

Table 2: Statistical summary of physical and chemical composition of water samples from the main lake and feeder streams of Eleyele Wetland.

	Main Lake (N=26)			**Feeding Stream (N=15)**		
Parameters	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**
Elev (m)	173	201	183.5	174	192	184.8
EC (uS/cm)	250	344	316.9	141	1252	426.5
TDS (mg/l)	213.8	334	241.5	105.8	939	319.9
pH	6.7	10.1	8.3	6.5	8.8	7.3
Temp. °C	28.6	32.7	31	25.8	30.9	28.1
Ca (mg/l)	8.94	71.83	25.26	10.68	152.49	45.96
Mg (mg/l)	3.87	16.00	8.73	3.18	18.50	9.90
Na (mg/l)	11.05	31.83	28.13	10.36	98.97	39.72
K (mg/l)	3.21	15.10	13.01	4.32	34.75	13.49
Si (mg/l)	0.92	27.53	3.39	1.39	14.24	11.06
Al (mg/l)	0.01	0.56	0.09	0.03	0.30	0.13
Fe (mg/l)	0.01	1.13	0.45	0.38	3.77	1.34
Mn (mg/l)	0.03	0.45	0.15	0.10	1.93	0.63
Ba (mg/l)	0.02	0.36	0.10	0.08	0.30	0.14
Sr (mg/l)	0.13	0.45	0.18	0.06	0.36	0.19

In general, it can be deduced that the observed profiles of the in-situ physical parameters of the water from the main lake and the feeder streams of the Eleyele Wetlands clearly demonstrate the impacts of human activities (direct discharge of household effluent and at times waste dumps) especially on the feeding stream, in terms of wetland water quality and the overall ecosystem quality. Nonetheless, it should be pointed out that the relatively low but uniform profile within the lake does not necessarily imply lack of contamination from the catchment area; rather it is an indication of possible dilution/volume effect.

As summarized in Table 2, the water quality results for the main lake revealed average concentration of 25.3 and 8.7mg/l for Ca and Mg and 28.1 and 13.1mg/l for Na and K. With exception of is with average concentration of 3.4mg/l, other major elements (Al, Fe, Mn, Ba and Sr) have concentrations of less than 1mg/l. For the feeding streams, the concentration profile follow similar trend with Ca and Mg having average concentration of 46 and 9.9mg/l respectively compared to 39.7 and 13.5mg/l for Na and K respectively. Similarly, with the exception of dissolved silica and Fe, other elements have concentration less than 1mg/l.

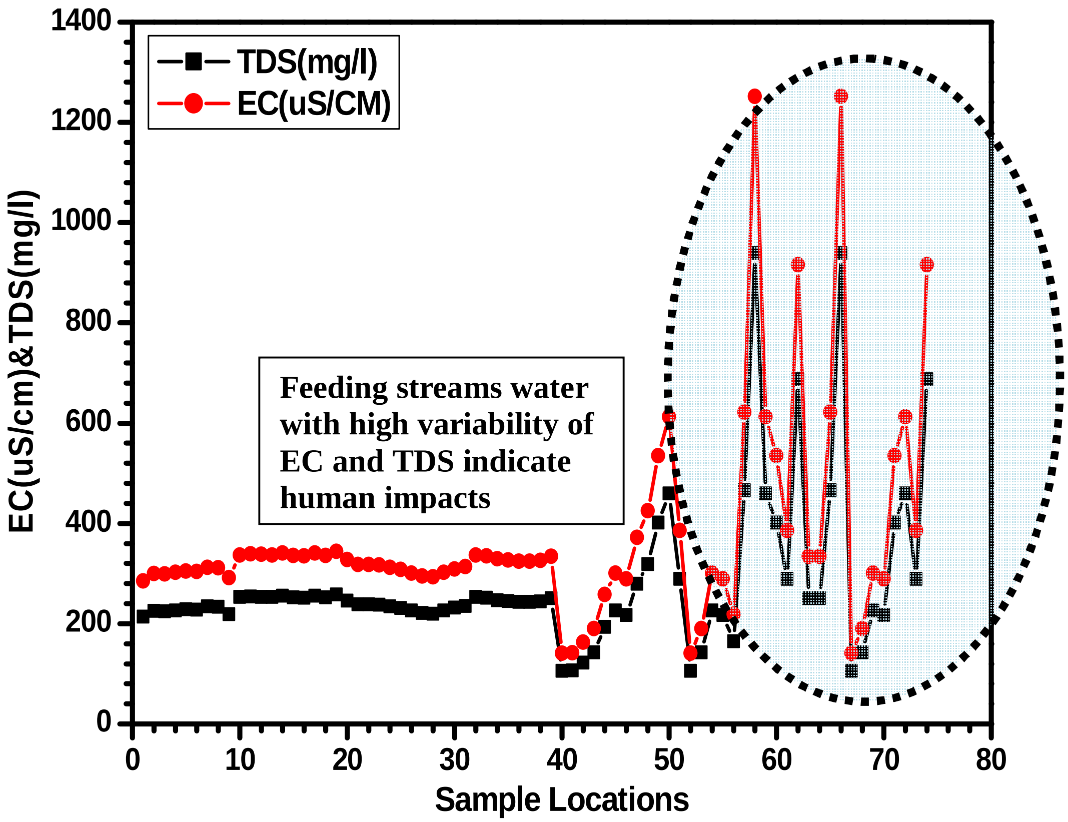

Figure 6: Plot of EC and TDS against the sampling locations highlighting the impacts of human land use activities on the feeding streams of the Wetland.

In general, the relatively concentration of the major cations (Ca, Mg, Na, K) in the Eleyele wetlands is a reflection of the relatively soluble nature of these elements as weathering products. However, a closer look at the data graphical plots of the major elements as presented in Figure 7a and b revealed more or less higher variability of the metal concentrations in the feeding stream compared to the mail lake waters. This can be attributed to possible anthropogenic discharges at the feeding streams on one hand and due to possible dilution effect at within main lake.

Nonetheless, the overall trends in the chemistry Ca>Na and K>Mg is generally a reflection of the chemical characteristics of the underlying bedrocks, the weathering of which release these elements as soluble components of weathered soil profile. Apparent dissolution of these, either by surface run-off or recharge infiltration into the shallow groundwater system, control or influence the observed chemical characters of the analyzed water samples from the Wetland Eleyele Wetland.

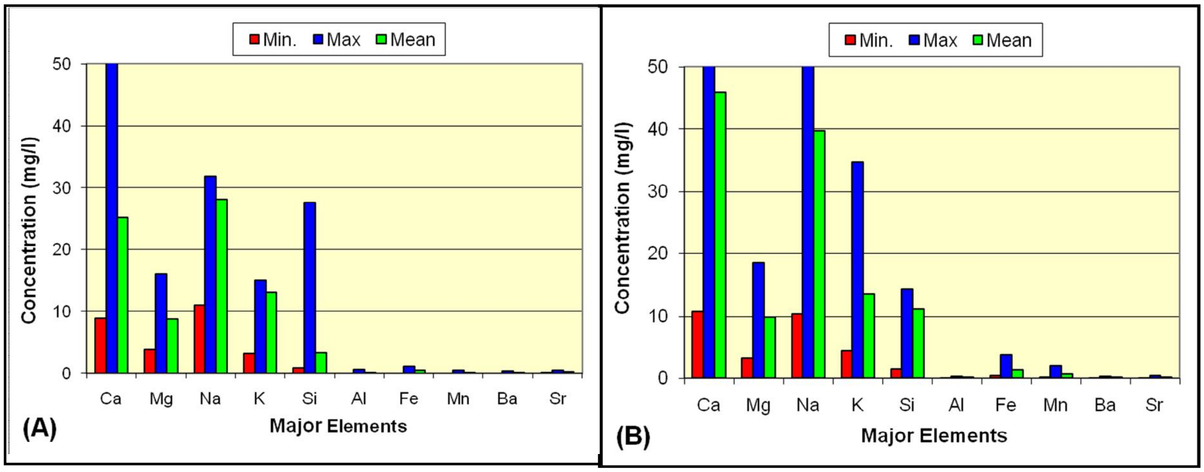

Figure 7: Profiles of major elements concentrations in water samples from (a) the main lake and (b) feeding stream.

Trace Elements in Waters of Eleyele Wetland

Due to the focal position of wetland in any landscape, usually at the receiving end of contaminant input from the catchment areas, an assessment of possible trace metal contamination of the urbanized Eleyele wetland was also undertaken. As summarized in Table 3, trace metal concentration of the main lake revealed a wide range with average of 1.97 – 3.9 ug/l for Cd, Pb and Cu, while Zn and B have higher values of 39.8ug/l and 22.5ug/l respectively. In addition, for the feeding streams, the trace metal concentration revealed similar trend with average value of 2.4 – 5.2 ug/l for Pb, Cu, Cd, and Co, while like in the lake waters, Zn and B have higher average value of 80.4ug/l and 24.8ug/l respectively. However, Ni exhibits similar concentration with average value of 7.9ug/l in the main lake and feeding streams.

Table 3: Comparison of the Trace metals concentrations with average (total) baseline / background concentrations of trace elements in Lakes and Rivers

Parameters	**Main Lake Water (N=26)**			**Feeding Stream Water (N=15)**			**Lakes/ Rivers***
	Max	**Mean**	**Median**	**Max**	**Mean**	**Median**	**Median**
Pb (µg/l)	9.90	2.63	2.30	19.70	5.18	3.60	0.022
Zn (µg/l)	173.0	39.80	23.55	513.20	80.40	37.60	0.116
Cu (µg/l)	7.90	3.92	3.45	15.80	5.08	3.70	0.058
Cd (µg/l)	5.16	1.97	1.69	4.91	2.37	1.43	0.005
Co (µg/l)	1.10	0.32	0.27	9.61	3.28	1.73	-
Ni (µg/l)	91.6	7.91	4.10	18.30	7.95	5.40	0.058
Cr (µg/l)	2.50	0.90	0.85	3.30	1.60	1.60	0.074
B (µg/l)	75.0	22.46	21.00	58.00	24.82	23.00	-

*Calculated average (total) concentrations of trace elements in Lakes and Rivers (Nriagu, 1990).

A closer evaluation of the data revealed higher trace metals concentrations in the feeding stream, like the major elements, as highlighted in Figures 8a and b. For example, the average concentrations of Pb, Zn, Cu and Cr in the feeding streams are 2-fold higher than those of the main lake. Co is about 6-fold enriched while B, Ni and Cd exhibit similar level of concentration in waters from both feeding streams and the main lake. The observed enrichment trend of most of the metals in the feeding stream is a clear confirmation of the urban anthropogenic waste (effluents) inputs into the feeding streams.

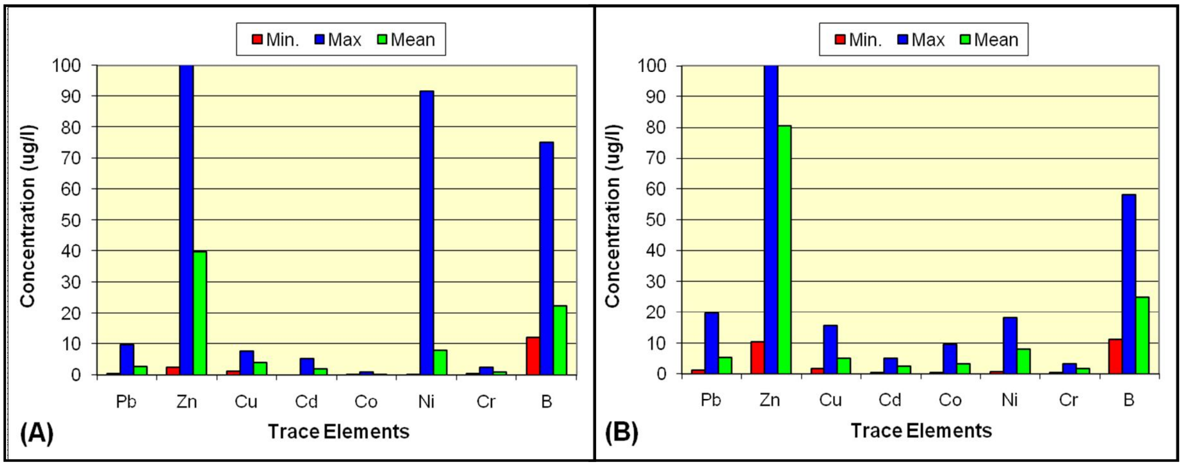

Figure 8: Profiles of trace elements concentrations in water samples from (a) the main lake and (b) feeding stream.

Nonetheless, comparison of the trace metal profiles in both the main lake and feedings stream with the average (total) baseline / background concentrations of trace elements in Lakes and Rivers (Adriano, 1986; Nriagu, 1990) as presented in Table 3, revealed considerable enrichments of most of the metal, suggesting urbanized anthropogenic inputs and degradation of the Eleyele Wetland as pictorially presented in Figure 9.

Figure 9: Photo images of urban effluent and waste dumps on a feeding Stream and Wetland buffer zone as a waste Dump site.

Nonetheless, the lower concentration in the water of the main lake can be attributed to dilution effect or most likely preferential partitioning into the bottom sediments within the lake. Hence, the need to assess the chemical characteristics of the bottom sediments, as presented in the section below.

Assessment of the Wetland Bottom Sediments and buffer zone soils

Usually, riparian soils and bottom sediments are of importance in respect of water quality function of wetlands. As surface water flows into wetlands, the eroded soils and water-borne sediments with adsorbed nutrients and pollutants have the opportunity to settle out the water column phase. However such preferential partitioning of contaminants in the solid phase is an indication of potential contamination threat, through possible biogeochemical-induced re-mobilization into the water phase in response to changes in physico-chemical conditions (Tijani and Onodera, 2009). As part of further assessment of the impact of the urbanized catchment on quality and degradation of the Eleyele Wetland, 26 bottom sediments samples from the main lake and 16 surrounding buffer zone soil samples within the catchment area were analyzed for possible metal contamination.

The overall results of the physico-chemical data for bottom sediments (Table 4) revealed similar trends with water soluble pH of 6.0-7.5 indicating slightly acidic to neutral conditions. However, the lower electrical conductivity (EC) values of 49 - 454µS/cm (av. 194µS/cm) for the wetland lake bottom sediment can be attributed to the sandy nature of most of the sediments which in turn is a reflection quartz-schist bedrock setting of the catchment area of the wetland. In addition, loss on ignition of 5.1 – 31.2% is a reflection of the total carbon content (1.1- 9.3%) of the analyzed bottom sediments. A higher correlation factor of 0.75 between LOI and total C compared to 0.26 with respect to total S suggest that organic matter decomposition and related biogeochemical processes within the lake are related to an oxidizing environment rather that a reducing environment. This may also be an indication of self purification and buffering capacity of the wetland.

As summarized in Table 4, the chemical character of the bottom sediments of the wetland lake is dominated in the decreasing concentration order by Si, Al, Fe and K with average concentration of 2.8, 6.7, 4.3 and 1.7mg/kg respectively. Other elements such as Ca, Mg, Na, Mn and P revealed average concentration of less than 1.0 mg/kg, an indication of their relative mobility/solubility in the course weathering processes. The observed chemical profile is a clear reflection of the catchment geology dominated by quartz-schist units on one hand. On the other hand it is a clear indication of the fact that the bottom sediments are products of catchment weathering and erosion.

However, the concentration profiles of the trace metals revealed enrichment of Zr, Ba, Sr, Nb, and Y with average concentration of 1,918; 658; 122; 19.7 and 108mg/kg respectively. Unlike the case of Ca, Na, Mg and others, the enrichments of these minor elements is due to the weathering resistance of their procusor minerals that have ability to survive erosion and transportation processes. However, some of the minor/trace elements especially Ba, Ni, exhibited values closer to the threshold concentrations defined by the Netherland Standards for uncontaminated soils (see Table 4). Nonetheless, the overall concentration profiles suggest low anthropogenic impacts from the urbanized catchment, with respect to metal accumulation in the bottom sediments of the Eleyele Wetland Lake.

In summary, it can be inferred that the geochemical or compositional characters of the bottoms sediments of the Eleyele Wetland lake are predominantly geogenically controlled; reflecting the geochemistry of the weathered catchment bedrock units. Though low trace metal enrichment in the sediments may be attributed to low clay contents and/or self biogeochemical purification process within the Lake ecosystem.

The quality of a soil is largely defined by the ability of soils' physical, biological and chemical properties to carry out specific or multiple functions, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Doran *et al.*, 1997). However, in wetland environments, soils functions are mainly ecological relating to biomass production, buffering / filtering and biochemical transformations and as biological habitat for soil organisms. Soil performs its functions by supporting plants structurally and supplying elements (both as micronutrients and macronutrients) essential for plant growth (Wild, 1988). Consequently, as part of further evaluation, soil quality assessment was employed for the rating of the wetland soil fertility in the study area based on the measured hydraulic and physical characteristic as presented in Table 5.

Table 4: Summary of the results of chemical analyses of major ions in the Lake bottom sediments (N=26)

Parameters (mg/kg)	Minimum	Maximum	Mean	Median	St. Dev.	*NL Standards
pH	6.9	7.4	7.2	7.0	0.1	
EC (uS/cm)	49.0	454.0	193.5	148.6	88.3	
LOI %	5.10	31.20	13.82	13.00	6.19	
Tot. C %	1.07	9.26	3.66	3.08	2.21	
Tot.S%	0.02	2.68	0.24	0.10	0.53	
Ca	0.11	1.10	0.52	0.46	0.29	5,000 – 30,000
Mg	0.07	0.32	0.19	0.19	0.06	1,000 – 15,000
Na	0.07	1.29	0.39	0.29	0.32	500 – 15,000
K	0.65	4.06	1.74	1.54	0.90	1,000 – 30,000
Si	18.65	38.13	28.88	30.30	4.81	
Al	3.02	12.59	6.70	5.96	2.47	
Fe	1.35	12.31	4.31	3.55	2.39	10,000 –
Mn	0.02	0.15	0.06	0.05	0.03	20 – 3,000
P	0.03	0.24	0.10	0.10	0.04	
Zr	501.0	4640.0	1917.8	1728.0	850.6	
Ba	311.0	1518.0	658.6	556.0	321.6	200 – 400
Sr	37.0	398.0	121.7	101.5	87.0	
Cr	5.0	20.0	10.4	9.5	4.0	100 – 250
Nb	10.0	31.0	19.7	20.0	6.0	
Ni	20.0	38.0	24.5	20.0	5.8	35 – 100
Y	30.0	254.0	107.8	101.0	54.4	
Ti	0.30	1.06	0.63	0.64	0.19	20 – 50
Sc	5.0	19.0	9.0	8.0	3.5	

*Netherlands Standard: Minimum values represent the natural baseline concentration, while the maximum values imply upper threshold limits (Source: HESS II, 2008).

Generally, the result of the physical properties rating of Eleyele wetland soils show varied class from prime to marginal quality status with bulk density of 1.5-1.8 g/cm3 indicates sandy-silt loam soil within medium to marginal class. High bulk density may imply compact soil with negative impact on root penetration or inadequate aeration (Arshad et al., 1996). In addition, this may also enhance runoff and erosion losses of soil and nutrients can be caused by excessive bulk density when surface water is restricted from moving through the soil (Evanylo and McGuinn, 2009).

Infiltration is important for storing water in the soil profile for plant growth and for reducing runoff and erosion (Lowery et al., 1996). In this study, hydraulic conductivity of 7.5 – 48cm/hr (see Table 5) implies well drained buffer zone soils with medium to marginal quality rating, especially in the western portion with quartz-schist bedrock setting. Also water-holding capacity of 29 – 41% (av. 34.6 %) suggests mostly sandy loam soils that had been influenced by cover removal and tillage which is said to reduces the content of organic matter and reduces pore volume *(*Evanylo and McGuinn, 2009).

Table 5: Comparative assessment of physical characteristics of Eleyele wetland soils with respect to soil quality/fertility rating standards

Soil Quality Class	**Class 1 (Prime)**	**Class 2 (Good)**	**Class 3 (Medium)**	**Class 4 (Marginal)**	**Class 5 (Unsuitable)**	**Eleyele Wetland**
Bulk Density (g/cm^3)	<1.25	1.25-1.3	1.3-1.5	1.5-1.65	>1.65	1.5 – 1.8
Porosity Vol. %	>53	51-53	43-51	38-43	<38	35 – 43
WHC (%)						29 – 41
Ksat (cm/hr)	50-80	40-50	10-40	<10	<10	7.5 – 48
Org. C mg/kg		<1.7	1.7-2.6	>2.6		6.7 – 33.7
pH		<5.5	5.5-7.0	7.0-8.0		4.2 – 6.8
CEC cmol/kg		<10	10-20	>20		5.3 – 25.3
N mg/kg	>300	200 - 300	100 - 200	100 - 50	<50	70.0 – 350.0
P mg/kg	>250	180-250	100-180	50 - 100	<50	127 - 150
K mg/kg	>300	175-300	100-175	50-100	<50	150 – 1630
Mg mg/kg	>180	80-180	40-80	20-40	<20	7.4 – 324.0
Fertility Class	**Very High**	**High**	**Medium**	**Low**	**Very Low**	

Source: FAO 1992; Roming, et al., 1995; McGrath et al.*, 2001.*

As presented in the table, the organic carbon and CEC also revealed concentration that are consistent with medium to high fertility rating. However, the pH-(KCl) revealed a relatively acidic soil with values of 4.2 – 6.8 compared to the typical range of (6.5 – 7.5) in pristine agricultural soils. Such low pH values can cause plant nutrient deficiencies (especially Ca, and Mg) and possible metal enrichment with respect to Mn and Al with negative effects on crop yield. Nitrate and phosphorus have values of 700 – 350mg/kg and 15.5 – 127.0 mg/kg respectively which compare reasonably well with typical range of values for uncontaminated arable soils and at the same time suggest soil fertility rating of medium to high quality. Nonetheless, the overall rating implies that the riparian buffer zone soils of the Eleyele wetland still in position to sustain 50–80% crop yield without any amendment application.

In addition to the above assessment of the soil fertility rating, quality degradation in terms of metal contamination was also undertaken. This is consequent to the fact that soils are the ultimate sink for pollutant metals in the terrestrial environment. In other words, quality degradation in terms of contaminant enrichments wetland can be better appreciated using the soil media. Usually, detection of such anthropogenic metal contamination may be difficult where large background of trace metals exist; except in urban soils and near major point sources of pollution (Nriagu, 1990).

Wetland soil contamination / degradation in this study was assessed based on the Netherlands soil contamination standards of three levels of contamination/pollution whereby A-values imply low or background concentrations of contaminants, B-values represent slight to moderate but permissible concentrations of contaminants and C-values imply high concentrations of contaminants above the permissible level (Table 6).

As highlighted in Table 6, selected trace metal concentrations (i.e. Mn, Fe, Cu and Zn) in the wetland soils revealed very low to slight contamination with respect to Cu and Zn with respective maximum concentrations well below the respective A-values. However, higher concentrations of Mn and Fe may be attributed to the natural weathering-induced ferruginization typical of tropical soils in the study area.

Table 6: Comparison of Metal Concentration in Eleyele Wetland Soils with NL-Standards

	Netherlands Standards (mg/kg)			**Eleyele Wetland Soils (mg/kg)**		
Metals	**A**	**B**	**C**	**Min**	**Max**	**Mean**
Mn	50	100	500	7.4	324.01	153.94
Fe	50	100	200	104.03	484.21	219.28
Cu	36	100	500	3.48	9.83	6.33
Zn	200	500	3000	6.26	109.12	23.86

A-values = low or background concentrations of contaminants,
B-values = slight to moderate but permissible concentrations of contaminants
C-values = high concentrations of contaminants above the permissible level.

Summary and Conclusions

In general it can be deduced that the observed profiles of the in-situ physical parameters of the water from the main lake and the feeder streams of the Eleyele Wetlands clearly demonstrate the impacts of human activities (direct discharge of household effluent and at times waste dumps) especially on the feeding stream, in terms of wetland water quality and the overall ecosystem quality. The observed chemical characteristic of the major elements of the water in Eleyele wetland is more or less a reflection of the geogenic induced weathering pedological processes of the catchment area as defined by the bedrock geology. However, the geochemical or compositional characters of the bottoms sediments of the Eleyele Wetland reflect the geochemistry of the weathered catchment bedrock units suggesting geogenic control. Nonetheless, the low trace metal enrichment in the bottom sediments may be attributed to low clay contents and/or self biogeochemical purification process within the Wetland Lake ecosystem.

Like in many developing countries, urban environments have greatly changed in Ibadan with increasing population leading to increasing pressures on agricultural lands as well as wetland and green areas. As highlighted earlier in the intervening period from 1984 to 2004, the built-up area within the catchment of Eleyele Wetland has increased by almost 70%. This has resulted in a reduction or lost of forest and agricultural areas around the Eleyele Wetland to be more than 60%. While this increase in urbanization may not have resulted in total loss or degradation of wetland soils in the study area, there are clear influence of urban catchment activities on water and bottom sediments of the feeding stream and the main wetland lake. The overall implication of the study is that there is the need to control the increasing encroachment of farming and building activities around the wetland to avoid removal of the vegetation and degradation of the ecosystem within buffer zone. Hence, the study recommends the adoption of Integrated Water Resources and Environmental Management (IWRM) in order to ensure proper ecosystem functioning of such urbanized wetland and thus safeguarding the overall quality of the wetland ecosystem.

Nonetheless, the quantification of the extent of the observed urban development activities on the water resources and bottom sediments quality warrant clear definition of associated quality indicators. This aspect of information gap can be regarded as one of the issues requiring further evaluation as part of future research study. Hence, there is the need for definition of soil and water quality indicators which can measure changes in these critical environmental media in Wetland ecosystems. Such indicators is expected to provide information for policy makers, planners, regulators on one hand and the soil-users (farmers), water users (water works, fishermen) and other stakeholder (land-use developers) on the other hand with overall intent of sustainable water resources management. However, such soil and water quality assessment indicators should not only highlight the “good” or “bad” quality, rather should depend on the applicability or useage to match a particular land use (Sparling and Schipper, 1998) and the status of the soil relative to a particular standard (Larson and Pierce, 1994). However, it should be pointed out that the selection of a set of soil and water quality indicators should be based on physical, biological and chemical attributes relevant to the ecosystem functioning of the wetlands.

The overall results highlight the negative impacts of the human-induced influence on the Wetland ecosystem through land-use and waste effluent discharges with attendant degradation / loss on one hand. On the other hand it also highlights the fact that wetland serves as purifier, buffer and sink for the dissolved contaminants from the feeding urban drainage water system. The overall implication of the study is that there is the need to control the increasing encroachment of farming and building activities around the wetland to avoid removal of the vegetation and degradation of the ecosystem within buffer zone. Hence, the study recommends the adoption of Integrated Water Resources and Environmental Management in order to ensure proper ecosystem functioning of such urbanized wetland and thus safeguarding the overall quality of the wetland ecosystem. Furthermore, there is the need to develop a list of soil and water quality indicators that should be considered in developing future quality assessment for urban wetland like Eleyele. Nonetheless, the selection of a such soil and water quality indicators should be based on physical, biological and chemical attributes relevant to the ecosystem functioning of the wetlands.

REFERENCES

Adriano, D.C., 1986. Trace Elements in the Terrestrial Environment. Springer, New York.

Arshad, M.A., B. Lowery, and B. Grossman. 1996. Physical tests for monitoring soil quality. p.123-142. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI.

Baba, M. K. 1993.Irrigation Development Strategies in sub-Saharan Africa: A comparative study of traditional and modern irrigation system in Bauchi State, Nigeria. Ecosystem and Environment 47-58.

Brereton, G. 1994. Summary report. Macquarie Marshes management strategy - Stage 1, biophysical investigations, natural resources management strategy. New South Wales Department of Water Resources, Dubbo, New South Wales,Australia.

Carsky R. J and T. M. Masajo (1992) “Effects of Top Sequence Position on Performance of Rice Varieties in Inland Varieties of West Africa”. Resource and crop management Monograph No. 9 Ibadan: International Institute for Tropical Agriculture Pp 1-6.

Doran, J.W., and M. Safley, 1997. Defining and Assessing Soil health and Sustainable Productivity. In: Pankhurst, C.E., Doube, B.M. and Gupta, V.V.S.R. (eds), Biological Indicators of Soil Health. CABI Publishing, Oxon, UK.

Evanylo, G. and R. McGuinn, 2009. Agricultural Management Practices And Soil Quality: Measuring, assessing, and comparing laboratory and field test kit indicators of soil quality attributes. Virginia Tech, Publication 452-400. 10p.

FAO, 1992. Irrigation Subsector review. Investment Centre Report No. 89/91 CJP-NIR 45 SR.

Frenken, K. (2005). "Irrigation in Africa in figures – AQUASTAT Survey – 2005" (PDF). Food and Agriculture Organization of the United Nations. ISBN 92-5-105414-2. ftp://ftp.fao.org/agl/aglw/docs/wr29_eng.pdf. Retrieved 2007-03-14.

Gosselink J. G. and R. E. Tuner 1978. The Role of hydrology in fresh water Wetland ecosystems. pp. 63 – 78.

HESS II 2008. The Harmonisation of Environmental Standards (HES) II: Interim Technical Report Cluster 10: Environmental Quality Standards 10.4b **–** Specific features of the standard setting for polluting substances contents in soils in Russia and abroad (EU – Russia Cooperation Programme; HES II web-site at www.ippc-russia.org).

Jones, H.A. and Hockey, R.D. (1964). The Geology of Part of South Western Nigeria, Bull Geol. Survey of Nigeria No. 31.

Larson, W.E. and Pierce, F.J. 1994. The Dynamics of Soil Quality as a Measure of

Sustainable Management. In (eds.) Doran, J.D., Coleman, D.C., Bezdicek, D.F. and Stewart, B.A. *Defining soil quality for a sustainable environment*. SSA, Madison, USA.

Lowery, B., M.A. Arshad, R. Lal, and W.J. Hickey. 1996. Soil water parameters and soil quality. p.143-157. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI.

McGrath, D., Carton, O.T., Diamond, S., O'Sullivan, A.M., Murphy, W.E., Rogers, P.A.M., Parle, P.J. and Byrne, E. 2001. Soil, herbage, feed and water. In: *Investigation of Animal Health Problems at Askeaton, Co. Limerick.* EPA, Johnstown Castle Estate, Wexford.

Millennium Ecosystem Assessment (2005): Ecosystems and Human Well-Being: Current State and Trends. Washington, DC: Island Press.

Nriagu, J.O. 1990: Human influence on the global cycling of trace metals. *Palaeogeography, Palaeoclimatology, Palaeoecology (Global and Planetary Change Section),* 82: 113-120.

Olayinka, A.I., Abimbola, A.F., Isibor, R.A., Rafiu, A.R., 1999. A geoelectrical and hydrogeochemical investigation of groundwater occurrence in Ibadan. SW. Nigeria. Environ. Geol. 37 (1–2), 31–39.

Raunet, M. 1985. Bas-fonds et riziculture en Afrique. Approche structurale et comparative. L'Agronomie Tropicale, 40(3):181-201.

Romig, D.E., M.J. Garlynd, R.F. Harris and K. McSweeney. 1995. How farmers assess soil health and soil quality. J. Soil Water Conservation. 50:225-232.

Sparling, G. and Schipper, L. 1998. *Soil Quality Monitoring in New Zealand: Concepts,* Approached and Interpretation (Technical report LCR 9798/060). Landcare Research, Hamilton, New Zealand.

Tijani, M.N., Okunlola, O.A. & Ikpe E.U. (2007): A geochemical Assessment of Water and bottom sediments contamination of Eleyele Lake Catchment, Ibadan, SW-Nigeria. Euro. Jour. Sci. Res.; Vol. 19(1): 105 – 120.

Tijani, M.N. and Onodera, S. (2009): Hydrogeochemical Assessment of Metals Contamination in an Urban Drainage System: A Case Study of Osogbo Township, SW-Nigeria. J. Water Resource and Protection, 2009, 3, 164-173.

Wild, A. 1988. Russell's soil condition and plant growth. Longman Scientific & Technical, Harlow, Essex, UK.

Williams, A. L., K. E. Wills, J. K. Janes, J. K. V. Schoor, P. C. D. Newton, AND M. J. Hovenden. 2009. Warming and free air CO2 enrichment alter demographics in four co-occurring grassland species. New Phytol. 176: 365–374.

