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A CONCEPTUAL AND ANALYTIC MULTILEVEL DECISION SUPPORT MODEL ALGORITHM FOR SUSTAINABLE DEVELOPMENT

O. Ibidapo-Obe, FAS

ABSTRACT

This paper conceptualizes and analyses Decision Support Models (DSM) in relation to modeling complex national development scenarios in a bid to rationalize decisions taken in the inherently hierarchical structure of governance. In it, hypothetical decision support models are developed using Multi-level Programming (MLP) Approach at both micro and macro developmental levels. Various parameter estimation models are proposed to determine Development Performance Indices (DPI) used as technological constants influencing decisions in modeling to accomplish specified and quantified set goals at both the micro and macro developmental levels. From this, the levels of attention to be committed to the various sectors are predictable. A set of hypothetical developmental decision-making scenarios are used as test cases for various DPI models.

Key Words and Phrases: Governance, Decision Support Models (DSM), Algorithm, Developmental Performance Indices (DPI), Performance Parameters, Political Expedience Parameter (PEP), Multilevel Programming (MLP).

1. Introduction

This paper develops models for the measurement of the underlying parameters central to economic growth especially in a developing economy [1, 2]. Key parameters in developing economies include indices of employment poverty, wellness, etc. Gross National Development transcends the mere issues on GDP growth or re-debasing of the parameters and indicators for economic growth and economic development. While the latter duo is a virile indicator of the former, more is required in the gross national development as it encompasses social and economic developments. Economic growth is expected to translate to economic development and a virile economic development should translate to enormous social benefits. Oftentimes, this direct causal relationship is delayed [11]. Economic development, distinguished from economic growth, results from an assessment of the economic development objectives with the available resources, core competencies and the infusion of greater productivity, technology and innovation, as well as improvement in human capital, resources, and access to large markets. Economic development transforms a traditional dual-system society into a productive framework in which everyone contributes and from which everyone receives benefits accordingly [3]. However, social development in terms of infrastructural provisions, basic social amenities and enriched quality of life when all segments of the society benefit from the fruits of economic growth through economic efficiency and equity are what truly can be described as development. No development is complete if the society is not adequately benefiting from economic growth. In, fact economic efficiency will be present with minimum negative externalities to society, including agency, transaction, secondary, and opportunity costs.

Such development should however be sustainable. Development is the vital summation of all efforts to increase the quality of life whilst sustainability is the continued successful upholding and enhancement of this quality of life by getting the necessary ingredient/resources such as human labour and ecological resources replenished. Development occurs when the intrinsic-aspect is applied through technology to generate the physical aspect. Technology confirms the existence of the intrinsic aspects and creates the physical aspect to manifest development.

Developmental issues are particularly very complex [7, 8, 10] and may be considered that their solutions are not easily amenable to mathematical analysis. However, with advances in software development methods and means of scientific analysis, such complex scenarios can be modeled, at the worst case, as scaled-down models

whose assumptions can be gradually relaxed to give room for more of reality. Developmental pursuits at any level (governmental, institutional or industrial) are based on goals set by the principal actors of such establishments amidst identifiable and non-identifiable constraints or limitations influenced in part or in all by available and reliable resources as well as availability, precision and nature of planning data necessary to make necessary developmental decisions.

It is only realistic that in every human decision making pursuit; subjective elements come in and may need to be factored into any objective evaluation of such decision-making modeling if any meaningful results will be obtained. In governmental decision making scenarios, for example, political elements (noise) will definitely add to the complexities of the decision making. The inclusion of these subjective elements, underscores the importance of the use of historical data, user-defined Development Performance Index (DPI) component or consensus parameters. For one, for any performance measure that needs to be used, the historical evolution of the development data must have been influenced by both subjective and objective elements of development and hence becomes a good tool to forecast, plan and analyze with.

2. Modeling Methodology

In this paper, the procedure is to conceptualize Multi-level Programming models for developmental decisions at the micro and macro levels (tiers) of governmental decision-making structure.

2.1 Developmental Decisions and the Nature of Multi-level Programming

2.1.1 *Multi-Level Programming*

The realizations of the relational effects of the variables of development are in hierarchies even at the macro-level. A good strategy for optimizing the function is to use the concept of multi-level optimization model [9].

Multi-level optimization models are employed to solve decentralized planning decision problems in which decisions are made at different hierarchical decision levels in a top-to-down fashion. Essentially the features of such Multi-level planning organizations are that interactive decision-making units exist within a predominantly hierarchical structure.

Each unit independently maximizes its own net benefit but is affected by the actions of other units through externalities and the external

effect of a Decision Maker's (DM's) problem can be reflected in both the objective function and the feasible decision space.

The mode of execution (algorithm) of such decision problem is that:

- The upper level DM sets his goal and accepts the independent decisions at the lower levels of the organization.
- The upper-level DM modifies it within the framework of the overall benefit of the organization.
- The upper level DM's action further constrains the lower level decision space and may or may not be acceptable at that level. If it is not acceptable, the upper level DM can still make a consensus that the constraints are relaxed further.
- This process is carried out until a satisfactory solution to all levels and units of decision-making is arrived at.

2.1.2 *Conceptual Multi-level Development Levels*

In typical developmental decision-making scenarios, decision-makers on issues of development may be in different echelon of the scheme having diverse contributions over which they have subjective controls. Conceptually, three typical echelons of decision-makers can be construed.

Inter-governmental decision levels

In some countries, some issues of development are shared across more than one level of governance (ministries) where each level has control over some aspects of the overall issue of development. In this kind of developmental scenario no single level has absolute control although some levels have supervisory role over their immediate lower level in the hierarchy of governance.

For example in some countries, there are three levels of governance: *the Federal, States and Local Governments* where the Federal government has direct and indirect supervisory roles over the States and Local Governments respectively while the States directly supervises the Local Governments. On issues like educational development, the local government has control over Basic Education (the primary level), the State has the largest control over Secondary Schools (although may be in control of self-owned tertiary institutions) while the Federal has control over Tertiary educational institutions (although may own some model secondary schools too). A similar picture ensues in other sectors such as Health, Education, Agriculture, Security etc. Controls exercised at each level of governance will be in terms of funding, administration and regulation. In these areas of control the Federal supervises the States while the States in turn supervises the Local Government.

Intra-governmental decision levels

Interestingly too, under a sole institutional governance, there are units and sub-units hierarchically supervised and in control of aspects of developmental issues. These also can constitute hierarchical decision-making organ of development.

Macro-organ of Inter and Intra-governmental decision levels

In the macroscopic perspective, the two scenarios of decision-making above are intertwined resulting in a gigantic structure encompassing both parallel and serial decision-making organs responsible for decisions on a developmental issue within and across governmental levels.

2.1.3 *The General Multi-Level Development Decision-Making Model*

The comprehensive General Multi-Level Development Decision-Making process is characterized by an apex decision-making unit under which are other levels of developmental decision-making units. The echelon of decision-making units is such that each decision-making unit at each level is responsible for supervision over a number of lower level decision-making units. Decision-making are supervised top to bottom and complemented at the same decision level (See Figure 1).

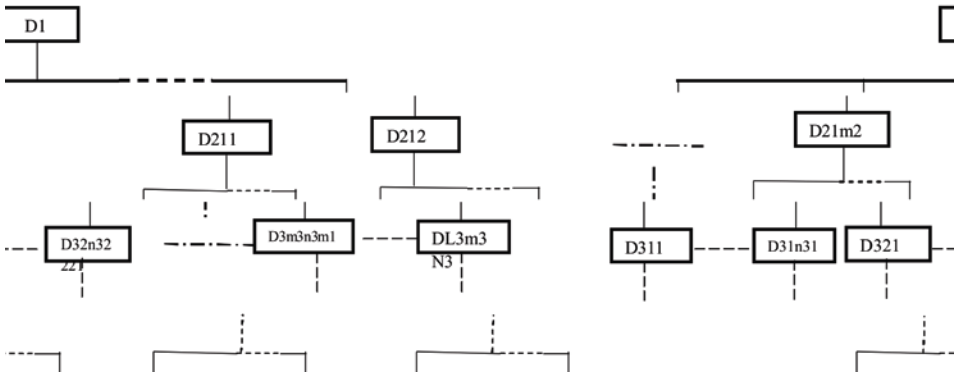

Figure 1. A Hierarchical Structure of Governance.

Mathematically expressed,

Let the developmental decision variable space (DDVS), be a Euclidean n-space i.e;

$$\Re^N \ni \mathbf{X} = (\mathbf{X_1}, \quad \mathbf{X_2}, \quad \ldots \mathbf{X_N}),$$

be partitioned among N-levels of decision-making hierarchies, where $X_r = \{X^{(rj)}\} = \{x_{rjk}^{uv}\} X_r = \{X^{(rj)}\} = \{x_{rjk}^{uv}\}$ is the rth decision-making vector comprising of the kth decision variables of the jth decision-making block at that level. In a full-blown hierarchical structure, the

jth block of the immediate lower level of a decision making echelon is connected directly to the uth decision making unit of the vth immediate upper decision making block, except at level r = 1.

$\mathfrak{R}^{n_{rj}} \ni X^{(rj)} = \left(x_{rj1}^{uv}, \quad x_{rj2}^{uv}, \quad \ldots x_{rjn_{rj}}^{uv}\right)$ For

$r = 1, \quad \ldots N \; , j = 1, 2, \ldots, m_r \; , k = 1, 2, \quad \ldots, n_{rj}$

representing the variables that each decision making block j at level r controls.

The objective of the decision-making programme, given $f(X)$ defined over $\mathfrak{R}^N$ and varying $X_r \in \mathfrak{R}^N X_r \in \mathfrak{R}^N$ given fixed

$X_{r+1}, X_{r+2}, \quad \ldots, X_N$ in

$\mathfrak{R}^{m_{(r+1)}} \times \mathfrak{R}^{m_{(r+2)}} \times \ldots \times \mathfrak{R}^{m_N}$ which in turn are realized from fixed $X^{(rj)} \in \mathfrak{R}^{m_r}$ for each decision block j, j = 1, 2, . . . , m_r whose decision are supervised by a unit u in block v at an immediate upper level r = r – 1. $r \neq 1$ with fixed

$X^{(r+1)j}, \quad X^{(r+2)j}, \ldots, X^{Nj} \in \mathfrak{R}^{n_{(r+1)j}} \times \mathfrak{R}^{n_{(k+1)j}} \times \ldots \mathfrak{R}^{n_{Nj}}$

for all j, j = 1, 2,. . , $m_{r+1}, \quad m_{r+2}, \quad \ldots, m_N$

respectively. The apex decision making objective translates to

$$\mathbf{P}^{(1)} \begin{cases} \mathbf{Max.}\ \{\mathbf{f}_1(\mathbf{X}) : \{X_1 | X_2, \quad X_3. \ldots, X_N\}\} \\ \mathbf{s.t.}\ \mathbf{X} \in \mathbf{S}^{(1)} = \mathbf{S} \\ \square \end{cases}$$

where the feasible decision-making region, $\mathbf{S} = \mathbf{S}^{(1)}$ defines the **Decision Level-One (DL-1) feasible region** and is defined by a set of constraints. Note that there is only one decision-making unit at the apex, thus for r = 1, $m_r = 1$.

The solution to $\mathbf{P}^{(1)}$ in $\mathfrak{R}_1^N$ for each fixed

$\{X_2, \quad X_3. \ldots, X_N\} = \left\{\mathbf{X}^{(2j)}, \quad \mathbf{X}^{(3j)}, \quad \ldots \mathbf{X}^{(Nj)}\right\}$ over

all decision block j,

$$j = 1, 2, \quad \ldots, m_r, \quad r = 2, \quad 3, \quad \ldots, \quad N$$

form a set,

$$S^{(2)} = \left\{\hat{X} \in S^{(1)}: f_1(X) = \text{Max. } f_1(X): \{X_1 | X_2, \quad X_3, \ldots, X_N\}\right\} \text{ over all blocks } j, j = 1, \ldots, m_r$$

, called the **Decision Level-Two (DL-2) feasible region** over which $f_2(X)$ is then maximized by varying X_1 for fixed $X_3, \quad X_4, \ldots, X_N$.

The problem at DL-2 is given by,

$$\mathbf{P}^{(2)} \begin{cases} \mathbf{Max.}\ \mathbf{f_2}(\mathbf{X}): \{\{X_2 | X_3, \quad X_4, \ldots, X_N\}\} \\ \mathbf{s.t.}\ \mathbf{X} \in \mathbf{S}^{(2)} \in \mathbf{S}^{(1)} \end{cases}$$

$p^{(2)}$ is solved at each decision block j by aggregating the solutions of the optimization problem,

$$\mathbf{w}^{(2j)} \begin{cases} \mathbf{Max.}\ \mathbf{g_{2j}}(\mathbf{X}): \left\{\left\{X^{(2j)} \middle| \bar{X}^{(2j)} = \left\{x_{3zk}^{jv}\right\}\right\}\right\} \\ \mathbf{s.t.}\ \mathbf{X} \in \mathbf{S}^{(2j)} \in \mathbf{S}^{(2)} \\ \mathbf{over\ all\ blocks\ j, j = 1, 2, \ldots, m_2\ at\ level\ 2} \end{cases}$$

Where $\bar{X}^{(2j)}$ is the set of all decision-making unit variables at the immediate lower level r = 3, over all blocks z and units k at that level over which DL-2j supervises.

$w^{(2j)}$ is also solved aggregating the optimal solutions of the individual decision-making units by

$$\mathbf{z}^{(2jk)} \begin{cases} \mathbf{Max.}\ \mathbf{h_{2jk}}(X): \left\{x_{2zk}^{jv} \middle| X^{3\bar{j}}\right\} \\ \mathbf{s.t.}\ X \in \mathbf{S}^{(2zk)} \in \mathbf{S}^{(2j)} \\ \mathbf{k = 1, 2, \ldots, n_{2j}\ at\ level\ 2} \end{cases}$$

In general, the DL-r feasible region is defined as.

$$S^{(rj)} = \left\{ \hat{X} \in S^{(r-1)j} : f_{(r-1)j}(X) = \text{Max. } f_{(r-1)j}(X) : \left\{ X^{(r-1)j} \,\middle|\, \left(X^{(rj)}, X^{(r+1)j}, \ldots, X^{(Nj)} \right) \right\} \right\}$$

The decision-making problem at each unit j of each level r is,

$$\mathbf{P^{(r)}} \begin{cases} \mathbf{Max.\ f_r\ (X)} : \{\{X_r | X_{r+1}, \quad X_{r+2}, \ldots, X_N\}\} \\ \mathbf{s.t.\ X \in S^{(r)} \in S^{(r-1)}} \end{cases}$$

$P^{(r)}$ is solved at each decision block level j by aggregating the solutions the optimization problem,

$$\mathbf{w^{(rj)}} \begin{cases} \mathbf{Max.\ g_{rj}\ (X)} : \left\{ \left\{ X^{(rj)} \middle| \bar{X}^{(rj)} = \left\{ x^{jv}_{(r+1)zk} \right\} \right\} \right\} \\ \mathbf{s.t.\ X^{(rj)} \in S^{(rj)} \in S^{(r)}} \\ \mathbf{over\ all\ blocks\ j, \quad j = 1, 2, \ldots, m_r\ at\ level\ r} \end{cases}$$

Where $\bar{X}^{(rj)}$ is the set of all decision-making unit variables at the immediate lower level r = r + 1, over all blocks z and units k at that level over which DL-rj supervises.

$W^{(rj)}$ is also solved aggregating the optimal solutions of the individual decision-making units by solving

$$\mathbf{z^{(rjk)}} \begin{cases} \mathbf{Max.\ h_{rjk}\ (X)} : \left\{ x^{jv}_{rzk} \middle| X^{r\bar{j}} \right\} \\ \mathbf{s.t.\ } x^{jv}_{rzk} \in \mathbf{S^{(rzk)} \in S^{(rj)}} \\ \mathbf{k = 1, 2, \ldots, n_{rjk}\ at\ level\ r} \end{cases}$$

The entire Multi-Level Decision problem is defined by the solution at the apex unit defined by,

$$P^{(N)} = \begin{cases} \underset{x \in S^{(N)}}{\mathbf{Max}} f_N(X): \{\{X\} | X_2, \quad X_3, \quad \ldots, \quad X_N\} \\ X \in \mathbf{S} \end{cases}$$

For this work, the linear variant of the model is adopted. For each decision-making level, this translates to

$$\left.\begin{array}{l} \underset{X_1}{\mathbf{Max}}\ z_1 = C_1 X \\ subject\ to: \\ A_1 X \leq B_1 \end{array}\right\}$$ Level 1 Decision Making

$$\left.\begin{array}{l}\underset{x_{21k}^{1v}}{\mathbf{Max}}\ z_{21k} = C_{21k}^{1v} X \\ \quad subject\ to: \\ A_{21k}X \leq B_{21k}\end{array}\right\} for\ all\ decision\ units\ k\ on\ level\ \mathbf{2}\ connected\ to\ level\ \mathbf{1}$$

$$\left.\begin{array}{l}\underset{x_{rjk}^{uv}}{\mathbf{Max}}\ z_{rjk} = C_{rjk}^{uv} X \\ \quad subject\ to: \\ A_{rjk}X \leq B_{rjk}\end{array}\right\} for\ all\ decision\ units\ k, block\ j\ on\ level\ r\ connected\ to\ vth\ unit,$$

$$block\ v\ on\ level\ \ r-\mathbf{1}\ \ block\ v\ on\ level\ \ r-\mathbf{1}$$

$$\left.\begin{array}{l}\underset{x_{Njk}^{uv}}{\mathbf{Max}}\ z_{Njk} = C_{Njk}^{uv} X \\ \quad subject\ to: \\ A_{Njk}X \leq B_{Njk}\end{array}\right\} for\ all\ decision\ units\ k, block\ j\ on\ level\ N\ connected\ to\ vth\ unit,$$

$$block\ v\ on\ level\ \ N-\mathbf{1}\ \ block\ v\ on\ level\ \ N-\mathbf{1}$$

Development decision variables,

$X_r = (X^{r1}, X^{r2}, \ldots, X^{rj}, \ldots X^{rm_r}),\ r = 1,2,\ \ldots, N\ where,\ X^{rj} = \left(x_{rjk}^{uv}\right)\ for\ j = 1,2,\ldots,m_r, k = 1,2,\ \ldots, n_{rj}$ for each level r widely vary.

The decision parameters, consists of three groups: the objective coefficients, the development constraints' (technological coefficients) and the set of bounds for the constraints at each developmental level. The objective coefficients are,

$$C_{rjk}^{uv},\quad r = 1,2,\ldots,N;\ j = 1,2,\ldots,m_r\ and\ k = 1,2,\ldots,\quad n_{rj}$$

The constraint technological coefficients at each level of development are,

$A_{rjk},\quad j = 1,2,\ldots,m_r\ and\ k = 1,2,\ldots,n_{rj}$ an $\left[\!\left[(m_r.n]\!\right]_{jk}\right) \times \mathbf{1}$ or $m_r \times n_{rj}$ matrix of constants representing constraints of development at each level r depending on whether the constraints are written for the whole level or for each decision block. Finally, the bounds on the constraints of development are,

$B_{rkj},\quad j = 1,2,\ldots,m_r\ and\ k = 1,2,\quad \ldots,n_{rj}$ a singleton of a column matrix $n_{rj} \times \mathbf{1}$, depending on how the technological constraints A_{rjk} are ordered representing bounds on the constraints of development at each level r.

In some respects, all the objectives at all levels may be subjected to a set of constraints

A_{rjk}, $j = 1, 2, \ldots, m_r$ and $k = 1, 2, \ldots, n_{rj}$ over all $r = 1, 2, \ldots, N$

.

The essence of this work is to conceptualize the analytical framework for the essentially hierarchical decisions involved in the development model in order to evolve a rational method of multi-level decision in that sphere. In effect, appropriate models must be developed for the estimation of C_{rjk}^{uv} (C- parameters) and A_{rjk} (A- parameters) for a particular development scenario at the either the macro-development or micro-development level. The B_{rjk} (B- parameters) will usually be specified at each level.

This hierarchical model can be viewed as deterministic, stochastic, fuzzy, fuzzy-stochastic and stochastic-fuzzy models depending on how the parameters engrained in various functions of the decision variables in the model. In the current work, the variables are grossly assumed deterministic and the parameters are also determined as such.

3. The Development Model.

Development is the vital summation of all efforts made to increase the quality of life whilst sustainability is the continued successful upholding and enhancement of this quality of life by getting the necessary ingredient/resources such as human labour and ecological resources replenished. Development occurs when the intrinsic aspect is applied through technology to generate the physical aspect. Technology confirms the existence of the intrinsic aspects and creates the physical aspect to manifest development. In segregating the components that make up development (although largely fuzzy because of the interrelationships of the indices); the model is hierarchical. It can therefore be resolved through multilevel programming (MLP).

3.1. A Typical Macro-Development Scenario and Variables

The decision-making organogram for optimizing development definitely consists of hierarchically-intertwined variables and parameters at both the micro and macro levels of decision-making. The objective of decision-making at any of the levels will be to optimize one or more functions of the variables constrained by limitations and bounds within individual or across the levels of decision-making.

A typical way to view development at the macro level is as function of Capital and Technology as depicted in the Figure 2 below.

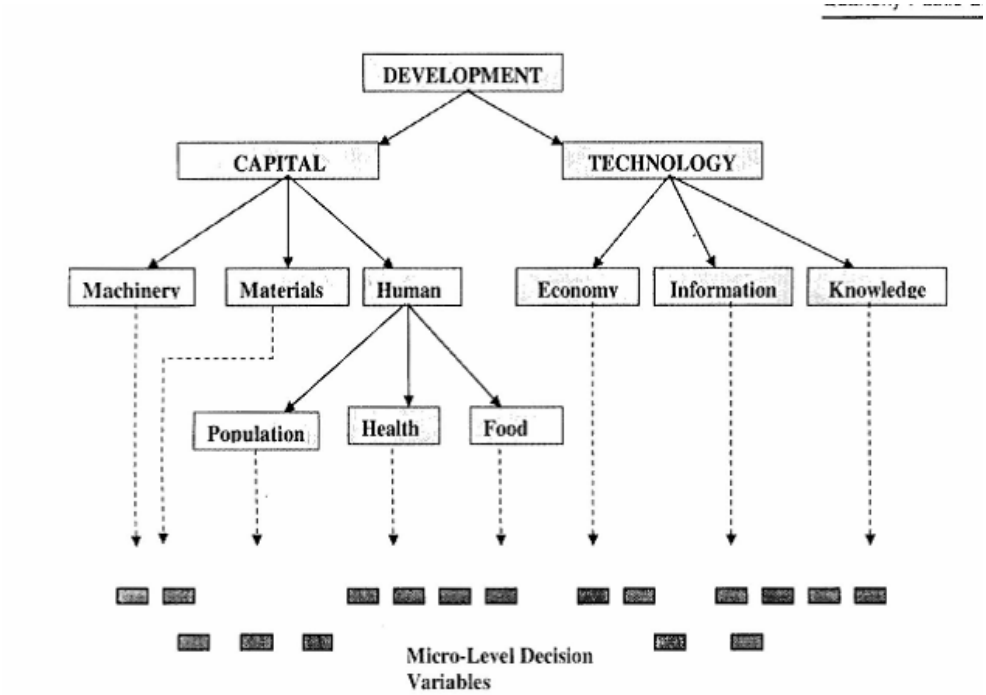

Figure 2: Hierarchical Representation of Macro and Micro Development Variables.

3.2 The Macro Model

Consider development (D) as a multi-variate non-linear function of Capital (C), Technology (T), Knowledge (K), Food (F) and Health (H),

$$\mathbf{D = D(C, T, K, F, H)}$$

Clearly **C, T, K**, **F** and **H** are not independent variables.
A compact analysis of the behaviour of **D** can be facilitated through the following **dimensionality reduction:**
Capital**(C)** can be defined as an inventory of infrastructure machinery (m_1) that is the plant, equipment, etc., materials (m_2) and human resources (r).

$$\boldsymbol{C = C}\ (m_1, m_2, r)$$

Since human resources, h itself can be viewed as function of population (P), health (H) and food (F), and then the functional representation for r is

$$r = r\ (P, H, F)$$

Thus, Capital ***C*** can be represented functionally as,

$$\mathbf{C = C}\ (m_1, m_2, r\ (P, H, F))$$

Following similar argument, since the technology variable T, depends on the average performance measure of all productive processes in the economy: l as the level of development and utilization of information technology: i as the average experience and intelligence in the society i.e. **T** becomes:

$$\mathbf{T} = \mathbf{T}(l, i)$$

Thus the development the resulting non-linear equation for **D** can be written as,

$$\mathbf{D} = \mathbf{D}(\mathbf{C}, \mathbf{T}) = \mathbf{D}(\mathbf{C}(m_1, m_2, r(P, H, F)), T(l, i)))$$

At the micro level, there are myriads of variables on which each of the variables above depends.

3.3 Modeling Sustainable Multi-level Development Model Parameters

The goal of sustainable development is an outcome achieved through joint effort among several interrelated parameters and requiring coordination at both vertical and horizontal levels. There exists dynamic triangular relationship among three key **Environmental**, **Economic** and **Social** parameters.

In the ensuing models [4], it is assumed that there are common indices of measurement of development parameters or at the worst that all such parameters are convertible to the same units. Such parameters may be performance or desired environmental, economic or/and social indicators which are engrained into the model to determine optimal allocation of resources or level of attention.

3.2.1. *Regression Models for Historical Performance Indices*

This group of models presumes that there exist historical data of performance indices used for decision-making over appreciable time duration. Since, development is a growing scenario, the linear or exponential growth regression models are used. These models may be applied to singular parameters of a decision-making unit, the set of all parameters of individual decision unit, the set of all parameters of all decision units at a level of decision-making or all parameters of the model, depending on size and adjudged inter-dependence. The parameters may be estimated individually or collectively as parameters of a block of decision units or level parameters.

The general task of regression analysis is defined as identification of a functional relationship between the independent variables $X = [x_1, x_2, \ldots, x_n]$ and dependent variables $Y = [y_1, y_2, \ldots, y_m]$ where n is a number of independent variables in each observation and m is a number of dependent variables. The regression model thus generally be is expressed as,

$$Y = f(X) + \varepsilon$$

where $f(X)$ a vector is function, $[f_1(X), f_2(X), \ldots, f_m(X)]$ and $[\epsilon_1, \varepsilon_2, \ldots, \varepsilon_m]$ is a vector of random error functional approximation. For the purpose of the ensuing analysis, linear relationship between the dependent variable Y and independent variable X are assumed giving rise to the relationships,

$$y = a_0 + a_1 x + \varepsilon$$

or generally,

$$Y = a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_n x_n + \varepsilon$$

referred to as simple linear and multiple linear regression models respectively.

The single development parameter $\hat{p}\hat{p}$ and the Vector development parameter $\hat{P}_{rj} = [\hat{p}_{rj1}, \hat{p}_{rj2}, \ldots, \hat{p}_{rjn_{rj}}]$ for a group of decision units in a decision block or

$\hat{P}_r = [\hat{p}_{r1}, \hat{p}_{r2}, \ldots, \hat{p}_{rm_r}]$ a group of decision blocks at a decision level r, $r = 1, 2, \ldots, N$,

$j = 1, 2, \ldots, m_r$

$\hat{p}_{rjk} = a_0 + a_1 p_{rjk} + \varepsilon$ for a single decision unit.

$$\hat{P}_{rj} = a_0 + a_1 p_{rj1} + a_2 p_{rj2} + \ldots + a_{n_{rj}} p_{rjn_{rj}} + \varepsilon_{rj}$$

for block decision parameters

$\hat{P}_r = a_0 + a_1 p_{r1} + a_2 p_{r2} + \ldots + a_{m_r} p_{rm_r} + \varepsilon_r$ for level decision parameters

The constants, a_0, a_1, $a_2, \ldots, a_{n_{rj}}$ or a_{rm_r} are estimated from available historical records of the parameters used in previous time periods. Thus the A- and C- parameters can be authentically determined. Development sustainability can be inferred from the use of this approach because all the three indicators of sustainability (social, economic and environmental) engrained in previous parameters are inherited via the historical data used.