Windmeijer, P.N. and Andriesse, W. (Editors). 1993. Inland Valleys in West Africa: An Agro-ecological Characterization of Rice-Growing Environments. ILRI Publication 52. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 160 p.

WASTE MANAGEMENT AND HEALTH IMPLICATIONS

Detection of Faecal Coliforms in Biofilms of Water Tankers in Odongunyan, Ikorodu - A Peri-Urban Lagos Settlement

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Abstract

Unavailability of public piped water in Odongunyan- a peri-urban community in Ikorodu Local Government of Lagos State, South West Nigeria compelled the people to seek water from other sources. Water transportation with the aid of commercial tankers is one of the means used to convey water from source to other areas of need within the community without adequate concern to its public health implications. This study investigated the presence of *Escherichia coli*- an indicator of faecal contamination in the biofilms of thirty water tankers in the community. Of the thirty tankers investigated for *E. coli* using the membrane filtration technique, all the tankers showed the presence of *E. coli* in their biofilms. The *E. coli* counts ranged between 1.3 x 10^4 cfu/cm^2 and 4.2 x 10^4 cfu/cm^2. The total plate counts ranged between 5.1 x 10^4 cfu/cm^2 and 9.8 x 10^4 cfu/cm^2 and the pH of the water collected in all the tankers also ranged between 6.54 -7.03. The results showed that the water tankers biofilms are loaded with faecal contaminants and there is need for sanitation legislation at local levels to ensure regular disinfection compliance by commercial water hawkers.

Keywords: Biofilms, coliforms, sanitation, Escherichia coli

Introduction

As populations grow, more people, for economic reasons settle at the outskirt of cities which usually are without proper town planning programmes and adequate access to potable and safe water. Natural water sources available to them. like wells, get contaminated easily due to the various human activities like shallow and unprotected latrines, unguided drainages, flooding, refuse dumping and seepages. However, drainage, safe storage and distribution of water supplies are critical factors that determine the extent to which many diseases are either contained or propagated in urban communities (Sutherst, 2004). The distances of available water sources compound the problems of availability, where women have to travel long distances to fetch water. Transport systems introduced by commercial operators, though solve the problem of availability; it however introduces another critical problem of sanitation of the water tankers. Majority of the commercial water tanker operators completely abandon sanitation of the tankers or leave it for a long period without washing, leading to biofilm formation in the water tankers. This has a great health implication on communities that rely substantially on water from these tankers. This is due to the fact that bacteria, growing in a free-living state after sometime, adhere to surfaces by producing extracellular polysaccharide, or in some cases, by means of specialised structures termed holdfasts (Marques *et al*, 2007). These bacteria form what is called microcolonies, which eventually accumulate to biofilms. The biofilms have even been found to contain microbes which may be deleterious to human health (Zottola and Sasahara, 1994). Biofilms primarily are usually composed of one bacterial species, but habitually develop to contain many other bacteria, thus creating an intricate community of microbes. *E. coli* is among the major etiologic agents endemic in essentially all developing countries that account for the estimated 1.5 million deaths per year usually transmitted in water. (Quadri *et al*, 2005). The bacterial species *Escherichia coli* is a normal inhabitant of the gastrointestinal tract of humans and other warm-blooded animals. While most *E. coli* strains do not cause human disease, some strains possess virulence factors which can cause life-threatening conditions (Grant *et al,* 1996). Several studies have confirmed that water-related diseases not only remain a leading cause of morbidity and mortality worldwide, but that the spectrum of disease is expanding and the incidence of many water-related microbial diseases is increasing (WHO, 2001; Payment*.,* 1991, 1997; Isaac-Renton *et al.,* 1996).

In peri-urban settlements that rely on water from distribution tankers, determination of the sanitary status of the tankers become indispensable due to biofilms' characteristic which is resistance to washing and protection from the common disinfectants that do not easily penetrate the polysaccharide matrix (Mattila-Sandholm and Wirtanen, *(*1992). Odongunyan community is a peri-urban settlement of Ikorodu, which is located on the outskirt of Lagos metropolis. The community is composed of people who have to travel several kilometres to their various places of work in the heart of the city of Lagos. Like many other peri-urban communities across the globe, it is characterised by poor drainages, poor access to safe piped water, poor sanitary facilities etc. Though a rapidly growing community, water facilities is below satisfactory, leading to a high reliance on commercial transport water tankers. The dearth of evidential facts on the progress made towards attaining the MDGs calls for concern particularly in the public health sector. There is a need to document our health status, including all facilities used in water systems thus giving clear perspective to government budgetary allocation and intervention programmes from local and international organizations to water improvements. The pathogenicity of these biofilms, particularly in water distribution networks, also need be determined periodically for a healthy water distribution, particularly in communities with poor sanitation and safe water facilities.

Materials and Methods

Interview with Water Tanker Drivers

A non formal interview was conducted with the drivers of the water tankers on the regularity of washing and disinfection of the water tankers.

Sample Collection

The method of Marques *et al* (2007) was adopted with slight modification. Sterile swab sticks were used to gently scrub an area of 1 cm^2 in the inner surfaces of the water tankers and transferred to tubes containing 9 ml of 0.1% (v/v) sterile peptone water for onward transfer to the laboratory. This was vigorously vortexed for 2 mins for adequate dissolution of the microbes into the peptone water from where the samples were later taken for use.

Microbiological Analysis

Marques *et al* (2007) method of isolation of microbes from swabs for total plate count was adopted with slight modification. This was carried out by using 0.5 ml aliquots, which was transferred onto Nutrient agar and incubated for 24 hr at 37°C after which the viable cells were counted. For the isolation of *Escherichia coli*, the method of Grant *et al* (1996) was adopted. The presence of *Escherichia coli* was selectively cultivated on M-FC Nutri Disks (pre-prepared pads impregnated with a selective medium for the detection of *E. Coli* and Faecal Coliforms in water and foodstuffs supplied by Wagtech International Ltd, UK.). In this case the remaining diluted sample of 9 ml of 0.1% (v/v) sterile peptone water (total volume, 10 ml) was filtered under vacuum by using a vacuum filtration unit (Wagtech Int. Ltd, UK) through a micropore paper and placed on the MFC Nutri Disks and incubated at 44.5^{o}C for 24 hrs.

Results and Discussion

The results of the microbiological analysis are presented in Table 1. The interviews with the tanker drivers confirmed that the issues of cleaning the tankers do not cross the mind of the tankers drivers at all. Majority of these tanker drivers are always excited about the number of trips they can make in a day which translates to more income for them. This is their daily practice. Moreover the consumers are also less concerned about the quality of the water. Their preoccupation is the availability of the water as they also have to compete to get the drivers to look at their side. The importance of the values of the total plate count and the coliform counts cannot be over emphasized. They both have exceeded the 0/ml values recommended by the WHO and other regulatory bodies concerning the number of organisms expected to be found in potable water (Barrell *et al*, 2000). One important fact about these values is that the difference between the total plate count and the values of the *E, coli is* wide, indicating that several other organisms may still be found in the biofilms whose health implications have not been considered at all. This research finding contradicts the position of Wingender and Flemming (2004) that pathogens may not be found in biofilms of distribution networks. This research shows that there is therefore a need for policy to monitor the sanitation of water tankers within communities like this.

Recommendation

It is recommended that the drivers be educated on the importance of maintaining a good sanitary state of the tankers. This should also be extended to the consumers through different community fora on the need to ensure that the water brought to them meets adequate sanitary conditions that could ensure their safety as they are the recipients of the inadequacies of the drivers. Furthermore, local regulatory bodies can stipulate laws at the local government's councils on the need for a regular disinfection of the tankers bearing in mind the nature of the biofilms and their resistance to disinfection. Offenders may be fined to serve as deterrence..

Table 1: Water Tanker Test Results

Sample	pH	Coliform Presence	Total Plate Count/ 10^4cells/cm^2	*Escherichia coli*/ 10^3cells/cm^2
001	7.22	+	63 ± 8.9	24 ± 9.4
002	6.78	+	69 ± 11.8	15 ± 3.4
003	6.54	+	98 ± 11.2	36 ± 4.1
004	7.00	+	81 ±10.6	29 ± 9.4
005	7.03	+	70 ± 9.6	21 ± 9.4
006	6.72	+	90 ± 6.2	35 ± 2.6
007	6.74	+	90 ± 23.7	43 ± 4.5
008	6.55	+	73 ± 6.9	32 ± 2.5
009	6.80	+	67 ± 5.2	30 ± 7.1
010	6.81	+	69 ± 4.8	36 ± 4.1
011	6.82	+	82 ± 5.2	37 ± 10.2
012	6.72	+	57 ± 7.3	26 ± 4.1
013	6.78	+	72 ± 7.2	39 ± 9.5
014	6.54	+	57 ± 6.2	40 ± 8.7
015	6.57	+	69 ± 5.2	42 ± 4.8
016	6.70	+	75 ± 4.9	42 ± 3.7
017	6.72	+	55 ± 14.3	24 ± 7.8
018	7.00	+	82 ± 17.3	25 ± 5.7
019	6.81	+	76 ± 3.3	33 ± 1.3
020	7.02	+	57 ± 2.3	29 ± 4.6
021	7.03	+	82 ± 6.9	45 ± 5.2
022	6.84	+	71 ± 9.7	42 ± 6.3
023	6.55	+	63 ± 9.5	63 ± 5.1
024	6.72	+	72 ± 7.2	18 ± 4.3
025	6.70	+	78 ± 6.6	35 ± 2.5
026	6.82	+	69 ± 14.3	13 ± 2.1
027	6.81	+	69 ± 8.2	22 ± 5.2
028	6.84	+	51 ± 8.6	18 ± 1.1
029	7.03	+	67 ± 5.8	31 ± 9.4
030	6.78	+	66 ± 16.2	37 ± 4.6

References

Barrell R. A. E., Hunter P. R. and Nichols G. (2000): Microbiological standards for water and their relationship to health risk. *Commun Dis Public Health* 3 (1): 8-13.

Grant S. B., Pendroy C. P., Mayer C. I., Bellin J. K. and Palmer C. J. (1996): Prevalence of enterohemorrhagic *Escherichia coli* in raw and treated municipal sewage. *Applied and Environmental Microbiology*, 62(9): 3466–3469

Issac-Renton J., Lewis L., Ong C. and Nulsen M. (1994): A second community outbreak of waterborne giardiasis in Canada and serological investigation of patients. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **88**: 395-399.

Juhna T., Birzniece D., Larsson S., Zulenkovs D., Sharipo A., Azevedo N. F., Me´nard-Szczebara F., Castagnet S., Fe´liers C. and Keevil C. W. (2007): Detection of *Escherichia coli* in Biofilms from Pipe Samples and Coupons in Drinking Water Distribution Networks. *Applied and Environmental Microbiology,* 73(22): 7456–7464

Kalmbach S., Manz W. and Szewzyk U. (1997): Isolation of new bacterial species from drinking water biofilms and proof of their in situ dominance with highly specific 16s rrna probes. *Applied and environmental microbiology,.* 63(11): 4164–4170

Marques S. C., Rezende J. O. S., Alves L. F., Silva B. C., Ronaldo, E., Luiz de A., Piccoli Hilsdorf R. (2007): Formation of biofilms by *Staphylococcus aureus* on stainless steel and glass surfaces and its resistance to some selected chemical sanitizers. *Braz. J. Microbiol*. 38(**3):** 538-543.

Mattila-Sandholm, T. and Wirtanen G. *(*1992): Biofilm formation in the industry: A review. *Food Reviews International*, 8(4): 573 – 603

Payment P. (1991): Antibody levels to selected enteric viruses in a normal randomly selected Canadian population. *Immunology and Infectious Diseases* 1, 317 - 322

Qadri F., Svennerholm A., Faruque A. S. G. and Sack R. B. (2005): Enterotoxigenic *Escherichia coli* in Developing Countries: Epidemiology, Microbiology, Clinical Features, Treatment, and Prevention. Clinical Microbiology Reviews 18 :(3) 465–483

Sutherst R. W. (2004): Global Change and Human Vulnerability to Vector-Borne Diseases. Clinical Microbiology Reviews 17 (1): 136–173 .

UNICEF (2009): Water, Sanitation and Hygiene in Nigeria. FACT SHEET

Williams M. M. and Braun-Howland E. B. (2003): Growth of *Escherichia coli* in model distribution system biofilms exposed to hypochlorous acid or monochloramine. *Appl. Environ Microbiol.* 69:5463–5471.

Wingender J., and Flemming, H. (2004): Contamination potential of drinking water distribution network biofilms. *Water Sci. Technol.* 49:277–286.

World Health Organization **(**2001): Global water supply and sanitation assessment 2000 Report. 1. Water supply statistics. 2. Water resources development. 3. Sanitation statistics. I. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. World Health Organization and UNICEF, Geneva, Switzerland

Zottola E.A. and Sasahara, K. C. (1994): Microbial biofilms in the food processing industry– Should they be a concern? *Int. J. Food Microbiol.*, 23(2), 125-148.

Exploiting the Potentials of Inland Valleys of Nigeria for Poverty Alleviation

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Abstract

Poverty is steering at the face of most developing countries particularly the Sub-Sahara Africa in spite of the abundance inland valleys which have the potential of growing three crops in sequence within a year without irrigation. Inland valleys show considerable potential for intensification and sustainable land use. The potential impact of this valley is related to the presence of water and total areas covered for the production of many food crops. However, they are only marginally utilized. The paper highlighted the abundance of this high potential natural resource, existing cropping systems in the inland valleys of Nigeria. It further elucidated (1) the potential of inland valley as a highly productive agricultural land source for resource poor farmer (2) the research interventions to increase productivity, and 3) other relevant issues pertaining to resilience of the systems, were reported. The yields of crops in inland valleys are generally much higher than on the uplands. The naturally abound inland valley in Nigeria is a high resource potential for food crop production. It is robust and resilient resource that could support triple cropping systems on sustainable basis without the fear of deterioration. Each component of the triple crops in the inland valley out yielded the single crop in the upland counterpart. Thus, for Nigeria and indeed Africa to be food sufficient, judicious management of wetlands may likely be the pathway to satisfactorily meeting the food supply of teaming population of a continent plagued by poor soils, drought and environmental destruction.

Key words: Inland valley, triple cropping systems

Introduction

Inland valleys which could also called 'bas-fonds', 'marigots', 'dambo', 'dwala', 'fadama', 'akuro' or 'vlei', are one of the various categories of wetlands, and are, perhaps, best defined in relation to the entire West African landscape. Tarnocai (1979) defined wetland as land having the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activities which are adapted to the wet environment.

Such flooded areas are generally considered to be more robust and resilient to land use pressure than the fragile uplands (Becker and Diallo, 1992; Gopal *et al*., 2000; Dixon and Wood, 2003). They are characterized by fine-textured soils (Abergel, 1993), are islands of biodiversity (Gawler, 2002), providers of clean water and air (Dixon, 2002) and potentially highly productive sites for agriculture (Becker and Johnson, 2001; FAO 2003). They are valuable for agriculture (grazing and crop production) and are important to international biodiversity as breeding grounds for migratory birds (World Bank, 2006).Inland valley is known to have considerable potential for intensification and sustainable land use (Izac *et al*., 1991; Windmeijer and Andriesse, 1993).

Tropical Asia, with about 1/13 of the world's land area, has more than 1/3 of the potentially arable lowlands (FFTC, 2007). This perhaps points to why Asia is leading in rice production. Wetlands in Sub-Saharan Africa are estimated to cover 228 million ha (FAO, 1998; Bergkamp, 2000). There is a preponderance of inland valleys in West Africa, where valley bottoms and hydromorphic fringes are estimated to occupy 22-52 million ha of land (Windmeijer and Andriesse, 1993). In rural West Africa, less than 10% of an estimated 55 million ha of wetlands are currently being used for agriculture (Thenkabail *et al*., 1995) suggesting that wetlands are grossly underutilized for food crop production in comparison to the Asia continent.

Nigeria has eight fadama areas (inland valley or flood plain). These include the Sokoto Basin, Chad Basin, Middle Niger Basin, Benue Basin, Southwestern Zone, South-Central, Southeastern and Basement Complex (World Bank 2006). The estimated 3 million ha of the fertile soils of the fadama in Nigeria, with residual moisture in the dry-season, offers attractive opportunities for the arable farmers to grow off-season high value crops (World Bank 2001; Adigbo and Adigbo, 2011), but this resource has not been fully exploited.

The success recorded in the First National Fadama Project stimulated the interest of World Bank in partnership with Global Environment Facility (GEF) to commit US$10 million grant to Second National Fadama Project to sustain it in 2006 (World Bank, 2006). The involvement World Bank in the Second and Third National Fadama Projects has popularized the use of fadama among farmers in Nigeria as a high potential resource for the production of fish, lowland rice, vegetables and other arable crops. It is pertinent to note that since inception, the First National Fadama Project in 1999 and the intervention of World Bank in second and Third Fadama Projects have not brought remarkable increase in rice production in Nigeria because rice was not a component of fadama project. For example, between 2001 and 2003, rice production in Nigeria was estimated at 2.03 million tonnes while consumption was 3.96 million Mg. The balance of 1.90 million Mg was obtained by importation (FAO, 2004). Whereas Nigeria as a nation has the inland valley resource and management potential to produce enough rice to meet local and as well as for exportation (FAOSTAT, 2008), ironically, Nigeria is the second largest importer of rice in the World after Philippine (Africa Rice Center, 2008a). In West Africa, Nigeria is the leading producer of rice in the West Africa sub-region [Africa Rice Center (WARDA), 2008b] but the quantity produced is far below consumption. Therefore, effective use of inland valleys to increase the crop production appeared to offer the greatest potential for closing the gap between production and consumption. Consequently, employment generation and poverty alleviation in the country will be enhanced. The objectives of this paper are to highlight the abundance of this high potential natural resource and the existing cropping systems in the inland valleys of Nigeria. It further elucidates (1) the potential of inland valley as a highly productive agricultural land source for resource poor farmer (2) the research interventions to increase productivity, (3) technologies that have enhanced the environment of inland valley for crop productivity to alleviate poverty and (4) other relevant issues pertaining to resilience of the systems.

Soil Biochemical Transformation of Nutrients under Waterlogged Conditions

The most characteristic management practice in paddy rice cultivation is water logging, or submergence of the land surface. This brings about anaerobic conditions in the soil, due to the very slow diffusion rate of oxygen through water. Biologically, after the oxygen reserve in the soil is exhausted and aerobic microorganisms have all died, facultative anaerobes dominate for some time. As the anaerobic conditions continue, these microorganisms are gradually replaced by obligate or strict anaerobes (FFTC, 2007). The biological changes are accompanied by a very characteristic succession of chemical transformations of materials. Following the disappearance of molecular oxygen, nitrate is used as a substrate for denitrifiers. Many fermentation reactions based on various organic substrates proceed along with these mineral transformations, producing carbon dioxide, ammoniacal nitrogen, low molecular weight organic acids, and so forth. As the soil becomes even more reductive, sulphate reducers, which are strict anaerobes, produce sulphides; and methanobacteria, also strict anaerobes, produce methane (FFTC, 2007).

Besides soil organic matter, there is another important source of N, i.e. biological N fixation. In paddy soils there are many microbes that are capable of fixing atmospheric N, such as blue-green algae, *Clostridia*, photosynthetic bacteria, and many of the heterotrophic bacteria in the rice rhizosphere. Estimates of the amount of biologically fixed N per crop of rice vary quite widely, but 30 to 40 kg/ha would be a reasonable figure. This amount of N is two or three times higher than the amount of N fixed in ordinary upland soils planted in non-leguminous crops. Interestingly enough, this amount of fixed N can explain the average yields of paddy obtained in unfertilized fields in southeast Asia (1.5 to 2 mt/ha) on the basis of 20 kg of N for 1 mt of paddy (FFTC, 2007). Therefore , paddy soils are equipped with an excellent N cycling mechanism, with an input through biological N fixation and an output through denitrification. This appears to set the basis for sustainability of rice cultivation as an efficient food production system (FFTC, 2007).

All these biochemical changes occur vigorously for the first month after submergence, when readily decomposable organic matter, the energy source for microorganisms, is abundantly available. Past this stage, there will be a period when the supply of oxygen by diffusion, though extremely slow, exceeds its consumption at the soil/water interface. As all the oxygen is trapped by such reduced substances as ferrous and manganese ions at the interface, a thin oxidized, orange coloured layer (normally a few millimeters thick) is differentiated from the underlying bulk of the strongly reduced, bluish-gray plow layer. Manganese oxides are solubilized as a result of reduction to manganese ions, likewise orange yellow to reddish colored iron oxides are reduced to soluble ferrous ions, decolorizing the soil. The great environmental difference between the oxidized and the reduced layers exerts a profound influence on nitrogen transformation in the later stages of paddy soil management.

Chemical Transformation of Nutrients under Waterlogged Conditions

The flooding of wetland soils alters both pH and the redox potential of the soil influences the availability of other nutrients as well. The pH of both acid and alkaline soil tends to converge on a pH of 7 when they are flooded. The redox potential, a measure of the intensity of oxidation or reduction of a chemical or biological system, indicates the state of oxidation (and hence availability) of several nutrients. In acid soils in a humid climate, P is present mainly in the form of iron phosphate (Fe-P) and aluminum phosphate (Al-P). Neither of these is readily soluble (Kyuma, 2003). There are, of course, organic forms of P that may be released during the process of organic matter decomposition. However, in contrast to N, the quantity of such organic P compounds is normally very low, compared to the mineral forms of P (FFTC, 2007).

In the process of anaerobiosis in paddy soils, iron phosphate tends to be reduced, with a release of some of the P in available forms. Moreover, reduction of iron oxides releases some of the occluded P into the soil. The reduction of paddy soils under submerged conditions is accompanied by an elevation in soil pH. This is the result of H^+ consumption as oxidized materials, such as NO<SUB>3$^-$ and Fe₂O<SUB>3, are reduced. Usually the pH of acid paddy soils stabilizes at around 6.5. The rise in pH enhances the solubility of iron phosphate and aluminum phosphate, by a factor of 10 times per unit rise in pH. This is another mechanism to raise the availability of P in paddy soils (Redman and Patrick, 1965; FFTC, 2007). The availability of major ions such as potassium, magnesium, sulphur and several trace nutrients such as iron and manganese is also affected by hydrologic conditions in the wetlands (Mohanty and Dash, 1982; FFTC, 2007).

Geological Transportation of Nutrients under Waterlogged Conditions

Nutrients are carried into wetlands by hydrologic inputs of precipitation, rivers flooding, tides and surface and subsurface groundwater influence. Outflow of nutrients is controlled primarily by the outflow of waters. These hydrologic/nutrient flows are also important determinants of wetland productivity and decomposition. Intra-system nutrient cycling is generally, in turn, tied to pathways such as primary productivity and decomposition. When productivity and decomposition rates are high, as in flowing water or pulsing hydroperiod wetlands, nutrient cycling is rapid. When productivity and decomposition processes are slow, as in isolated ombrotropic bogs, nutrient cycling is also slow (Mitsch and Gosselink, 1993).

The hydroperiod of wetland has a significant effect on nutrient transformation and on the availability of nutrients to vegetation. Nitrogen availability is affected in wetland by the reduced conditions that result from waterlogged soil. Typically, a narrow oxidized surface layer develops over the anaerobic zone in wetland soils, causing a combination of reactions in the nitrogen cycle-nitrification and denitrification that may result in substantial losses of N to the atmosphere. Ammonium nitrogen often accumulates in wetland soils since the anaerobic environment favours the reduced ionic form over the nitrate common in agricultural soils.

Yield Potentials of Inland Valley (Rainfed Lowland) Compared to other Ecologies

The yield of rice in inland valleys is generally much higher than on the uplands (IITA, 1980; 1988). There is enough residual soil moisture or shallow groundwater table for crops other than rice in dry season (Raunet, 1984). The average yields of the world's rice-growing areas are 4.9, 2.3, 1.5 and 1.2 t/ha for irrigated, rainfed lowland, flood prone and upland respectively while the average yield of West Africa's rice-growing area are 5.0, 2.1, 1.3 and 1.0 for irrigated, rainfed lowland, flood prone and upland respectively (Anon, 1993). The cost of irrigation equipment is, however, prohibiting for resource-poor farmers to acquire for rice production in Nigeria. Therefore, the rainfed lowland rice in the available inland valley that gives relatively higher yield of rice as compared to the upland can be taken advantage of, at no extra cost.

Out of the total land area of 1,642000 ha devoted rice cultivation in Nigeria, 1, 5, 16, 30 and 48% is grown to mangrove swamp, deep water rice, irrigated lowland, rainfed upland and rainfed lowland respectively. In West Africa, however, of the total land area of 4,011,000 ha devoted to cultivation of rice, 4, 9, 12, 44 and 31% is planted to mangrove swamp, deep water, irrigated lowland, rainfed upland and rainfed lowland respectively (Lançon and Erenstein, 2002). Therefore, to increase the production of rice, vegetable and other upland crops, intensified use of the inland valleys is inevitable.

Comparison of Paddy Soils and Upland Soils

The tilth is not as important in paddy soils as in upland soils. As long as enough water is available to keep the soils submerged, the balance between water retention and aeration, which is vital for upland soil, can be disregarded. Furthermore, a heavy clay soils with a very hard, dry consistency is difficult to till under upland conditions, but is relatively easy to plow and till in flooded lowlands with two buffalo or oxen.

The high level of resistance of paddy soils to erosive forces is even more important, from the viewpoint of sustainability. Upland soils tend to be eroded away unless they are properly protected. This is particularly true in the tropics, where the erosivity of rainfall is very high, and where upland soils usually have poor resistance to erosion. Paddy soils are most resistant to erosion when they are terraced and there are ridges around the field, as measures to retain surface water. In addition, paddy fields in the lowlands receive new sediments deposited from run-off that carries eroded topsoil down from the uplands, thus perpetuating soil fertility and productivity.

In upland farming, crop rotation is a necessity to avoid a decline in yield due to diseases and pests that arise from a monoculture situation (soil sickness). In paddy fields, on the other hand, rice can be grown year after year without any clear sign of yield decline, over a considerable length of time. The alternation from aerobic to anaerobic conditions in a yearly cycle of rice farming is the best measure to remove the causes of soil sickness. No pathogens or soil-borne animals can survive such a drastic change in the redox environment.

Cropping Systems in the Inland Valley

During the rainy season, inland valley soils are usually saturated and anaerobic, but they dry up and soon become aerobic in the dry season. Under aerobic conditions the ammonium (NH_4) form of soil mineral N is oxidized to nitrate (NO_3) which may accumulate in the soil or be utilized by the crop grown there (George *et al*., 1992). Most of the NO_3 that is not utilized by the plant may be lost through leaching and denitrification when the soils are subsequently flooded for rice cultivation

Under traditional farming in Nigeria, one crop of rice is grown per year because swamps are not developed and water flow is not controlled (WARDA, 1993). Some farmers grow one single crop of lowland rice (lowland rice–fallow–fallow) in the main season and abandon the inland valleys until the following year. Most farmers practice double cropping in the inland valleys. That is, lowland rice is planted in the main cropping season between April and May when the rains have become steady and is harvested in August and September depending on the length of maturity of the variety. The inland valleys are then allowed to drain until such a time when the land is no longer saturated and will support upland crop, such as vegetables or maize (Zea mays L.) during the dry season (lowland rice–fallow–vegetable sequence). Considerable opportunity exists for growing the third crop between the main crop (lowland rice) and the dry season cropping (Adigbo *et al*., 2007). This is a niche that has not been fully exploited. This niche is too short to accommodate another lowland rice crop. Moreover, the available moisture may not be sufficient to support a lowland rice crop.

The niche in question covers the months of September, October, November and earlier part of December. The soil in the niche is anaerobic-aerobic transition which is associated with the general reduction and oxidation transformations of nutrient elements. The niche has relatively better weather (longer sunshine hours, cloud-free and optimum temperature for rice crop) than the main cropping season (Adigbo *et al*., 2010).

Research Intervention Enhancing Productivity of Inland Valley in Nigeria

An experiment carried out in the University of Agriculture, Abeokuta, Nigeria has shown that a third crop could be grown in the niche between the main crop (lowland rice) and the dry season cropping (Adigbo *et al.*, 2007). This same study postulated that early maturing upland rice is the only likely crop that could be optimised in the niche without reducing the yields of lowland and vegetable. However, (Adigbo *et al.*, 2007) reported that the following constraints were associated with the upland rice component during the study: 1) Upland rice sown by dry dibble method in saturated soil had poor establishment due to high moisture and this consequently, led to low yield, 2) the upland rice component in the sequence decreased the overall benefit/cost ratio of triple cropping rather than increasing it and 3) for the three-crop sequence to be economically viable, the cost of production of upland rice component should be reduced so as to increase economic return and benefit/cost ratio.

A study was carried to address the constraint (1) mentioned above and the result showed that up to 2.28 t ha^{1} of grain yield could be obtained when rice seeds were established by adopting pre-germinated dibble and transplanted methods in saturated soil (Adigbo *et al*., 2010).The grain yield obtained in the inland valley was substantially higher than the obtainable grain yield of 1.5, 1.19 and 1.38 t ha^{-1} as reported by IITA (1990), Adigbo *et al*. (2003) and Africa Rice Center 2008a), respectively in the upland ecology. Adigbo (2008) addressed constraints (2) and (3) above by identifying some varieties of lowland New Rice for African (NERICA) whose ratooned crops were capable of producing grain yields of 2.24 to 4.66 t ha^{-1}. Rice ratooning is the practice of harvesting grain from tillers originating from the stubble of previously harvested crop (main crop) and it enhances rice grain yield without increasing land area because it provides higher resources use efficiency per unit land area per unit of time (Jason *et al*., 2005).

Rice ratooning offers an opportunity to increase cropping intensity per unit of cultivated area because a ratooned crop has shorter growth duration than the main crop. In addition, ratooned may be grown with 50% less labour, since neither land preparation nor planting is needed while the crop uses 60% less water than the main crop. A yield of the ratooned crop of 50% of the main crop may be achieved if crop management practices are used efficiently (Oad *et al*., 2002).

It is pertinent to note that intensive crop management practices such as triple cropping in the inland valley enhances nutrient uptake while achieving high yields can be a principal way to achieve reduction of Green House Gas (GHG) emissions from crop production (Snyderet *et al*., 2007). These authors further added that the following crop, soil, and fertilizer management factors help minimize net Global Warming Potential (GWP): (1) choice of the right combination of adapted varieties or hybrids, planting date, and plant population to maximize crop biomass production; (2) use of tactical water and N management, including frequent N applications to achieve high N use efficiency with minimal opportunity for N_2O emissions; and (3) use of crop residue management approaches that favour a build-up of soil organic carbon in the wetlands.
The performance of cowpea in inland valley during the dry season were not only comparable to upland yield but had a better grain quality than the uplands (Adigbo *et al*, 2007; Adigbo, 2009a). It also shows that cowpea obtained from the inland valley generally had higher monetary value and benefit-cost ratio than that of the upland. This was attributed to the fact that harvesting period of cowpea in the inland valley coincides with the peak of dry season when agricultural produces are not only scarce but more expensive (Adigbo and Adigbo, 2011). Oloyin variety which, command the highest premium in the market and had similar grain yield with the two improved varieties tested in the inland valley.

Study on intercrop of amaranth and cowpea in the inland valley during the dry season showed that the maturity period of amaranth intercropped with cowpea did not coincide **w**ith the flowering and pod formation stages of cowpea when the control of insect pests is crucial to sustain production (Adigbo, 2009a)**.** This makes the mixture of cowpea and amaranth to be compatible in terms of insecticidal spray suggesting that cowpea particularly the local variety that taste better and command higher premium price in the market could be intercropped with amaranth during the dry season when all major food stuffs are expensive. The intercropped further showed that land equivalent ratio was 1.33 –1.90 indicating that that intercrop was more efficient than the usual sole cropping of vegetables during the dry season. Thus, amaranth could be intercropped with cowpea without the fear of chemical contamination (Adigbo, 2009a). Besides, amaranth, being a leafy crop, responded positively to the residual fertilizer carryover from the preceding lowland rice-upland rice sequence suggesting that it is a better utilizer of N fertilizer than either cowpea or okra (Adigbo, 2009b). This confirms the finding of Mohanty *et al*. (1989) who reported that rice, as a succeeding crop appeared to be a better utilizer of residual fertilizer N.

Sawah Rice Production Systems

The concept and term sawah refers to manmade improved rice growing environment with demarcated, bunded, puddled and leveled rice field with water inlets and outlets using power tiller for weed and water control in the inland valley which can be springs or pumps (Wakatsuki *et al*., 2005). The Sawah system of rice production ensures proper management of the rice environment leading to efficient and higher rice grains production with higher returns is a better option to current systems (Wakatsuki, 2005). It is one of the most efficient systems that will ensure adequate production to meet the ever increasing demand and save the country from the use of scare foreign exchange resources for its importation (Buri *et al*., 2007).

The project is embarking on the process of mass adoption for the whole country with its attendant challenges of procurement of power tillers used in land preparation. *Three key learnings*: (1) Sawah system enhances soil and water management which is important for sustainable rice production; (2) The Sawah package increases rice yield significantly; (3) The dissemination of the Sawah technology through a participatory learning approach enhances rapid adoption among rice farmer.

It is well-known that weeds can be controlled by means of water control. But it is not well evaluated that the nitrogen fixation by soil microbes under a submerged sawah systems could reach 20 – 100 kg/ha/year in Japan and 20 – 200 kg/ha/year in the tropics depending on the level of soil fertility and water management (Kyuma 2003, Hirose and Wakatsuki 2002). This amount is comparable with the nitrogen fixation amount by leguminous plants. Under submerged condition, because of reduction of ferric iron to ferrous iron, phosphorous availability is increased and acid pH is neutralized, hence micro-nutrients availability is also increased (Kyuma, 2003). There are other benefits of sawah systems. The eutrophication mechanisms are not only encouraging the growth of rice plant but also encourage the growth of various algae that increase the nitrogen fixation. The quantitative evaluation of nitrogen fixation in sawah systems including the role of algae will be also important future research topics.

Under nitrate rich submerged water conditions, sawah systems encourage denitrification. Easily decomposable organic matter becomes substrate of various denitrifyers. Purification of the nitrate polluted water is another function of sawah system (Kyuma, 2003).

Performance of Lowland Rice-Ratooned Rice Sequence in Inland Valley as influenced by Fertilizer Rates in Sawah Rice Production Systems

The study was carried out to investigate the sustainable triple cropping in sawah rice based cropping systems with minimal fertilizer application. The test crops are lowland rice and ratooned rice were planted in May, late September and December, respectively and harvested in September and December. The treatments for lowland rice are 90:45:45, 60:30:30, 45:22.5:22.5 and 30:15:15 NPK kg ha^{-1} as the main plot. The fertilizer rates for the ratooned rice are 0, 30, 60, 90 N kg ha^{-1} as the subplot. The objectives were to 1) determine the minimum fertilizer rate of sawah rice given the beneficial effects of sawah as expressed in literature 2) investigate the residual effect of sawah rice and N-fertilizer rates on the performance of ratooned rice and 3) evaluate the residual effects of sawah rice-ratooned rice sequence on the performance of okra.

Plate 1: Sand filling bags to control water in sawah rice field after transplanting.

Plate 2: Sand filled bags used to divert water into sawah field


Plate 3: The sawah field 2 two weeks after transplanting and water introduction

The results obtained from sawah field trial showed that the fertilizer rates had similar effects on chlorophyll content of the leaves determined at 11, 12 weeks after transplanting as well as the flag leaf at maturity. The application of 30:15:15 kg NPK ha^{-1} fertilizer would be adequate to produce maximum grain yield for the main lowland rice crop in sawah rice production systems. However, the plant height and chlorophyll content of the second crop of ratooned rice were influence by N-fertilizer rates but the grain yields were similar. It also shows that ratooned rice crop treated with 30 kg N ha^{-1} fertilizer could produce maximum grain yield (1.39 -1.62 t ha^{-1}) that is equal to the obtainable yield in the upland ecology (1.38 - 1.50 t ha^{-1}). The overall grain yield ranged between 4.47 and 5.65 t ha^{-1} $year^{-1}$. Sawah rice based production system could enhance the productivity of inland valley with minimal resources that is affordable by the resource poor farmers (Adigbo *et al*., 2011)

Conclusion

It is very glaring that naturally abound inland valley in Nigeria is a high resource potential for food crop production. It is robust and resilient resource that could support triple cropping systems on sustainable basis without the fear of deterioration. Each component of the triple crop in the inland valley out yielded the single crop in the upland counterpart. Thus, for Nigeria and indeed Africa to be food sufficient, judicious management of wetlands may likely be the pathway to satisfactorily meeting the food supply of teaming population of a continent plagued by poor soils, drought and environmental destruction..

References

Abergel J. (1993) Mise en valeur agricole des bas-fonds du Sahel: Typologie, fonctionnement hydroloque, potentialités agricoles. Rapport Finale, CORAF-R3S. Ouagadougou, Burkina Faso, CIEH.

Adigbo. S.O., Okeleye, K.A., O.J. Ariyo and V.I.O. Olowe. Effects of Mucuna (Mucuna utilis L.) residue incorporation and nitrogen levels on the performance of upland rice. Nigeria Agricultural Journal. Vol. 34: 49-57

Adigbo. S.O., Okeleye, K.A. and Adigbo, V.B. 2007. Performance of upland rice fitted into lowland rice and vegetable/cowpea sequence in inland valley, Agron. J. 99 (2007) 377-383.

Adigbo, S.O. 2008. Evaluation of Lowland Rice 'NERICA Varieties' and their Ratooning Ability in an Inland Valley.
http://a-c-s.confex.com/crops/208am/webprogram/Sesion4350.html

Adigbo S.O. 2009a Performance of cowpea intercropped with amaranth in an inland valley of a derived savanna. Agricultura Tropica et Subtropica Vol. 42 (2) 59-64

Adigbo S.O. 2009b. Effects of low land rice-upland rice-vegetables/cowpea sequence on vegetable and cowpea rainfed inland valley Agricultura Tropica et Subtropica vol. 42 (3) 2009 10 5-109

Adigbo, S. O., Ojerinde, A. O., Ajayi, O.and Nwilene F. E. 2010. Effects of sowing methods on upland rice in lowland Rice-Vegetable Sequence in Inland Valley Journal of Agricultural Science and Technology. Volume 4, No.3 (Serial No.28)

Adigbo, S.O. and Adigbo, V.B. 2011. Effects of site and insecticide application on growth and grain yield of local and improved cowpea varieties in south-western NigeriaArchives of Agronomy and Soil Science Vol. 57, No. 2, April 2011, 179–191

Adigbo, S.O.; Wakatsuki, T.; Fabusoro, E.; Alarima, C.I.; Olowe, V.I.O.; Adeyemi, O.R. Alao, O.A. and Odedina, J.N. 2011. Performance of lowland rice-ratooned rice-vegetable sequence in inland valley as influenced by fertilizer rates in sawah rice production systems. 1st International Conference on rice for food, market and development held at the Raw Material Research Development Council, Maitama, Abuja, Nigeria. Available online: http://www.rice-Africa.com/acceptedpapers/index.html.

Africa Rice Center (WARDA).2008a. Africa Rice Trends 2007. Cotonou, Benin: Africa Rice Center (WARDA). 84 pp.

Africa Rice Center (WARDA)/FAO/SAA. 2008b. NERICA®: the New Rice for Africa – a Compendium. EA Somado, RG Guei and SO Keya (eds.). Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp

Anon 1993. Rice Almanac. International Rice Research Institute, Los Banos. Laguna. Philippines; 142pp.

Balek, J. 1983. Hydrology and water resource in tropical regions Elseivier publ., Amsterdam, pp 123-134

Bergkamp G., Pirot, J.Y.and Hostettler, S. 2000. Integrated Wetlands and Water Resources Management, IUCN, Gland, Switzerland, 2000.

Becker, L. and Diallo, R. (1992) Characterization and classification of rice agro-ecosystems in Côte d'Ivoire. West Africa Rice Development Association, Bouaké, Côte d'Ivoire. 135 pp.

Becker, M. and Johnson, D.E. (2001) Improved water control and crop management effects on lowland rice productivity in West Africa. Nutrient Cycling in Agroecosystems 59, 119-127.

Buri, M.M.; Issaka, R.N. and Wakatsuki, T. (2007): The sawah technology of rice production for lowlands: An effective tool for poverty alleviation in Southern Ghana. Paper presented at the 4th international conference of the Africa soil science society organized at the Ghana Institute of Management and Public Administration (GIMPA), Accra, Ghana from 7th-13th January, 2007.

Dixon, A.B. (2002) The hydrological impacts and sustainability of wetland drainage cultivation in Illubator, Ethiopia. Land Degrad. Develop. 13(1), 17-31.

Dixon, A.B. and Wood, A.P. (2003) Wetland cultivation and hydrological management in eastern Africa: Matching community and hydrological needs through sustainable wetland use. Natural Resources Forum 27(2), 117-129.

Food and Agriculture Organization (FAO). 1998. Wetland Characterization and Classification for Sustainable Agricultural Development, FAO Regional Office for Africa, Rome, FAO SAFR, ISBN 0-7974-1928-4, 1998. Available online at: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/X6611E/x6611e03.htm

Food and Agriculture Organization of the United Nations (FAO) (2003) World Soil Resources. http://www.fao.org/ag/agl/agll/wrb/wrbmaps/htm/soilres.htm.
FAO (2004) Fact sheet No 5 on International Year of Rice www.rice2004.org
Food & Fertilizer Technology Center (FFTC) 2007. Ecological sustainability of the paddy soil-rice system in Asia, Available online at: http://www.agnet.org/library, 2007

Gawler, M. (2002) Strategies for wise use of wetlands. Best practices in participatory management. International IUCN, WWF Publication No. 56, Wageningen, The Netherlands.

George, T.; Ladha, J.K.; Buresh, R.J. and Garrity, D.P. 1992. .Managing native and legume -fixed nitrogen in lowland rice-based cropping systems. Plant Soil 141: 69-91.

Gopal, B., Junk, W.J. and Davis, J.A. (2000) Biodiversity in wetlands: Assessment function and conservation. Volume 1. Blackhuys Publishers, Leiden, The Netherlands. 353 pp.

International Institute of Tropical Agriculture (IITA). 1980. Consolidated report of UNDP/FAO/IITA Sierra Leone rice project. International Institute of Tropical Agriculture, Ibadan, Nigeria. pp 18-20

IITA, 1988. International Institute of Tropical Agriculture's strategy plan 1989-2000. IITA, Ibadan, Nigeria. pp 85-86

IITA 1990. IITA Annual Report 1989/1990. Ibadan,Nigeria. pp 82-43

Izac, A-M.; Swift, M.J. and Andriesse, W. 1991. A strategy for inland valley agro ecosystems research in West and Central Africa. RCMP Research Monograph No. 5. Research and Crop Management Program, International Institute of Agriculture, Ibadan, Nigeria. 24pp.

Kyuma K. 2003: Paddy Soil Science, 305 pp., Kyoto University Press
Jason, B., James, P.L., and Ronald, P.R. 2005. Fertilization of ratoon rice in Louisiana State University. Journal of Crop Science 53 (2): 10-15.

Lançon, F and Erenstein, O. 2002. Potential and prospects for rice production in West Africa. Paper presented at the Sub-Regional Workshop on harmonization policies and Co-ordination programmes on rice in ECOWAS Sub-Region Accra, Ghana 25-28 February, 2002

Mitsch, W.G. and Gosselink, J.G. (eds) 1993 Wetlands. Second Edition. Van Nostrand Reinhold. New York. pp 114-175.

Mohanty S.K., Panda M.M., Mosic A.R., Mahapatra P., Reddy M.D. (1998): 15N balance studies in a rice-green gram-rice cropping system. Journal of Indian Society of Soil Science, 46 (2): 232–238.

Oad, F.C; Ponpe, S.C; Memon, N.; Oad, N.L. and Hazzan. Z. 2002. Rice Rationing management. Pakistan Journal of Applied Sciences 2(1): 20-35.

Raunet, M.1984. Les potentialiles agicoles des bas-fonds en region inter tropicales: l' example de la cultire du ble de contre-saison a Madagasca. Agronomic Tropicale. 39:121-135.

Redman, F.H and Patrick, W.H. Jr. 1965. Effect of submergence on several biological and chemical soil properties. Louisiana Agricultural Experimental Station, Bull. No. 592. Louisiana State University. Baton Rouge.15pp.

Snyder, C.S., T.W. Bruulsema, and T.L. Jensen. 2007. Greenhouse gas emissions from cropping systems and the influence of fertilizer management—a literature review.

International Plant Nutrition Institute, Norcross, Georgia, U.S.A. www.ipni.net

Tarnocai, C. 1979. Canadian Wetland Registry. In: Proceedings of a workshop on Canadian wetlands environment. C.D.A. Rubec and F.C. Pollett (eds) Canadian Land Directorate, Ecological Classification Series No 12, pp 9-38.

Thenkabail, S. Prasad, S. Nolte, C. 1995. Mapping and characterizing inland valley agroecosystems of West and Central Africa: A methodology integrating remote sensing, global positioning system, and ground truth data in a geographic information systems framework, RCMD Monograph, No. 16, IITA, Ibadan, Nigeria, 1995.

West Africa Rice Development Association (WARDA) 1993. Development of lands, in: Training in Rice Production, Instructor's Manual, West Africa Rice Development Association, Hong Kong, 1993, pp. 29-46.

Wakatsuki, T.; Otoo, E.and Olaniyan O.G. (2002) Restoration of degraded inland watersheds in West Africa: eco-technology approach. In: Proceeding of 17th WCSS, 14–21 August 2002, Thailand, 12021–12028

Wakatsuki, T.; Buri M.M.and Fashola, O.O. 2005 Ecological engineering for sustainable rice production and the restoration of degraded watersheds in West Africa. In: Proceedings of rice research conference, IRRI, pp 336–366

Windmeijer, P.N and Andriesse, W. (eds), 1993. Inland valleys in West Africa. An agro-ecological characterization of rice growing environments. Publication 52. International Institute for land Reclamation and Improvement, Wageningen, The Netherlands, 160 pp.

World Bank, 2001. Second Fadama Development Project (SFDP), Livestock Component, Available online at: http://www.usaid.gov/ng/downloads/markets/fadamalivestock.doc.

World Bank, 2006. Press Release, Nigeria Receives Aid to Manage At-Risk Water Ecosystems, Accessed on the 8th December, 2006, Available online at: http://usinfo.state.gov.

Aflatoxins in Smoked-dried Fish sold in Abeokuta, Ogun State, South-west Nigeria

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Abstract

This study estimated the aflatoxin contamination of smoked-dried fish samples of *Alestes nurse* (Silverside fish), *Synodontis budgeti* (Catfish), *Ilisha Africana* (West African Shad), *Gymnallabes typus* (Catfish), *Ethmalosa fimbriata* (Bonga), *Chrysichthys nigrodigitatus* (Siver Catfish), *Schilbe uranoscopus* (Butter fish), *Cynoglossus browni* (Sole), *Clarias gariepinus* (Mud Catfish), *Calamoichthys calabaricus* (Rope fish) in Abeokuta, Ogun State, Southwestern Nigeria. Fifty smoked-dried fish samples sold at two different markets in Abeokuta town, Lafenwa and Itoku in Abeokuta, Ogun State, Nigeria were found to be lightly contaminated with aflatoxin ($P<0.05$), after testing for their aflatoxin levels using Veratox quantitative aflatoxin test. The aflatoxin concentrations in the samples were between 0.030ppb-1.150ppb with a mean of 0.5980±0.1050 ppb. Rope fish had the lowest aflatoxin concentration while Mud catfish had the highest aflatoxin concentration. Aflatoxins are known to be carcinogenic (causing hepatoma – cancer of the liver), acute hepatitis, reduced red blood cell and decreased immune system in man. Prolonged intake of smoked fish with these metabolites may constitute potential public health hazard. Smoked-dried fishes stored for sale in Abeokuta markets were not heavily contaminated with aflatoxins.

Keywords: Smoked-dried fish, Aflatoxin, Aflatoxicosis, Cancer, *Aspergillus species*

Introduction

In Nigeria, fish smoking is the most practiced preservation method. Practically all species of fish available in the country can be smoked and it has been estimated that 70-80 percent of the domestic marine and freshwater catch is consumed in smoked form. Smoke drying methods used in Nigeria require low capital investment and it is conducted in fishermen camps and fish processing centuries in traditional smoking kilns of clay, cement blocks, drums or iron sheets

Smoked fish constitute a major source of animal protein for a vast majority of the population in Nigeria, particularly the rural population (Eyo, 1992). Aflatoxin is a toxic compound produced by *Aspergillus flavus* and *A. parasiticus.* The molds can grow in improperly stored feeds and feeds with inferior quality of ingredients. Aflatoxins represent a serious source of contamination in foods and feeds in many parts of the world. These toxins have been incriminated as the cause of high mortality in livestock and in some cases of death in human beings. Aflatoxin B1 is known to be the most significant form that causes serious risk to animals and human health (Murjani, 2003). Before now, fungi were regarded as causing only anesthetics spoilage of food. But in 1966, when the famous "Turkey X" diseases killed 10,000 turkey poultry in Great Britain, western world became aware that common spoilage molds could produce significant of toxigenic fungi and potentially toxic compounds have been discovered. Aflatoxins, a group of toxic metabolites produced by certain *Aspergillus species* have been found to be carcinogenic, tetratogenic and mutagenic to several species of experiment animals. Aflatoxin occurs in a variety of crops and animal products. The conditions that contribute to fungal growth and production of aflatoxins are a hot and humid climate, moisture content of 16% and above, favorable substrate characteristics and factors that decrease the host's immunity such as insect damage. Aflatoxins have a high melting point of 250°C. It has been proved that food items do carry residue of the toxin. Thus, it is certain that human beings are exposed to aflatoxins through contaminated food items among which fish is an important component (Murjani, 2003).

According to ICRI (2000), humans are exposed to aflatoxins by consuming foods contaminated with products of fungal growth. Such exposure is difficult to avoid because fungal growth in foods is not easy to prevent. Although heavily contaminated food supplies are not permitted in market places in developed countries, concern still remains for the possible adverse effects resulting from long-term exposure to low levels of aflatoxins in the food supply. Evidence of acute aflatoxicosis in humans has been reported from many parts of the world. The syndrome is characterized by vomiting, abdominal pain, pulmonary oedema, convulsions, coma, and death with cerebral oedema and fatty involvement of the liver, kidney, and heart.

The expression of aflatoxin- related diseases in humans may be influenced by factors such as age, sex, nutritional status, and/or concurrent exposure to other causative agents such as viral hepatitis (HBV) or parasite infestation. Ingestion of aflatoxin, viral diseases, and hereditary factors has also been suggested as possible aetiological agents of childhood cirrhosis. There are evidences to indicate that children exposed to aflatoxin-infested breast milk and dietary items such as unrefined groundnut oil, may develop cirrhosis. Malnourished children are also prone to childhood cirrhosis on consumption of contaminated food. Several investigators have suggested aflatoxin as an aetiological agent of Reye's syndrome in children in Thailand and New Zealand, though; there is no conclusive evidence yet. Epidemiological studies have shown the involvement of aflatoxins in Kwashiorkor, an evidence of malnourishment in children. The diagnostic features of Kwashiorkor are oedema and damage to liver, among others. Hence, it is very important to reduce the dietary intake of aflatoxins by following the procedures for monitoring levels of aflatoxins in foodstuffs. The principal target organ for aflatoxins is the liver. After the invasion of aflatoxins into the liver, lipids infiltrate hepatocytes, leading to necrosis or liver cell death.

Materials and Methods

Sample Collection

Smoke dried fishes were randomly sampled and purchased from two different marketing sites, Itoku and Lafenwa in Abeokuta town, Ogun State, Nigeria. Five samples of related species were grouped together to make ten composite samples totaling fifty samples in all. They were subsequently packed in sterile polyethylene bags and tagged accordingly, and taken to Zartech Veterinary laboratory for analyses.

Assay Principles

Veratox for Aflatoxin is a direct competitive ELISA in a microwell format which allows the user to obtain exact concentrations in part per billion (ppb). Free aflatoxin in the samples and controls are allowed to compete with enzyme-labeled aflatoxin (conjugate) for the antibody binding sites. After a wash step, substrate is added, which reacts with the bound conjugate to produce blue colour. Bluer colour means less aflatoxin. The test is read in a micro-well reader to yield optical densities of the controls from the standard curve, and the sample optical densities are plotted against the curve to calculate the exact concentration of aflatoxin.

Sample Preparation and Extraction

The collected samples (smoked-dried fish) were ground into powdery form with the use of high-speed blender, thoroughly mixed together and made into composite, followed by weighing on an electronic scale. 5 grams of the representative sample was put into an extraction cup. 25ml of 70% methanol was added, the extraction cup was covered and manually shaken for 3 minutes; the mixture was then allowed to settle down. The extract was filtered by pouring 5ml through a Whatman #1 filter syringe, and filtrate was collected as a sample. The sample was now ready for testing.

Test Procedure

The kit (containing coated well, mixing well, conjugate, subscript and stop solution) was set at room temperature (20^0C). A well holder was obtained and 1 red-marked mixing well for each sample tested plus 4 red-marked wells for controls, and placed in the well holder. An equal number of antibody-coated wells were removed. One end of strip was marked with a "1", and strip was placed in the well holder with the marked end on the left. Marking the inside or bottom of the wells was avoided. Each reagent was mixed swirling the reagent bottle prior to use. 100µl of conjugate from the blue-labeled bottle was placed in each red-marked mixing well. Using a new pipette tip for each, 100µl of controls and samples were transferred to the red-marked mixing wells as described below:

0	5	15	50	S1	S2	S3	S4	S5	S6	S7	S8	Strip 1
S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	Strip2

Using a 12-channel pipettor, mix the liquid in the well and swirled up and down for 3 times. 100µl was transferred to the anti-body coated wells, then the red-marked mixing wells. The timer was set for 2 minutes, mixing the wells by forward pipetting and set at room temperature for incubations by sliding the mixing wells back and forth on a flat surface without splashing the wells. The content of the antibody wells was shaken vigorously, filled with distilled water and dumped out. Then, wells were turned upside-down and tap-dried with towel until the remaining water has been removed. With new tips on the 12-channel pipettor, 100µl of substrate was added into the wells. The timer was set for 3 minutes; the wells were mixed by sliding back and forth on a flat surface. The mixture was then discarded and the reagent boat was rinsed with distilled water. Red Stop solution was poured from the red-labeled bottle into the labeled reagent boat. Excess substrate from the 12-channel pipette tips was ejected, and 100µl of Red Stop solution was pipetted into each well, mixed back and forth on a flat surface and discarded. The bottom of the micro-wells was wiped with a dry towel such that there was no fluid remaining; the plate was taking into the micro-well reader using a 650nm filter. Air bubbles were eliminated, as they could affect analytical results.

Statistical Analysis

The result was read and calculated using Neogen's Veratox software, while T-test was used to test for the significant level of the means.

Results

Sample Analysis

The result of the total aflatoxin concentrations expressed in part per billion (ppb) obtained from the sampling of ten smoked-dried fish species (Table 1) purchased from local markets in Abeokuta are shown in Table 2 and Figure 1. Aflatoxin concentrations of the smoked-dried fish samples ranged from 0.030 ppb to 1.150 ppb with a mean of 0.5980±0.1050 ppb.

Table 1: Identified smoked-dried fishes sampled from the two markets (Itoku and Lafenwa) totaling fifty

Scientific names	Common names
Alestes nurse	Silverside fish
Synodontis budgeti	Catfish
Ethmalosa fimbriata	Bonga fish
Schilbe uranoscopus	Butterfish
Clarias gariepinus	Mudcatfish
Gymnallabes typus	Catfish
Ilisha Africana	West African Shad
Chrysichthys nigrodigitatus	Silver catfish
Cynoglossus browni	Sole
Calamoichthys calabaricus	Rope fish

PLATES SHOWING THE SAMPLED SMOKED-DRIED FISH SPECIES

Plate 1: ***Ethmalosa fimbriata***

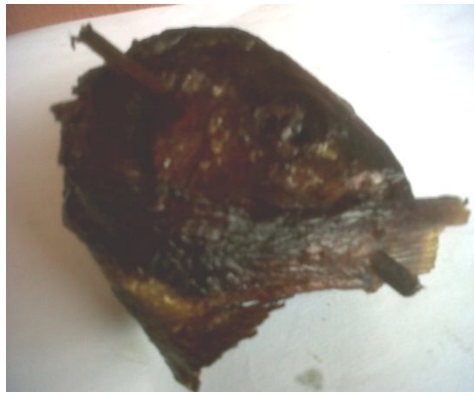

Plate 2: ***Synodontis budgeti***

Plate 3: ***Ilisha africana***

Plate 4: ***Calamoichthys calabaricus***

Plate 5: ***Clarias gariepinus***

Plate 6: ***Schilbe uranoscopus***

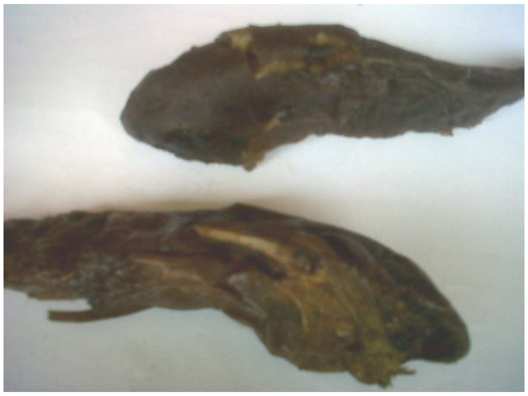
Plate 7: ***Chrysichthys nigrodigitatus***


Plate 8: ***Gymnallabes typus***


Plate 9: ***Cynoglossus browni***


Plate 10: ***Alestes nurse***

Table 2: Result of Laboratory Analysis for the Aflatoxin Levels of the Smoked-dried fishes sampled from the two markets

Slope: -2.090 **Correlation Co-efficient** **Units: ppb**

Sample	Description	Optical Density	Preliminary Result	Dilution Factor	Final Result
1	0 ppb	1.220	0.0000		
2	5 ppb	0.752	5.290		
3	15 ppb	0.497	13.480		
4	50 ppb	0.203	52.620		
5	A	1.184	0.190	1.0	0.190 ± 0.105
6	B	1.121	0.620	1.0	0.620 ± 0.105
7	C	1.117	0.650	1.0	0.650 ± 0.105
8	D	1.127	0.570	1.0	0.570 ± 0.105
9	E	1.056	1.150	1.0	1.150 ± 0.105
10	F	1.096	0.810	1.0	0.810 ± 0.105
11	G	1.154	0.380	1.0	0.380 ± 0.105
12	H	1.083	0.910	1.0	0.910 ± 0.105
13	I	1.114	0.670	1.0	0.670 ± 0.105
14	J	1.214	0.030	1.0	0.030 ± 0.105

Keys:
A: *Alestes nurse*
B: *Synodontis budgeti*
C: *Ethmalosa fimbriata*
D: *Schilbe uranoscopus*
E: *Clarias gariepinus*
F: *Gymnallabes typus*
G: *Ilisha Africana*
H: *Chrysichthys nigrodigitatus*
I: *Cynoglossus browni*
J: *Calamoichthys calabaricus*

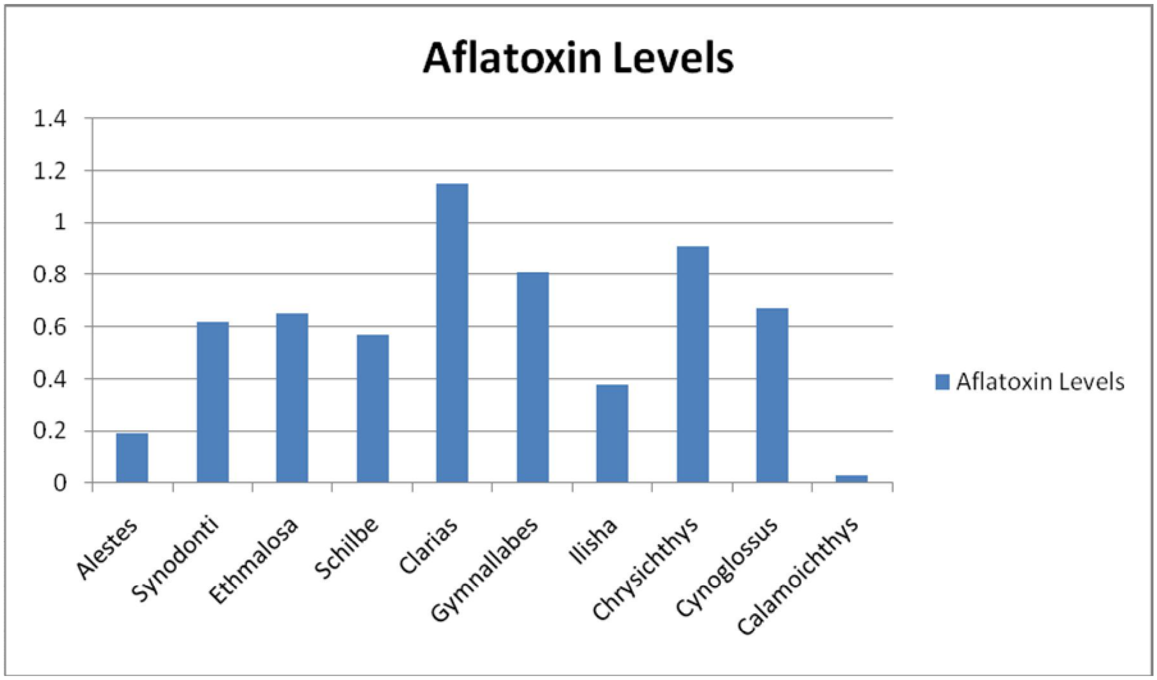

Figure 1: Aflatoxin concentrations in the different smoked-dried fish samples

Discussion

Results obtained from this study showed that aflatoxins were found to be associated with smoked-dried fishes sold in different markets in Abeokuta, but in non-significant levels (P<0.05) (0.030ppb-1.150ppb) that may not be toxic to human health, according to the regulatory levels for aflatoxins issued by the Food and Administration (FDA) of the United States (The FDA regulatory levels for aflatoxin intake for humans and all animal species is maximum of 20 ppb). Adebayo-Tayo *et al.* (2006), reported different results in marketed smoked-dried fish stored for sale in Uyo, Akwa-Ibom State, whereby the presence of aflatoxins were in higher concentrations (The aflatoxin concentrations were between 1.5ppb – 8.1ppb) in the samples, which might make their consumption hazardous to health. Such a higher difference in aflatoxin concentrations might be as a result of higher relative humidity usually recorded in Uyo, unlike Abeokuta town. However, this could favour the accumulation of aflatoxin due to high moisture content when displayed for sale in the market. The processes of handling fishes are also prone to aflatoxin contamination especially in artisanal fishery due to unhygienic methods of preservation. According to Akande and Tobor (1992), in artisanal fishery, freshly caught fish are covered with damp sacks and at times, they are mixed with wet grass or water weeds to reduce the temperature. Fish treated this way is prone to contamination with microorganisms such as bacteria and fungi. This indicates that spoilage of fish starts shortly after harvesting. During the smoke-drying period, smoking kilns used in artisanal fishery and the overloading of the fishes on the trays leads to improper processing which in turn encourages aflatoxin contamination (Eyo, 1992). During storage of smoked-dried fish products, good storage practices are not adhered to, hence stores are not well ventilated and pests can easily gain access into the stores. The environment in which fishes are displayed in the market is not always hygienic and this is another avenue for aflatoxin contamination. Very often, retailers display the smoked-dried fishes in open trays beside the gutter on refuse heaps; this also encourages fungal attack and subsequent production of toxins. This is in agreement with the report of Akande and Tobor (1992). The result also revealed that aflatoxins were detected in all of the samples. The aflatoxin concentration ranged from 0.030ppb-1.150ppb. Rope fish had the lowest aflatoxin concentration while Mud catfish had the highest aflatoxin concentration.

The extracted smoked-dried fish samples produced bluish and greenish spots during laboratory analysis. Sharma (2002) reported that the two major metabolites of *Aspergillus sp*. called aflatoxins were designated B and G because they fluoresce blue (B) and green (G) when exposed to long-wave ultraviolet light.