3.3.2. ***Moving Average Parameter Estimation Model***

Just as for the regression model estimation, historical data of development parameters can also be used in Moving Average Models to estimate development parameters.

3.3.3. ***Direct Contributory Development Parameter Estimation Models.*** The ensuing series of development parameter estimation models assume that performance Indices for social, economic and environmental indicators can be obtained from a particular penultimate planning period and thus be used to determine such parameters for the planning period in view.

In the ensuing models,

s_{rjk} , e_{rjk} and v_{rjk} represent single decision units of social, economic and environmental parameters.

$S_{rj} = [s_{rj1}, s_{rj2}, \ldots, s_{rjn_{rj}}]$,

$E_{rj} = [e_{rj1}, e_{rj2}, \ldots, e_{rjn_{rj}}]$, and

$V_{rj} = [v_{rj1}, v_{rj2}, \ldots, v_{rjn_{rj}}]$ represent the vectors of social, economic and environmental parameters at a decision block unit j, $j = 1, \ldots, m_r$ $j = 1, \ldots, m_r$ and level r, $r = 1, 2, \ldots, N.$ $S_r = [s_{r1}, s_{r2}, \ldots, s_{rm_r}]$,

$E_r = [e_{r1}, e_{r2}, \ldots, e_{rm_r}]$ and

$V_r = [v_{r1}, v_{r2}, \ldots, v_{rm_r}]$ $V_r = [v_{r1}, v_{r2}, \ldots, v_{rm_r}]$ represent the vectors of social, economic and environmental parameters at a decision level r, $r = 1, 2, \ldots, N.$

These models also incorporate Political Expedience Parameters (PEP),

$P_{rj} = [p_{rj1}, p_{rj2}, \ldots, p_{rjn_{rj}}]$ or

$P_r = [p_{r1}, p_{r2}, \ldots, p_{rm_r}]$, to cater for possible political intrigues which cannot be estranged from development decision issues.

3.3.4. ***Average Additive Parameter Models***

Averages are unbiased estimators. The additive model assumes equal contributions from the three indicators in other to sustain the development scenarios of the penultimate planning period. Thus,

$\hat{y}_{rjk} = \frac{1}{3}(s_{rj} + e_{rjk} + v_{rjk} \pm p_{rjk})$ for a single decision unit k

$$\hat{Y}_{rj} = \frac{1}{3n_{rj}}\left(S_{rj} + E_{rj} + V_{rj} \pm P_{rj}\right)$$ for block decision parameters.

$$\hat{Y}_{r} = \frac{1}{3m_{r}}\left(S_{r} + E_{r} + V_{r} \pm P_{r}\right)$$ for decision level parameters

Following the same argument above, other models such as the *Average Additive Reciprocal Parameter Models, Average Pair-wise Multiplicative Reciprocal Parameter Models and Hybridized Average Parameter Models* can be built for estimation of the parameters of the model.

4. Hypothetical Test Problem

A regional road agency is to determine the level of commitment to three hierarchies of road-jurisdictions (the Central-Regional, Sub-Regional and District jurisdictions) under its control from allocated funds. For rational sustainable development each jurisdiction has to determine *sustainable parametric values* for its contribution to each road jurisdiction's lot in its domain. The projected fund available to it from different sub-regional and district levels is X.

A developmental test problem is postulated here as

$$X = (x_{10_0}, x_{21_0}, x_{22_0}, x_{23_0}, x_{31_1}, x_{31_2}, x_{31_3}, x_{32_1}, x_{32_2}, x_{32_3}, x_{33_1}, x_{33_2}, x_{33_3})$$

Solution Methodology

This study employs Genetic Algorithm approach [5] to solve the hierarchical decision problem.

Apart from the conventional GA operators this scheme uses remedial operators to fix infeasible chromosomes that do not satisfy constraints at different levels of the hierarchical decision making process. The remedial scheme is described in detail below. Furthermore, in this study and as used in [5], fitness functions for the chromosomes is based on construction of hierarchical form of feasible degree used in [6]. A novel double point cross-over scheme using the fore-knowledge of degrees of infeasibility is deployed.

Algorithm: ***Genetic Algorithm for Semi-Cooperative Multifollower Trilevel Programme***
Begin
Read [I, J, $N_i N_i$, $B\ B$, $P\ P$, M, C, G, T, Term_Crit., Flag_off]

Initialize Term_Crit. = False, t = 0, Flag_off = False

Generate Initial GA population ‘generate population size $P(0)\,P(0)$

DO While Term_Crit. = False is false ‘Execute while termination criterion

Check Level 1 Feasibility

Remediate Leader Constraint(s) ‘Make $P(t)P(t)$ feasible - satisfying the

Evaluate ‘evaluate $P(t)P(t)$, obtain leader optimal variable values

Constraint Satisfaction *level 2* *‘chromosomes not satisfying go to Buffer* $\bar{P}(t)\bar{P}(t)$

Update $|P(t)|\ |P(t)|$ ‘update number of feasible chromosomes

DO While $|P(t)| \geq T\ |P(t)| \geq T$ *‘Execute if remaining number of chromosomes greater or equal to threshold value*

DO While $i \leq I\ i \leq I$ *‘Level 2 decision units*

Constraint Satisfaction *level 3* *‘chromosomes not satisfying go to Buffer* $\bar{P}(t)\bar{P}(t)$

Update $|P(t)|\ |P(t)|$ ‘update number of feasible chromosomes

OD

DO While $i \leq I\ i \leq I$ *‘Level 2 decision units*
Evaluate *‘evaluate feasibility degrees for unit Level 2 unit I*

DO While $n_i \leq N_i n_i \leq N_i$ *'Level 3 decision units in block under i*

Evaluate *'evaluate feasibility degrees for unit* $n_i \;\; n_i$ *under Block i*

OD
OD

Merge *'make* $P(t)P(t) = P(t)P(t) + \bar{P}(t)\bar{P}(t)$

Crossover *'genetic operator*
Mutate *'genetic operator*
t = t + 1

'check Term_Crit.

OD *'Exit loop remaining number of chromosomes less than threshold value*
OD *'Leave main execution loop when Term_Crit. = TrueEnd of algorithm*

Conclusion and Extensions

The approach in this paper for the solution of hierarchical decision problem and tested with a hypothetical decision problem has demonstrated the potential of the mathematical programming and Genetic Algorithm to solve the postulated decision problems. However, this decision support problem solving approach can be made interactive and contributory. A complete interactive software, in which the problem can be formulated from practical point of view and all players contribute, before the optimization tool (the Genetic Algorithm) can provide various scenarios to the decision makers, is being developed. Furthermore, the subject of uncertainty is key in decision-making problems as most development parameters are bugged with it. To obtain precise parameters may be difficult but achievable. As further extensions, we exploit the possibilities of using imprecise data and model formulations under Fuzzy and Stochastic uncertainties and combinations of both in the ensuing works.

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REFERENCES

References.

1. Ibidapo-Obe. O. (2006) "Modeling, Identification/Estimation in Stochastic Systems". In Badiru, A.B.: *Handbook of Industrial and Systems Engineering.* 14: I - 16. CRC Press, Taylor and Francis Group, New York.
2. lbidapo-Obe O. and Sunday Asaolu (2006): "Optimization Problems in Applied Sciences: From Classical through Stochastic to Intelligent Metal-heuristic Approaches". In Badiru, A.B. *Handbook of Industrial and Systems Engineering.* 22: 1-18; CRC Press, Taylor and Francis Group, New York.
3. . Kooros, S. K and Badeaux, L. M; Economic Development Planning Models: A Comparative Assessment. *International Research Journal of Finance and Economics*. Issue 7 (2007) *pp 120 -139*
4. Marti, K. (1996), "Stochastic Optimization Methods in Engineering". *In System Modeling and Optimization.* J. Dolezal, 1. Fiedler (eds.) Chapman and Hall, London
5. Ogunwolu, L., Ibidapo-Obe, O. and Onyedikan, C. (2014): Modelling and Analysis of a Supply Chain with Supply, Production and Distribution Reliability Consideration. Int. J. Sup. Chain Mgt. Vol. 3, No. 1. Pp.41-51.
6. Osman, M. S., Abd El-Wahed, W. F., Mervat M. K. El Shafei, and Hanaa B. Abd El Wahab. A Solution Methodology of Bi-Level Linear Programming Based on Genetic Algorithm. Journal of Mathematics and Statistics 5 (4): 352 – 359,
7. Takagi, T. and Sugeno, M. (1985) "Fuzzy identification of systems and its applications to modeling and control", *IEEE Trans. Syst. Man Cybern.*, vol. 15, pp. 116-132.
8. Zadeh, L.A. (1965) Fuzzy Sets. *lnformation and Control* 8:338-35~.
9. Zhang, G., Lu,J., Montero, J. and Zeng, Y(2010): Model, Solution concept and kth-best algorithm for linear trilevel programming. Information Sciences. Vol.180, pp. 481-492.
10. Zimmermann, H. (1992) *Fuzzy Set Theory and its Applications.* Kluwcr Academic Publishers Boston.
11. http://www.unescap.org/drpad/vc/orientation/M8_intro.htm

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FOSTERING UNIVERSITY – INDUSTRY LINKAGES IN NIGERIA: CASE STUDY OF SOME RMRDC PROJECTS

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ABSTRACT

Different governments over the years have implemented a number of development programmes in Nigeria including the present Transformation Agenda which is implementing reforms in different sectors including agriculture, aviation, railways and roads, power, manufacturing, education etc. Unfortunately, although the country is currently the largest economy in Africa and 26th in the world, in terms of Competitiveness, Nigeria was ranked 95th out of 131 countries in 2007 and 120 out of 148 countries in 2013 in Global Competitiveness Index, GCI (WEF, 2014). This ranking places Nigeria in the poorest pool of countries like Mali, Uganda and Liberia. The top 10 economies with high GCI share characteristics of strong institutions and innovation. This paper suggests that for Nigerian economy to significantly improve, it must shift from a consumption to a production based economy. This can be achieved through a functional National System of Innovation (NSI) which must be based on the Triple Helix Concept. A major aspect of the NSI is University – Industry Linkage.[*]

[*] **Keywords:** University Industry linkage; research and development; commercialization; entrepreneurship; innovation.

The paper calls on Universities to pursue such linkages in form of University technology transfer offices, University spin off companies, entrepreneurship and industrial training centres, joint projects with industry, university science, technology and business parks, etc. The benefits of such linkages are identified to include: assisting the university in raising additional funds to augment dwindling government funding, industries will have more access to innovation from universities, the university will be able to produce graduates that are relevant to industry, etc. The challenges facing such linkages include the fear that commercial interests may interfere with long term teaching and research agenda, inadequate research facilities, shortage of venture capital companies, lack of entrepreneurial skills, difficulty in forging partnerships among industry, government and universities. Examples of projects executed by the Raw Materials Research and Development Council that were able to overcome some of the challenges are presented.

It is suggested that Universities should undergo reforms to become Entrepreneurial and developmental in orientation while reinforcing the traditional teaching and research function. Government and Industries should partner with Universities to foster University – Industry Linkages through the establishment of: cutting edge research culture to solve local, regional and national problems and University Industrial/ Business Parks where staff and students can develop and apply innovations to solve human problems. When fully implemented, the country can achieve an inclusive growth and sustainable development based on value addition to abundant natural resources in Nigeria through innovations.

1. Introduction

Nigeria is currently battling with the challenges of development especially the issue of inclusive economic growth and sustainable development. This is because, although some economic indices show that the economy is stable and growing, evidence on ground show that more and more people are becoming impoverished and infrastructure deficit is prevalent. By every available index of development, the country is still under-developed although sometimes the country is classified as a developing country depending on who is doing the assessment. The Global Competitiveness Index ranked Nigeria as 95th country out of 131 countries in 2008 and 120 out of 148 in 2014 and this is manifested in poor standard of living. On a positive note however, the country is currently the largest economy in Africa and 26th in the world (Onwualu et al, 2008; Anya, 2008; Onwualu, 2014a; 2014b; 2014c; WEF, 2014).

Currently, transportation infrastructure is weak, including roads, railways, waterways and indeed aviation (Onwualu et al., 2013). The problem of electricity appears insurmountable even with all the laudable efforts by the present government in privatization of the sector and building of new power plants as well as transmission and distribution lines. Although the country made good progress with Information and Communication Technology (ICT), it appears the Mobile networks are gradually failing in providing efficient and reliable services to their subscribers. Most of agriculture is still in the hands of peasant farmers, resulting in low production and poor value addition with the resultant effect that food import and agro raw materials import bills are high. When other sectors are considered, namely employment, housing, water, human rights, education, healthcare, manufacturing, commerce, institutions, corruption, security, etc., the story is not far from the picture painted above. The result of all these is that the standard of living of the average Nigerian is very poor. By one estimate, over 60% of Nigerians live below the poverty line of surviving on less than one US Dollar per day.

What is more worrisome is the fact that with the discovery of crude oil, Nigeria has earned huge sums of money from sale of crude oil over the years. The money has been used at various times to execute development programmes including the 1st, 2nd, 3rd and 4th National Development Plans, Structural Adjustment Programme (SAP), National Rolling Plans, National Economic Empowerment and Development Strategy (NEEDS), Vision 2010, Vision 2020, Seven Point Agenda, Millennium Development Goals (MDGs), and currently, Transformation Agenda (Onwualu, 2014abc).

It must be acknowledged that the present attempt by the Federal Government is the only successful attempt in recent times to address the development challenges facing Nigeria. At least today, the power sector is now in the hands of private sector operators and new power plants are being built even by state governments and private sector. The petroleum industry is also being liberalized. Infrastructure deficits are being addressed resuscitation of rail system, rehabilitation of airports, and the production economy as represented by agriculture and manufacturing are being addressed through a number of programmes - Agricultural Transformation Agenda (ATA), Nigeria Industrial Revolution Plan (NIRP), New Industrial Policy, National Enterprise Development Programme (NEDEP), Automotive Sector Reform, Transformation of the Solid Minerals Sector, National Integrated Infrastructure Master Plan, etc (NIRP, 2014, Onwualu, 2014). All these are being supported by the recently inaugurated National Conference which hopefully will address all issues facing Nigeria. As President Goodluck Jonathan noted in his speech while

inaugurating the conference, "in the early 60s countries such as Brazil, Indonesia, Malaysia, India, Taiwan, China, were in the same class of underdeveloped economies as Nigeria". Today, all these countries have overtaken Nigeria economically. Thus serious efforts must be made to overcome the challenges of development facing Nigeria.

For most of the developed world and the emerging countries of eastern Europe, Asia and South America, research has shown that innovation has been the bedrock of their development efforts (Onwualu, 2013; Onwualu, 2014; USOTA, 1995). Those countries invested and are still investing in innovation in all sectors to become competitive in production and service industries, governance and institutions, trade and investment as well as human development (education, healthcare) and security. Thus Nigeria cannot run away from fostering the emergence of a national system of innovation to drive economic development. At the foundation of this is the role of knowledge centres, especially Universities and Research Institutes. Universities world over are expanding their mandates from purely "teaching and research" to teaching, research and development. The development aspect refers to making Universities to teach and do research that can drive economic development. In other words, Universities should be transformed to become Entrepreneurial or Developmental Universities (Hannon, 2013). This will not only ensure that Universities impact positively towards the development of their host communities and the economic development of the nation at large but also produce graduates that are sought after by industry and also can be employers of labour.

The Entrepreneurial University or Developmental University Concept is underpinned by sustainable Research – Industry Linkages (Wu, 2007; Esebuwufu, et al, 2012; Hughes, 2006; Adeoti, 2007). In this paper we give an overview of the National System of Innovation and University –Industry Linkages. Building on that, the paper discusses how Universities can strengthen Research and Development as well as University Industry linkages in Nigeria. Case studies on the efforts of Raw Materials Research and Development Council (RMRDC) in facilitating this process are presented. Strategies are presented on how Universities and indeed other knowledge centres can strengthen and sustain cutting edge Research as well as University Industry Linkages towards the overall development of staff, students and the University as well as contributing to local, regional and national development through commercialization of R&D results in partnership with industries. For the purposes of this paper, the word University is used represent Knowledge Centres including Universities,

Polytechnics, Colleges of Education, Research Institutes and R&D Units in large scale industries.

2. National System of Innovation and Economic Development

The high level of economic development attained by the developed world was achieved and currently maintained and advanced as a result of conscious efforts and actions to innovate in all sectors (Fujita and Hill, 2004; Mowery and Rosenberg, 1993; Wu, 2007). These efforts and actions are carried out by three important sections of the society namely Government Institutions, Research Organizations and Industrial Organizations working together. The National System of Innovation (NSI) therefore, is a formal organization linking these three groups using the Triple Helix Concept. A country may have a robust or large number of components of the Innovation System but if they do not operate as a system, the innovation process does not produce a steady flow of innovative and competitive goods and services and therefore growth does not occur. This appears to be the case in Nigeria where there is a large number of members of the innovation system but they do not appear to be working as a system and so do not innovate.

In the National Innovation System (NIS), Government through Ministries, Departments and Agencies (MDAs) formulate and implement policies that affect the operations of Research Organizations and Industries. On the other hand, research organizations come up with new ideas and technologies for producing innovative and competitive goods and services. They also, through research, develop new and improved methods of governance and social order. Industries produce the actual goods and services for the society but can only grow if there are good government policies and if research organizations come up with technologies that enable them to produce on a competitive basis. The wheel of national growth can only turn in a sustainable manner if the interaction among these three groups is healthy and sustained.

The components of the Nigerian Innovation System (NIS) are large, on individual basis. Government establishments in Nigeria are over 500. The number of industries is difficult to estimate but there are at least 1000 large scale industries, over 2 million Small and Medium Enterprises (SMEs) and over 20 million enterprises in the informal sector usually classified as artisans and market men and women (Onwualu, et al., 2013). On the Research side, there are at least 45 Colleges of Education, 50 Mono/Polytechnics, 129 Universities and 60 Research and Development Institutes, owned by the Federal Government, State Governments and private sector.

As shown by many other writers, this massive number of organizations would have been giving Nigeria a steady stream of innovations which would have been making industries to be producing competitive goods and services as well as making government institutions to function more efficiently, thereby encouraging sustainable development (Adeoti, 2007; Anya, 2008). For this to happen, they must operate according to the Triple Helix Concept. This cannot happen by accident, but must be established, nurtured and maintained consciously. So far the three groups of institutions in Nigeria appear to be working independent of each other. Even within each group, it is rare to see different organizations working together effectively. This is why sometimes two or three government departments or agencies work on the same problem without any form of collaboration. In most cases, research centres work on industrial problems without any collaboration with industry. This is why most of the R&D results continue to gather dust in the shelves of libraries and workshop floors of Universities and research institutes.

The first formal attempt to midwife the emergence of a National System of Innovation (NSI) or National Innovation System (NIS) in Nigeria was in 2009 when the Raw Materials Research and Development Council (RMRDC) in collaboration with relevant stakeholders hosted an International Conference on "Building a National System of Innovation" in Abuja (RMRDC, 2009). A major recommendation of that conference was the formation NSI. Following this, an MOU was signed in 2010 to form an NSI for Nigeria with the lead organizations to include National Universities Commission (NUC), Raw Materials Research and Development Council (RMRDC), National Office for Technology Acquisition and Promotion (NOTAP), World Bank STEP B Project and African Technology Studies Network (ATPS).

However, this attempt has not fully taken off due to challenges of relationships between the relevant parastatals and their parent ministries, coordination, collaboration, bringing the private sector into the fold and budgetary issues. It is believed that the concept of NSI should be pursued as it holds the key to a continuous generation of innovation and their application in solving societal problems and for economic development. One major component or arm of the NSI is University – Industry Linkages which this paper seeks to address.

3. University Industry Linkages

University Industry Linkages (UIL) come in different forms and therefore mean different things to different people. In its narrow definition, it involves a University as represented by a researcher or a

group of researchers working with an industry (public or private) to actualize an innovation which impacts an industry and thus the wider society. This mechanism which focuses on innovation can be achieved through several means (Etzkowitz et al, 2000; Poyago – Theotoky et al, 2002; Homma et al., 2008). First, a University researcher can come up with an idea for commercialization and enters into a contract with an industry through a spin-off company of the University. Secondly, an industry can contract a University researcher to conduct R&D for the firm, which it commercializes. Thirdly, a University can help a firm develop the Science behind a product or idea and the firm goes ahead to develop the product or technology. Finally, there can be joint collaboration between a firm, and a University to develop a product or technology. In each of the cases above, the focus is on developing an innovation.

But University-Industry Linkage does not necessarily have to directly lead to a product or technology innovation. It can be targeted at strengthening or reforming institutions and structures in order to make innovation to happen. Thus University- Industry Linkages can take any of, or a combination of the following forms (Ssebuwufu et al, 2012; Kolawole, 2014; Onwualu, 2006; 2008; 2010; 2012; 2013; 2014; Doorley and Kirk, 2007):

- University Technology Transfer Offices and Intellectual Property Offices
- University Consultancy Services
- University Spin off Companies
- University Science/Industrial/Technology Parks
- University Technology Incubation Centres
- University Science Centres
- University Museums (Historical, Biodiversity, Science, Technology Government)
- University Hall of Fame
- University Enterprises
- Professorial Chairs
- Scholarships and Fellowships for staff and students
- Award of Honorary Doctorates and Special Awards to Industrialists and Public Office Holders
- University Infrastructure Development (Labouratories, ICT Facilities, Sporting Facilities, Hostels, Business Parks)
- Offer of places for SIWES, Internships, and Sabbatical positions by Industries for University staff and students.

The important feature of these projects is that they are done in collaboration with a body outside the University, a government agency, commercial outfit or an industry which in most cases provides the necessary funding either as outright grant or under some form of PPP

arrangement. These forms of linkages have been used by other countries to ensure a continuous flow of innovation from Universities to the production and service sectors and vice versa (Wu, 2013; Hughes, 2006; Hannon, 2013; Clark, 1998; Etzkontitz, 2008).

The benefits of University – Industry Linkages include (Adeoti, 2007):

- It enables universities to be relevant and more useful to their host communities thereby reducing conflicts
- It enables researchers to learn from industry and vice versa
- It enables Universities raise additional funds for services to augment dwindling budgetary allocations
- Researchers are able to know directly problems requiring solutions from industry, thus facilitating commercialization of research findings;
- Industries are able to benefit from more innovations thereby becoming more competitive and ensuring higher profits
- It makes it easier for students to find jobs on graduation
- It enables Universities produce graduates that are relevant to industry
- It facilitates development, adaptation and deployment of innovations on a continuous basis thereby ensuring competitiveness in industry

Although University Industry Linkages have many advantages, especially helping the University to survive contemporary harsh operating environments, many Universities in Nigeria are finding it difficult to refocus and reform existing structures in order to practically benefit from the evolving paradigm shift. This difficulty is as a result of some constraints namely (Onyebisi et al, 1996; Nnadi, 2000; Ilori et al, 1995; Ssebuwufu, et al, 2012):

- Commercial interests may interfere with long term research agenda and so are reluctant to pursue such interests
- Involvement of staff in enterprises may deplete resources for classroom teaching which is the primary function of the university
- Shortage of Venture Capital Companies and funds to support innovation and linkages
- Inadequate research and development infrastructure
- Promotion guidelines do not give as much credit to commercialization as publications.
- Lack of established networks in form of the Triple Helix
- Lack of entrepreneurial skills and knowledge among academic staff
- Difficulty in penetrating industrial and government organizations by academic staff of universities.
- The perception by industry that University – Industry Linkages are for Corporate Social Responsibility and not for business.

- Reluctance of industries to open their doors to universities due to the need to protect trade secrets and intellectual property
- Lack of trust among key members of the triple helix

In order to overcome some of these challenges, government has set up a number of Institutions to act as a bridge between universities and industries. The list of the institutions can be found in the websites of most Ministries or R&D centres (Onwualu et al., 2013). One of such organizations is the Raw Materials Research and Development Council (RMRDC) Abuja. A few example of the projects executed by the Council can show how to encourage Research Industry Linkages in Nigeria.

4. Case Study of some RMRDC Projects

4.1 RMRDC Background

The Raw Materials Research and Development Council, (RMRDC) is a parastatal of the Federal Ministry of Science and Technology (FMST). The Council was set up by the Federal Government of Nigeria to promote the utilization of natural resources of Nigeria as raw materials for industries. The Council implements its mandate through a number of programmes including: Information generation and dissemination on Nigeria's Raw Materials; Research and Development in raw materials; Pilot plants; Joint Venture factories for pioneer industries, commercialization of R&D results and capacity building in Process Equipment and processing of raw materials (www.rmrdc.gov.ng); RMRDC, 2011; 2012; 2013). These programmes are designed to have projects which are implemented with the Triple Helix in mind. Thus in almost all the projects, effort is made to have academia (Universities, Polytechnics, Research Institutes); Industrialists (large scale and SMEs) and government agencies working together in line with the triple helix model. The projects cover the following industrial subsectors:

- Food and Beverage
- Textile, Leather and Livestock
- Wood, Pulp and Paper
- Chemicals and Pharmaceuticals
- Plastic, Rubber and Foam
- Metallic and Non-Metallic Minerals
- Industrial Equipment including Vehicles
- Electrical and Electronics
- Motor Vehicle and Miscellaneous Assembly
- Advanced Materials

The major programmes of RMRDC are designed to address challenges and gaps in the areas of information, knowledge, technology, supply chain, skills, investments which have made it impossible for industries

to achieve significant progress in local sourcing of raw materials. The Council facilitates by providing funds for research, logistics, industrial equipment, research facilities, marketing of products and also supervises the implementation of the projects (RMRDC, 2006-2013; Onwualu and Obasi, 2013; Onwualu, 2014abc).

4.2 Capacity Building in Process Equipment Design and Development

In order to address the skills gap, RMRDC executes capacity building programmes to improve the skills of operators in the area of process equipment design and development. Under this programme there are three main projects namely:

- National Process Equipment Design Competition
- Mathematical Modeling of Process Equipment and Plants
- Computer Aided Process Equipment Design (CAPED)

The National Design Competition is organized every two years. For each competition, the Council decides on a technology of importance to the economy and calls for entries from all over Nigeria. Design teams are encouraged to be made up of multi-disciplinary teams. The best four designs are given financial awards and the best is in addition given a grant to fabricate the technology for use by an SME. A recent competition was won by Obafemi Awolowo University, Ile Ife and they have almost completed the fabrication of a rotary dryer which can be used to dry crops (Fig 1). When completed, this will be installed for a processor towards commercialization. The point to note here is that there were over 50 entries and membership of each team was a mixture of academics, field engineers and government workers. In addition, SMEs that will use the dryer have been contacted.

Closely related to this is the Project on Mathematical Modeling of Process Equipment. This project is a collaboration between RMRDC and National Mathematical Centre (NMC), Abuja. The RMRDC provides the fund which is administered by NMC. During the last award, Researchers from 5 universities won grants to carry out mathematical modeling of different processes required in processing raw materials. The CAPED group is made up of Professors from 6 universities who meet every two months at RMRDC to work with resident engineers to develop softwares for design and analysis of some process equipment. The group has worked on spray dryer, air cyclones, heat exchangers and hydro cyclones.

Fig 1 Rotary dryer for cassava processing

4.3 Raw Materials Processing Clusters

One of the major programmes of RMRDC is promotion of Small and Medium Enterprises (SME) Clusters for processing raw materials. The concept of the project is to harness innovations coming out of research centres, including universities and facilitating their injection into productive activities by SMEs. Each Cluster revolves around a particular raw material prevalent in that location. Examples of such clusters are shown in Fig. 2. Some of the projects under the Clusters Programme are being implemented in collaboration with some Universities. Examples include the Spice Development Projects which involve Federal University of Technology, Owerri; Tiger Foods Ltd, Onitsha and a Cooperative Society in Warri (Fig 3). As part of the project, a laboratory for analysis of spices was equipped at Federal University of Technology, Owerri. Another project – Establishment of Cashew Processing factories involved Kogi State University, Ayagba, Federal University of Agriculture, Abeokuta and a private company (Fig. 4). The factories are run by the University's Spin off companies. The Council has also been involved in promoting the processing of Moringa into different products (oil, water treatment powder, tea, milk, etc). In these projects, some universities (Nnamdi Azikiwe University, Ahmadu Bello University) were involved, with some SMEs (Fig 5).