Aflatoxins are highly carcinogenic causing hepatoma (cancer of the liver) and have also been associated with acute hepatitis in man, mostly the developing world (Eaton and Groopman, 1994). Aflatoxin have been reported in grapes in France (Sage *et al.,* 2002), edible nuts and nut products, milk and milk products (Prasad, 1992), bush mango seeds (Adebayo-Tayo *et al.*, 2006). The implication of this report is that, though in Abeokuta most of the populace feed on smoked-dried fishes, it can be confirmed that most of the consumers would have been consuming aflatoxins. Though, in relatively small amount, prolong intake of these aflatoxins may constitute a health hazard. Goldbatt and Stolloff (1983) reported that aflatoxins occurred in the human diet and this could pass from feed to milk. Since improper smoking and drying of fishes may lead to insect infestation, fungal attack, fragmentation and degradation of the product (Eyo, 1992), it is therefore important that both the artisanal fishermen and the marketers should adopt a better method of preservation. Better smoking kilns should be provided for artisanal fishermen at subsidized rates and fish product should be well stored.

References

Adebayo-Tayo, B.C., A.A. Onilude, C. Bukola, A. Abiodun and Ukpe, G.P. (2006), Mycofloral of Smoke-Dried Fishes Sold in Uyo, Eastern Nigeria. *World Journal of Agricultural Sciences*, 4 (3): 346-350

Akande, G.R. and J.G. Tobor, (1992), Improved utilization and increased availability of fishing products as an effective control of aggravated animal protein deficiency induced malnutrition in Nigeria. Proceedings of the 10th annual conference of the Fisheries Society of Nigeria, pp: 18-31

Eaton, D.L. and J.D. Groopman (1994), The Toxicology of Aflatoxins, Academic Press, New York, NT, pp: 383-426

Eyo, A.A. (1992), Traditional and improved fish handling, preservation and processing techniques, NAERLS/NIFER national workshop on fish processing, storage, marketing and utilization, pp: 15

Goldblatt, L.A. and L. Stoloff (1983), History and occurrence of aflatoxins, In: Naguib, K., Naguib, M.M. Park, D.L. and Pohland, A.E. (Eds), Proceedings of International symposium on mycotoxins, general organization for Government Printing Offices, Cairo, pp: 33-46

Murgani, G. (2003), Aflatoxicosis in fish and its relevance to human health, Shaping the future, pp: 5668-5673

Prasad, T. (1992), Detection of fungi in stored grains and estimation of mycotoxins in Seed pathology, In: Mathur, S.B and Jorgensen, J. (Eds.), Proceeding of the seminar. 20-25 June 1998, Copenhagen, Denmark, pp: 175-81

Sage, L., S. Krivobok, E. Delbos, F. Seigle, and E.E. Creppy (2002), Fungal flora and ochratoxin Murands A production in grapes and musts from France, *Journal of Agricultural and Food Chemistry*, 50: 1306

Sharma, O.P. (2002), Textbook of fungi, Tata McGraw – Hill, New Delhi, India, pp: 160-161

Earthworm as Bio-indicator of Heavy Metal Pollution around Lafarge, Wapco Cement Factory, Ewekoro, Nigeria

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Abstract

Heavy metal pollution of terrestrial and aquatic ecosystems has long been recognized as a serious environmental concern. The use of earthworm as bio-index of soil heavy metal pollution was hereby examined. Using the Lagos/Abeokuta express road as transect, four replicates each of soil and earthworm samples were collected from five points: 100m north, 500m south, 1000m north, 1000m south, 2000m north of the Lafarge WAPCO cement factory, Ewekoro and a sixth point at the Arboretum, University of Agriculture, Abeokuta (control site). Using spectro-photometry method, heavy metal concentrations (Pb, Cu, Mn, Zn, Cd, Co) were measured in all samples of soil and earthworm. Histological studies were conducted on earthworm sections. All data obtained were subjected to analysis of variance and post hoc tests to establish significance at ($p<0.05$). Heavy metal concentrations in earthworm and soil decreased significantly ($p<0.05$) with increasing distance from the factory. The heavy metal concentrations in soil and earthworm around the factory were significantly higher than that obtained at the control site ($P<0.05$). Histological studies on the earthworm body wall revealed dark spots and patches on the tissues of the earthworm samples collected from the cement factory area compared with clear earthworm tissues at the control site. Bioaccumulation of heavy metal in soil and earthworm was noticeable around West Africa Portland Cement factory, Ewekoro, Nigeria and could serve as a possible bio-index of heavy metal pollution.

Key words: Bio-indicator, Bio-index, Earthworm, Heavy metal, Spectro-photometry

Introduction

Soil is the region on the earth's crust where Geology and Biology meet; it is the land surface that provides a home to plant animal and microbial life (Pelczar *et al.*, 1993). Soil samples differ in their content of heavy metal and pH depending on climate, soil origin, composition and human activities (Hashem and Al-Obaid, 1996). Heavy metals in the soil have received attention as environmental contaminants because of their extended persistence, and toxicity to many organisms (Hashem and Al-Obaid, 1996).

Heavy metal contaminated soils constitute a huge problem as it affects human health and environmental quality (Otitoloju., 2009). The anthropogenic sources of the heavy metals, in soils are either primary sources, i.e. the heavy metals are added to the soil as an outcome of working the soil, such as fertilization or secondary sources where heavy metals are added to the soil as a consequence of a nearby activity, such as smelting or aerial deposition (Ferguson, 1990).

Cement dusts are particulate air pollutant generated from cement production processes. They are produced during blasting of raw materials, grinding of cement clinker and packaging or loading of finished cement. It is one of the major means by which heavy metal could be added to the soil. Notably among the heavy metals added to the soil through cement production includes: cadmium, copper, lead and zinc (Shemback, 2009).

Earthworms contribute to the aeration of the soil, hence the need for its study. In earthworm toxicity testing, the organisms are in close contact with soil and can be used to evaluate bioavailability (Connor, 1988). In addition, the earthworm is a representative of soil fauna and recognized to be a relatively sensitive indicator (Connor, 1988). In soils, earthworms constitute 60–80% of the animal biomass and play a critical ecological role (Double and Brown, 1988). For example, it is estimated that under favourable conditions, earthworms can move up to 18 tons of soil per acre per year. Being continuously exposed to the soil through direct dermal contact and ingestion of soil materials, earthworms are therefore in close contact with exogenous dusts (Double and Brown, 1988). This study is therefore aimed at establishing the level of bioaccumulation of heavy metal in earthworm species found around the cement manufacturing industry.

Study Location

The experimental area is LAFARGE Cement factory, WAPCO, Ewekoro, within Latitude 6º 54'N and Longitude 3º 13' E. The cement factory is situated within Ewekoro Local Government area of Ogun state, SW Nigeria between June and September, 2010. Six soil sites were selected viz: 100meters north of the dust stack, 500meters south of the dust stack, 1000meters north of the dust stack, 1000meters south of the dust stack and 2km south of the factory. University of Agriculture Abeokuta arboretum was used as control.

Materials and Methods

All the six sites used were randomly sampled using a quadrant to collect the soil samples. The top 10cm of soil was sampled and hand sorted to remove root and litters. This was done in four replicates with each replicate obtained from an area of $50cm^2$. The samples were stored in labeled polythene bags prior to analysis. 1.00g of thoroughly mixed soil samples were digested using 15ml of concentrated $HN0_3$, 5ml of concentrated Hydrochloric Acid (HCl) at 100^oC for 20 min. This was done after drying the soil samples at 80^oC in a digestion microwave oven. The samples were then filtered using cotton wool and diluted to 50 ml with distilled water and kept in sample bottles.

The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer, (VGR System model 210). Co, Cu, Pb, Zn, Cd and Mn were recorded in parts per million. The result in parts per million were calculated as follows:

$$\text{PPM (mineral)} = \frac{\text{Reading from AAS} \times \text{Volume of digest}}{\text{Weight of Sample}}$$

Earthworm Collection and Analysis

Earthworms were collected using the quadrant $50cm^2$. Sampling was done on four different points on each of the six sites from a depth of 10cm. Five to ten earthworms from each of the six locations were collected and identified using the description of Owa (1992). The earthworms collected were kept in aerated plastic containers with wet soil samples from the point of collection.

The dry earthworms were crushed, and then digested as follows: 1.00g of sample was mixed with 15ml conc. HNO3 and 5 ml conc. HCl, and heated progressively to 150^oC at 800 kPa in 250ml conical flask using a hot plate for 2hrs. After cooling at ambient temperature, the solution was filtered using cotton wool and made up to 50 ml with distilled water. The metal contents were determined by Atomic Absorption Spectrophotometer, (VGR System model 210) for Co, Cu, Pb, Zn,Cd and Mn.The result in parts per million were calculated as follows:

$$\text{PPM (mineral)} = \frac{\text{Reading from AAS} \times \text{Volume of digest}}{\text{Weight of Sample}}$$

Histological Analysis of Earthworm Samples

Earthworm sample from each of the five locations which were stored in FAA were later taken and washed with distilled water after which the abdominal portion of each earthworm were dehydrated by passing them through increasing concentration of ethanol 50%, 70%, 90%, and 100% one hour each. This was done to remove water from the tissues. The dehydrate portions were then cleared in three changes of xylene to remove excess alcohol from the tissues. The portions were thereafter impregnated in three changes of molten wax to remove xylene from the tissue and to replace it with paraffin wax. The portions were embedded in molten wax and allowed to solidify. The block were mounted on the microtome and sectioned.

Statistical Analysis

For all the parameters that were tested, comparisons of means were analyzed statistically, using one-way Analysis of Variance (ANOVA) and Pearson chi–square statistics at probability of $P<0.05$. Relationships were then tested using the Pearson correlation index at the same probability. All statistical analysis was performed using SPSS 16.0 software.

Table 1: Heavy Metal Concentration in Soil across the Six Locations (X±SD)

	Cd	Co	Cu	Mn	Pb	Zn
100m NF	10.35±1.02[c]	11.2833±11.28[c]	2.3333±0.29[b]	208.52±27.01[b]	50.3167±0.55[e]	98.3833±2.24[c]
1000m NF	7.6±0.96[b]	1.2167±0.03[a]	2.35±0.1[b]	104.48±33.9[a]	34.3167±1.99[c]	82.7167±8.0[b]
2000m NF	4.7333±1.38[a]	3.7±0.43[a]	1.3167±0.08[a]	85.6167±0.55[a]	19.0333±2.64[b]	16.4167±0.49[a]
500m SF	9±3.0[c]	5.6667±0.29[b]	8.2167±1.4[c]	183.951.2[b]	44.9000±0.13[d]	107.23±0.55[c]
1000m SF	4.3±2.04[a]	1.15±0.26[a]	1.5± 0.1[a]	88.1833±21.59[a]	16.5333±2.07[b]	19.2833±8.18[a]
UNAAB	2.825±0.81[a]	1.6933±0.02[a]	0.9167±0.8[a]	68.575±13.9[a]	7.85±3.55[a]	14.3±0.07[a]

a, b, c indicates significant difference in metal concentration across the column (P<0.05); Data are in mg/kg dry weights; NF: North of factory; SF: South of factory

Table 2: Heavy Metal Concentration in Earthworm (X±SD)

	Cd	Co	Cu	Mn	Pb	Zn
100m NF	21.866±2.01[c]	2.63±0.06[b]	6.8±1.04[c]	131.33±18.8[d]	25.13±0.81[c]	216.87±0.84[d]
1000m NF	9.933±0.06[a]	0.667±0.06[a]	1.93±0.05[a]	106.13±2.31[c]	15.47±3.8[b]	84.83±0.40[b]
2000m NF	9.966±0.06[a]	2.7±0.12[b]	4±0[b]	79.06±0.58[b]	24±3.46[c]	133.27±1.0[c]
500m SF	14.7±3.16[b]	0.867±0.81[a]	4.367±1.76[b]	67.96±9.4[a]	21.3±0.61[c]	142.57±0.55[d]
1000m SF	7.667±1.1[a]	0.5±0.1[a]	1.2±0[a]	52.6±11.1[a]	10.07±1.52[a]	42.45±0.21[a]
UNAAB	ENP	ENP	ENP	ENP	ENP	ENP

a, b, c indicates significant difference in metal concentration across the column (P<0.05); Data are in mg/kg dry weights; NF: North of factory; SF: South of factory; ENP: Earthworm not present

Results and Discussion

Concentration of heavy metals tested in soil samples collected from the six locations decreased with increasing distance from the factory area (Table 1). Cd, Co, Cu, Mn, Pb and Zn showed a decreasing metal concentration from 100m NF, 1000m NF and 2000m NF. Metal concentrations at 500m SF were higher than 1000m SF. Soil samples collected from UNAAB arboretum had the least metal concentration for all the metals tested. The heavy metal concentrations in soil samples collected from the six locations decreased in this order; Mn> Zn> Pb> Cd> Co> Cu. A steady decrease in the concentration of Cd, Co, Cu, Pb and Zn was recorded from the earthworm, *Hyperiodrilus africanus* as we moved away North of the Factory, 100m NF, 1000m NF and 2000m NF with the least concentrations of the heavy metals recorded from the earthworm samples collected from UNAAB Arboretum as shown in Table 2.

It was further observed that nearly in all sampling locations the concentrations of the heavy metals in the earthworm samples were higher than soil samples from the same location whereas earthworms and soil samples from the UNAAB Arboretum (Control location) showed only slight variation in the concentrations of the heavy metals. On another hand, Mn and Co concentrations were exceptionally higher in the soil samples of the Arboretum than the earthworm samples. This might probably be due to some form of mechanism in the earthworms which increases the concentration of these two heavy metals in the earthworms collected from the non contaminated soils of the Arboretum.

On a comparative basis the concentration of Mn was the highest (68.58 mg/kg) for all the metals analyzed while the lowest was Cu with a concentration of 0.92 mg/kg in the soil samples. This trend of a highest Mn concentration and a lowest Cu concentration obtained in this study is similar to the reported work of Anderson and Laursen (1982) who worked *on Lumbricus terrestris* in uncontaminated soils.

In contrast to the earlier observation of earthworm metals concentration being higher than soil metal concentration in the control site, it was observed that in nearly all cases, the concentration of metals in the soil samples were higher than those of the earthworm samples, with the exception of Cd and Zn concentrations which had higher concentrations in earthworms than in soil samples.

This observation may be due to the chemical changes which occur in the alimentary tracts of earthworms and hence render various metals more available to plants. It may also be as a result of in built earthworm body mechanism which reduces the rate at which the earthworm absorbs heavy metal from contaminated soils. Also mineralization of dead earthworms releases accumulated heavy metals back to the environment (Morgan and Morgan 1993).

The general trend of the metals concentrated either in the soil or in the earthworms show that Mn (131.33 - 208 mg/kg) had the highest concentration while Cu had the lowest (5.217 -6.8 mg/kg) and follow a general trend of Mn > Zn > Pb > Cd > Co > Cu. Though this trend may not be exclusive, it follows to an extent the reported trend of Sposito (1992) in his work on trace metal in arid zone soils amended with sewage sludge of which the trend Mn > Zn > Pb > Cu > Cr > Cd was reported.The main variation observed lies with the cadmium concentration. In this work, rather than Cadmium being the least in terms of heavy metal concentration, copper had the least concentration. This is however in conformity with the work of Al-Yemeni and Hashem (2006) who had reported that cadmium concentration was more than cobalt which was also more than nickel in soil samples collected around Aramco Gulf Operation Company Saudi Arabia.

PLATE 1: Transverse section of control earthworm showing normal tissue arrangement. The outer ring (pink) consists of the epidermis, circular muscles, and longitudinal muscle (radiating lines). (X400)

NOTE:
A: EPIDERMIS
B: LONGITUDINAL MUSCLES
C: COELOM
D: TYPHLOSOL

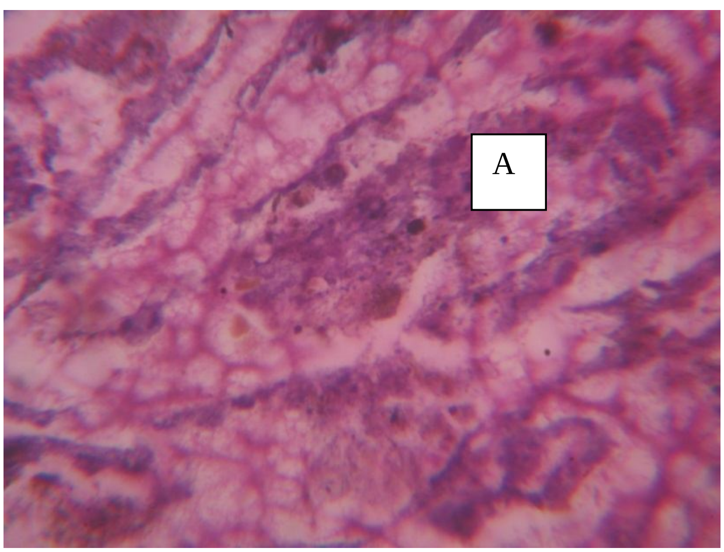

PLATE 2: Transverse section of earthworm collected from 500meter south of the dust stack. (X400)
NOTE: A: DARK SPOTS WHICH LOOKS LIKE ANTHRACOSIS AND SILICOSIS OF THE LUNGS

Furthermore, this present study revealed that heavy metal concentration in soil and earthworm decreased with increasing distance away from the factory area. The histological studies showed that earthworm samples collected at 500meter south of the dust stack, 1000meters south of the dust stack, 1000meters north of the factory and 2000meters north of the factory showed dark patches on their tissues (plate 2). Whereas earthworm samples collected at UNAAB arboretum have clear surface (Plate 1). The histological studies revealed on the body wall of the earthworms what seemed like anthracosis and silicosis of the human lungs. Anthracosis was described by McGraw-Hill (2002) as a generic term for the blackening of tissues, often understood to mean carbon dust deposition in the lung and lymph nodes, which does not itself cause disease, and is usually present in urban dwellers, and in those working in certain occupations eg, coal mining. The condition was also described as heavy black deposits of carbon; a common necropsy found in the lung tissues of dogs which have passed a busy working life in a heavily industrialized city (Saunders, 2007).The dark spots were visibly present in all the body wall tissues of the earthworm collected from the factory area as seen from plates 2. However, plate 1 showed that earthworms collected from control site (UNAAB Arboretum) had clearer tissues when compared with the ones from the factory area.

In conclusion, this study confirms that the earthworm (*Hyperiodrilus africanus*) can serve as a bio-indicator in polluted environments.

References

Al-Yemeni, M.N. and Hashem, A.R. (2006). Heavy metal and microbial analysis of soil sample collected from Aramco Gulf Operations Company, Al- khafji, (AGOC) Saudi Arabia. Saudi Journal of Biological Sciences. 13(2) 129-133.

Anderson, C. and Laursen., 1982. Distribution of heavy metals in *Lumbricus terrestris, Aporrectode longe* and *A. rosea* measured by atomic absorption and X-ray fluorescence spectrometry. Pedobiologia. 24: 347 - 56.

Connor G. O', J. Environ. Qual., (1988), 17, 715. Double and Brown, in ''Earthworm Ecology'', ed. C. Edwards, St. Lucie Press, Boca Raton, FL, 1998, pp. 179–211.

Ferguson, J.E. (1990). The Heavy Element, Chemistry, New-York: Pergamon Press, pp: 61
Hashem, A.R. and Al-Obaid, A.M. 1996.

Effect of Cadmium on the Growth of *Aspergillus flavus* and *Ulocladium chalmydosporum. Internat. J. Exper. Bot,* 59 (1/2):171-175.

McGraw Hill (2002), Anthracosis, Science and Technology Dictionary Morgan, J. E. & A. J.

Morgan. (1993). Seasonal changes in the tissue metal (Cd, Zn and Pb) concentration in two ecophysiologically dissimilar earthworm species, pollution monitoring implication. *Environ. Pollut*. 82: 1 - 7

Pelczar, M.J., Chan, E.C.S. and Krieg, N.R. 993). Microbiology: *Concept and Application* International edition McGraw-Hill, USA. pp 281-324.

Saunders, W.B, (2007). Pathologic Basic Disease Philadelphia.

Shemback J, (2009), http//www.cementkiln.com

Sposito, R. C. (1992). Trace metal chemistry in arid - zone field soils amended with sewage sludge I. Fractionation of Ni, Cu, Zn and Pb in solid phases. Soil Sci Soc. Am. J. 46: 260 - 264.

Otitoloju, A.A., Ajikobi, D.O and Egonmwan, R.I.(2009). The open environmental pollution and toxicology journal, 1: 79-88.

Owa, S.O. (1992). Taxonomy and Distribution of Nigerian earthworms of the family Eudrilidae and their use as possible indicators of soi properties. PhD thesis Obafemi Awolowo University, Ile-Ife, Nigeria.

Tertiary Hospital Wastewater Treatment using Reed Bed Technology Planted with V*etiveria nigritana* benth and P*hragmites karka* retz

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Abstract

Tertiary hospital wastewater in Nigeria constitutes a risk to public health due to inadequate treatment. Reed bed technology using locally available macrophytes holds tremendous potentials for biological wastewater treatment. The use of *Vetiver*ia *nigritana* and *Phragmites karka* in CW for the removal of organic and inorganic pollutants from tertiary hospital was therefore investigated. Characteristics of wastewater such as pH, Nitrates (NO_3^-), Phosphates (PO_4^{3-}) and Ammonia (NH_3) contents, Suspended Solids (SS), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO) from the University College Hospital, Ibadan were evaluated using American Public Health Association's (APHA) methods. The optimal dilution ratio of wastewater was determined by varying wastewater concentration (3:1, 1:3, 1:1, 4:0 and 0:4 wastewater to water) while monitoring growth rate of the macrophytes. Four 3.1 x 3.4 x 0.7 m Reed bed prototypes with *Vetiver*ia *nigritana* and *Phragmites karka* planted on 0.2 m deep, 10-15 mm sized granite overlaid by 0.2m washed sand and control bed were evaluated. Composition of wastewater displayed considerable variability (pH 7.5 ± 0.3, NO_3^- 2 ± 0.1mg/L, 3 PO_4^{3-} 3.9 ± 2.5mg/L, NH_3 19.5 ± 6.3mg/L, SS 204.1 ± 23.9mg/L, DO 0.9 ± 0.8 mg/L and BOD 310.6 ± 29.9 mg/L). The 1:3 waste water to water dilution ratios supported the most rapid growth of macrophytes. The prototype reed bed showed reduction of BOD 82.0% and 85.0%, TDS 72.0% and 73.0%, PO_4^{3-} 78.0% and 81.0%, NO_3^- 61.0% and 65.0% for *V. nigritana and P. karka* respectively. *Vetiveria nigritana* and *Phragmites karka* were found to be efficient in wastewater treatment using Reed bed Technology.

Keywords: Reed bed, *Vetiver*ia *nigritana*, *Phragmites karka,* wastewater, tertiary hospital

Introduction

Severe water pollution and insufficient supply are some of the major problems facing the water environment around the globe. The scarcity of fresh water is predicted to become the greatest single threat to international stability, global food supply and human health. Water quality deterioration can be attributed to pollution entering surface and groundwater from sources such as runoff, municipal and industrial discharges (Truong, 2000; Hanping *et al*, 2004).

In Nigeria, domestic wastewater disposal into near-by river is a common phenomenon. Most urban rivers and streams are dumping ground for domestic wastewater as exemplified by River Kaduna, River Ogba in Edo State, River Ogunpa in Oyo State and River Ogun. Organic contaminants entering the systems from municipal wastewater treatment plants or as raw wastewater is some of the major sources of organic wastes entering our waterways. It has been reported that 4.6 million people died from diarrhea disease and a sizeable number of casualties was experienced from ascariasis, guinea worm and trachoma due to deterioration of the water quality (Akpata and Ekundayo, 1998).

Water quality deterioration due to Nigeria's tertiary hospitals has various environmental consequences, the immediate environment is seriously affected, septicity which causes offensive odour and breeding of flies that are capable of threatening the health of the community results; the receiving waters is not spared as wastewater flows through the largely populated residential and commercial areas of neighbouring cities and there is uncontrolled access to the water by the public. Discharge of nutrients-rich wastewater, nitrates and phosphates in particular would lead to eutrophication, which will seriously destabilize the ecosystem of the water bodies.

In the past years there has been an increasing interest in using more rustic methods to treat urban wastewater as well as industrial wastewater containing heavy metals or organic chemicals. Reed bed technology offering an alternative treatment that can satisfy these requirements are currently being used (Salmon *et al*, 1998). Reed bed technology is an engineered system designed and constructed to utilize natural processes for water quality improvement, it combines physical, chemical and biological treatment processes in water quality improvement. Reed bed involves wetland vegetation, soils and the associated microbial assemblages to assist in treating wastewaters (Davies *et al*, 2005). It is a wastewater treatment facility duplicating the processes occurring in natural wetlands. Reed bed is a complex integrated system in which water, plants, animals, microorganisms and the environment; sun, soil and air interact to improve water quality. Distinctive features of this system according to Cooper *et al,* (1989) include the roots of the plants that grow vertically and horizontally to provide maximum contact with the wastewater and substrate. Effluents are treated by aerobic biological activity at the rhizophere and inlet zone while anoxic and anaerobic treatment takes place at the middle and base of the system.

The choice of substrate in Reed bed is of major importance as it provides support for the living organisms, serves as storage medium for many contaminants, many chemical and biological (especially microbial) transformations take place within the substrates, their permeability affects the movement of water through the wetlands (Calheiros, *et al*, 2008). Vegetation in CW performs remarkable metabolic and absorption functions, their transport system take up nutrients and contaminants from the substrates or water. Macrophytes have been shown to have a significant and positive effect on wastewater pollution removal (Brisson and Chazarenc, 2008; Akratos and Tsihrintzis, 2007).

This present study is aimed at investigating the efficiency of Reed bed Technology; using locally available macrophytes (*Vetiver*ia *nigritana* and *Phragmites karka*) on the removal of pollutants from wastewater generated in a tertiary hospital.

Methodology

The study area of the research work is the University College sewage farm, University College Teaching Hospital (N 07.40583^0, E 03.90384^0 203m), Ibadan (UCH), Oyo State. The existing treatment plant in UCH has eight drying beds that are supposed to be charged with stabilized sludge from the digester with a total surface area of 900m^2. One of the existing disused concrete walled drying beds was used as the reed bed. The sludge drying bed was divided into two equal parts and the first half of the bed was partitioned into five cells (Plate 1). Each of the included cell was rectangular in cross-section and the cells at the edges were trapezoidal in cross-section. The cell at the centre was used as the control bed, to either side were two beds planted with *Vetiveria nigritana* and *Phragmites karka.*

All the beds have a uniform depth of 0.7 m; the two cells at the edges were 310 x 340 cm while the remaining three were 250 x 340 cm each. They were separated by sandcrete blocks, well rendered to prevent percolation of wastewater. Each of the beds has a slope of 2% to allow the wastewater pass through the bed under gravity with ease.

The substrate materials used in this study were washed granite and washed sand. The coarse substrate was made up of 200 mm deep 10-15mm granite, while the fine substrate layer was 200mm thick (Cu = 2.435 and Cc = 1.094). Transplanted rhizomes of the two locally available macrophytes, *Phragmites karka* (commonly known as reeds) and *Vetiveria nigritana* (the Nigerian specie of Vetiver) were used. *Vetiveria nigritana* was collected from the Department of Agronomy, University of Ibadan and *Phragmites karka* obtained from Igbobele water course, Badagry, Nigeria.

Plate 1: Reed bed prototype cells showing the irrigation pipe and the sludge drying beds

The beds were irrigated uniformly with a pumping machine connected to a 150 mm diameter PVC pipe, this was perforated at intervals of 100mm for uniformity of loading and proper aeration. The effluent from the under drain of the trickling filters' media were collected from the inspection chamber and was used to feed the Reed bed. Effluent from the bed was collected through an opening of 6 mm diameter PVC pipe attached to the base of the cell. The Valeport 'Braystoke' BFM002 miniature current meter designed for the measurement of flow velocities in effluent water was used for flow measurement. Samples were collected and analysed using standard methods for examination of water and wastewater (APHA, 1994). Samples were stored at 4^0C and analysis conducted within three hours of sample collection.

Results and Discussion

The raw wastewater discharged into the treatment plant is mainly domestic in character with minor effluents joining from the wards, theatres and clinics. Toxic chemicals from the pathology laboratories are discharged into septic tanks attached to the laboratories. A summary of the physical and chemical parameters of the influent grey water during the study period is presented in Table 1.

Table 1: Characteristics of Wastewater from the University College Hospital

Parameters	Range	Mean
Temperature ^{0}C	24.9-32	30.48±0.96
Ph	7.1 – 7.9	7.49±0.27
Dissolved Oxygen (mg/l)	0.05 – 2.01	0.84±0.79
Dissolved Solids (mg/l)	414 – 630	481±81.11
Suspended Solids	167 – 231	204.1±23.9
BOD (mg/l)	210 – 370.6	310.56±29.91
NO_3 – N (mg/l)	0.032 – 0.150	0.141±0.06
PO_4 – P (mg/l)	2.014 – 8.50	3.94±2.52
NH_4 – N (mg/l)	10.2 – 30.0	19.45±6.31

Pollutant parameters in the wastewater displayed considerable variability in concentration throughout the study period. These variations are consistent with reported variability of pollutant concentration in wastewater within individual sites. The wastewater generated at the University College Hospital varies during the time of the day and season of the year (Figure 1). The peak flow of 221.30 ± 3.81m^3/day and 367.85 ± 26.36m^3/day in the dry and wet season respectively occurred between 7:00am and 8:00am. The lowest flow rates of 0.80m^3/sec to 0.90m^3/sec (69.12m^3/day and 177.7m^3/day) for the dry and wet seasons respectively were observed between the hours of 12noon and 2pm.

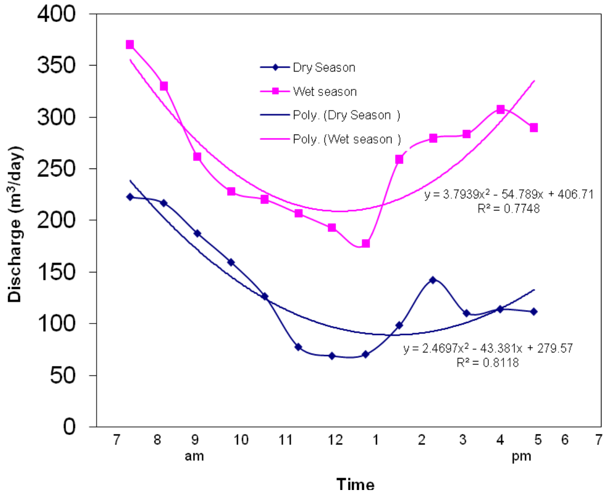

Figure 1: Variation in wastewater discharge with time at the University College Hospital Ibadan

Figure 2 shows optimal dilution ratio of wastewater by varying the concentration of wastewater on the height of plants, width of stem and number of leaves of *P. karka*. The results agree with the work of Bragato *et al,* (2006) where low nutrient concentration of the sewage entering the wetland had minimal effect on the growth of *Phragmites australis.*

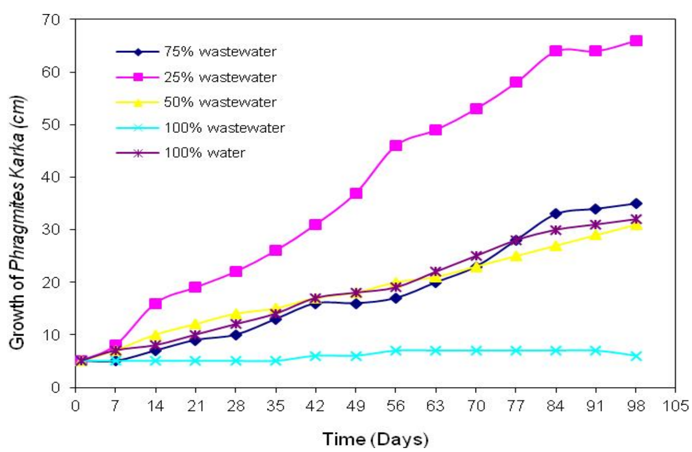

Figure2: Effect of variation in concentration of wastewater on the growth rate of *Phragmites Karka*

The results obtained from the dilution of wastewater on the growth rate of *V. nigritana* showed that it has high tolerant rate at elevated levels of nutrients, as opined by Ralph and Truong (2004). The 1:3 ratio mix of wastewater to water still proved to be the best mix at the initial stage of growth as observed in *P. karka*, it could be seen from Figure 3 that the nutrient concentration did not adversely affect the other proportions during the initial growth as was observed in *P. karka*.

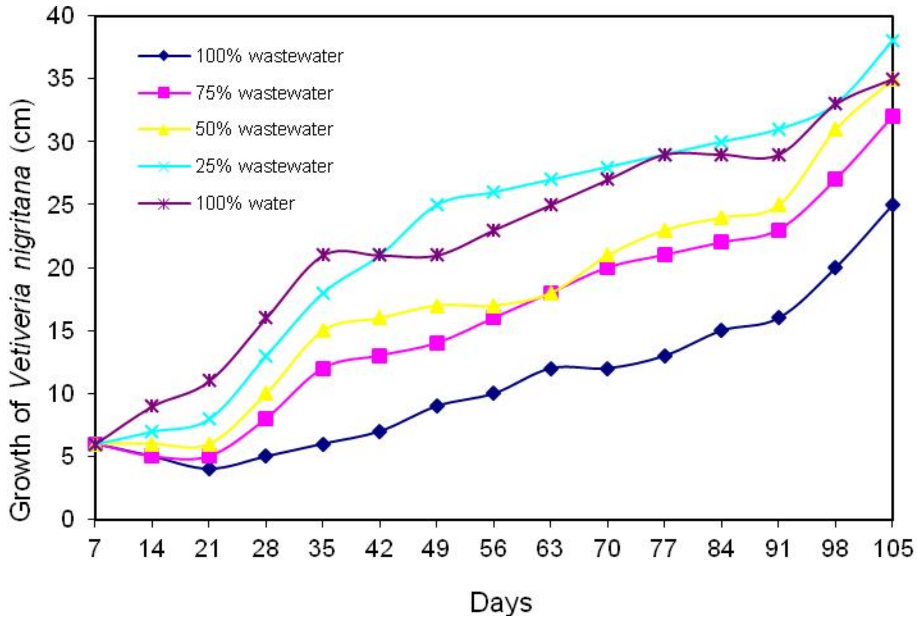

Figure 3: Effect of variation in concentration of wastewater on the growth rate of *V. nigritana*

Effluents from the prototype Reed bed showed tremendous improvement in the reduction of wastewater pollutants. The influent fed into the prototype having BOD of 293.5 ± 20.43mg/L was reduced to 53.83 ± 16.2mg/L and 44.03 ± 17.5mg/L for the cells with *V. nigritana* and *P. karka* respectively. The prototype also showed that Reed bed accounts for a large fraction of TSS removal in wastewater with a reduction from 213.5 ± 9.24mg/L to 59.78 ± 10.15mg/L and 57.64 ± 8.23mg/L for *V. nigritana* and *P. karka* respectively.

Nitrate was reduced from 0.141 ± 0.003mg/L to 0.055 ± 0.011mg/L and 0.049 ± 0.014mg/L while Phosphate level was reduced from 2.36 ± 0.05mg/L to 0.52 ± 0.21mg/L and 0.45 ± 0.65mg/L for *V. nigritana* and *P. karka* respectively. Results from the control bed gave BOD, TSS, NO_3 and PO_4 values of 132.5 ± 15.6mg/L, 105.63 ± 8.81mg/L, 0.126 ± 0.019mg/L and 1.37 ± 0.179mg/L respectively.

Conclusion

The composition of wastewater generated from the University College Hospital Treatment plant is similar to that of domestic wastewater and is in the medium classification of wastewater. The wastewater discharges from the treatment plant has two peak periods during the dry and wet season and the flow rate could be represented by a polynomial mathematical model. The study also reveals that Reed bed Technology using locally available macrophytes (*Vetiveria nigritana and Phragmites Karka*) is efficient for the treatment of wastewater from a tertiary healthcare facility.

References

Akpata, T.V.I and Ekundayo, J.A. (1998) Faecal Pollution of the Lagos Lagoon, Nigerian Journal of Science, 12, pp. 44-51

Akratos C. and Tsihrintzis V. (2007) Effect of Temperature, HRT, Vegetation and Porous Media on Removal Efficiency of Pilot-Scale Horizontal Subsurface Flow Constructed Wetlands, Ecological Engineering, 29, pp. 173 – 191

Bragato C, Brix H. and Malagoli M. (2006) Accumulation of nutrients and heavy metals in *Phragmites australis* (Cav.) Trin. Ex Steudel and *Bolboschoenus maritimus* (L.) Palla in constructed wetland and of the Venice lagoon watershed, Environmental Pollution, 144, pp. 967-975

Brisson J. and Chazarenc F. (2008) Maximizing Pollutant Removal in Constructed Wetlands: Should we pay more attention to macrophytes species selection? Science of the Total Environment doi:10.1016/j.scitotenv.2008.05.047

Calheiros, C.S.C, Rengel A.O.S.S, Castro, P.M.L. (2008) Evaluation of Different Substrates on the growth of Typhalatifolia in Constructed Wetlands treating Tannery wastewater over long term operation. Bio resource Technology

Cooper P.F., Hobson J.A., Jones S. (1989) Sewage Treatment by Reed bed Systems. Journal of Institute of Water Environment and Management (JIWEN), Vol.3, pp. 60 – 81

Davies, L.C, Caries C.C., Novais J.M., and Matins-Dias S. (2005) Phyto remediation of Textile Effluents containing azo dye by using *Phragmites australis* in a Vertical Flow Intermittently Feeding Constructed Wetland, Ecological Engineering, 25, 594-605

Hanping X., Honghua K., Zhooping D., Peng T. and Shizhong L. (2004), Ecological effectiveness of Vetiver Constructed Wetlands in Treating Oil Refined Wastewater. Conference Proceeding, Vetiver and Water, 3rd International Conference China

Ralph Ash and Paul Truong (2004) The Use of Vetiver grass for Sewage Treatment. Paper for Sewage Management QEPA Conference, April 5-7, 2004, Cairns, Australia

Salmon C, Crabos, J.L, Sambuco J.P, Bessiere J.M, Baseres A, Caumette P, Beccou J.C (1998), Artificial Wetland Performance in the Purification efficiency of hydrocarbon wastewater. Water, Air and Pollution 104, pp. 313 – 329

Troung Paul (2000) Vetiver System for Water Quality Improvement, Proceedings; Vetiver and Water, 3rd International Conference, China pg. 61-72

Assessment of Impact and Safety Status of Remediation of Lead Contaminated Soil using Excavation Method: A Case Study of Olodo, Ibadan, Southwestern Nigeria

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Abstract

This study aimed to assess the impact and safety status of the excavated waste site of a lead-acid accumulator factory. Soil samples (3 each) were collected from the five pits of depth 1 m each at four angles and one at the centre of the site at interval of 0.5 m. Five soil samples were also collected from five different locations outside the site as a control. All the samples were analysed after pulverisation and digestion using AAS analytical instrument for major, trace and heavy metals such as, Ca, Mg, K, Na, Mn, Cu, Fe, Zn, Co, Cr, Cd, Pb and Ni. Ten water samples were collected, four from shallow hand dug well and six from surface water around the site, and analysed for major ions and trace metals. Using Hakanson (1980) approach, contamination factor of Mn, Zn, Cr and Ni showed low to considerable contamination in A and C-horizon but low contamination factor in B-horizon. This is probably due to the fact that B-horizon could be more porous which served as medium for leaching into C-horizon. Fe, Cu, Cd, Co and Pb revealed considerable contamination factor to very high contamination factor which increase from A-horizon (surface soil) through B to C-horizon (subsurface soil). Degree of contamination show the soil is highly contaminated from top soil through B to C-horizon. Surface water revealed higher concentration of Pb, Cd and Fe in samples from the downstream of the dumpsite which could be due to wash-off by erosion into the rivers.

Keywords: Urbanization, Environment, Sustainability, Contamination Factor and Safety status

Introduction

Environment has been an endowment and gift of nature to man. However, due to man's careless and indiscriminate activities, this gift has become a threat to his existence. The most important environmental components are soil and water, which are poise to alteration by direct or indirect human activities. In the urban centres of most of developing countries, industrial and municipal wastes were usually dumped in an open space in locations believed to be the outskirt of the town. In no time, due to rapid development and expansion of the urban centres across the world, these areas, which were in the past waste sites suddenly turns to site

for housing development, especially for immigrants from the rural areas who are desperate to have at least a building in the relatively developed city centres which they believed can earn them opportunity to enjoy the social amenities and infrastructures.
A waste site in Olodo, which is one of the villages around Ibadan in southwestern Nigeria in late 1980s to late 2000, used to be a waste site for moribund lead acid manufacturing company known as EXIDE BATTERY. Ibadan, being a one of the fastest growing cities in the world and the largest city in West Africa, has in recent time expanded and encapsulated most of the villages around it. Olodo village is not an exemption. This led to the allocation of the site, which used to be a waste dump in the past, to people, for housing development. In 2006, there was outbreak of diseases which was traced to Lead poisoning among the inhabitants of the Olodo village by the medical experts and some researchers. These forced both the Federal and Oyo State Ministry of Environment to intervene and compelled the company to carry out excavations on the site for proper remediation of the contaminated soil. This type of soil has deviated from the natural function of soils, which include sustaining biological productivity of soil, maintaining the quality of surrounding air and water environments, as well as promoting plant, animal, and human health (Doran et al., 1996).

Several workers have carried out environmental assessment on soil and water in different locations around the world using different approaches such as geophysical, geochemical and hydrogeochemical methods (Sing and Sing, 2010; Adepelumi et al., 2008; Boreysza et al., 2006; Shakar et al., 2000). Odewande and Abimbola (2008) assessed the contamination and migration level of hydrocarbon contents in both water and soil. Arsenic pollution was also assessed using the geochemical method and saltwater intrusions into freshwater aquifer were delineated using the VES method. In this work, geochemical method was used in the assessment of the waste site soil. In recent times, however, in developing countries of Africa, little or no attention has been laid on the assessment of decontaminated and remediated soil and water. This is due to nonchalant attitude of the government towards environmental status in these parts of the world.

Study Area

The study area is a waste site, which is located in east central part of Olodo village, located north-east of Ibadan, southwestern Nigeria between Longitude 7^{0}13’39’’N - 7^{0}33’39’’N and Latitude 3^{0}49’56’’E - 407’58’’E (Figures 1 and 2). Geology of Ibadan and environs falls wholly within the Pre-Cambrian rocks of Southwestern Nigeria which is part of the Nigerian Basement Complex. The rock types have undergone various episodes of tectonism depicted by foliation of the rock (Rahaman, 1976). Major rock types underlying the area include mica schist, quartzite and quartz schist, biotite and biotite-hornblende-gneiss, granite-gneiss and migmatite. Minor rock types are Augen-gneiss, pegmatite and amphibolites (Jones and Hockey, 1964). The study area is underlain by a thick overburden, which comprises mainly lateritic soil, with the impression of the parent rocks still showing in some areas.

Field Sampling and Analytical Method

Fifteen (15) soil samples were collected from five (5) pits (each of 1 m deep), which were dug on the edges and centre of rectangular shaped dump site from which tree soil samples were collected from top, depth 0.5 m and 1 m respectively. Four (4) top soil samples were also collected from the area outside the site which was use as a control for those ones stated earlier. Six surface water were collected, 2 from upstream, midstream and downstream along the river flowing eastward along the down-slope of the site. Four shallow hand-dug well were sampled within the vicinity of the site. Physico-chemical parameters of the water samples such as pH, EC, TDS and temperature were measured on the field using multiparameter portable meter (model Testr-35). Analysis of cations and trace metals in soil and water samples were carried out using AAS, while the anions in the water samples were analysed using Ion Chromatography methods. The analytical results were subjected to statistical analysis such as descriptive statistics, factor analysis and evaluation in respect of background value of relevant trace metals from existing literature. Furthermore, following the approach of Hakanson (1980), contamination factor (CF) and degree of contamination (C_{deg}) were calculated with the formula writhen below. Groundwater and surface water characterisation was carried out using Piper and Schoeller diagrams, while quality assessment was done by comparing the analytical values with their respective WHO standard values.

$$CF = \frac{Cm}{Bm}$$

$$C_{\deg} = \sum \left[\frac{C_m}{B_m} \right] i$$

were Cm= Concentration of metals in Sediment
Bm= Background concentration of metal in sediment.
i = Number of Metals considered in the study
CF = Contamination Factor.
C_{deg}= Degree of Contamination

Results and Discussion

Statistical summary of the results of chemical analysis of major cations and trace metals in the soil are shown in the Table 1. Results of major cations, such as Ca, Mg, K and Na revealed average values of 291.55, 163.05, 605.89 and 3915.37; 3682.11, 2092, 3237 and 2139; 2536.24, 1407.33, 1724.45 and 1454.05; 7454., 8506.22, 4658.48 and 322.9124 mg/g for topsoil, subsoil at depth 0.5 m and 1.0 m and controlled soil respectively. Trace metals Mn, Fe, Cu, Zn, Co, Cr, Cd, Pb, and Ni have values of 357.07, 232.98, 833.71 and 732.61; 49010.47, 33710.23, 74330.3 and 20783.0; 80.66, 67.50, 100.23 and 24.27; 73.30, 85.12, 242.36 and 60.41; 37.21, 22.09, 44.32, and 16.52; 29.86, 26.28, 41.92, and 35.98; (9.26, 6.28, 11.15 and 1.48; 2881.65, 1804.52, 2827.43 and 1258.51; 35.74, 36.37, 38.55, and 18.75mg/g respectively. All the major ions, except Calcium, have concentrations greater than their background values across the depth of topsoil (0.0 m), B-horizon (0.5 m) and C-Horizon which is the evidence of contamination within the excavated waste site. Trace metals in the soil indicated higher concentration far above their background values (Table 1). Correlations in Table 2 reveal high values among Ca, Fe, Mg, Na, Zn, Co, Mn, and Ni at 0.01 significant level. This is an indication of impact of the waste on the soil which could be due to leaching from the excavated waste as a result of residence time and dissolution of these metals in the rain water that infiltrated the soil.

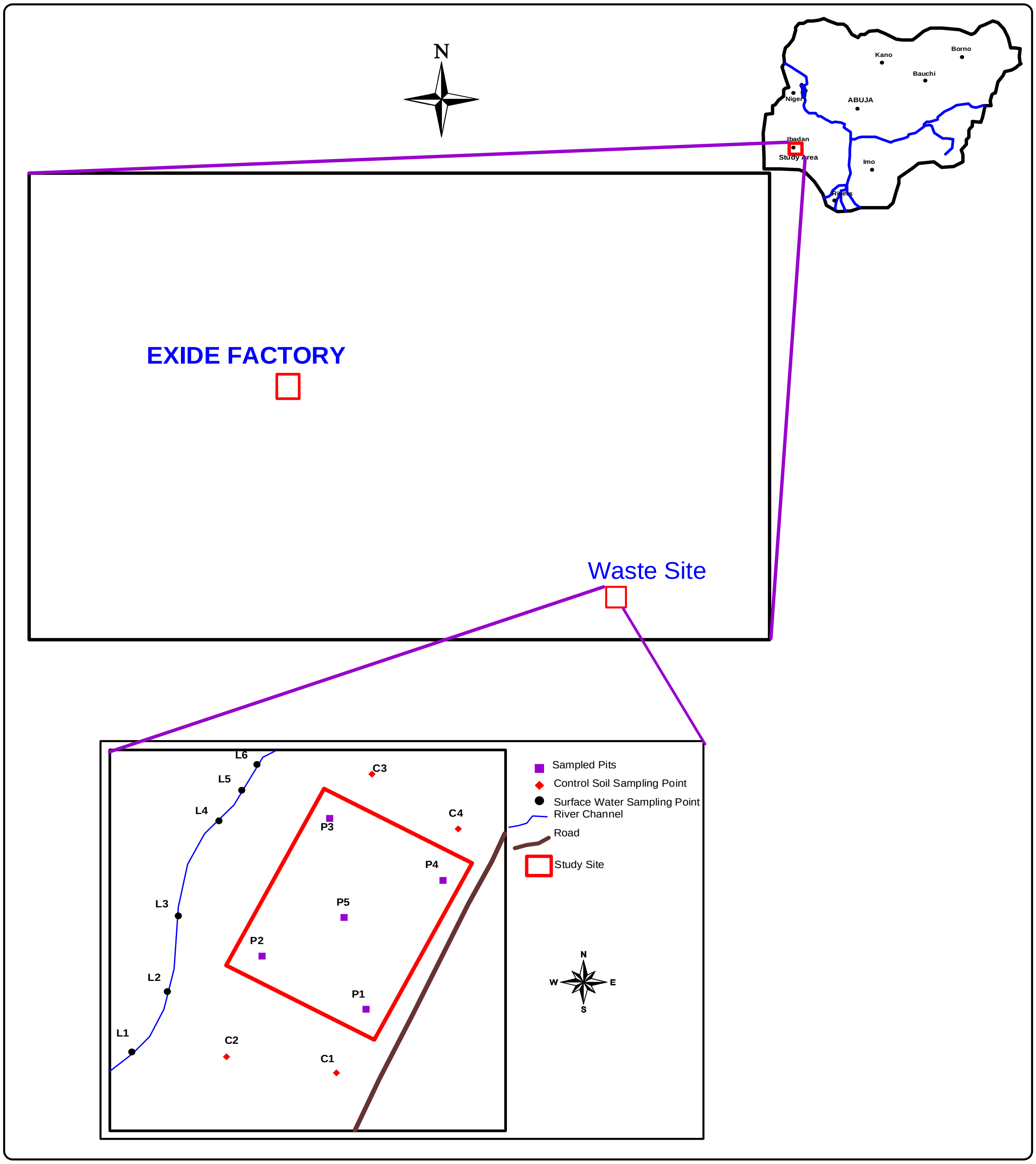

Figure: 1. Aerial Photo Image of the Study area, (Adapted from Google-earth Image, 2011)

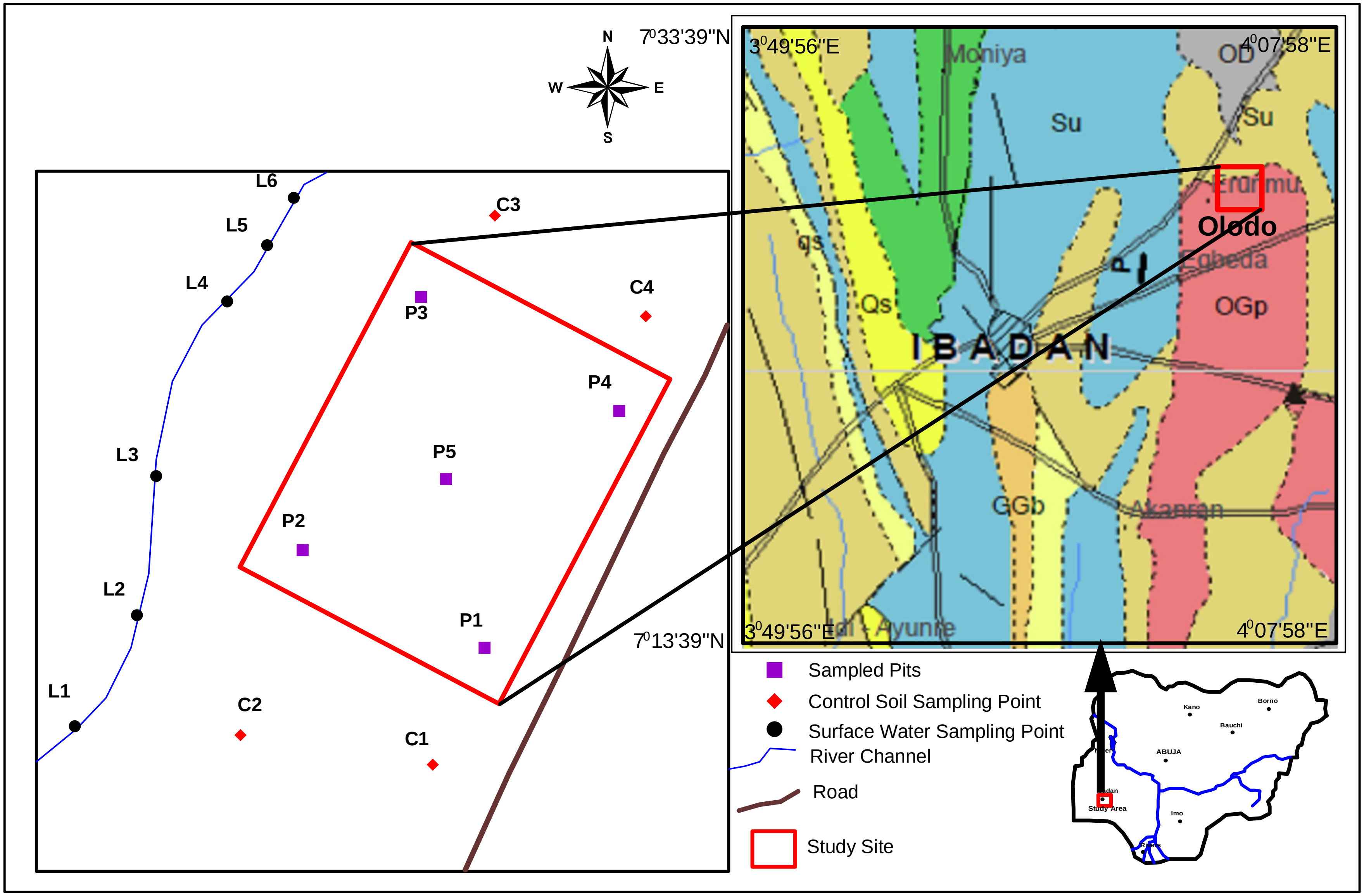

Figure: 2. Map of the study with Sketch of the dump site. (Modified from NGSA, 2006)

Table 1: Statistical Summary of the Chemical analysis of the Soil sampled from the Pits and the controlled soil sample.

PARAMETERS	TOP SOIL AT 0.0M N=5			SOIL AT DEPTH 0.5M N=5			SOIL AT DEPTH 1.0M N=5			CONTROL SOIL SAMPLE N=4			BC-SW	
PAR(mg/g)	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**AVE**	**MIN**	**MAX**	**MEDIAN**	
Ca	291.55	120.13	885.04	163.05	121.53	280.06	605.892	49.54	2000.06	3915.37	66.04	13300.1	4800	5571
Mg	3682.11	2260.14	5750.12	2092.30	1445.63	2590.34	3237.36	2705.68	3700.17	2139.14	1370.33	3735.42	1300	511
K	2536.24	1325.68	4430.17	1407.33	870.11	1805.36	1724.45	1115.6	2415.67	1454.05	1030.42	2060.17	9400	31328
Na	7454.24	1860.17	12750.82	8506.22	1110.06	19100.23	4658.48	780.84	10300.2	322.908	243.51	428.75	560	21685
Mn	757.07	248.17	1320.34	232.98	149.57	306.08	833.706	487.51	1150.38	732.613	373.84	1430.34	395	228.6
Fe	49010.47	32900.08	71250.17	33710.23	28250.16	43300.19	74330.3	36750.1	105750	20763	8750.58	29950.6	27400	15555
Cu	80.66	48.75	108.55	67.50	42.55	90.15	100.228	70.25	170.04	24.275	19.75	30.55	21.5	12.4
Zn	73.30	63.55	87.55	85.12	59.95	137.52	242.358	148.06	328.55	60.4075	56.61	65.55	108	70.7
Co	37.21	14.45	61.95	22.09	9.92	34.80	44.342	19.46	81.56	16.515	8.86	24.93	18.4	4.1
Cr	29.86	25.28	37.23	26.28	21.83	36.08	41.918	24.73	63.95	35.9775	21.73	64.45	58	83.4
Cd	9.26	1.95	32.83	6.28	2.05	12.35	11.15	2.95	22.9	1.4825	1.15	1.78	0.1	0.19
Pb	2881.65	419.54	10630.04	1804.52	600.53	5465.43	2827.43	1131.04	5515.46	1258.51	176.54	2450.81	46.4	67.9
Ni	35.74	19.64	42.83	36.35	17.45	55.35	38.546	20.53	61.13	18.75	13.65	23.36	24.1	11.4

BC-SW Background Concentration in Southwest Soil.

Table.2. Correlation between Major Cations and Trace Metals in Soil

Parameters	Ca	Mg	K	Na	Mn	Fe	Cu	Zn	Co	Cr	Cd	Pb	Ni
Ca	1												
Mg	.166	1											
K	.022	**.886****	1										
Na	-.296	.303	.351	1									
Mn	**.499***	**.455***	.321	-.185	1								
Fe	-.190	**.550****	**.431***	.337	.145	1							
Cu	-.327	.239	-.008	.204	-.185	**.496***	1						
Zn	.106	.175	-.023	-.046	.300	**.653****	.391*	1					
Co	-.133	**.571****	**.558****	.397*	**.540****	**.730****	.096	**.444***	1				
Cr	-.152	-.012	-.060	-.147	.179	-.040	.147	**.434***	-.047	1			
Cd	.175	.044	.044	-.021	.259	**.458***	.051	.373	**.503***	-.169	1		
Pb	.144	-.279	-.397*	-.372	-.199	-.100	.386	.219	-.358	.153	-.003	1	
Ni	-.232	.381	**.451***	.703**	.143	**.631****	-.026	.281	**.764****	-.212	**.496***	-.405*	1

*Correlation is Significant at the 0.05 Level (1-Tailed)

**Correlation is Significant at the 0.01 Level (1-Tail)

FACTOR AND COMPONENT ANALYSIS

Table: 3 Factor and Component Analysis of the soil Major ions and Trace Metals.

	Component		
Parameters	**1**	**2**	**3**
Co	0.919	-0.015	0.099
Fe	0.836	0.373	0.008
Ni	0.830	-0.055	-0.336
Mg	0.741	-0.246	0.198
K	0.702	-0.395	0.006
Cd	0.480	0.257	0.100
Cu	0.227	0.704	-0.088
Pb	-0.388	0.652	0.188
Zn	0.462	0.641	0.442
Mn	0.419	-0.302	0.766
Na	0.537	-0.077	-0.656
Ca	-0.126	-0.556	0.579
Cr	-0.057	0.384	0.424
%Variance	33.397	17.446	15.755
Cumulative	33.397	50.844	66.599

Several authors such Tijani et al (2005) and Abimbola et al (2008) have employed the Principal Component statistical method. This analysis was performed on the soil analytical data in order to better understand their interrelationships, source and to explore the reduction of the experimental variables. Components, eigenvalues and associated variance are explained in the chemical data and communities. All the three components had eigenvalues higher than one (the most significant one) (Miller and Miller 2000). Component 1 assigned factor values ranging from 0.537 in Na to 0.919 in Co which include Ca, Mg, K, Fe and Ni. Component 2 has factor range from 0.641 to 0.704 with metals member of Cu, Pb and Zn while Component 3 comprises of Mn with factor value 0.766. Percentage variance values of Component 1, 2 and 3 are 33.79, 17.446 and 15.755% respectively. Component 1 revealed a typical lateritic soil chemically enriched by chemical leaching from the waste while Components 2 and 3 typified soils containing disseminated metals from the degraded solid metals from electrode materials of the battery waste.

Soil Contamination Assessment

Analytical results from the surface and sub-surface soil samples from the excavated waste site was subjected to evaluation using Hakanson (1980) for their Contamination Factor (CF) and assessment of Degree of Contamination (C_{deg}). The values revealed low to very high level of contamination from the top soil to sub-surface soil at depth 0.5 m and 1 m respectively. The results also revealed considerable to very high degree of contamination from the topsoil to the sub-surface soil with highest degree of contamination observed in the sub-surface soil named Horizon-C which is probably due to gravitational effect on leached metals. See Tables 4, 5, 6 and 7.

Table.4. Degree of Contamination Classification

Index Range	**Description**
Cdeg<8	Low degree of contamination
8<Cdeg<16	Moderate degree of contamination
16<Cdeg<32	Considerable degree of contamination
32<Cdeg	Very high degree of contamination

Table.5. Contamination Factor Classification

Index Range	Description
C'f>1	Low contamination factor
1<C'f<3	Moderate contamination factor
3<C'f<6	Considerable contamination factor
6<C'f	Very high contamination factor

Table.6. Summary of Contamination Factors of Trace metals in the Soil

	Top Soil		B-Horizon		C-Horizon		Control Samples	
Trace Metals	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Mn	0.67	3.54	0.40	0.82	1.31	3.08	0.1	3.83
Fe	3.76	8.14	3.23	4.95	4.20	12.08	0.1	3.42
Cu	2.53	5.62	2.20	4.67	3.64	8.81	0.1	1.58
Zn	1.12	1.55	1.06	2.43	2.62	5.80	0.1	1.16
Co	1.63	6.99	1.12	3.93	2.20	9.21	0.1	2.81
Cr	1.16	1.71	1.00	1.66	1.14	2.94	0.1	2.97
Cd	1.70	28.55	1.78	10.74	2.57	19.91	0.1	1.55
Pb	2.38	60.21	3.40	30.96	6.41	31.24	0.1	13.88
Ni	1.44	3.14	1.28	4.05	1.50	4.48	0.1	1.71

Table.7. Classification of degree of contamination base on number of samples from each depth

Soil Type	Soil Degree of Contamination			
	Cdeg<8	**8<Cdeg<16**	**16<Cdeg<32**	**32<Cdeg**
Top Soil	0%	0%	40%	60%
B-Horizon	0%	0%	80%	20%
C-Horizon	0%	0%	0%	100%
Control Samples	0%	25%	75%	0%

Environmental Status and Implications

The trilinear diagrams of Piper (1953) are very useful in determining chemical relationships in groundwater in more definite terms than is possible with other plotting methods (Schoeller, 1965). Piper's trilinear diagram method is used to classify the groundwater, based on basic geochemical characters of the constituent ionic concentrations. This can be a very useful tool in detection of contamination as the expected water characterization in the basement rock groundwater is HCO_3^- water type. Any other types found here is an indication of anomalies, which could be due to mineral dissolution or point source pollution. Chemical data of the groundwater samples collected from the study area are plotted in the Piper's diagram (Figure 3). The diagram revealed two water type in the study area with 20% of SO_4-Cl and 80% of Na(K)-HCO_3. The SO_4-Cl water type indicates pollution and contamination from the waste site as a result of possible run-off that discharged directly into the adjacent river. 80% of the sample revealed low contamination and pollution which could be as a result of dilution in one hand on surface water and soil attenuation on the other hand in the shallow hand dug well samples. The sampled water also revealed higher values of some trace metals (Figure 5) such as Mn, Fe and Pb. Analytical hydrochemical data when compared with their respective WHO (1993) standard (Table 8) revealed that cation such as Na and Cl show values higher than the standard while trace metals such as Mn, Ni, Pb, Cd and Fe also recorded higher values, all of which agree with the result in the bar chart and schoeller diagram and form an indication of pollution and contamination from the excavated site. Water physicochemical parameters such as pH, EC and TDS show range of values from 7.20-7.60, 250-2660us/cm and 187.5-1995mg/l with mean values of 7.54, 913.10 us/cm and 684.83 mg/l respectively. The high value of EC is an indication of high dissolved ions in the water which is responsible for degradation of cement block in the foundation of the buildings under construction within the excavated site. In addition, inhalation of dust from this area by inhabitant can lead to serious lung ailment.