Fig 2. Cassava and cashew processing clusters

Fig 3. Spices development programme

Fig 4. Cashew processing programme

Fig 5. Development of Moringa products

4.4 Production and Processing of Tropical Fruits into Juices and Concentrates

This project was co-funded by World Bank Step B Project and involved the upgrading of tissue culture technology facilities in some research institutes, production and distributions of elite varieties of pine apple, citrus, banana and mango as well as encouraging private investors to establish fruit juice concentrate plants. Figure 6 shows that a number of institutions were involved including academia and industries. The main aim of the project was to address the issue of importation of fruit juice concentrate into Nigeria by encouraging the emergence of fruit juice concentrate plants and ensuring that there are adequate supply of fruits at the right price.

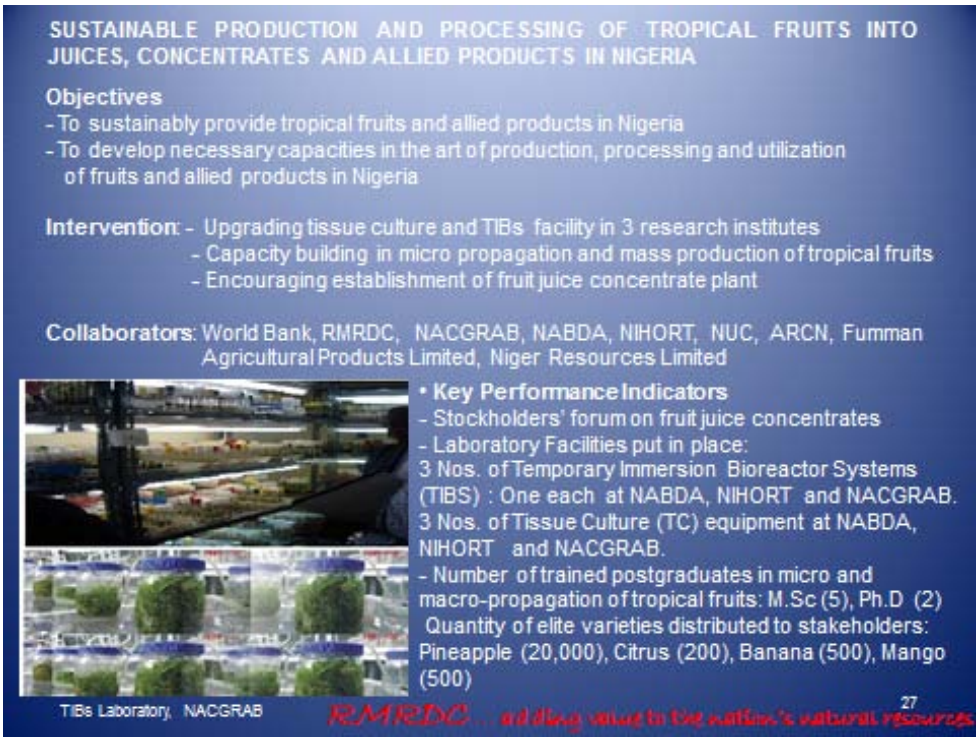

Fig 6. Processing of fruits and fruit juice concentrate

4.5 Milk Collection and Preservation Centre

In these projects, RMRDC promoted the principle of collection and preservation of milk in order to improve milk production by local communities. As shown in Fig 7, a University and some government agencies and the local community were involved in the collaborative project.

Fig. 7. Milk collection and preservation

4.6 Research and Development (R&D)

The Council over the years funded over 100 research and development projects. Some of these were executed by staff of some Universities and Research Institutes in collaboration with some industries. In most of the projects, these researchers are made to work with industries and some of the R&D are tested in industries thus establishing the required link between the University and industry. A good example is the project on making automotive brake pad using palm kernel shell as the friction material. The projects was done by a research team from Obafemi Awolowo University, with funding and supervision from Raw Materials Research and Development Council (RMRDC) and National Automotive Council (NAC). Samples of the commercial version of the product have been produced by a company in Lagos and arrangements are being made for full commercialization of the product (Fig 8). Other projects include: solar powered salt processing; kilishi processing; essential oil production; wood seasoning technology; ceramic glaze materials processing; limestone processing; kaolin processing; glazier putty production, etc. These are all industrial and commercial projects in which researchers, industrialists, entrepreneurs and government agencies were involved.

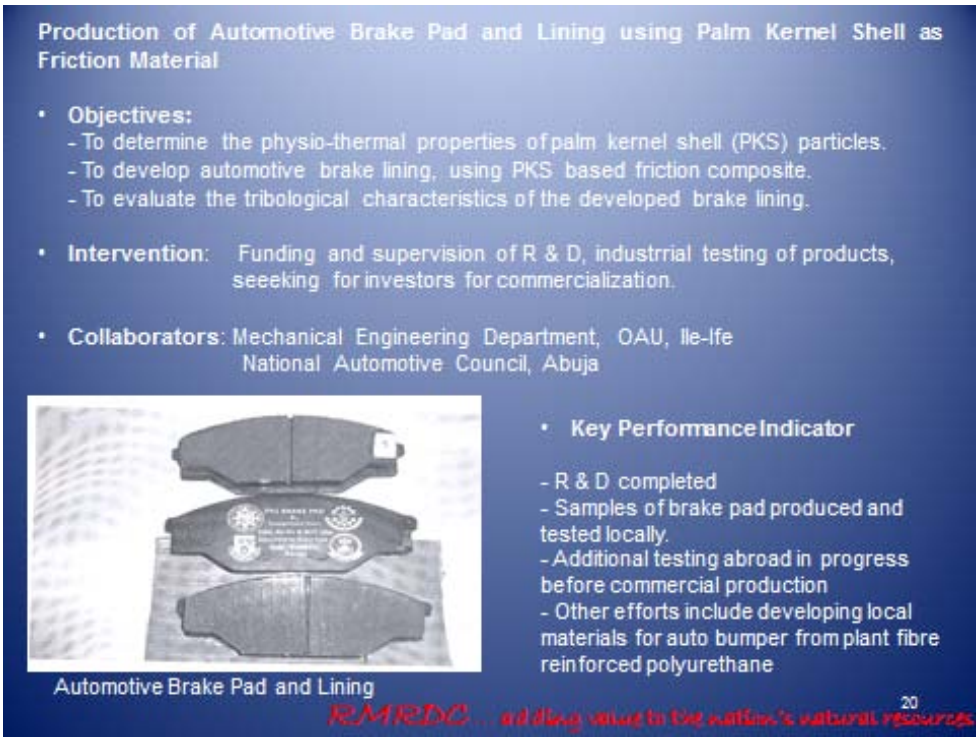

Fig 8. Production of brake pad from palm kernel shells

4.7 Research – Industry Networking Platforms

The Raw Materials Research and Development Council provides platforms for researchers to network with industries and government agencies. These are usually in form of training workshops, seminars, round tables in which the organized private sector (Manufacturers Association of Nigeria, MAN; Association of Chambers of Commerce; Nigerian Association of Small and Medium enterprises, NASME) are invited as well as relevant Ministries, Departments and Agencies (MDAs). The speakers in most of the workshops are researchers from Universities and Industrialists and Entrepreneurs. In some cases, the Council facilitates the formation of groups that bring researchers and industrialists together. Examples include the Pan African Competitiveness Forum (PACF) for Industrial Cluster development and Moringa Development Association of Nigeria (MDAN) for Moringa Development. Specialized exhibitions are also hosted by RMRDC. These include the RMRDC Techno Expo which holds in Abuja every two years and RMRDC NIRAM Expo which holds in Lagos. While Techno Expo showcases process equipment developed locally, NIRAM Expo showcases raw materials used by industries (RMRDC, 2011). In addition, RMRDC provides International Networking Platforms which can link researchers to some organizations outside Nigeria. The Council is currently: Secretariat of G77 Action Committee on Raw Materials (ACRM); Africa Regional Focal Point of World Association of

Industrial and Technological Research Organizations (WAITRO); and focal Point of African Technology Policy Studies Network (ATPS). The Council is also a focal point for the Non Aligned Movement Science and Technology Centre. Recently, RMRDC brought University researchers together under the Nigerian Knowledge Transfer Partnership at the National Universities Commission (NUC).

4.8 Techno Economic Surveys and Survey of Commodities

On an annual basis, RMRDC conducts national surveys of the Industrial sector to identify challenges, potentials, successes and other issues having to do with importation of raw materials, capacity utilization of industries, etc. Closely related to these surveys are the surveys of agricultural raw materials and mineral raw materials to determine their occurrence, production outputs, reserve estimates, process technologies, etc. All these information are used to populate the National Raw Materials Information System which gives information on Raw Materials available in each of the over 9000 wards in Nigeria (www.rmrdc.gov.ng). Such surveys are usually conducted by multi-disciplinary teams made up of University researchers, industrialists and government workers, thus providing necessary personal and institutional linkages among these groups (RMRDC, 2006; 2009; 2013).

5. Strategies for Strengthening Research – Industry Linkages

We have seen that there is an urgent need to establish and/or strengthen University – Industry Linkages. On the part of Universities this is very important because of: pressure from government wanting more from less input in universities; employers wanting graduates with knowledge and skills to enhance innovation and competitiveness; students wanting value for money; parents wanting the best opportunities for their children; dwindling government funding and growing unemployment in the country (Hannon, 2013). On the part of industry, there is the need to partner with Universities to ensure steady inflow of innovation that can make them more competitive besides the fact that the linkage can be part of Corporate Social Responsibility. The case studies shown here represent a few of what an institution is doing to promote Research – Industry Linkages and Commercialization of research findings. We note that some other institutions are doing similar interventions in other sectors of the economy but a lot still needs to be done to expand the interventions to all sectors of the economy.

From available literature, these linkages do not happen by accident. The enabling environment must be cultivated within the institution so that both staff and management can be equipped with the necessary skills to initiate, pursue and establish linkages. From the experiences

of the case studies, serious efforts must be made to overcome the inertia that has been working against a robust research industry linkage system in Nigeria. The following strategies are suggested.

5.1 Actions to be taken by Universities and Research Institutes

- Cultivating research culture by encouraging staff to execute cutting edge research directed at solving immediate problems of the University and host community as well as that of the Nigerian economy and the world. Every University should maintain a Research Grant Scheme, equip laboratories and have a functional University Research Committee.
- Establishment of University-Industry Linkage Office to be manned by competent and experienced staff. This office in consultation with different faculties and schools should set up targets with viable projects and assist staff in pursing the projects, including funding. The office should also conduct regular training seminars for staff. This can be operated in collaboration with the Intellectual Property Office where it exists.
- Establishment of Science/Technology/Business Parks by the University using the Cluster Model approach (Onwualu and Obasi, 2009). These parks which should be run commercially will enable staff and students with potential innovations to try out their ideas by establishing spin off companies. Multinationals will also have the opportunity of setting up shop in such parks. This should be done under Public Private Partnership (PPP) arrangement.
- Take steps to ensure that every project for Bachelors, Masters or PhD degree of the University is targeted to solve a national or global problem whether at the basic research or applied research level.
- Compilation and continuous maintenance of an inventory of potential innovations from the University and marketing this to the industrial and Government Sector through appropriate means including research fairs, electronic newsletters, trade fairs, and attendance at Organized Private Sector meetings and through an active website.

5.2 Actions to be taken by Government

- Formulation and implementation of appropriate policies to facilitate more robust University-Industry Linkage. The recently approved Science Technology and Innovation (STI) Policy of Federal Ministry of Science and Technology should be implemented with adequate funding.
- Provision of funds that can be accessed by Universities and Industries in implementing joint projects. This can be done

through the proposed National Fund for Innovation and Competitiveness or through existing funds such as Tertiary Education Fund (TETFUND), Petroleum Technology Development Fund (PTDF), National Information technology Development Fund (NITDA), Raw Materials Research and Development Fund (RMRDC), National Automotive Council Fund (NAC), Small and Medium Enterprises Development Agency Fund (SMEDAN), development banks, including: Central Bank of Nigeria (CBN), Bank of Industry (BoI), Bank of Agriculture (BoA), Nigeria Export Import Bank (NEXIM), Urband Development Bank, etc).

- State and Local Governments should partner with universities in establishing Industrial/Technology/Business Parks.
- MDAs should compile research and development related problems and challenge universities to solve them. Conscious efforts should be made by government to engage Universities in Consultancies and studies.
- Government should support the take-off of the National System of Innovation with linkages with Nigerians in the Diaspora through an innovative funding mechanism.

5.3 Actions to be taken by Industries

- Continuous compilation of problems that require solutions which the industries are ready to pay for and seeking for these to be solved by universities. These can be done through the OPS such as MAN, NACCIMMA. Bankers Committee.
- Establishing laboratories, workshops, etc. within University campuses or Industrial Parks such that as they use the facilities for commercial work, Universities can also use them for research.
- Increase support to Universities in form of research grants, endowments, professorial chairs, scholarships, etc
- Ensuring that a certain percentage of their R&D which is normally done abroad is done within Nigeria in collaboration with Universities.
- Accepting researchers and students on short term stay with the industries.

6. Conclusions

The economic and developmental problems facing Nigeria today can be solved by a judicious application of Science, Technology and Innovation (STI) or Science, Engineering, Technology and Innovation (SETI) through a functional National System of Innovation (NSI) operating with the Triple Helix Concept. A major component of the NSI is University – Industry Linkage which can be used to drive Innovations

in Industries thereby driving Competitiveness. The Federal Government has established a number of Agencies such as RMRDC to among other things facilitate University – Industry Linkages. The case studies highlighted in this paper show that with appropriate funding, supervision and encouragement, Researchers, Industrialists, Entrepreneurs and Government can work together towards solving the challenges of development facing Nigeria.

Universities should undergo reforms to become Entrepreneurial and developmental in orientation while reinforcing the traditional teaching and research function. Government and Industries should partner with Universities to foster University – Industry Linkages through establishment of: Cutting Edge Research Culture to solve local, regional and national problems and University Industrial/Business Parks where staff and students can develop and apply innovations. The National System of Innovation (NIS) should be mobilized to start functioning to ensure that endogenous technological innovations are developed and applied to solving the problems confronting the Nigerian economy through Research – Industry Linkages.