Table 8 Statistical Summary of the chemical analysis of Major ions and Trace Metals in Water

Water Samples N=10

Parameters	Min	Max	Mean	Std. Dev	WHO STD
Ca^{2+}(mg/l)	13.57	61.86	30.44	17.11	75
Mg^{2+}(mg/l)	5.15	19.96	11.58	5.79	20
Na^{+}(mg/l)	21.22	642.58	158.08	236.00	200
K^{+}(mg/l)	1.39	9.92	6.05	3.58	200
HCO^{-}_{3}(mg/l)	36.60	250.10	81.13	63.27	100
Cl^{-}(mg/l)	25.20	237.60	82.08	82.25	200
SO_4^{2-}(mg/l)	0.05	0.22	0.11	0.05	250
NO_3(mg/l)	0.50	4.27	1.50	1.26	10
Mn^{2-}(mg/l)	0.02	1.03	0.29	0.31	0.1
Fe^{2+}(mg/l)	0.30	2.84	1.03	0.77	1.00
Cu^{2+}(mg/l)	0.01	0.05	0.03	0.01	0.5
Zi (mg/l)	0.05	0.22	0.11	0.05	0.01
Co (mg/l)	0.00	0.02	0.00	0.01	0.01
Cr (mg/l)	0.00	0.00	0.00	0.00	0.05
Cd (mg/l)	0.00	0.06	0.01	0.02	0.003
Pb(mg/l)	0.02	1.17	0.32	0.36	0.01
Ni (mg/l)	0.00	0.09	0.02	0.03	0.02
pH (mg/l)	7.20	7.60	7.34	0.12	6.2-7.8
EC(us/cm)	250.00	2660.00	913.10	927.18	500
TDS(mg/l)	187.50	1995.00	684.83	695.38	300

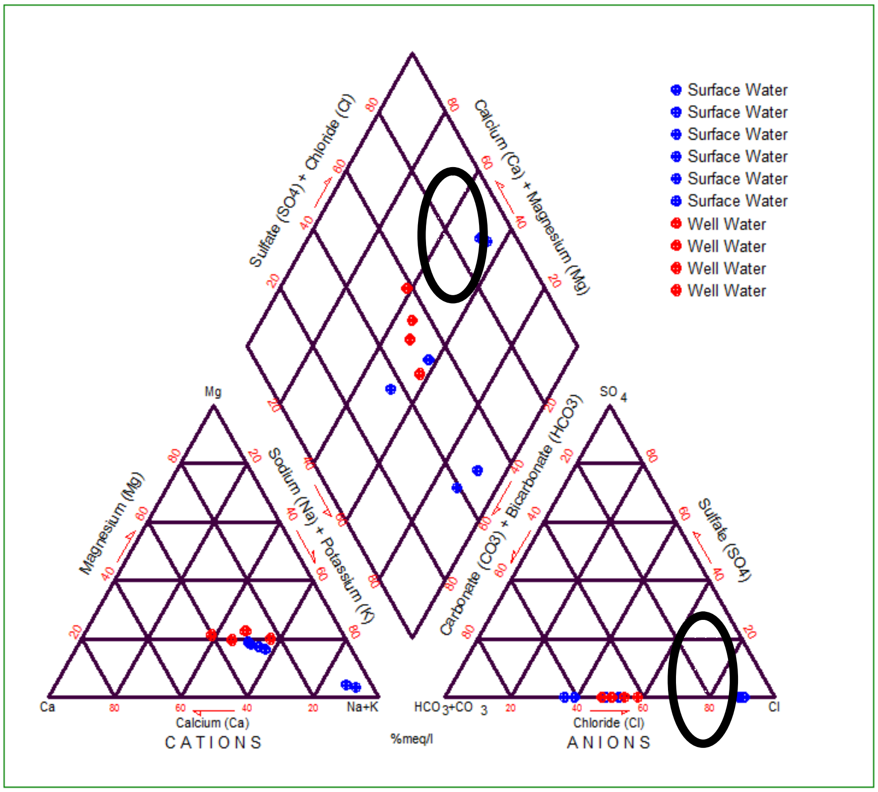

Figure: 3. Piper trilinear plot of the hydrochemical data

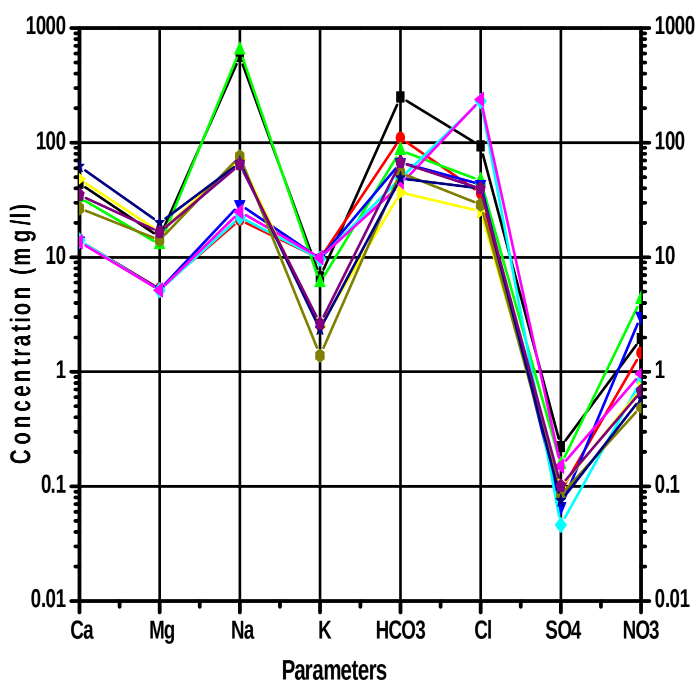

Figure: 4 Schoeller Diagram for major ions in water

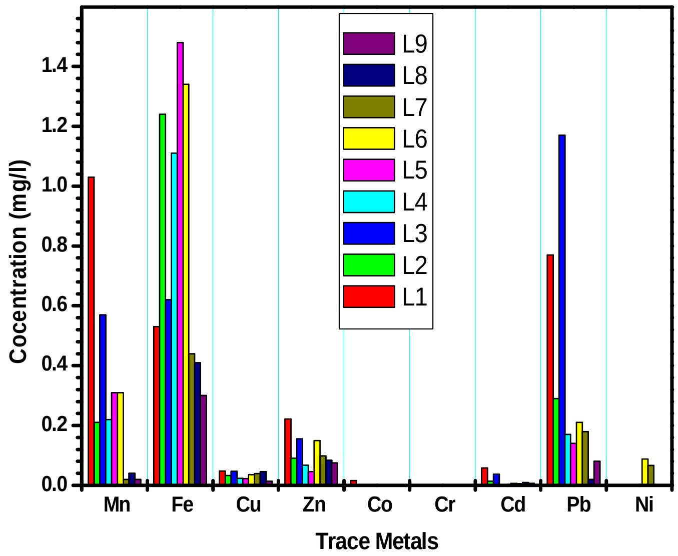

Figure: 5. Bar Chart showing the Trace Metals Distribution in water

Conclusion

This study has assessed the impacts and safety status of excavation carried out on the waste site of moribound EXIDE battery factory located in Olodo village, Ibadan, southwestern Nigeria. Results revealed considerable to very high degree of contamination of soil samples from surface and subsurface soil of the site. Contamination was also observed on the soil samples outside the site which could be as a result of contamination through wash-off by surface erosion, as the site is located on sloppy terrain which encourages down-slope movement of sediments. Piper and Schoeller diagram also revealed the impact of the waste on groundwater quality of the area as most of the samples have higher values of some trace metals. This revealed the need for pre and post excavation geochemical assessment of any waste site for better understanding of the type, scope and method to be employed for effective and efficient remediation of contaminated soil. Further detail remediation and decontamination measure should be carried out to avoid any outbreak of diseases in the near future as the area is occupied by inhabitant who believed the waste has being completely removed. Finally, geochemical mapping should be encouraged as such will help in environmental auditing, urban planning and development and proper land use.

References

Adepelumi A. A., Ako B. D., Ajayi T. A. Afolabi O and Omotoso E. J. **2008**, Delineation of Saltwater Intrusion into the freshwater aquifer of Lekki Peninsula, Lagos, Nigeria, Environmental Geology Journal. Vol.8.No.3: 1194-1200.

Boreysza, Fabritius and Laures. 2006. Arsenic pollution of groundwater in Bangladesh, Water Resources Engineering and Management Proceeding – WAREM.

Doran, J. W., **2002**. Soil health and global sustainability: translating science into practice. Agriculture, Ecosystem & Environment 88, 119–127.

Hakanson, L., **1980**. An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res., 14: 975-1001.

Jones H. A. and hockey R. D., **1964**. The Geology of parts of Southwestern Nigeria. Geology Survey of Nig. Bull. 31 pp 1-10

Odewande A. A. and Abimbola F. A. **2008**. Contamination indices and heavy metal concentrations in urban soil of Ibadan metropolis, southwestern Nigeria. Envir. Geochem. Health. Vol 30. P243-254.

Piper A. M. **1953**. A graphic procedure in the chemical interpretation of water analysis. US Geological Survey Groundwater Note 12

Rahaman, M. N. **1976**. Review of the basement geology of southwestern Nigeria, in geology of Nigeria, edited by C. A. Kogbe, Elizabethan pub. Co. Lagos. pp. 41 - 58

Schoeller H **1967.** Geochemistry of groundwater. An international guide for research and practice. UNESCO, Chapter 15, pp 1–18

Shakeri A., Moore F. and Modabberi S. **2000.** Heavy Metal Contamination and Distribution in the Shiraz Industrial Complex Zone Soil, South Shiraz, Iran. World Applied Science Journal. Vol. 6(3): 413-425.

Sing D. and Sing F. C. **2010** Impact of direct soil exposures from airborne dust and Geophag on Human Health. International Journal of Environmental Resources and Public Health, Vol. 7, 1205-1223.

Tijani M. N., Olatunji A. S., Sangolade, O. O. and Chukwurah, B. N. **2005.** Hydrochemical evaluation of seawater influence on water quality in metropolitan Lagos, Nigeria. Afriac Geoscience Review, Vol. 12, No. 3: 225-240.

WHO, **1993**. Guidelines for Drinking Water Quality. WHO, Geneva.

Distribution and Effect of some Heavy Metals in Selected Organs and Tissues of Albino Rats Exposed to Vehicular Exhaust Fumes

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Abstract

Vehicular exhaust fume has been greatly implicated as one of the major environmental pollutants all over the world, especially in developing nations. A study was carried out to investigate heavy metals distribution and effect on the soft tissues of Albino rats placed in close proximity to busy roads in Abeokuta. A total of 45 rats were randomly allotted to 3 groups of fifteen rats each. Two groups were placed in close proximity to busy roads while the third group (Control) was kept in Forestry Nursery of the University of Agriculture, Abeokuta Ogun State for 8 weeks respectively. The various organs were removed, digested by standard procedures and analyzed for heavy metals (Fe, Cr, Mn, Zn, Pd and Co) with Atomic Absorption Spectrophotometry. The result show a significantly higher concentration of heavy metals (Fe, Mn, Zn, Pd and Co) ($p<0.05$) in the lung, heart and liver tissues of the rats at busy roads compared to control. Histopathological examination of internal organs (heart, lung, kidney and liver) of rats at busy roads revealed histopathological damage as compared to the control. The results above indicated that vehicular exhaust fumes may have adverse physiological effects on the rats and hence humans living in close proximity to busy roads will be predisposed to automobile pollution.

Keywords: Albino rat, vehicular exhaust fumes, heavy metals.

Introduction

Heavy metals are chemical elements with specific gravity that is at least five times the specific gravity of water (Passow *et al*., 1961; Hawkes, 1997). Examples of heavy metals commonly found in the environment include lead, cadmium, mercury, zinc, arsenic, bismuth etc. These metals are particularly dangerous because they tend to bio-accumulate in the body tissues and organs (Luckey *et al*., 1975; Babalola et al., 2005). Heavy metal exposure is a public concern in Nigeria due to the increasing evidence concerning the effect of these heavy metals on the cognitive development of the populace especially, the young ones (Abulude *et al*, 2003). The number of people living in cities worldwide increased dramatically during the last part of the 20^{th} century. According to Chirenje *et al.* (2003), more than a third of the world population lived in the cities.

In developing countries, the air quality crisis in cities is often attributed in large measures (40–80%) to vehicular emission. In Nigeria, the main source of lead pollution is through automobile exhaust because of the use of leaded petrol. Tetraethyl lead is commonly used as an anti-knocking additive to improve the quality of petrol in Nigeria and many other countries (Dioka *et al*., 2004; Kamal and Kumar, 1998). However, tetraethyl lead, added as an antiknock agent, caused serious air pollution in urban areas (Davis, 1990).

It is indeed now a common knowledge that heavy metals including lead, cadmium, mercury are toxic with no beneficial effects to humans and wildlife (Tyler, 1981 and Borgmann, 1983).Lead compounds are the major pollutants emitted by automobiles. Approximately 90% of absorbed lead is reported to be stored in the bone with a half life of 600 - 3000 days. The remaining 10% is stored in soft tissues like kidney, liver and brain. The half life of lead in these tissues ranges from 40 - 50 days (Hawkes, 1997).

Lead impairs learning, memory and audio-visual functions in children. Toxic effects of lead also include Nephrotoxicity, Hepatotoxicity and Cardiovascular damage (Hawkes, 1997). The carcinogenic effect of lead has been receiving increasing attention. Research has shown that lead causes oxidative stress in the body by inducing the generation of free radicals thereby reducing the antioxidant defence system of the cells (Hawkes, 1997). Effect of lead on reproductive systems is also well documented. Lead causes sterility in males by damaging the germinal epithelium and also spermatocytes (Kamal and Kumar, 1998). In females, menstrual irregularities, preterm deliveries and still births have been reported (WHO, 1986).

This research work was carried out to examine tissue distribution of heavy metals in albino rats exposed to vehicular exhaust fumes. The result will shed more light on heavy metals distribution pattern in human beings exposed to lead.

Material and Methods

Animal

A total of 45 healthy albino rats weighing between 100 and 120 g were used consisting of 3 groups of fifteen rats each. Two groups were placed in close proximity to busy roads at Oke-Ilewo and Ijemo roads respectively in Abeokuta, Ogun State while the third group (Control) was kept in Forestry Nursery of the University of Agriculture, Abeokuta far away from traffic movement for 8 weeks respectively. The animals were first acclimatized for 7 days in the forestry nursery of the University of Agriculture, Abeokuta where they had free access to food and clean water before exposure. At the completion of the exposure period, the rats were sacrificed and the following organs were obtained (a) Liver (b) Heart (c) Lung.

Tissues and Organ Digestion

The organs were freeze dried and 1 g of each organ/tissue was grinded to fine powder and 5 ml HNO_3 was added in a clean test tube. The mixture in the test tubes was plugged with cotton wool and it was left on the bench overnight to solubilize. On the second day, the digested sample was heated at 100°C in water bath for 20 min. It was allowed to cool after which 1 ml of hydrogen peroxide was added to each tube to prevent excessive foaming. It was allowed to stand on the bench overnight again. On the third day, the samples were heated again at 100°C for 1 h and allowed to cool at room temperature. It was thereafter diluted with distilled water to a final volume of 25 ml and stored in a 30 ml polyethylene bottle for later analysis by A.A.S.

Test for Accumulation of Heavy Metals in Organs

The vital organs including liver, lung and heart were analysed for chromium, cobalt, iron, manganese, lead and zinc by Atomic Absorption Spectrometry.

Histological Studies of Some Soft Tissues

The heart, lung, liver, kidney and spleen were collected from each group of sacrificed rats using standard method by summer and summer, (1968) and stored in 1% formalin in appropriately labelled bottles. The organs were thereafter dehydrated by passing them through increasing concentration of ethanol 50%, 70%, 90% and 100% one hour each this is to remove water from the tissues. The dehydrated organs were then cleared in three changes of xylene to remove excess alcohol from the tissues. The organs were thereafter impregnated in 3 changes of molten wax to remove xylene from the tissue to replace it with paraffin wax. The organs were embedded in molten wax and allowed to solidify. The block were mounted on the microtome and sectioned at 5 microns. Sectioned tissues were mounted on the slide placed on the hot plate to melt the wax. Staining of the tissues was done by following the procedure for haematocylin and eosin staining method. The stained were thereafter observed under the compound microscope for observable aberrations and photomicrographs of the slide were taken.

Statistical Analysis

Data obtained were analyzed by one way analysis of variance (ANOVA) follow by Duncan's multiple range test (DMRT) using statistical software package (SPSS for Windows). The results were presented as Mean ± SD. $P < 0.05$ were regarded as statistically significant.

Results and Discussion

The heavy metals composition of soft tissues sample varied with the type of soft tissues and locations as seen in Figure 1 to 3. The Zn, Co, Mn, Pd and Fe compositions were significantly higher in ijemo road compared to Oke-Ilewo road and forestry nursery of the University of Agriculture, Abeokuta concentrations. The main reasons for numerical higher concentration of heavy metals in Ijemo road might be attributed to the exposure of vehicular exhaust fumes. This area of the city has high traffic congestion. In addition, the Albino rats had significantly longer exposure to vehicle exhaust fumes compared with other places.

A similar result was obtained by Abudule *et al*. (2006) with higher concentration of Pd and Co in busy road compared to non busy roads. Idrees (2009) observed a similar result of high concentration of Zn and Pd in busy roads. Vidhya (2007) obtained high concentration of Pd in busy road. A study by Ogunsola *et al.* (1994) from Nigeria has shown that traffic wardens have a higher blood lead levels than controls and they also have reduced spirometric measurements than controls. Sofoluwe (1968), working in Lagos, Nigeria visited the homes of 98 children

suffering from bronchiolitis and pneumonia and found that these patients had been exposed to high concentrations of carbon monoxide, nitrogen dioxide, sulphur dioxide and benzene.
Heavy metal concentrations were observed in the control rats. A similar result was obtained by Babalola *et al*. (2005). The distribution of heavy metals in the organs from the blood is probable that some quantity of this metal was present in the food given to the animals. The calcium supplement in the feed contains traces of lead hence animals that graze on these contaminated feed will contain substantial amount of lead. The presence of heavy metals in the blood and tissues of the control rats that were not placed close to busy road can also be attributed to the factor mentioned above.

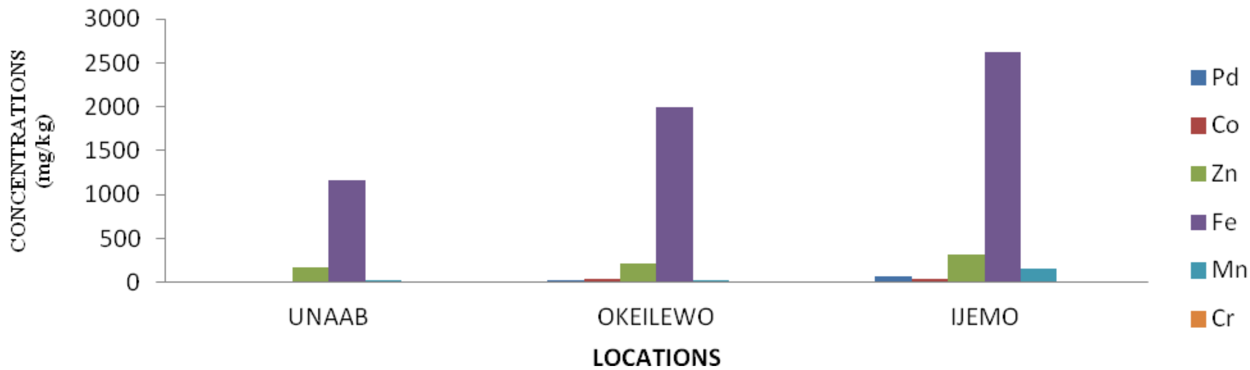

Fig.1. Variations of concentrations of metals in the Lungs of Albino rats among the three locations

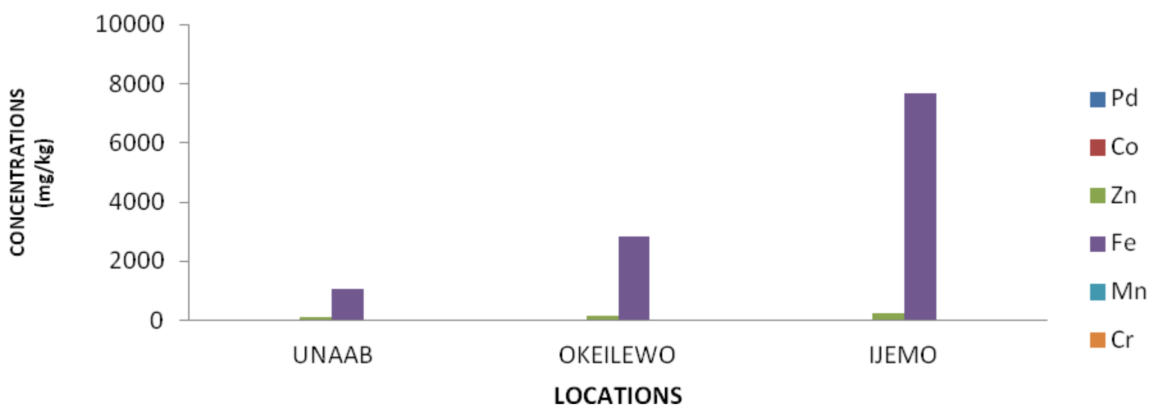

Fig.2. Variations of concentrations of metals in the Livers of Albino rats among the three locations

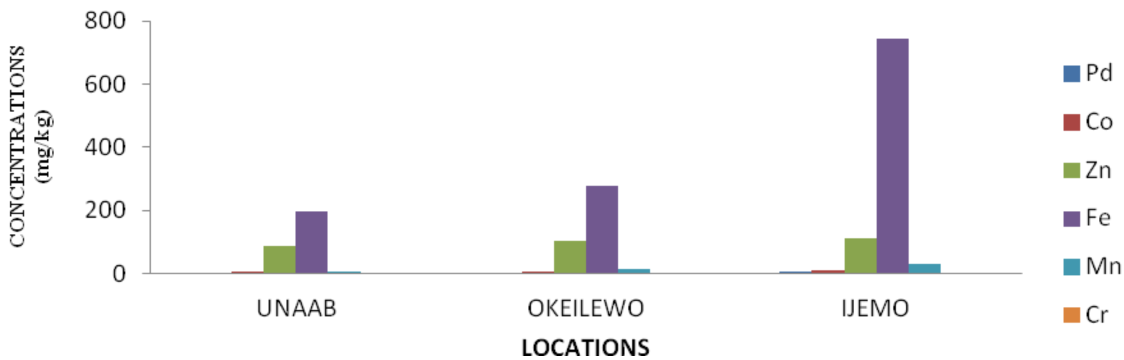

Fig.3. Variations of concentrations of metals in the Heart of Albino rats among the three locations

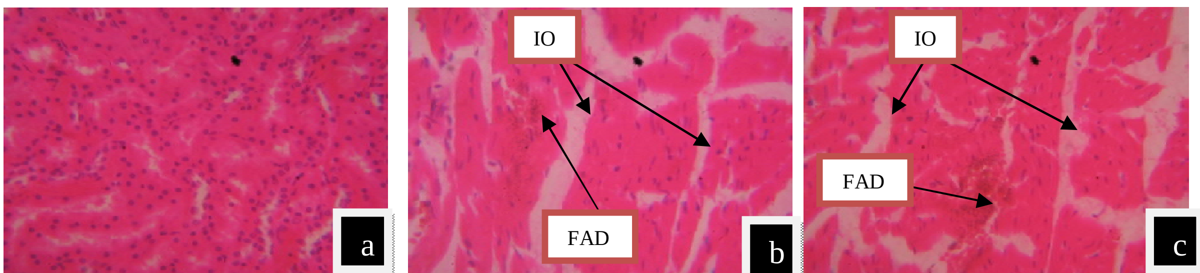

Plate 1 shows photomicrograph of heart section of rat: (a) at control showed normal appearance (H & E; X 350), (b) at Oke ilewo showing mild interstitial Oedema (IO) with focal area degeneration (FAD) (H & E; X 350) and (c) at Ijemo showing severe interstitial Oedema (IO) with focal area degeneration (FAD) (H & E; X 350).

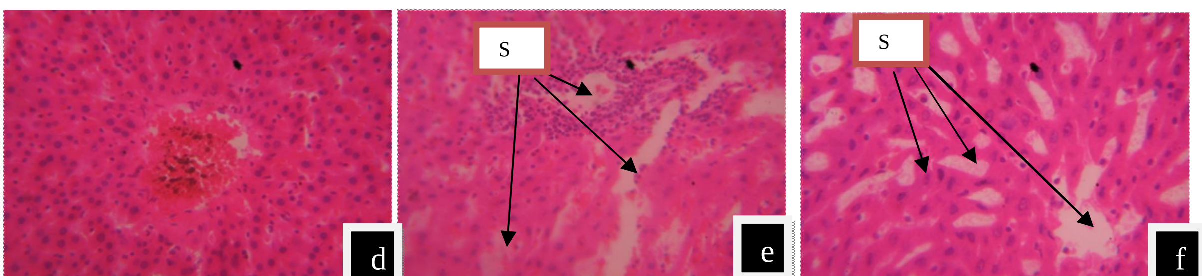

Plate 2 shows photomicrograph of liver section of rat : (d) at control showed normal appearance (H & E; X 350), (e) at Oke ilewo road showing mild focal area of periportal mononuclear Cellular infiltration with moderate sinusoidal dilation (SD) and (f) at Ijemo road showing mild focal area of periportal mononuclear Cellular infiltration with moderate sinusoidal dilation (SD).

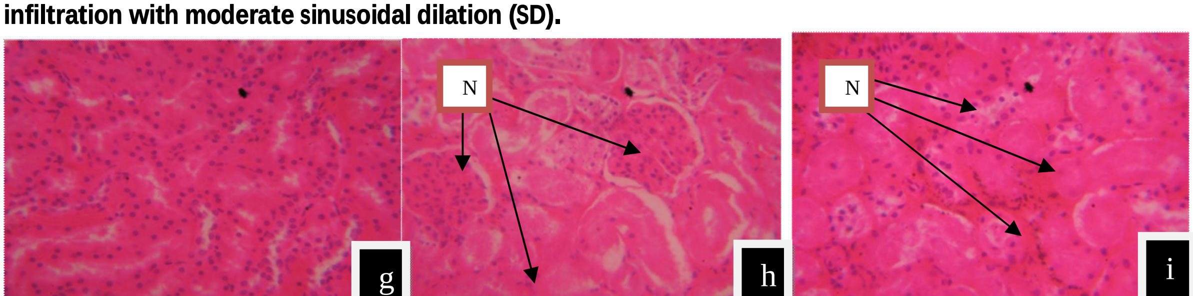

Plate 3 shows photomicrograph of the kidney section of rat: (g) at control showed normal appearance (H & E; x350), (h) rat at Ijemo showed mild tubular nephrosis (N) in the renal tubular epithelia (H & E; X350) and (i) rat at Oke-Ilewo road showed mild tubular nephrosis (N) in the renal tubular epithelia (H & E; X350)

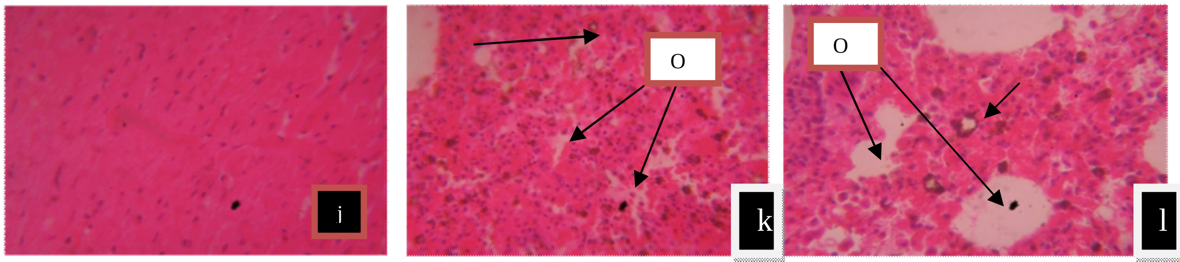

Plate 4 shows photomicrograph of the lung section of rat (j) at control showed normal appearance (H & E; x350), (k) at Oke Ilewo road showed mild Haemosiderosis (H) and oedema fluid (OF) (H & E ; x350) and (l) at Ijemo road showed diffuse haemosiderosis (H) and oedema Fluid (OF) (H & E ; x350)

There was significant pathological difference between the soft tissues of Albino rats exposed and unexposed to vehicular exhaust fumes. In the heart, diffuse interstitial oedema leading to degeneration of the myofibres was observed in the exposed rats but no significant change was observed in the heart of the unexposed rats. In the lung, diffuse thickened of the alveolar wall with red blood cells, oedema fluid and alveolar macrophages. Also, alveolar spaces filled with red blood cell and diffuse haemosiderosis with erythrophagocytosis were observed in the exposed rats but no significant change was observed in the lung of the unexposed rats. Kavita *et a*l. (2010) reported a similar result when rats were exposed to diesel exhaust. He observed marked lymphocytes aggregation, oedematous changes in alveolar septa and bronchioles. Also, thickening of alveolar walls and small blood vessels were observed. The long-term exposure period induce the development of lung tumours (Ma and Ma, 2002).

In the kidney, diffuse tubular nephrosis in the renal tubular epithelail were observed in the exposed rats but no significant change was observed in the kidney of the unexposed rats. In the liver, showed focal areas of periportal mononuclear cellular infiltration with moderate diffuse sinusoidal dilation of the liver of Albino rats but no significant change was observed in the liver of the unexposed rats

Conclusion

The result of this study generally revealed the histological damage and presence of heavy metals in the soft tissues of Albino rats placed in close proximity to busy roads of Abeokuta cities. The level of the heavy metal at the moment is high enough to call for intervention by government agencies. The accumulation of heavy metals in the soft tissues of Albino rats along busy roads could be as a result continual usage of the road by vehicles driven with leaded petrol. This can also lead to serious health issues of human who live in cities. Indeed, vehicular exhaust fumes pollution need urgent control measure to reduce its menace on human population.

References

Abulude, F.O., Akinjagunla, Y.S. and Omoniyi, A. (2006). An Investigation into the Effect of Vehicle Exhaust Fumes on the Level of Some Heavy Metals in Cows Blood. *Research Journal of Biological Sciences*. 1(1-4):9-11.

Babalola, O.O., Ojo, L.O. and Aderemi, M.O. (2005). Lead levels in some biological samples of automechanics in Abeokuta, Nigeria. *Indian J. Biochem. Biophys*. 42: 401-403.

Borgmann, U. (1983).'Metal Speciation and Toxicity of Free Metal Ions to Aquatic Biota', In: J. O. Nriagu (ed), Aquatic Toxicity, Advances in Environmental Science and Technology, Vol. 13, John Wiley and Sons, New York, pp 47-73

.

Chirenje, T., MA, L.Q., Szulczewski, R., Littlell, K.M. and Zillioux, E. (2003). Arsenic distribution in Florida urban soils, *J. Evinron. Quality*, 109: 1-22.

Davis, B. E. (1990). Heavy Metal in Soils. Blackie and Son Ltd., Glasgow and London.177-196.

Dioka, C.E., Orisakwe, O.E., Adeniyi, F.A.A. and Meludu, S.C. (2004). Liver and Renal function tests in artisans occupationally exposed to Lead in Mechanic village in Nnewi, Nigeria. *Int. J. Environ. Res. Public Health* 1: 21-25.

Hawkes, S.J. (1997). What is a heavy metal? *J. Chem. Edu*. 74: 1374-1378.

Idrees F. A. (2009). Assessment of Trace Metal Distribution and Contamination in Surface Soils of Amman, Jordan. *Jordan Journal of Chemistry.* 4(1): 77-87.

Kamala, K. and Kumar, B.D. (1998). Lead toxicity. Indian Pediatr. 35: 209-216.Kavita, G.,

Basudeb, B., Shyam, B.L. and Arunabha, R. (2010). Effects of diesel exhaust, heavy metals and pesticides on various organ systems: Possible mechanisms and strategies for prevention and treatment. *Indian Journal of Experimental Biology*. 48:710-712.

Luckey TD, Venugopal B, Hutchson D (1975). Heavy metal toxicity, safety and homology. *Qual. Suf. Thieme Stuttgart, Supplement,* 1: 120.

Ma, J.Y and Ma, J.K. (2002).The dual effect of the particulate and organic components of diesel exhaust particles on the alteration of pulmonary immune/ inflammatory responses and metabolic enzymes. *J . Environ Sci Health c Environ Carcinog Ecotoxicol Rev*.20:17

Ogunsola, O.J., Oluwole, A.F. and Asubiojo, O.I. (1994). Environmental impact of vehicular traffic in Nigeria; health aspects. *Sci. Total Environ.* **147:**111-6.