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REFERENCES

Anya, A.O. 2008. Education, scholarship, and the wealth of the nation: the search forthe dielectics of sustainable development. Valedictory Lecture, University of Nigeria, Nsukka.

Adeoti, J.O. 2007. University Industry Linkage and the Challenge of Creating Developmental Universities in Nigeria. www.herp.net.org. pg 375-387.

Clark, B 1998. Creating entrepreneurial Universities. Organizational Pathways of Transformation Pergamon Press

Dooley, L.; and Kirk, D. 2007. University-Industry Collaboration: Grafting theentrepreneurial paradigm into academic structures. European Journal of Innovation management. 10(3): 316-332.

Etzkowitz, H. Webster, A; Grehartt, C and Cantisano, T. 2000. The future of the University and the University of the future. Evolution of Ivory Tower to entrepreneurial paradigm. Research Policy 29(2): 313-330.
Etzkowtitz, H. 2008. The triple helix: University – Industry – Government Innovation in Action. Routledge, New York.

Fujita, K. and Hill, R.C. 2004. Innovative Tokyo. Paper presented at the World Bank Workshop on Creative Industries in Asia, Bangkook.

Hannon, P. D. 2013. Why is the Entrepreneurial University Important? Journal of Innovation Management 1,2: 10-17.

Homma, H; Ikeda, N; and Attalage, R.A. 2008. Strengthening University-Industry Linkage in developing countries through international cooperation: case of Sri Lanka through Cooperation of Toyohashi University of Technology, Japan. Innovative Techniques in Instruction Technology, E-Learning, E-Assessment and Education. Pg 432-436.

Hughes, A. 2006. University – Industry Linkages and UK Science and Innovation Policy. Working Paper No. 326 Centre For Business Research, University of Cambridge.

Ilori, M.O.; Oyebisi, T.O.; and Nessr, N. I. 1995. Models for transferring technology from the laboratory to the industries. University of Lagos Journal of Business 1 (1)

Kolawole, M. O. 2014. Academic Industry Linkages for the advancement of engineering research and Practice. Paper presented at the Institutions of electrical and Electronics Engineers (IEEE) Nigeria Section conference.

Mowery, D.C. and Rosenberg, N. 1993. The United States national Innovation System. In R.R. Nelson (Ed), National Innovation Systems: a comparative analysis. Oxford University Press, UK.

Nnadi, I. 2000. Mechanisms for effective transfer of research and development Outputs from research Institutes to Domestic Industries. Paper presented at National conference on Commercialization of Research Outputs, Abuja.

NIRP, 2014. Nigeria Industrial Revolution Plan. Federal Ministry of Industry, Trade and Investment, Nigeria

Onwualu, A.P. 2006. Creating effective linkages between research and agribusiness. ThisDay Newspaper. 11: pg 33

Onwualu, A.P. and Obasi, S.C. 2009. Repositioning traditional MSME clusters in developing countries for competitiveness: the RMRDC Cluster model. Presented at Innovate India Conference, Bangalure, India.

Onwualu, A.P. 2010. Research-Industry Linkage: the role of RMRDC. Paper presented at
23rd Africa Science Revival Day held at Federal University of Technology, Yola, 13th July, 2010.

Onwualu, A.P. 2012. Fast-tracking the attainment of Vision 20-2020 through techno
-entrepreneurship. Paper presented at Yaba College of Technology Conference and Research Fair. July 23rd to 25th, 2012, Lagos.

Onwualu, A.P. 2013. Place of Science Research in Industrial and National Development.
Paper presented at Nigerian Academy of Science – NLNG Nigeria Science Prize regional Sensitization Workshop, Lagos.

Onwualu, A.P. and Obasi, E. 2013. Process Technologies for small and medium enterprise clusters in Nigeria. Datmaz Digital Press, Abuja.

Onwualu, A.P.; Obasi, E., Olife, I.C.; Inyang, A. 2013. Unlocking the potentials of
Nigeria's non oil sector. Pitmak publishers Ltd, Abuja

Onwualu, A.P. 2014a. Towards Nigeria's Competitiveness in the Global Economy: the
Role of Engineering Capability, Entrepreneurship and Innovation. Paper presented at a Conference on Building the next Generation by ScieTech Network, Abuja.

Onwualu, A. P. 2014b. Fostering research industry linkages in Nigeria: the RMRDC Experience. Presented at a Public Lecture, Federal University of Technology, Minna.
Onwualu, A.P. 2014c. Commercializing Engineering: an imperative for national development. Proceedings, 23rd Engineering Assembly, Council for Regulation of Engineering in Nigeria, Abuja. Pg 1-34.

Onwualu, A.P. 2014d. Engineering for Sustainable Development in Nigeria. Invited Lead paper presented at Prof. Gordian Ezekwe Memorial Lecture and 2014 National Conference, Faculty of Engineering, Nnamdi Azikiwe University, Awka, 19th May, 2014.

Onyebisi, T. O. Ilori, M. O.; and Nassar, 1996. Industry – academic relations: an assessment of the linkages between a university and some enterprises in Nigeria. Technovation 16(4): 203-209.

Poyago – Theotoky, J; Beath, J. and Siegel, D. S. 2002. Universities and fundamental research. Reflections on the growth of University – Industri partnerships. Oxford Review of Economic Policy. 18(1): 10-20.

RMRDC. 2005. Directory of machinery and equipment fabricators for processing raw
materials and Raw Materials Resources on Local Government Basis in Nigeria. Raw Materials Research and Development Council (RMRDC), Abuja.

RMRDC. 2010. Leveraging Innovation and Resources management for Sustainable
Development. RMRDC Proceedings Series 024. Raw Materials Research and Development Council (RMRDC), Abuja.

RMRDC. 2010. Modern Trends in Mineral Processing. Proceedings of an International
Conference. RMRDC Proceedings Series 020. Raw Materials Research and Development Council (RMRDC), Abuja.

RMRDC. 2011. Local Raw Materials Content Development: an Imperative to Vision
20:2020. Proceedings of RMRDC Techno Expo. RMRDC Proceedings Series 026. Raw Materials Research and Development Council (RMRDC), Abuja.

RMRDC 2006, 2009, 20012. Reports of Techno-Economic Surveys of different sectors of MAN, RMRDc, Abuja.

RMRDC, 2006-2013. Annual Report, various years. Raw Materials Research and Development Council, Abuja

Ssebuwufu, J.; Ludwick, T. and Beland, M. 2012. Strengthening University – Industry Linkages in Africa: A study of Institutional capacities and graps. Association of African Universities, Accra.

USOTA. 1995. Innovation and Commercialization of emerging technologies. United States Office for Technology Assessment, Washington.

WEF, 2014. Global competitiveness index. World report 2014.

Wu, V, 2013. University – Industry Linkage – The case of Taiwan www.oecd.org.stilinno/275452/.pdf.

Wu, W. 2007. Cultivating Research Universities and Industrial Linkages in china, the case of Shanghai World Development 35(6): 1075-1093.

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AN EVALUATION OF THE LEVELS OF POLYCHLORINATED BIPHENYLS (PCBs) CONTAMINATION OF THE LAGOS LAGOON, NIGERIA*

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ABSTRACT

The production and use of the toxicant, polychlorinated biphenyls (PCBs) have been banned in developed countries but significant quantities of these chemicals are still present in the environment, especially in developing countries like Nigeria. Significant users of PCBs containing products include private electrical generators, major industrial facilities, oil refineries, textile mills, cement industries, paint industries, etc. Assessment of the level of these toxic micro pollutants is important for the protection of human health and the environment. In continuation of our studies on the environmental status of the Lagos Lagoon, we have investigated the levels of PCBs contamination of the Lagoon – a major source of sea foods for the populace of Lagos. Seventy-two (72) PCBs were analyzed for in water, sediment, invertebrates and twelve species of fish from the Lagoon, including commercially important fish sold to local markets, using Gas chromatography/ Mass selective Detector (GC/MSD). No PCBs were detected in the water. Low chlorinated PCBs accounted for 34.9% sediment PCBs. Highest total sediment PCBs of 149.52, 95.54ng/g and 78.87ng/g d. w. were obtained in 2004, 2007, and 2008 respectively. PCB153 was found in all the fish and in all invertebrates, with Lutjanus dentatus (fish) *and* Callinectus amnicola *(crab) showing the highest concentrations of 6.10 and 12.0ng/g respectively. Presently the risks associated with PCB exposures in the Lagos lagoon appear to be low but this situation may change drastically if unsustainable activities and continued use and poor disposal of industrial waste are not abated.*

* **Keywords:** Polychlorinated Biphenyls, environmental pollution, Lagos Lagoon.

1. Introduction

Polychlorinated biphenyls (PCBs) have been used industrially since 1929 [16], and are entirely of anthropogenic/industrial origin. PCBs are one of 21 classes of persistent organic pollutants (POPs) which, due to their damaging effects on human health and the environment, have been restricted by the 2001 Stockholm Convention on Persistent Organic Pollutants. Incidents of exposure to PCB pollution have resulted in human, ecological and economic damages and attendant costs. The total amount of PCB-contaminated waste in Nigeria is estimated to be 3,400 tons [19]. Ignorance of the dangers of unsafe use and unregulated disposal of PCB-contaminated products expose humans, animals and the environment to the negative effects of PCBs. Such PCB-contaminated products include carbonless copy paper, old computers, electronic devices, old fluorescent lighting fixtures, appliances containing PCB capacitors, old microscope oils, and old hydraulic oils, transformers, capacitors and ballasts, paint additives, and hydraulic fluid additives among other goods.

Exposures to PCBs in a city like Lagos which is the most populated city in Nigeria, presently harboring not less than 18% of the total population (150 million) and about 80-85% of the industries in Nigeria (Alo, B.et.al, 2014) [4] may be on increase due to poor MSW management practices [22]. The concern about PCBs in the Lagos Lagoon is that the Lagos lagoon is the major source of seafood to the people of Lagos.

Consumption of PCB-contaminated foods is the most significant route of exposure to PCBs for the general human population [6] & [14]. Ecological exposure to PCBs is primarily an issue of bioaccumulation resulting in chronic effects rather than direct toxicity. Studies have shown that several health effects are associated with PCB contamination [5] & [27]. These include: Acne, rashes, irritation of the nose and lungs, gastrointestinal discomfort, effects on blood and liver, depression and fatigue. Different PCB congeners show different modes of toxic actions [13]. Exposure of organisms to coplanar PCBs in combination with other POPs e.g. mutagenic polycyclic aromatic hydrocarbons (PAHs), increases the rate of DNA adduct formation which increases the rate of activation of a number of carcinogens and mutagens [20]. Also, PCBs are known endocrine disruptors.

PCB congeners have a low solubility in water, and high octanol-water partition coefficients, bioaccumulation potential, and high resistance to biodegradation. This is even further investigated by the physico-chemical properties of PCBs and the unregulated disposal of PCB containing waste in our inadequate MSW management practices. In

continuation of our ongoing studies on the environmental status of the Lagos Lagoon, we hereby investigate and determine the levels of PCBs in Lagos lagoon marine environment. The objectives of this study therefore are to determine the levels of PCBs in Lagos lagoon, to assess their bioaccumulation in the lagoon biota and to relate their risks to humans that consume the fish and invertebrates from the Lagos lagoon.

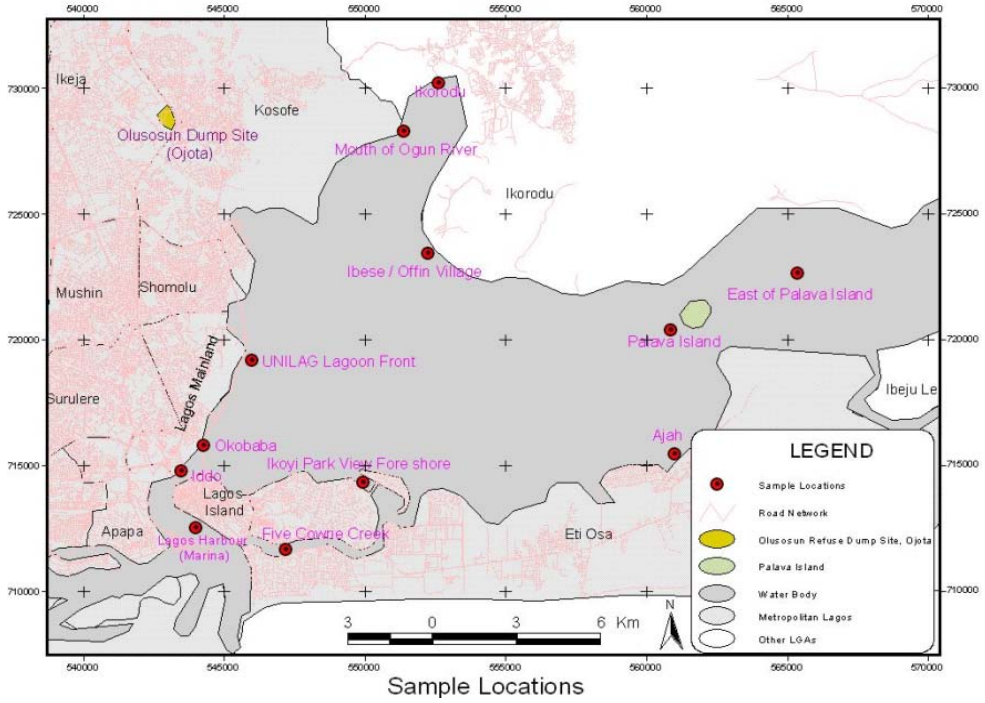

Fig. 1: Map of Lagos lagoon showing sample locations

2. Methodology

2.1 Sampling

Water, sediment, fish and invertebrate samples were collected quarterly between the years from February 2004 to June 2008 from six locations on the Lagos lagoon. These locations were chosen based on accessibility, and also areas close to, and far from the expected pollution gradients (high municipal, shipping, and industrial activities). The locations were marked by a global positioning system (GPS).

Water samples (IL volume) were collected from the surface by submerging pre-cleaned (washed with warm water and liquid soap using a brush, after which it was properly rinsed with tap water, dried and rinsed with acetone and then rinsed with n-hexane) Winchester amber glass bottles by hand into the water. Sediment samples were

collected using a Van Veen Grab sampler operated from a boat at the depths between 0.5 and 10m.

Fish and vertebrate samples were collected from six different locations of the lagoon (same locations for water and sediment sampling) by trapping overnight. These samples were representative of frequently consumed food items. All the samples were identified and stored in the cold room below 4°C prior to preparation and analysis. The samples were analysed at the laboratories of the University of Lagos and the Great Lakes Institute for Environmental Research (GLIER), University of Windsor (Canada) where they were individually weighed, measured, and stored in the cold room below 4°C prior to preparation and analysis.

Table 1: Biota samples

Sample code	FISH NAME	Collection location	Number of sample	Length (mean and range) (cm)	Body weight ranges (g)
F1	*Caranx hippos* (Agaza)	Okobaba	3	10.4 – 12.7	24.43 – 67.69
F2	*Mugil cephalus* (mullet)	Okobaba	2	20.2	58.13 - 150.2
F3	*Sphyraena barracuda* (barracuda)	Aja	2	17.9 – 19.2	106.10 – 126.31
F4	*Sarotherodon melanotheron* (Tilapia)	Unilag lagoon front	2	13.0 – 16.4	53.19 – 70.54
F5	*Tilapia guineensis* (Tilapia)	Unilag lagoon front	2	12.6 – 14.1	50.52 – 54.24
F6	*Ethmalosa fimbriata* (Bonga)	East of Palava Island	3	14 6 – 17.5	47.22 – 55.81
F9	*Tarpon atlanticus* (megalops)	Unilag lagoon front	1	82.4	1880
F10	*Scomberomorus tritor* (mackerel) (Ayo)	Aja	1	21.3	86.34
F11	*Lutjanus agennes* (African red snapper)	Okobaba	2	21.2 – 24.5	108.60 – 168.12
F12	*Pomadasys jubelini* (Grunter)	Okobaba	4	16.2 - 18.0	80.30 - 87.52
F15	*Chrysichthys nigrodigitatus* (Catfish) (Obokun)	Five cowrie creek	4	30.3 – 35.8	145.63 – 190.51
F20	*Lutjanus dentatus* (African brown snapper)	Okobaba	4	24.1 - 27.9	170.25 - 202.31
SS	*Penaeus* (Crayfish)	Unilag lagoon front	20	4.2 – 5.3	1.92 - 4.36
SB	*Macrobranchium*	Mouth of Ogun	7	9.1 – 10.3	15.83 -

	vollehoevenii (Shrimps)	River			19.19
CS	*Callinectes amnicola* (young blue crabs)	Unilag lagoon front	7	5.2 – 6.0	27.87 – 34.16
CB	*Callinectes amnicola* (matured blue crabs with eggs)	Mouth of Ogun River	3	10.9 – 12.6	95.32 – 116.24
CE	*Callinectes amnicola* eggs				

2.2 Sample extraction and analysis:

Sample extractions were carried out according to established methods [18] & [3].

Sample extracts obtained after Florisil cleanup were combined and rotor-evaporated to 1ml and analyzed for PCBs by gas chromatography. Analysis was run on a Hewlett-Packard (Avondale, USA) Model 5890/5970 Gas Chromatograph with a mass selective detector (quadrupole mass analyzer, 70eV) equipped with a Hewlett-Packard 7673A auto-sampler. Samples (1µl) were injected using a splitless injection mode at 250°C injection temperature and GC-MSD interface temperature of 280°C.

A mixture of three ^{13}C-labelled PCBs (13C - PCB 52, 13C - PCB 153 and 13C – PCB 37) was used as surrogate standard. The PCBs were identified and quantified by comparison of retention times and spectra of internal standards. The chromatograms obtained were analyzed using MSD Chemstation software. First, the Isooctane blank, then the internal standards, the surrogate standard spike, the method blank, the Standard Reference Materials (SRM), and then each of the sample chromatograms were integrated and analysed. The methods reported above included the processing of blanks, duplicates and standard mixtures between each group of samples. The detection limit ranged between 0.03 to 0.11ng/g for the PCBs. For the fish homogenates the mean percent recoveries were 84.46, 78.10, and 76.39 for 13C-PCB 37, 13C-PCB52, and and13C-PCB153 respectively.

2.3 Lipid content determination

The lipid content of each sample was determined by gravimetric method. The extracts were concentrated to about 2mL, transferred into a 10mL volumetric flask with n-hexane, and then made up to 10mL level. 1mL of the lipid was pipetted and added to a dried weighed aluminum weigh boat. The solvent was first allowed to evaporate by carefully placing it on paper towel in the fume hood. The boat was then placed in an oven at 110°C for 1 hour, after which it was allowed to cool in a desiccator, re-weighed and the % lipid content calculated.

3. Results and Discussion

3.1 PCB Distribution across Sample Types at Different Locations on the Lagos Lagoon

Table 2: Total levels of PCBs in Water, Sediment and Biota of Lagos Lagoon in 2007

LOCATION	SAMPLES	Sum of PCBs (ng/g)	Sum of PCBs (ng/g lipid)	% Lipid or organic carbon
Five Cowrie Creek	Water (ng/mL)	0.00	0.00	0.00
	Sediment	0.00	0.00	0.80
	F15: Catfish *(Chrysichthys Nigrodigitatus)*	10.31	20.93	49.26
Unilag Lagoon Front	Water (ng/mL)	0.00	0.00	0.00
	Sediment	20.86	579.44	3.6
	SS: Crayfish (*Penaeus)*	1.27	94.78	1.34
	CS: Young blue crabs*(Callinectus amnicola)*	46.38	2127.52	2.18
	F4: Tilapia (Saratherod-on melanotheron)	30.36	1150.00	2.64
	F5: Tilapia *(Tilapia guineensis)*	20.65	1064.43	1.94
	F9: Megalops *(Tarpon Atlanticus)*	44.30	1466.89	3.02
Okobaba	Water (ng/mL)	0.00	0.00	0.00
	Sediment	105.53	989.96	10.66
	F1: Agaza *(Caranx hippos)*	31.81	896.06	3.55
	F2: Mullet *(Mugil cephalus)*	28.89	854.73	3.38
	F11: African red snapper *(Lutjanus agennes)*	27.74	678.24	4.09
	F12: Grunter *(Pomadasys Jubelini)*	8.40	535.03	1.57
	F20: African brown snapper *(Lutjanus Dentatus*)	31.20	1122.30	2.78
Mouth of Ogun River	Water (ng/mL)	0.00	0.00	0.00
	Sediment	2.71	315.12	0.86
	SB: Pink shrimps *(Macrobranchium*	1.75	84.14	2.08

	Vollenloevensis)			
	CB: Matured blue crabs *(Callinectus amnicola)*	6.41	212.25	3.02
	CE: Crab eggs	39.84	222.82	17.88
Ajah	Water (ng/mL)	0.00	0.00	0.00
	Sediment	6.71	36.87	18.20
	F3: Barracuda *(Sphyraena barracuda)*	3.338	477.14	0.7
	F10: Mackerel *(Scomberomorus Tritor)*	8.64	960.00	0.90
East of Palava Island	Water (ng/mL)	0.00	0.00	0.00
	Sediment	0.00	0.00	0.96
	F6: Bonga *(Edmalosa fimbriata)*	33.60	2709.68	1.24

The sum PCBs ranged from 2.71 to 105.53ng/g dry weight in sediment at the Mouth of Ogun River and Okobaba respectively; PCBs were not detected in sediments from two locations (Five Cowrie Creek and the East of Palava Island). This was probably due to the nature of the sediment (predominantly sandy) at Five Cowrie Creek, and also the fact that East of Palava Island is far removed from areas of high industrial activities. Sum (16) PCBs in three locations ranged from 2.71 to 20.81ng/g dry weight (table 2), showing that at these locations the values did not exceed the interim marine sediment quality guidelines (ISQGs) value of 21.5ng/g [7] & [9], and were also within the values obtained at similar places elsewhere. For example, sum PCBs ranging between 7µg/kg to 50µg/kg were reported in sediments from Lake Worth, Fort Worth, Texas, USA [15]. At Okobaba (a location not far from the disused power plant at Ijora and near the major Lagos mainland wood-processing facility), sum sediment PCBs of 105.53ng/g dry weight indicated that Okobaba sediments were comparatively highly contaminated as it exceeded the ISQG of 21.5ng/g. The variation in concentration by sample type disappeared on organic carbon normalization as observed in table 2.

The sum PCBs in all the biota assessed ranged from 1.27 to 46.38ng/g dry weight, with young blue crabs having the highest in this study. At the Mouth of Ogun River, sum (42) PCBs ranged from 1.75ng/g dry weight in shrimps to 39.84ng/g dry weight in crab eggs (Table 2). A report on sum PCBs in fish of Lagos lagoon gave values ranging from 0.63 to 2.94mg/kg wet weight [1]. Mean PCB concentrations ranging from 0.11 to 0.29ng/g wet weight had previously been reported in fish

from the Mouth of Ogun River location of Lagos lagoon [23]. Comparing with sum PCBs of the source clams from Potomac River in the US (Fort Foote) of 73ug/Kg, sum PCBs of fish and invertebrates from Lagos lagoon were lower than both the reference control level and the FDA (US Food and Drug Administration) food action level of 200 ug/Kg. It should be noted that these results do not signify safety of the Lagos Lagoon from PCB contamination, considering the fact that PCB concentrations in some Lagos soils are high [2].

3.2 PCB Distribution Between 2004 and 2008

Table 3: PCBs in Water, Sediment and Biota of Lagos Lagoon between 2004 and 2008

YEAR	PCBs (Total of 71 PCBs)			
	Water	Sediment	Fish	Invertebrates
2004		54 congeners found PCB74 (95.54ng/g) Okobaba		
2006	ND	23 congeners found PCB74 (161.97ng/g) Iddo	42 congeners found PCB17 (20.25ng/g) Mullets	15 congeners found PCB17 (28.30ng/g) Crab eggs
2007	ND	20 congeners found PCB70/76 (78.87ng/g) Iddo		
2008			8 congeners found PCB66 (205.07ng/g) Mullets	

Water:
No PCBs were detected in the water samples. The absence of PCBs in the water samples strongly reflected the hydrophobic nature of PCBs which caused their removal from water by sorption to suspended particles and bottom sediments. A study found that PCBs introduced to surface waters tend to be taken up by phytoplankton, with consecutive rapid sinking in sorbed state and degradation or solubilization along the water column [21]. Total PCB concentrations ranging from 0.000120ng/mL to 0.000020ng/mL were reported in urban influenced open sea waters of Barcelona and Valencia [17].

Sediment:
In the sediments, the number of PCBs was found to decline with time. In February 2004, 54 PCBs were found in the lagoon sediment and PCB 74 constituted the highest concentration (95.54ng/g), which was found at Okobaba (a location not far from the disused power plant at Ijora). In this study, the abundance of lower PCBs such as PCB 74 (2,4,4',5 chlorobiphenyl) in the sediment could be attributed to the fact

that lower chlorinated PCBs (2-4 chlorine substitutions) are more persistent in anaerobic sediments while higher chlorinated PCBs (5-8 chlorine substitutions) are rapidly degraded, according to [24].

In December 2006, the sediment PCBs in the lagoon declined to 23, and PCB 74 still presented the highest concentration (161.97ng/g d. w) at Iddo (the closest location to the disused power plant at Ijora). Though low chlorinated PCBs accounted for only 34.78% of the PCBs in the sediments, their individual concentrations were much higher than those of the higher ones.

In May 2007, twenty PCBs were found in the lagoon sediments, with PCB70/76 (a low chlorinated congener) having the highest concentration (78.87ng/g) at Iddo. The PCBs were probably dispersed from the source point at Ijora and other local sources via runoffs to Iddo.

Biota:

In the fish tissues, forty two PCBs were found which showed that more PCBs were found in fish than in sediments, and this reflected high bioaccumulation of PCBs in fish. Higher PCBs (28 of these PCBs) were more bioaccumulated than the lower ones. This reflected the fact that lower PCBs are usually more rapidly metabolized than higher ones due to the presence of more unsubstituted ring positions available for metabolic attack [24]. PCB 17 (2,2'4 chlorophenyl), a nonplanar PCB, presented the highest concentration of 20.25ng/g d. w. in mullets *(Mugil cephalus).* PCB153 (2,2',4,4',5,5' chlorophenyl), another nonplanar PCB, was found in all the fish samples and had the next highest concentrations in almost all the fish samples. This agreed with a Canadian study on herring gall which showed PCB 153 (2,2'4,4'5,5' chlorobiphenyl) as one of the most strongly bioaccumulated PCBs [21]. The study on herring gall also showed that the congeners that were strongly bioaccumulative had one feature in common: they lacked free adjacent meta-para positions on the rings and they were predominantly nonplanar [24]. Though PCB 17 (2,2'4 chlorobiphenyl) is a low chlorinated PCB congener, the high bioaccumulation was possibly due to its nonplanar nature, chemical availability, bioavailabilty, and feeding habits of the fish amongst other factors. 15 PCBs were found in the invertebrates and PCB 17 (2,2'4 chlorobiphenyl), a nonplanar PCB, still presented the highest concentration (28.30ng/g d. w.) in crab (*Callinectes amnicola*) eggs. Both fish and invertebrates bioaccumulated PCB 17 most in their fillet tissues. In this study, invertebrates bioaccumulated higher concentrations of the PCBs (ranging from 5.23 to 17.07ng/g d. w. mean PCBs), though fewer in number, than what the fish bioaccumulated (ranging from 0.56 to 1.93ng/g d. w. mean PCBs).

The implication of the availability and bioaccumulation pattern of PCBs in Lagos lagoon was assessed. Many toxic endpoints, including porphyria, indices of hepatotoxicity, and mortality of embryos of birds have been linked to the degree to which planar polychlorinated compounds bind to Ah receptor [12]. Similarly organisms that are exposed to coplanar PCBs in combination with, for example, mutagenic PAHs may result in increased DNA adduct formation because the former induce P4501A/2 (metabolism catalizing haemoprotein) [26]. No planar (congeners having chlorine substitution in all ortho positions) or coplanar (congeners with no chlorine substitution in ortho positions) PCB was bioaccumulated by any fish or invertebrate in this study. Thirty one of the PCBs bioaccumulated were nonplanar (congeners having substitution of chlorine atoms in adjacent ortho positions). Eleven of the PCBs (24%) bioaccumulated were close to coplanar (congeners having one chlorine substitution in ortho position) but their concentrations were low, except in megalops *(Tarpon Atlanticus)* where eight of them were bioaccumulated in concentrations up to 2.61ng/g d. w. There was therefore no high risk of PCB pollution in the lagoon.