Passow, H.A. Rothstein, H. and Clarkson ,T.W. (1961). The general pharmacology of the heavy metals. *Pharmacol. Rev***.** 13: 185-225.

Sofoluwe, G.O. (1968). Smoke pollution in dwellings of infants with bronchopneumonia. *Arch. Environ. Hlth.* **16:**670-672.

Sumner, A T. and Sumner, B. E. H .(1969). A laboratory manual of Microtechnique and Histochemistry. Blackwell Scienctific publication, Oxford. 85pp.

Tyler, T. G. (1981). Heavy metals in soil biology and biochemistry. In: Soil Biochemistry, Marcel Dekker, New York, pp. 33.

Vidhya, L., Dhandapani, M., Sekar, M. AND Mahimairaja, S. (2007). Lead pollution in soil, water and plants due to automobile emission in urban environments in Coimbatore. *Madras Agric. J.*, 94 (1-6): 89-96.

WHO. (1986). Lead-environment Aspects environment health Criteria. 85: 2-4.

Waste Disposal Site Selection using Remote Sensing and GIS: A Study of Akure and its Environs, Southwest-Nigeria

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Abstract

Waste disposal has been a serious challenge in Nigerian cities especially as rural-urban migration intensifies. While overwhelming scientific evidences abound that global warming is taking a significant toll on the Earth and its occupants, Nigeria is striving to join other countries in mitigating the effects. One way of intensifying the mitigation is through appropriate and environmentally-friendly waste disposal and management. All manners of wastes are usually disposed of without any serious consideration for the environment. Open incineration is a very common means of waste disposal in developing countries. In spite of the meager contributions of this group of nations to industrial growth, open incineration method of waste disposal hugely adds to the problem of climate change. It has been observed that there is the tendency to dispose wastes indiscriminately and in an uncoordinated manner, thereby resulting in unhealthy environment. In this study, a satellite imagery covering Akure and its environs was analysed using ArcView GIS 3.2a to develop a user interface for selecting a waste disposal site with special emphasis on geologically suitable conditions. This study aims at demonstrating the potential and efficiency of using GIS in selecting sites for the storage of biodegradable solid wastes. Results show suitable areas where landfill sites can be safely and aesthetically located within the study area, putting urban growth rate into consideration.

Keywords: Remote sensing, GIS, Waste disposal, Urbanization

Introduction

Waste can be defined as any substance or article which requires to be disposed of as being broken, worn out, contaminated or otherwise spoilt. Source reduction, recycling and waste transformation are methods widely used to manage solid waste. However, in all these methods there is always a residual matter to be disposed of even after the recovery process. The technique of getting rid of these wastes in an economic and environmentally friendly approach is called "sanitary landfilling" (Tchobanoglas and Kreith, 2002). Sanitary landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. Urbanization can be regarded as the quality or state of becoming a city, and therefore having the characteristics pertaining to, and related to being a city. Among the several advantages of urbanization is industrialization which in turn brings about the growth of population within cities and thus the generation of wastes in its different forms, types and quantities. Therefore, as a city grows, the need arises for a suitable and efficient waste disposal scheme to be put in place to manage these wastes. To achieve this, an efficient waste disposal site should be created where wastes can be safely dumped or better still, recycled.

According to Howard and Irwin (1978), an ideal waste disposal site is the one that is located reasonably close to the source of the waste, has convenient transportation access, is not situated in a low-lying area or floodplain, and is underlain by geologically stable, strong and competent rock material. It is therefore imperative that many factors must be incorporated into sanitary landfill siting decisions; Geographic Information System (GIS) is ideal for this kind of assessment study due to its ability to manage large volume of spatial data from a variety of sources. With growth in population and attendant increase in the amount of waste generated, appropriate disposal is fast becoming a serious problem within urban centres. For example, Akure has been growing in terms of population, infrastructure, commerce and industry since it became a state capital in 1976; this has consequently resulted in more waste generation. While refuse burning has been the most common means of waste disposal, it visibly poses environmental health hazards. During the rains most of the poorly disposed of refuse block drainages, spill onto roads, and occupy adjacent water bodies, thereby rendering the surrounding filthy and repulsive.

Some guidelines have been proposed for the siting and design of sanitary landfills in developing countries (Diaz, 1997). Some of these guidelines include geological and hydrogeological considerations. Based on these guidelines and using remotely sensed data in a GIS environment, Atejioye and Anifowose (2005) carried out a study on selecting a suitable waste disposal site within the main campus of the Federal University of Technology, Akure. The study was used as a pivot for the current investigation which is extended to other parts of Ondo and Ekiti States.

Study Area

The study area is bounded by Latitudes 7^0 and $7^0 30'$N, and Longitudes 5^0 and $5^0 30'$E covering parts of Ondo and Ekiti States in southwestern Nigeria. Towns covered by the study include Akure, Emure, Idanre, Ijare, Iju, Ikere, Ilara, Isarun, Ise-Ekiti, Ita-Ogbolu, Oba-Ile and Owena. The area is underlain by Precambrian rocks comprising Migmatite-Gneiss-Quartzite complex; the rocks include migmatites which grade into banded gneiss, and intruded by granites, prophyritic granites and charnockites (Anifowose, 2000). Some bands of quartzites also exist as residual hills and ridges within the study area. The rocks also exhibit varieties of structural features such as foliations, folds and fractures. The general trend of the rocks is in the NNE-SSW direction, while several short fractures trend N-S (Atejioye & Anifowose, 2005). These rocks have been variously subjected to intense deformation resulting in their folding and fracturing (Oluyide, 1988). The drainage pattern is generally dendritic with southward flow of the rivers and their tributaries. The area enjoys two alternating seasons in a year - the rainy season which spans about nine months from March to November with a brief break in August, and the dry season thereafter. The rainy season is marked by heavy rainfall with mean annual ranges between 1000mm and 2000mm. Temperature in this area is generally high and ranges between 25^OC and 30^OC, with a relative humidity of about 80% (Udo, 1978). Majority of the occupants are subsistence farmers who also cultivate cash crops like cocoa, kolanuts and oil palm, while civil servants and petty traders live mostly in the cities.

Materials and Methods

A satellite imagery covering the study area (Figure 1) was downloaded from Google Earth™; a topographical map of Akure area on a scale of 1:100,000 and a geological map covering the area on a scale of 1:250,000 were also obtained (Figure 2). During ground truthing, a Garmin™ hand-held GPS was used to measure the coordinates of some points in the study area for the purpose of georeferencing the maps which had earlier been scanned into ArcView™3.2 GIS environment. Towns and other major settlements were extracted from the satellite imagery while major road network were extracted from both the topographical map and the imagery (Figure 3); fractures, rivers and quartzite bodies were extracted from the geological map (Akingbade, 2010; Omole, 2010). Buffer zones were created for each of the considered factors at specific, environmentally safe predetermined distances away from potential landfill sites (Sener *et al.,* 2006). The distances were 500m, 250m, 250m, 2km and 500m for rivers, fractures, quartzite bodies, settlements and major road network, respectively. The map layers for the buffered zones were combined (Figure 4) to delineate unsuitable and potentially suitable landfill sites.

Results and Discussion

Numerous fractures were identified and delineated particularly in the granitic rocks in parts of Idanre, Iju, Ita-Ogbolu, Iresi, Ijare and Ikere (Figure 3). Other areas which are equally fractured were observed to have been underlain by massive quartzites which exist in parts of Igbara-Odo, Igbara-Oke, Ibuji and Ero areas. Such fractures are known to act as passageways for underground flow (Langer, 1995); hence the selection of such an area as landfill site may lead to groundwater pollution. Other areas underlain by migmatite-gneisses are preferred because they are more geologically suitable. The potential landfill sites delineated in the study area are situated on migmatite gneiss because an ideal landfill, according to Yildrim (1997), must be situated over a competent rock of limited permeability; then the probability of groundwater pollution either chemically or microbially will be very low.

The most suitable site for Alade and Idanre areas is about 7km and 11.5km southwest from the settlements respectively around $7^{0}14'$N/$5^{0}04'$E coordinate, in an area that is underlain by migmatite-gneiss. The most suitable site for Owena, Ilara and Ijare areas is about 6km, 6.6km and 4km away from the town centres respectively around $7^{0}37'$N and $5^{0}06'$E coordinate, and also underlain by migmatite-gneiss. For Ikere, Iju and Ogbese areas, the most suitable site is situated about 8.5km, 7.5km and 5.4km away from the town centres respectively at $7^{0}45'$N and $5^{0}30'$E coordinate, with migmatite-gneiss as the bedrock. Finally, the most suitable site for Akure, Oba-Ile and Oda areas is 9km, 13.5km and 6.8km away from the centre of the settlements respectively at $7^{0}17'$N and $5^{0}18'$E, with the bedrock being migmatite-gneiss.

Conclusion

Solid waste disposal in open places should be abandoned because of its inherent potential for air and groundwater pollution coupled with its obvious linkage with serious health, aesthetic and environmental problems. A number of potential sites which generally satisfy the minimum international requirements were identified for the purpose of effective sanitary landfill-type waste disposal. Among these areas, selection should be made through careful field checks. The integration of GIS in Multicriteria Decision Analysis (MCDA) is a powerful tool in solving landfill site selection problem, because it provides efficient spatial data manipulation and presentation. It helps to situate and design landfill in such a way that no harmful substances as a result of incineration reach the atmosphere, biosphere and hydrosphere in unacceptable quantities, thereby ensuring that climate change-induced gases are drastically reduced. While it is important to emphasize that GIS analysis is not a substitute for geological/geotechnical field exploration, it is efficient in identifying areas that are more suitable and directs efforts to such areas for detailed field studies. Finally, the selection of the final sites requires further geotechnical and hydrogeological analyses to ensure conformity with the stringent standards required for design and construction of such facility.

Acknowledgement

The authors wish to acknowledge the technical staff at the Centre for Space Research and Applications, Federal University of Technology, Akure for their useful contributions.

References

Akingbade, O.E. 2010. Waste disposal site delineation in Akure area using Remote sensing and GIS. *Unpublished B.Tech thesis, Federal University of Technology, Akure*, 51p.

Anifowose, A.Y.B. 2000. Stabilization of lateritic soils as a raw material for building blocks. *Bulletin of Engineering Geology and the Environment*, No.58, pp. 151-157.

Atejioye, A.A. and Anifowose, A.Y.B. 2005**.** GIS technology in the selection of waste disposal site: A case study. *Journal of Research in Science and Management*, Vol.3 No.1, pp. 66-73.

Daniel, D.E. 1993. Landfills and impoundments. In: D.E. Daniel (Ed.) *Geotechnical practice for waste disposal*. Chapman and Hall, London, pp. 97-112.

Diaz, L.F. 1997. Proposed guidelines for siting and designing sanitary landfills in developing countries. In: L. Uhre (Ed.) *International Directory for Solid Waste Management 1997/8*. James & James (Science Publishers) Ltd., London, pp. 226-236.

Howard, A.D. and Irwin, R. 1978. Geology in environmental planning. McGraw Hill Books, 478p.

Langer, M. 1995. Engineering geology and waste disposal. Scientific Report Recommendations of the IAEG Commission No 14, *Bulletin of the International Association of Engineering Geology*, No 51, pp. 5-29.

Oluyide, P.O. 1988. Structural trends in the Nigerian basement complex. In: P.O. Oluyide, W.C. Mbonu, A.E. Ogezi, I.G. Egbuniwe, A.C. Umeji (Eds.), *Precambrian Geology of Nigeria*. Geological Survey of Nigeria, Kaduna, pp. 93-98.

Omole, K.E. 2010. Delineation of potential waste disposal sites in Akure area, southwestern Nigeria. *Unpublished B.Tech thesis, Federal University of Technology, Akure*, 47p.

Sener, B., Suzen, M.L. and Doyman, V. 2006. Landfill site selection using Geographic Information System. *Turkish Journal of Environmental Geology*, Vol. 49, pp. 376-388.

Tchobanglas, G. and Kreith, F. 2002. Handbook of solid waste management. McGraw Hill Books, New York, 248p.

Udo, R.K. 1978. A Comprehensive geography of West Africa. Heinemann Publishers, Ibadan, 304p.

Yildrim, M. 1997. Engineering geological evaluation of solid waste landfill sites: two examples from Istanbul, Turkey. *Bulletin of the International Association of Engineering Geology*, No 55, pp. 151-158.

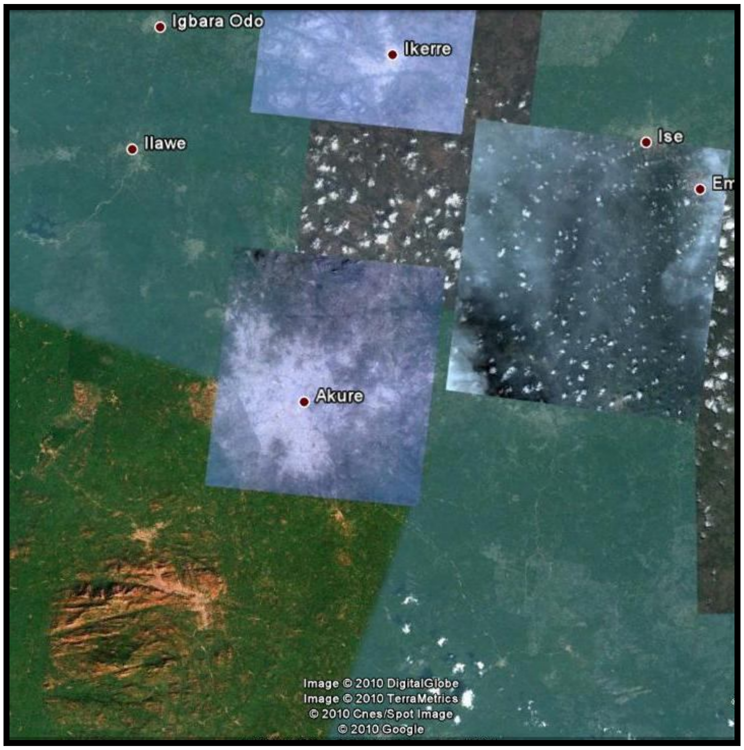

Figure 1: Satellite imagery covering the study area (Source: www.googleearth.com)

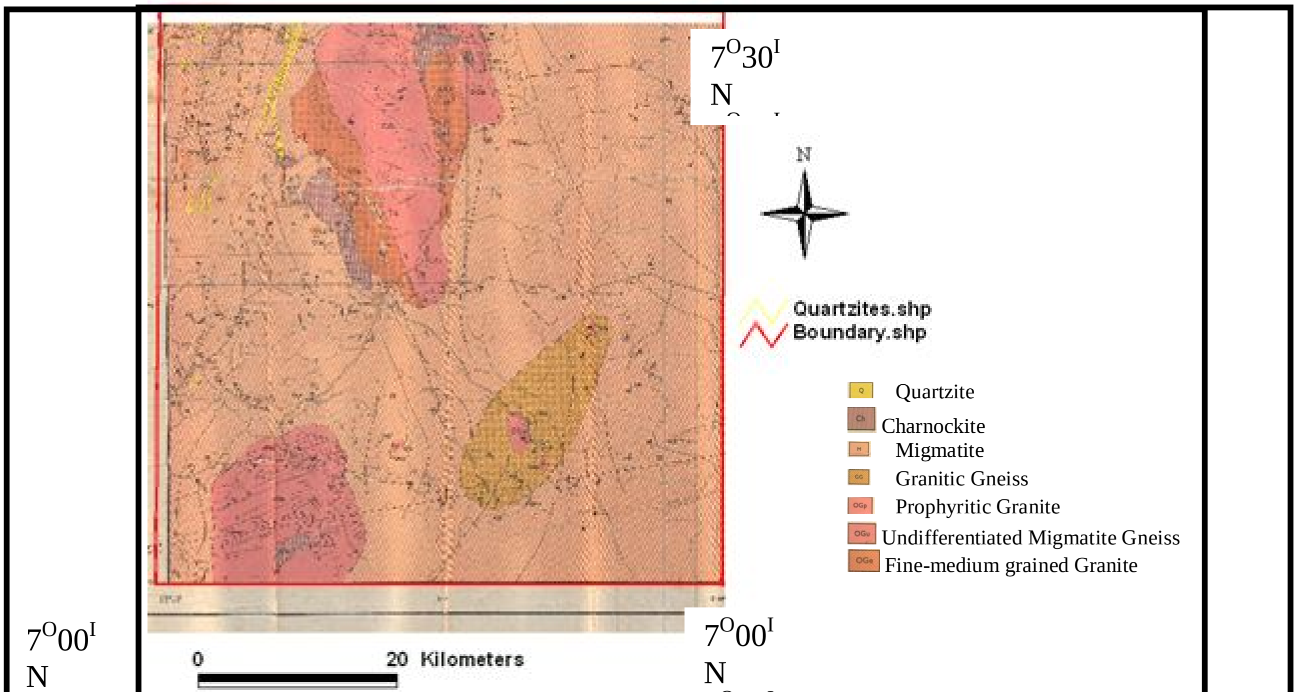

Figure 2: Geological map of the study area

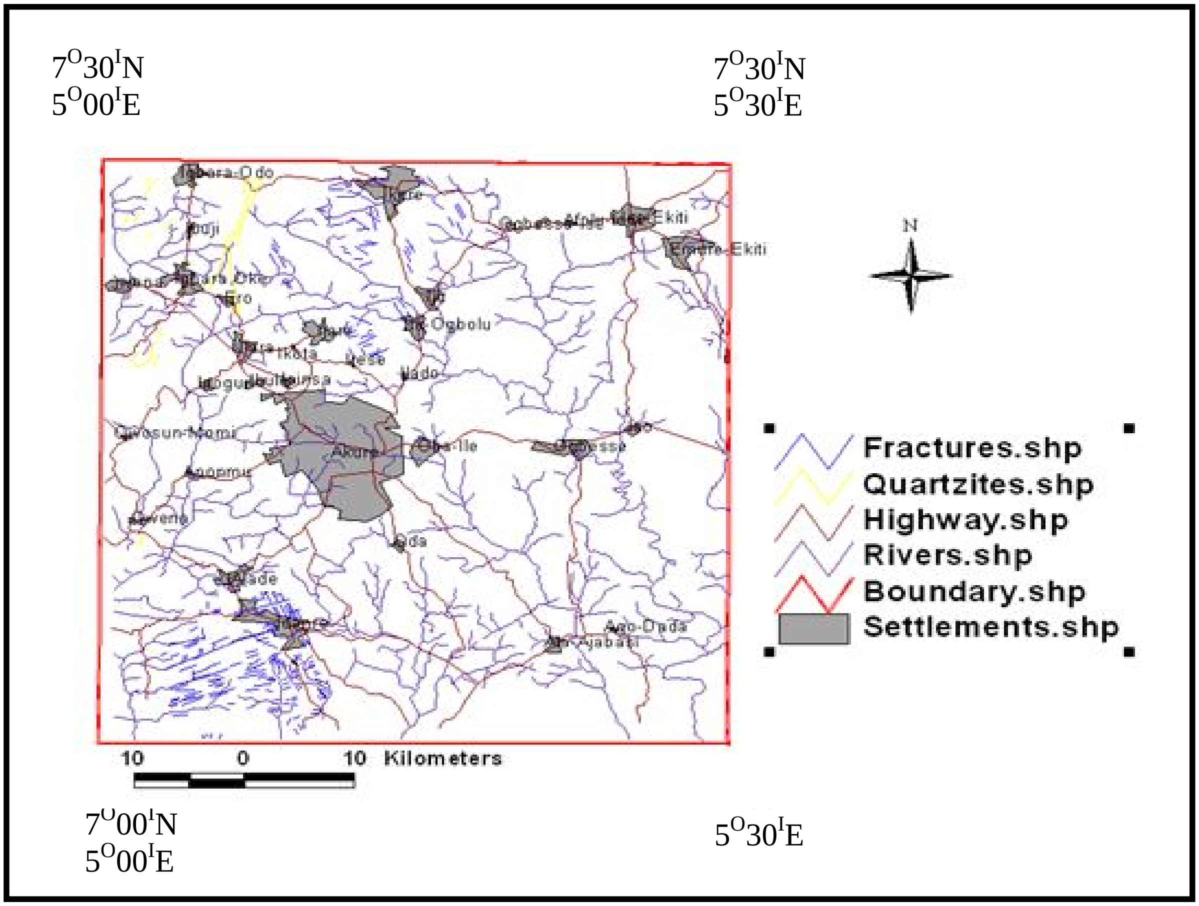

Figure 3: A map of the study area showing delineated quartzite bodies, fractures and drainage system

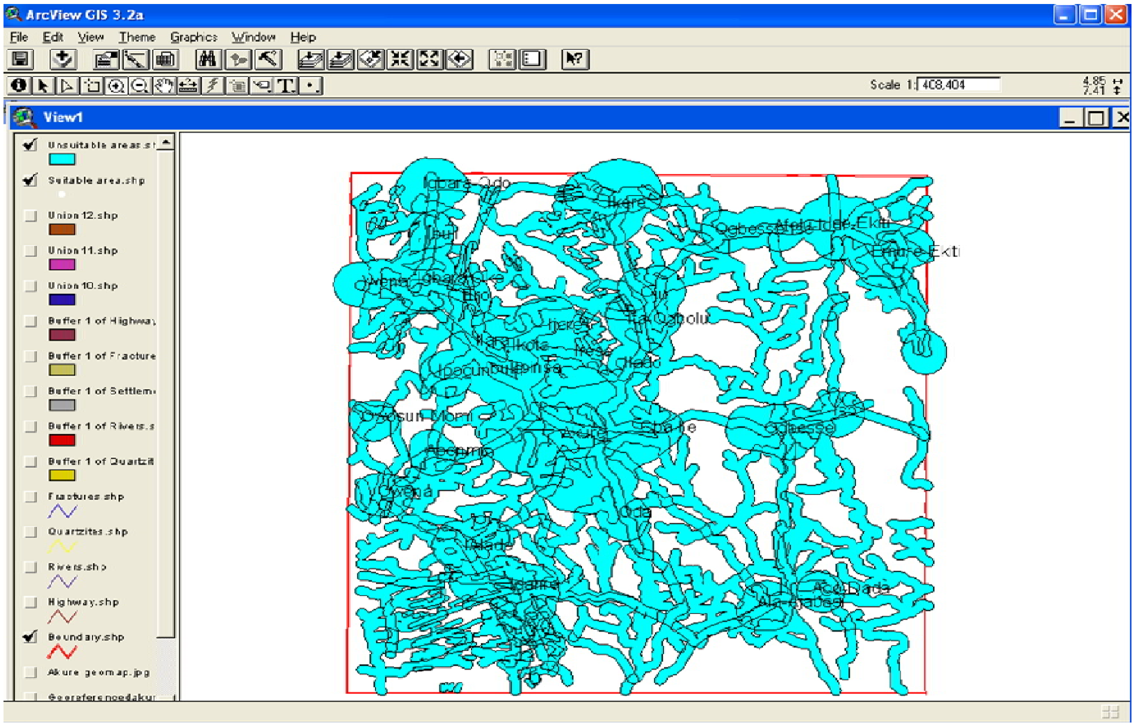

Figure 4: Suitability map based on the buffering factors

Evaluation of Sustainable Water Demand in a Coastal Environment using WEAP Model

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Abstract

Ogun river basin, located in southwestern Nigeria, is one of the major river basins under the management of Ogun-Oshun River Basin Development Authority. Different water uses, including domestic, commercial, industrial and agricultural takes place within the basin. As population and economic activities increase, water demand also increases, which makes it imperative for water resources planners to take into account the consequent water demand challenges. In this study, Water Evaluation and Planning (WEAP) model is used to evaluate the impacts of possible water demands on the water resources of Ogun river basin up to the year 2020. Two scenarios were simulated: the first concerns the previous and current accounts of water demand in the basin from 2006 to 2011 while the second simulates the future water demand in the basin from 2012 to 2020. The water demand utilization, unmet demand, demand site coverage, supply delivered, stream flows and water storage were analysed for each scenario by integrating various hydrological components, such as hydrological year cycles, precipitation and dams. Each scenario also made key assumptions with respect to the gross domestic product, population growth rate, irrigation efficiency and complementary sources of water. The results of the model for the previous and current scenarios indicate that the water demand for domestic, commercial, industrial and agricultural uses are 4.7×10^9 m^3, 9.5×10^8 m^3, 6.8×10^8 m^3 and 3.4×10^4 m^3 respectively while the corresponding values for the total water demand, supply required and supply delivered are 6.7×10^9 m^3, 7.7×10^9 m^3 and 3.6×10^9 m^3, thereby making the unmet total water demand to be 4.1×10^9 m^3. The model prediction for the years 2012-2020 indicates that the water demand for domestic uses will be the highest at 5.3×10^{10} m^3. The demand from commercial, industrial and agricultural uses are 1.1×10^{10}, 2.5×10^9 and 1.4×10^9 m^3 respectively. The total water demand, supply required and supply delivered are 6.8×10^{10} m^3 , 7.9×10^{10} m^3 and 10×10^9 m^3 respectively resulting in unmet total water demand of 6.9×10^{10} m^3, at an average annual rate of 7.7×10^9 m^3. The Ogun River therefore, may not be able to satisfy the future water demand of water users in the basin. To reduce unmet demand, waste water treatment, introduction of water meters to check wastage, building of new dams or increasing the capacities of existing ones, groundwater development, information dissemination and development of manpower in the field of water resources are recommended.

Keywords: WEAP model, water demand, water supply, Ogun River basin, water uses

Introduction
Water is a vital resource for every human activity. Water makes life possible. Without it, life and civilization cannot develop or survive. Water forms the largest part of most living matter and is vital to man just as air and food are (Ayoade, 2003). The management and maintenance of water is thus very important (Fiorilloa, 2007).

The accelerating growth of human population, the rapid advances made in industry and agriculture have resulted in a rapidly increasing use of water by man, to the extent that the availability of water as well as the control of excessive water has become a critical factor in the development of every regions of the world (Williams, 2010). Over the decades, water supply management has proved to be insufficient to deal with strong competition for water with growing per capital water use, increasing population, urbanization pollution and storages (Wang Xiao – Jun et al, 2009). Also, the need for domestic, industrial and agricultural water supply is growing, but the absence of demand management strategies means that the increase in demand will likely outstrip the available supply, hence water scarcity (UNESCO, 2006).

The issue of water scarcity in the world and its implication on development of new political and economic relations among countries may result to crisis in the future. The management of water resources as a common resource would require trade-off among countries and water users (Yang and Zehnder, 2007). The need therefore to device means by which available water can be consumed and allocated among the various uses is pertinent.

Ogun river basin is one the five major river basins under the management of Ogun-Osun River Basin Development Authority (ORBDA) and it lies within the coastal environment. Due to the potential of Ogun river basin as a major source of water supply, this study developed a plan that will allow for the sustainable and rational utilization, conservation and management of available water resources within Ogun river basin using Water Evaluation and Planning (WEAP) Model. The study also determined the future water demand for various uses, proffered alternative strategies for water conservation through storage mechanism that will meet water demand within the basin.

The Study Area
Ogun river basin is one of the 5 major basins under the management of Ogun Oshun River Basin Development Authority. Others are Yewa, Sasa, Oshun, and Ona basins. Different water users i.e. domestic, commercial, industrial and agricultural activities, are present in the basin. Ogun River rises in the Iganran Hills (503 m) east of Shaki in the northwestern part of Oyo State and flows southwards for approximately 410 km, before discharging into Lagos lagoon. The river's main tributary, Oyan, which rises to the west of Shaki incorporates, Ofiki and Opeki rivers. The Ikere Gorge dam is situated on the Ogun River, 8 km east of Iseyin in Oyo state. The basin lies between latitudes 6^o 33 and 8^o 58 N and between longitudes 2^o 40 and 4^o 10. The total area is about 23,700 km^2 (Figure 1).

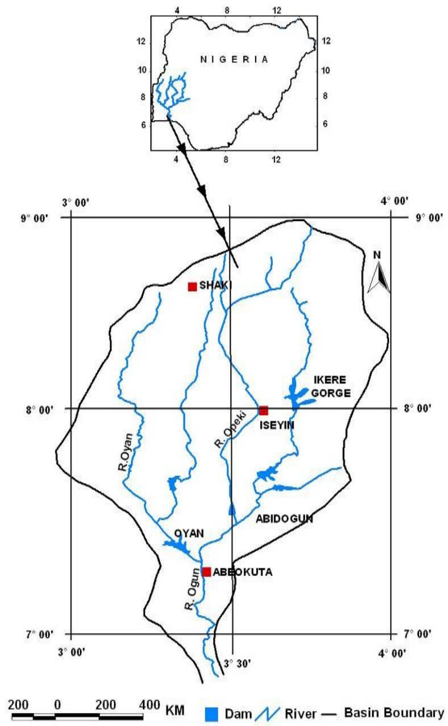

Figure 1: The Ogun River Drainage Basin

Methodology

Ogun river basin faces freshwater management challenges, some of which include allocation of limited water resources, inadequate environmental quality monitoring, and policies for sustainable water use. The evaluation process considered the identified issues as well as both hydrologic and institutional aspects in the assessment of water demand within the basin. The investigated water demand includes water consumption for human needs, agriculture (irrigation), and industries.

WEAP software was used to evaluate the future water demands in Ogun-Oshun River Basin. A full range of water development and management options were evaluated, which takes account of multiple and competing uses of water systems. In the WEAP, the typical scenario modeling effort consists of three steps. First, a Current Account year, which is chosen to serve as the base year of the model; second, a Reference scenario that is established from the Current Account to simulate likely evolution of the system without intervention; and third "what-if" scenarios created to alter the "Reference Scenario" and evaluate the effects of changes in policies and/or technologies. The data used in modeling for current accounts, ranges from 2006 to 2020 (Tables 1 and 2). In the allocation of the available resources therefore, a number of options were tested by developing several scenarios from where future water demands are projected.

Geographical information system (GIS) tool was used to configure the system and geo-reference the area of study. Primary and secondary data on water supply and demand for domestic, industrial, commercial were obtained from Ogun State Water Corporation. Irrigation water requirement, reservoir capacity, location and operation rules, gauge heights, river head flows and climatic data, such as rainfall and temperature, were obtained from Ogun Osun River Basin Development Authority and the Meteorological Station at the Federal University of Agriculture, Abeokuta. Population data for Ogun River Basin was obtained from National Population Commission.

Key assumptions were made; these are the user defined parameters employed throughout the WEAP model. The assumptions are:

- Level of GDP growth;
- Population growth rate;
- Level of technological irrigation efficiency;
- Other complimentary source of water usage.

The use of key assumptions enables a faster set up of the current situation, the scenarios, and simplifies changes in the characteristics of reservoirs and demand sites.

WEAP model is structured in a way that the water resources system is represented in terms of river, groundwater, reservoirs withdrawals, transmission and wastewater treatment facilities, ecosystem requirements, and return flow. Other representations include flow requirements, runoff river hydrology, water demand sites and pollution (Sieber et al, 2005). The model also consists of five main views, namely Schematic, Data, Results, Overviews and Notes.

The schematic view, which is the study area and other polygon parameter were created using a GIS based tools, where raster files were imported to the system as a background for schematic layers. Drag and drop method was used to create objects such as demand nodes, reservoir, transmission link and return flow, which were positioned within the study area. Streams in the area were also redrawn by using the interactive drag and drop button on the WEAP model (Figure 2).

The current account (baseline) year represent the basic definition of the water system as it currently exists. The year 2006 was selected as the starting year for all scenarios due to data availability for water demand, supply, irrigation and hydrological information such as inflow and rainfall. The WEAP software takes into account water demand for all demand sites, which include domestic, commercial, industrial and agriculture (middle and lower Ogun irrigation project). Two main parameters were identified; the Annual Activity Levels and Annual Water Use Rate.

The annual activity/demand level represents the amount of water required by each demand. Losses, reuse and efficiency are accounted for separately. Water consumption was calculated by multiplying the overall level of activity by a water use rate. Activity levels are used in WEAP's demand analysis as a measure of social and economic activity. WEAP multiplies activity levels down each chain of branches to get the total activity. The Annual Water Use Rate is not the total amount used but it is the average annual water consumption per unit of activity.

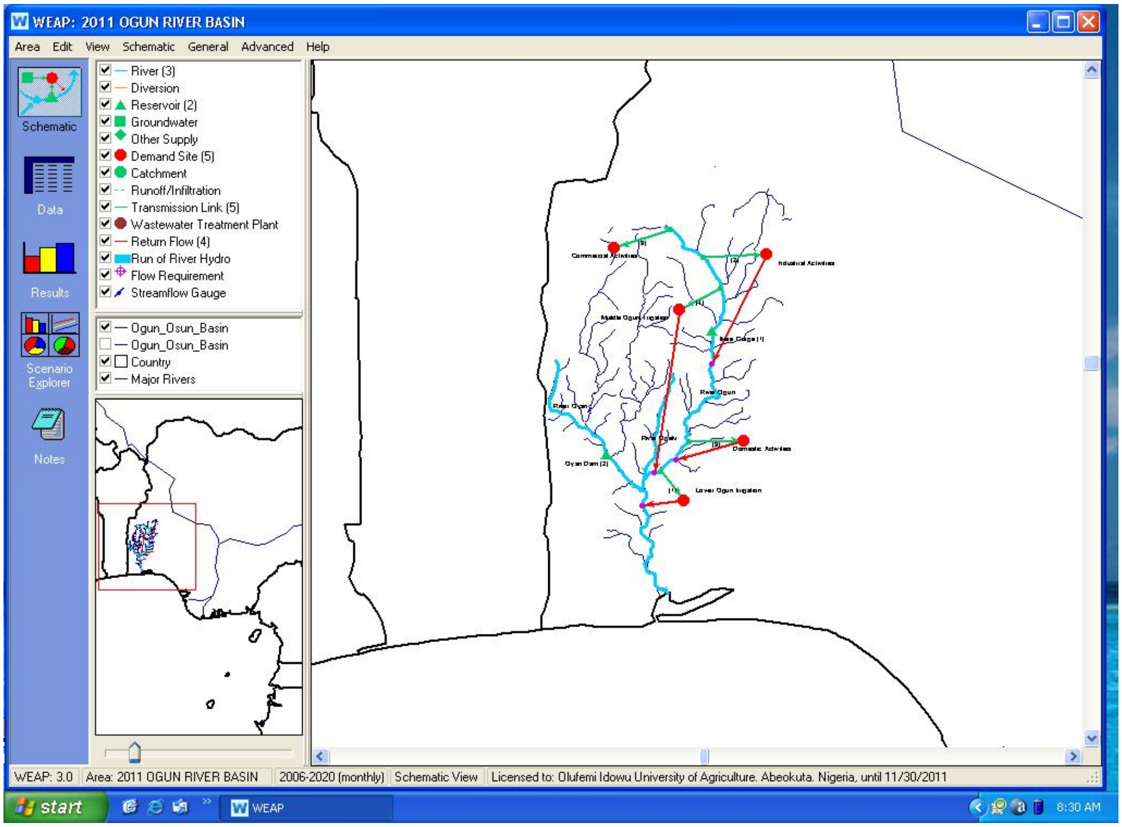

Figure 2: The Schematic Map of Ogun River Basin as at 2011 produced from the GIS raster layer

Table 1: Past data used to calculate resources demand for the period (2006 - 2020)

Reference Account:	**2006-2011**				
Population:	**2485182 persons**				
Demand sites:	**Industrial**	**Commercial**	**Domestic**	**Middle Ogun**	**Lower Ogun irrigation**
Annual activity (10^6 m^3)	48.227	16.29	12.22	325.68	369.1
Annual water rate (%)	1.59	4.71	30.88	46.32	40.87

Source: Ogun State Water Corporation, 2011

The average of the annual inflow of the river head flows for rivers Ogun, Opeki, and Oyan from 2006-2011 were determined as presented in Table 2. The minimum and maximum values were taken as a very dry and very wet year respectively, while the normal year was the mid point between the very dry and the normal. This was used in the model to accommodate future changes in hydrological patterns. Maximum and minimum water storage data and the net evaporation values for Oyan and Ikere Gorge dams were obtained to account for the difference between evaporation and precipitation on the reservoir surface.

Table 2: Average Monthly River flows ($m^3 s^{-1}$)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
River Ogun	0.53	0.52	0.38	1.16	0.36	1.63	4.08	64.44	132.86	136.70	37.78	2.35
River Opeki	9.17	8.28	10.03	17.49	26.79	24.00	46.52	77.52	87.69	64.32	26.73	9.68
River Oyan	0.65	0.46	0.78	0.41	2.34	2.37	7.40	8.11	13.32	8.41	8.90	0.82

Source: Ogun – Osun River Basin Development Authority, 2011

Current Account of the water system was first created. Based on a variety of economic, demographic, hydrological and technological trends, the “Reference” projection was established. Then a policy scenario was developed with alternative assumptions about future development. The scenario can address a broad range of ‘’what if” questions such as: what if population growth and economic development patterns changes?, what if reservoir operating rules are altered?, what if new sources of water pollution are added?, what if a water – recycling program is implemented?, what if a more efficient irrigation technique is implemented?, what if ecosystem requirements are tightened?, what if various demand management strategies is implemented?, and what if climate change alters the hydrology? These scenarios are viewed simultaneously in the results for easy comparison of their effects on the water system. The results were accessed and every model output was displayed in the next software chapter while the overview allows accessibility of key indicators in the model. Notes were eventually added to the model for documentation of the key assumptions.

Results and Discussion

The reference scenario covers 2012 – 2020 in this study and it is the base scenario that uses the actual data to help in understanding the best estimates about the studied period. The objective of a reference scenario is to help planner and water resources manager understand what could occur if current trend continues and to understand the real situation. Reference scenarios can also be useful for identifying where knowledge is weak, analyze likely trends and where more information needs to be collected. Also, it is important for designing contingency plans where there is a lot of risk and uncertainty. In this study, the reference scenario replicates real situation and the result for projected water demand is shown in Table 3.

The amount of water available for future use among the various demand sites is shown in Table 3. Water demand for various demand sites vary according to water use rate. As the population within the basin increases, water demand for demand site also increases. For instance, the demand for domestic activities is $5.3 \times 10^{10} m^3$, which is the largest amount. On the other hand, middle and lower Ogun irrigation have marginal increment in water demand due to low level of irrigation practice within the area. Thus, for the months of July to December, irrigation at lower and middle Ogun region has almost 100% demand site coverage (Table 4). Excess water is available to meet up water use rate during the period due to small irrigated farmland, high precipitation, and minimal technological improvement in the agricultural activities within the basin. In addition, the demand site coverage between the period of March and April was due to seasonal variability of rainfall. Commercial, domestic and industrial activity has 99.9% water demands from the month of February to May because the onset of rainfall, which begins around March/April, coincides with when the river has minimum water flow.

Table 3: Projected yearly water demand (10^6 m^3) for year 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	SUM
Commercial Activities	353.6	456.1	588.4	759.1	979.2	1,263.2	1,629.5	2,102.0	2,711.6	10,842.6
Domestic Activities	1,736.9	2,240.2	2,889.3	3,726.5	4,806.2	6,198.8	7,994.9	10,311.5	13,299.2	53,203.6
Industrial Activities	172.9	193.8	216.4	240.7	266.9	295.2	325.6	358.3	393.5	2,463.3
Lower Ogun Irrigation	57.0	64.7	72.5	80.6	88.8	97.3	105.9	114.7	123.8	805.3
Middle Ogun Irrigation	40.1	44.7	49.4	54.2	59.1	64.2	69.3	74.6	80.0	535.6
Sum	2,360.5	2,999.5	3,816.0	4,861.0	6,200.3	7,918.6	10,125.2	12,961.1	16,608.1	67,850.4

Source: WEAP model Author's Computation, 2011

Table 4: Monthly water supply coverage in percentage for various water uses

	January	February	March	April	May	June	July	August	September	October	November	December
Commercial Activities	4.1	0	0	0	0	17.8	68.7	61.3	35.2	75.9	34.2	20.3
Domestic Activities	4.1	0	0	0	0	17.8	68.7	61.3	35.2	75.9	34.2	20.3
Industrial Activities	50.2	0	0	0	0	58.3	100	100	100	100	100	99.5
Lower Ogun Irrigation	99.9	98.4	96.8	95.2	94.4	99.1	100	100	100	100	100	100
Middle Ogun Irrigation	99.9	72.9	30.7	41.1	94.4	99.1	100	100	100	100	100	100

Source: WEAP model Author's Computation, 2011

The annual water supply requirement for domestic, commercial and industrial activities are 6.3 x $10^{10}m^3$, 1.2 x $10^{10}m^3$ and 2.6 x 10^9 m^3 respectively (Table 5). The result also shows steady annual increase due to the gradual increase in population growth within the basin (Table 6). Middle and lower Ogun Irrigation project shows slight or no increase in supply requirement over the extended period of time with 6.0 x10^8 m^3 and 1.0 x 10^9 m^3 respectively (Figure 3). The lower amount of water demand utilization within the use category is due to the level of technological improvement and irrigation efficiency. But the amounts of supply delivered in the month of January to May are reduced drastically due to little or no river flow during the period. Thus both middle and lower Ogun irrigation project has 61.7% reliability, industrial activities 56.7%, while commercial and domestic activities have 13.9% each (Figure 4). The values are attributable to the differences in the annual water use rate.

Table 5: Annual water supply requirement (10^6 m^3) for various uses from 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	SUM
Commercial Activities	392.9	506.8	653.8	843.4	1,088.0	1,403.5	1,810.5	2,335.6	3,012.9	12,047.4
Domestic Activities	2,043.4	2,635.5	3,399.2	4,384.1	5,654.4	7,292.7	9,405.8	12,131.1	15,646.1	62,592.4
Industrial Activities	182.0	204.0	227.7	253.4	281	310.7	342.7	377.2	414.2	2,592.9
Lower Ogun Irrigation	71.3	80.9	90.7	100.7	111.0	121.6	132.4	143.4	154.7	1,006.7
Middle Ogun Irrigation	47.2	52.6	58.1	63.8	69.6	75.5	81.6	87.8	94.1	630.1
Sum	2,736.8	3,479.8	4,429.5	5,645.4	7,203.9	9,204.1	11,773.0	15,075.1	19,322.0	78,869.5

Source: WEAP model Author's Computation, 2011

Table 6: Projected water supply ($10^6 m^3$) for the year 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	SUM
Commercial Activities	117.5	129.7	136.1	134.4	132.1	129.3	126.2	121.6	117.8	1,144.7
Domestic Activities	611.3	674.5	707.7	698.4	686.6	671.7	655.5	631.9	611.6	5,949.0
Industrial Activities	116.4	127.6	131.6	134.8	142.9	156.6	172.8	190.1	205.7	1,378.5
Lower Ogun Irrigation	70.5	79.9	89.5	99.3	109.2	119.3	129.5	139.8	150.2	987.1
idle Ogun Irrigation	40.8	44.9	49.1	53.3	57.4	61.9	66.3	70.7	75.1	519.5
Sum	956.5	1,056.6	1,113.9	1,120.1	1,128.2	1,138.8	1,150.2	1,154.2	1,160.3	9,978.8

Source: WEAP model Author's Computation, 2011

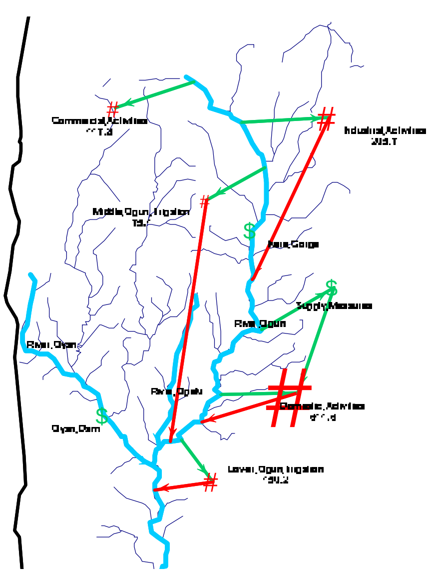

Figure 3: Schematic illustration of supply delivered

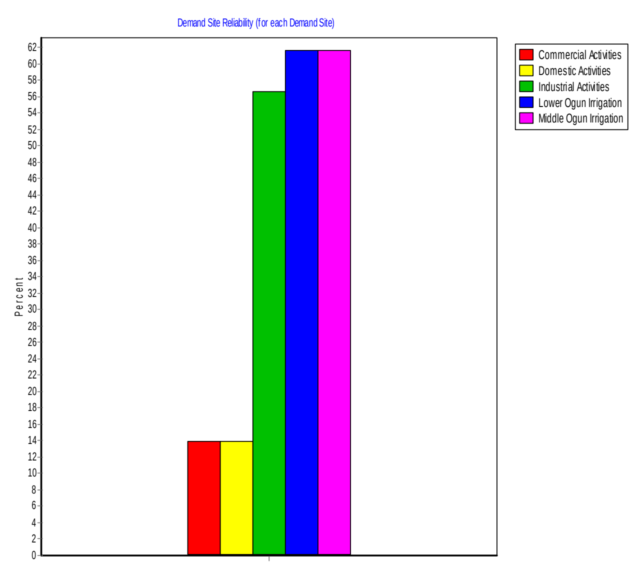

Figure 4: Demand site reliability for various water uses

Unmet Water Demand

As a result of water supply requirement and that which is demanded, a large shortfall is experienced among the various water uses (Table 7 and Figure 5). The model is able to simulate the results and show seasonality and variation between years. Figure 5 shows the unmet demand at the different demand sites. The Figure shows that the unmet demands occur from February to May during the onset of rainfall, and towards November to December during the cessation of rainfall with a mark variation in domestic water use. The annual unmet demand for domestic, commercial and industrial activities are 5.7×10^{10} m^3, 1.1×10^{10} m^3 and 1.2×10^9 m^3 respectively (Table 7). In addition to the seasonal rainfall distribution pattern (i.e. dry & wet season) that affects water availability within Ogun basin. Increase in population and GDP growth rate, which increases the standard of living of the people invariably increases water use rate within the basin. On the other hand, middle and lower Ogun irrigation project has sufficient water supply hence the absence of unmet demand, which makes water available for other uses.

Table 7: Variation in yearly unmet water demand (10^6 m^3) for various uses (2012-2020)

	2012	2013	2014	2015	2016	2017	2018	2019	2020	SUM
Commercial Activities	275.4	377.1	517.7	709.0	955.9	1,274.2	1,684.3	2,213.9	2,895.1	10,902.7
Domestic Activities	1,432.2	1,961.1	2,691.5	3,685.6	4,967.8	6,621.1	8,750.3	11,499.3	15,034.5	56,643.4
Industrial Activities	65.5	76.4	96.2	118.6	138.1	154.1	170.0	187.0	208.6	1,214.4
Lower Ogun Irrigation	0.8	1	1.2	1.5	1.8	2.3	2.9	3.6	4.5	19.6
Middle Ogun Irrigation	6.4	7.6	9	10.5	12.1	13.6	15.3	17	19	110.6
Sum	1,780.2	2,423.2	3,315.6	4,525.2	6,075.7	8,065.3	10,622.8	13,920.9	18,161.7	68,890.7

Source: WEAP model Author's Computation, 2011

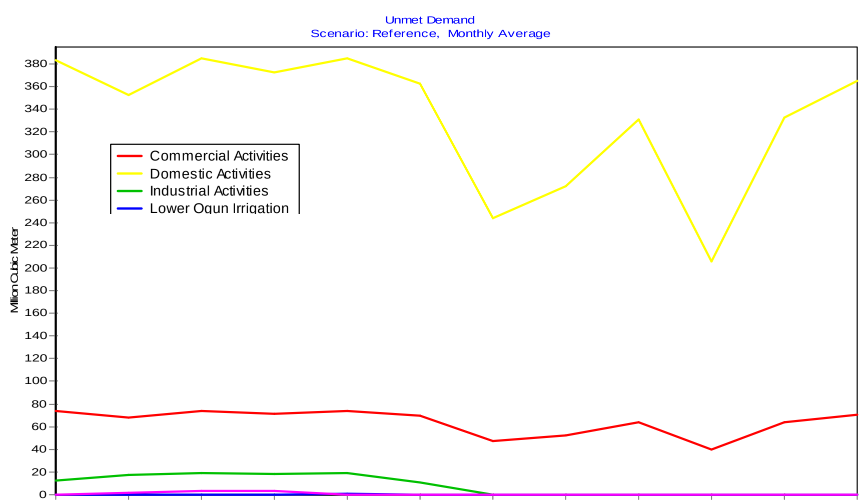

Figure 5: Monthly average unmet demand for various water uses in $10^6 m^3$

Application of Water Year Method Scenario (2006-2011)

The Water Year Method allows the usage of historical data in a simplified form that explores the effects of future changes in hydrological patterns. The method is a useful tool in testing hypothetical event and helps to understand and explore in simple ways the sensitivity to climatic change. The fractions are derived from historical flows by statistical analysis. The years are first grouped into five sets and then their variation from the norm is computed to reach the coefficient. The years are sorted from lowest to highest for 2006 to 2020 for the average annual inflow. The results of the scenario help to supplement the previous simulated method. In the end the coefficient is computed as the average divided by the normal water year average.

The most important parameter in the water year method is the coefficient for the water year definition, which includes 0.7, 0.8, 1, 1.3 and 1.45 for very dry, dry, normal, wet, and very wet respectively. The water year definition specifies how much more or less water flows into the system in that year relative to a normal water year. Figure 6 shows some level of water hydrology (head flow), which has greater implications for Rivers Ogun and Opeki in that order. The variation is due partly to climatic change and largely to hydrological pattern affecting the trend of water variation. It should be noted that the amount of water demand differences will be significant in the short run as the variation tends to compensate for the losses from year to year. In the long run however, the effect tends to be visible. The stream flow for all the three rivers in the month of October has been very high, indicating that the monthly average precipitation values are very high during the months of July to October, thereby increasing the volume of stream flow for the period (Figures 7 and 8).

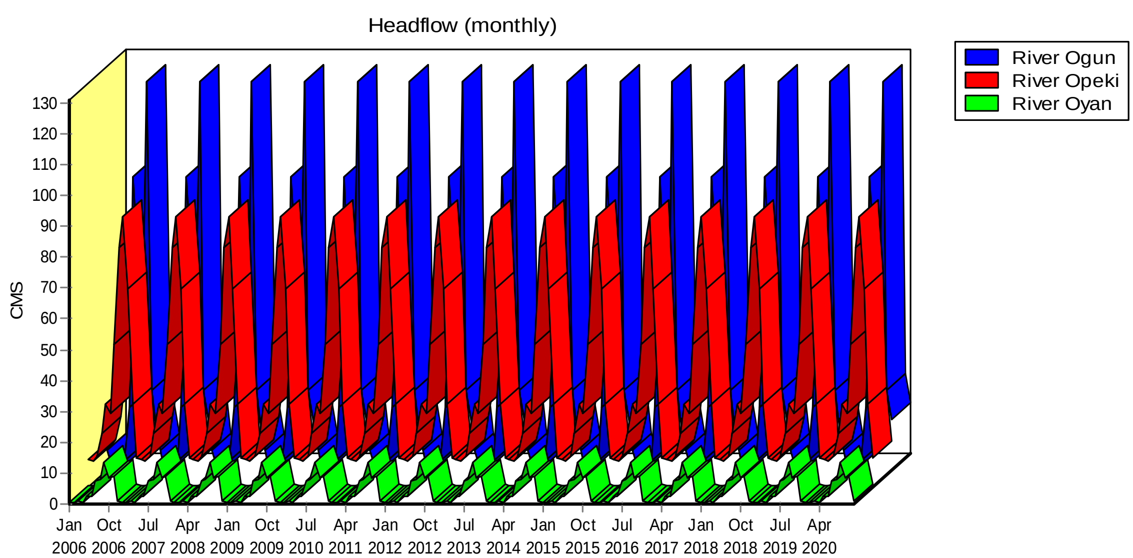

Figure 6: Annual river flow m^3 s^{-1} for the year 2006-2020

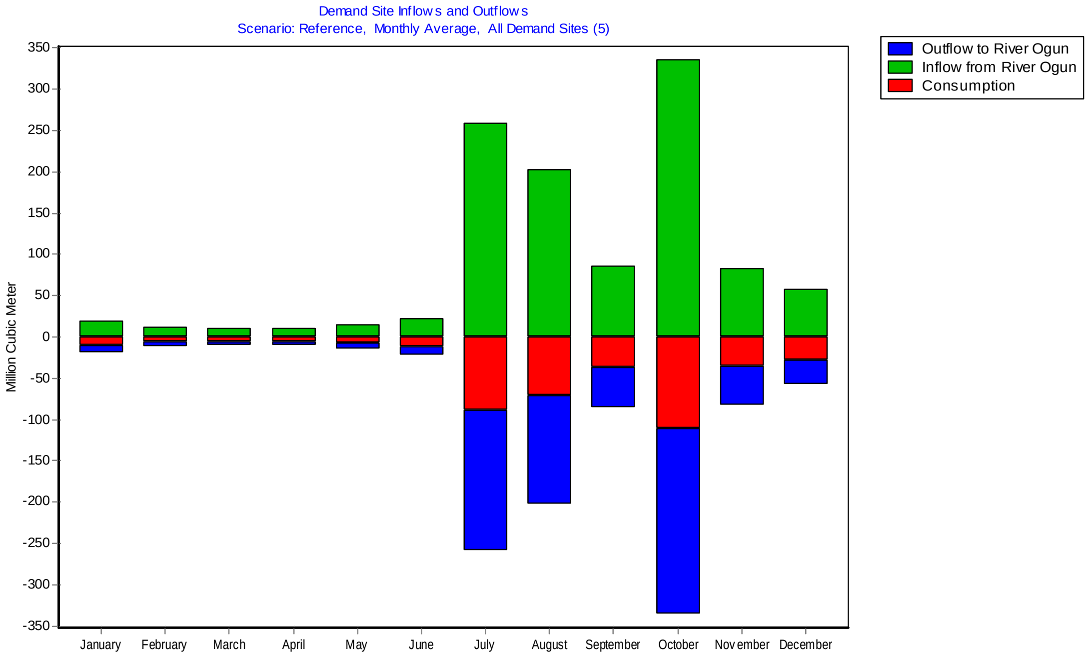

Figure 7: Monthly inflows and outflows of River Ogun and rate of consumption in 10^6 m^3

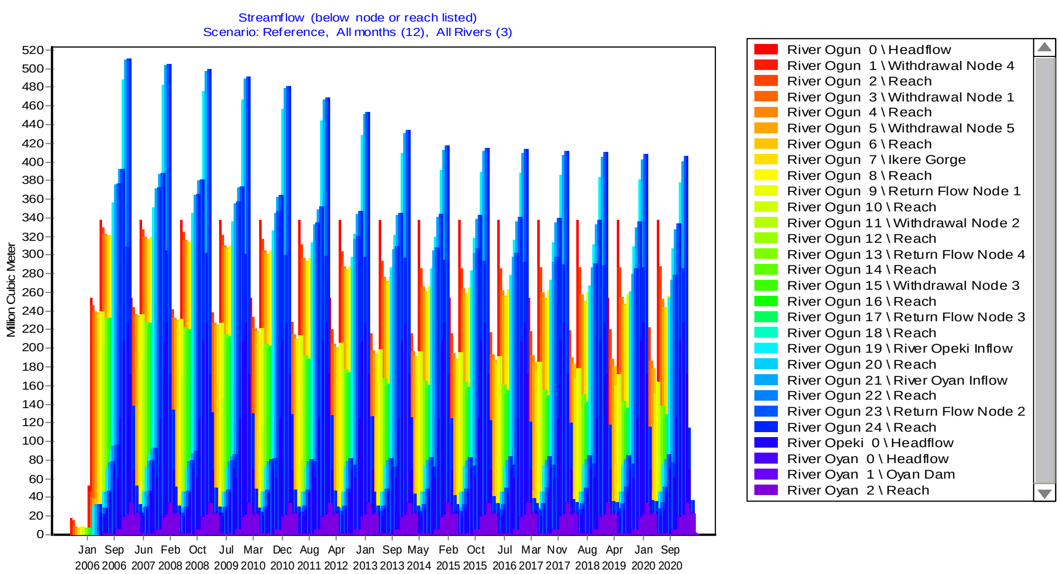

Figure 8: Annual stream flow in 10^6 m^3 for the year 2006-2020

Also in Figure 8, the inflow of water in the month of September for river Opeki and Oyan head flow are 2.27 X 10^8 m^3 and 3.45 X 10^7 m^3 respectively. In the month of October, the head flow of river Ogun is 3.37 X 10^8 m^3. Discharges from both rivers Opeki and Oyan into river Ogun is responsible for the observed increase in Ogun river flow. The increase is also attributable to the rainfall distribution pattern in the basin. Rainfall values are expectedly high during raining season, thereby increasing the volume of stream flow for the period. Figure 8 equally depicts more outflows from the areas due to high runoff generated by peak water level.

Table 8 further summarizes the derivation of unmet water demand as follows:

Required standard Unmet Water Demand:-
Delivered Supply – Required Supply = (9,978.8 – 78,865.5) = - 68,890.7 = **- 6.89 X $10^{10}m^3$**

Present Unmet Water Demand:-
Delivered Supply – Water Demand = (9,978.8 – 67,850.4) = - 57,871.6 = **- 5.79 X $10^{10}m^3$**

Table 8: Summary of various components as computed by WEAP Model for year 2012-2020

	Water Demand	Water Required	Water Delivered	Unmet Water Demand
Commercial Activities	10,842.6	12,047.4	1,144.7	10,902.7
Domestic Activities	53,203.6	62,592.4	5,949.0	56,643.4
Industrial Activities	2,463.3	2,592.9	1,378.5	1,214.4
Middle Ogun Irrigation	805.3	1,006.7	987.1	19.6
Lower Ogun Irrigation	535.6	630.1	519.5	110.6
SUM	67,850.4	78,869.5	9,978.8	68,890.7

NB: The Negative sign shows lack of water or unmet water demand; Source: WEAP Model Computation, 2011

Conclusions

Water resources are finite, while demands are increasing dramatically, driven by relentless growth of human activity in recent decades. River Ogun, Opeki and Oyan are vital source of freshwater for economic activities that include agricultural, industrial and commercial purposes. From the evaluation carried out in this study, the reservoirs do not suffer from water shortage.

The study revealed that the main consumption in Ogun river basin is the domestic demand, followed by commercial and industrial demand. For agricultural use, the middle and lower Ogun irrigation project have low level of water demand because irrigation practices, though still at infancy stage within the basin, is efficient and there is some level of technological improvement. The low level of water demanded from the river also in part depend on the availability of other complimentary water sources such as self supply boreholes and hand dug wells in urban areas, and self supply wells and streams in rural areas.

The WEAP simulation for the reference scenario from year 2012 to 2020 are 6.79 X 10^{10} m^3, 7.89 X 10^{10} m^3 and 9.98 10^9 m^3 for water demand, required supply and delivered supply respectively. Using the standard water per capita of 90 litres per person per day, the unmet water demand is 6.89 X 10^{10} m^3. Given the present water utilization status quo i.e. using below the standard water per capita use as stipulated by the United Nations, the unmet water demand stands at 5.79 X $10^{10}m^3$.

The monthly unmet demand for the various demand sites is pronounced between the months of March and June, and the effect is also noticed during August rainfall break and towards the month of December. The middle and lower Ogun irrigation project however have little or no unmet demand for the reported periods.

This study shows decline in the projected water supply for domestic and commercial activities from year 2014 to 2020, invariably resulting to rise in the unmet demand. There is also variation in the water delivered, attributable to the projected hydrological pattern within the basin. The implication of the projected scenario gives concern for water availability in the nearest future. There is therefore the need to be proactive in tackling the challenges of unmet water demand to avoid impending water crisis. Appropriate solutions should include but not limited to setting up of water metering systems, expansion of existing reservoirs, coupled with proper water resources monitoring through data acquisition. The above findings will no doubt help relevant authorities in making adequate provision for future water utilization.

References

Ayoade, J. O. (2003), *Tropical Hydrology and Water Resources*, Macmillan Publishers Ltd, London, ISBN: 0-333-45946-6

Fiorilloa, F., Palestirini, A., Polidori, P. and Socci. (2007), Modeling Water Policies with Sustainability Constraints: A Dynamic Accounting Analysis, Ecological Economics, 63 (2-3), pp. 392-402

Stockholm Environment Institute, SEI. (2001), WEAP: Water Evaluation and Planning system – user guide, Boston, USA

Sieber, J., Huber-Lee, A., & Raskin, P. (2002), WEAP: Water Evaluation And Planning System User Guide (WEAP 21), Stockholm Environmental Institute—Boston, and Tellus Institute, User Guide for WEAP 21, Boston, MA

Sieber, J., Yates, D., Huber Lee, A., & Purkey, D. (2005), WEAP: A demand, priority, and preference driven water planning model: Part 1, model characteristics, *Water International*, 30(4), pp. 487–500

UNESCO (2006), Water: a shared responsibility, The UN World Water Development Report 2, UNESCO, Paris

Wang Xiao – Jun, Zhang-Jian-Yun, Liu Jiu-Fu, Wang Guo-Qing, He Rui-Min, Wang Yan-Can, Zhang Ming and Liu Cui-Shan (2009), Water Demand Management instead of Water Supply Management: A Case Study of Yulin City in Northwestern China; Improving Integrated Surface and Groundwater Resources Management in Vulnerable and Changing World – IAS Publication, 330 pp.

Williams, J. S. (2010), United State Involvement in UNESCO's International Hydrological Program, U.S. Geological Survey

Yang, H., and Zehnder, A.J.B, (2007), A water resources threshold and its implication for food security, Environmental Science and Technology, 37 (14), pp. 3048-3045.

Environmental Management Conference
September 12 – 15, 2011

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Theme: Managing Coastal and Wetland Areas of Nigeria

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Communiqué

An Environmental Management Conference was held from September 12 -15, 2011 at the University of Agriculture, Abeokuta with the theme "Managing Coastal and Wetland Areas of Nigeria".
Assessing the challenges and solutions to environmental management in the coastal and wetland areas of Nigeria, professionals in the water, public health, urban planning and infrastructural development sectors discussed best practices, regulation and innovations for provision of safe and green environment. The following recommendations were made:

1. Experts in environmental and urban development should generate and make use of appropriate maps in developmental projects of fragile environments like the coastal and wetland areas;
2. Reclamation and regeneration of coastal and wetland areas of Nigeria;
3. Promotion of ecotourism to boost the economy of the country;
4. The government should be proactive in providing information on natural disasters like flood, seismic and volcanic activities by providing adequate number of seismic monitoring and hydrometeorological stations for sustainable monitoring and forecasting of natural hazards;
5. Enforcement of environmental policies to curb dumping of solid wastes and discharge of industrial effluents into the natural ecosystems by the advocate of polluter-pays policy;
6. The need to control the increasing encroachment of farming and building activities around the wetland to avoid soil erosion, removal of the vegetation and degradation of the ecosystem ;
7. Development of a mandatory localized sustainability reporting framework for deforestation, and land degradation due to oil and gas exploitation in line with international best practices;
8. Observation of high degree of surface water and shallow groundwater pollution calls for immediate action with respect to governmental operation of regulatory laws in respective local government areas in the country;
9. The inability of surface water development alone to satisfy the future water demand of water users was recognised. To reduce unmet demand, waste water treatment, introduction of water meters to check wastage, building of new dams or increasing the capacities of existing ones, groundwater development, information dissemination and development of manpower in the field of water resources are recommended.

These recommendations are specifically made in good faith for the attention of the following arms of government whom we consider as the direct stakeholders:

1. Federal Ministry of Water Resources
2. State Water Corporations
3. River Basin Development Authorities
4. Nigeria Integrated Water Resources Management Commission
5. Nigeria Society of Engineers
6. National Institute of Land Surveyors
7. Nigerian Mining and Geosciences Society
8. Federal Ministry of Environment

We regard this phenomenon as a critical challenge to all stakeholders, and we sincerely expect that ad hoc programmes would be initiated for a proper implementation of the remedial measures on all the above enumerated problems.

Prof. O. Martins
Chairman Local Organizing Committee

Dr. E. A. Meshida
Chairman Technical Sub-Committee

September 14, 2011

Acknowledgement

The Local Organising Committee of the Environmental Management Conference 2011, wishes to acknowledge the support of the Federal University of Agriculture, Abeokuta and Africa Geoscience Review, Paris, France.

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