In 2008 only wholefish samples were assessed. Eight PCBs congeners were found in the wholefish samples, and the concentration of PCB 66 (2,3',4,4' chlorobiphenyl, with structure close to coplanar congener) in mullets (205.07ng/g d. w.) was the highest. PCB 66 has one free meta position adjacent to the meta-para positions on the other ring. Chemical availability and the physiological characteristics of mullets seemed to be the major reasons for high bioaccumulation of PCB 66, a lower PCB, in the wholefish. PCB 66 was the only PCB found in all the wholefish types and sizes. Though PCB 66 (2,3',4,4' chlorophenyl) was found in mullets, the risks to aqutic biota and humans was not high as planar and coplanar congeners were not bioaccumulated. More PCBs were found in tilapia than in the mullets and catfish, though in smaller concentrations. This result revealed tilapia as having possible behavior specific characteristics of bioaccumulating PCBs when continuously exposed to them.

Mullets were found to be the most contaminated fish with PCBs, both in fillet tissue and whole fish assessments. This study revealed lower PCB concentrations in the mullet fillet tissues than what were obtained in the wholefish; therefore it could be safer to avoid consuming mullet wholefish.

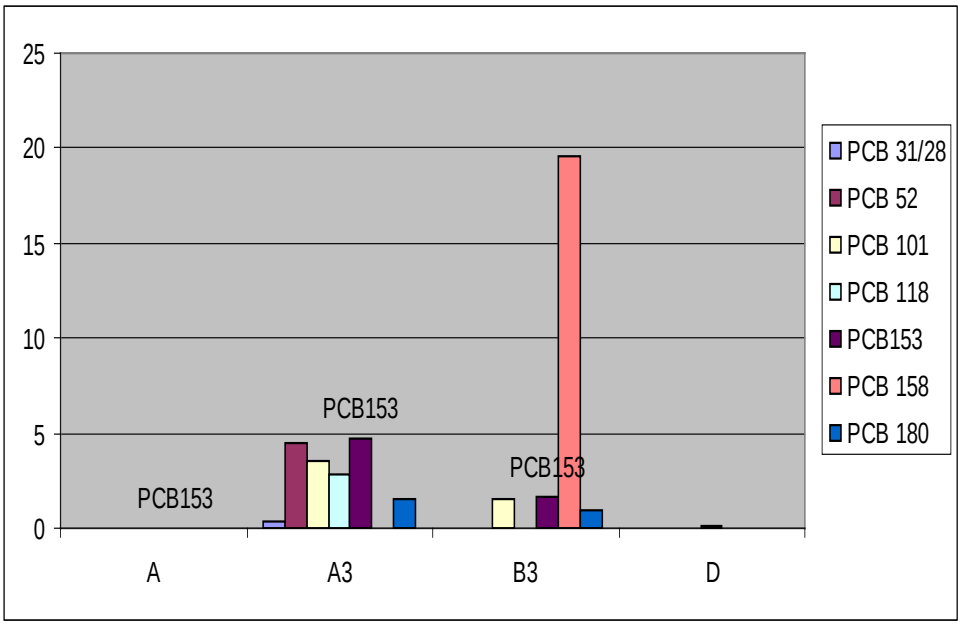

Fig. 2: PCBs (ng/g) in February 2004 sediment

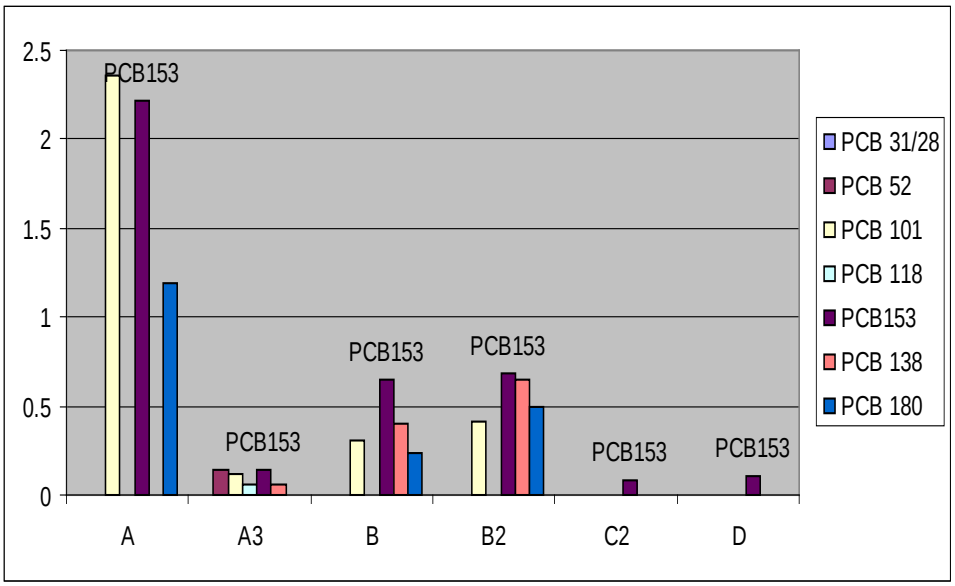

Fig. 3: PCBs (ng/g) in December 2006 sediments

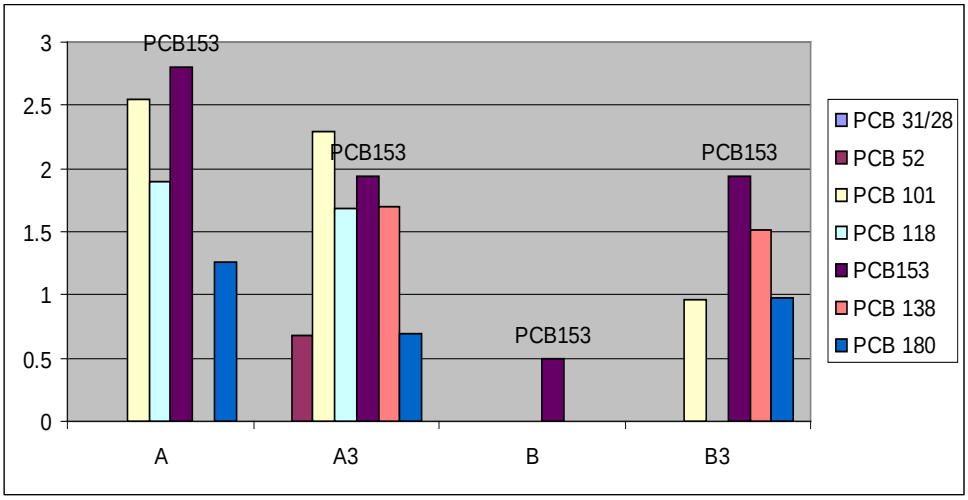

Fig. 4: PCBs (ng/g) in May 2007 sediments

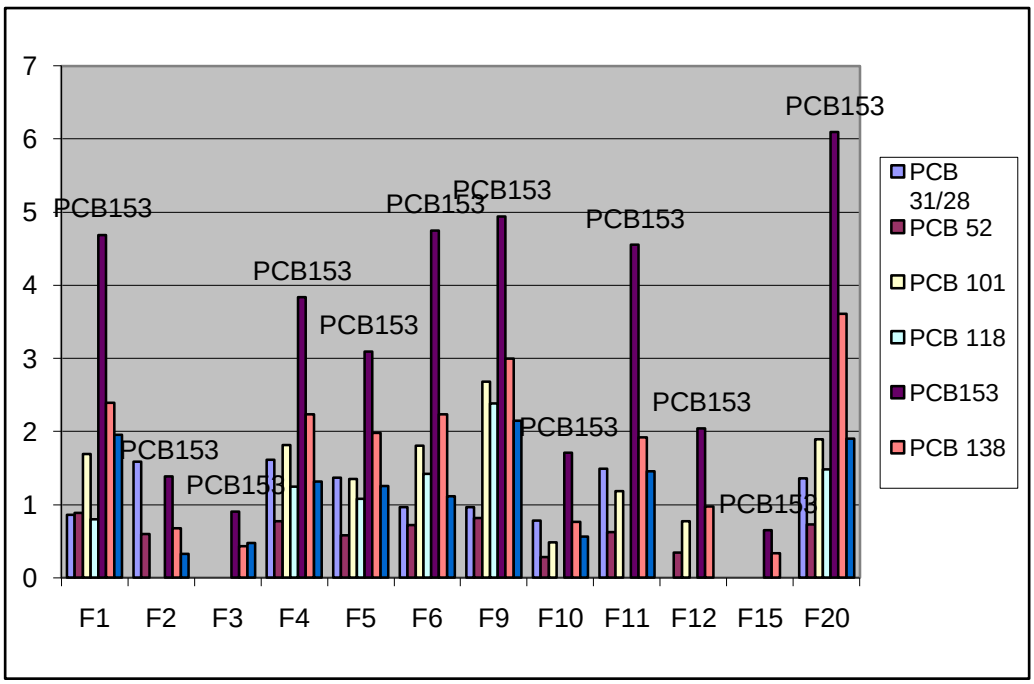

Fig. 5: PCBs (ng/g) in fish tissues

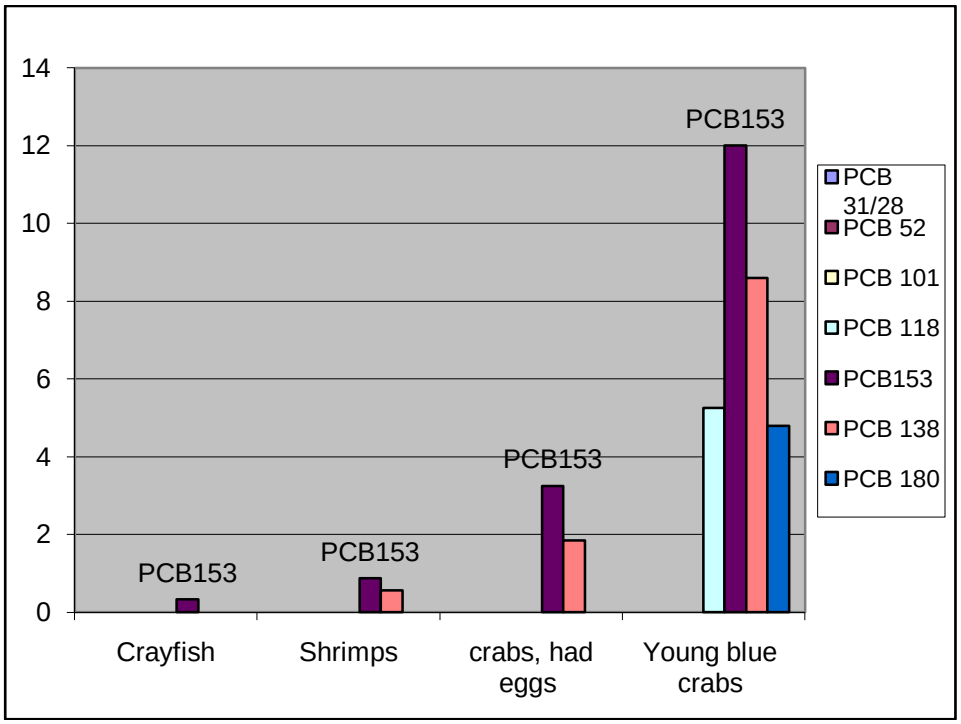

Fig. 6: PCBs (ng/g) in invertebrates

In assessing the seven indicator PCBs, PCB 153 was found in all sample types and was the most abundant between 2004 and 2007 (Figs. 1 to 5). Iddo, Okobaba and Lagos habour at Marina were the most contaminated locations with PCBs as shown in Figs. 1 to 3.

In Feb., 2004 PCB 153 was the most abundant at Okobaba (B3). In Dec., 2006 and May 2007, PCB 153 was found to be the most abundant, at same location, Iddo (A). Data for PCB 153 (a relatively abundant PCB congener) were used by the NMP (National Monitoring Programme) for UK coastal waters, to give an overall impression of contamination by PCBs [9]. Previously published data suggest that PCB levels in some coastal and riverine sediment can be locally elevated, especially in areas of high industrial activity [8].

3.3 Linkages between congener concentrations and wholefish size and type

Table 4: Whole fish type, size, length, weight and lipid content

Size	Length (cm)	Weight (g)	Catfish % lipid	Mullet %lipid	Tilapia %lipid	Mean % lipid
1	15-18.5	27.8-64.1	1.3143	9.3427	8.8165	6.4911
2	17.2-21	45.6-90	1.9234	9.2151	7.2584	6.1323
3	18.3-24	93.3-113.6	2.1280	4.0473	5.7939	3.9897
4	20-26	158.3-194.9	1.9920	6.7340	6.4263	5.0507
5	22.2-36	189.4-419.4	7.3932	3.3984	5.1353	5.3089

The result showed that in catfish, the youngest had the lowest lipid content while the oldest had the highest lipid content. The reverse was the case with mullets and tilapia. In the three fish types, the trend in increase or decrease in lipid contents with size was disrupted in the fourth size.

Table 5: Linkages between PCB concentrations and wholefish size and type

Dependent Variable: Concentrations

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	31551.361(a)	13	2427.028	2.164	.026
Intercept	2376.325	1	2376.325	2.119	.152
Fish	5138.117	2	2569.059	2.290	.112
PCBs	20576.232	7	2939.462	2.621	.022
Size	5814.752	4	1453.688	1.296	.284
Error	56082.951	50	1121.659		
Total	110292.753	64			
Corrected Total	87634.312	63			

R Squared = .360 (Adjusted R Squared = .194)

3.3 Assessment of the differences in congener composition within fish and invertebrates using multifactorial analyses of variance (MANOVA)

Table 6: Differences in PCB composition within fish and invertebrates

Dependent Variable: Concentrations

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	898.153(a)	24	37.423	3.577	.000
Intercept	116.035	1	116.035	11.092	.001
PCBs	398.652	7	56.950	5.444	.000
Biota	466.988	17	27.470	2.626	.003
Error	659.053	63	10.461		
Total	2213.790	88			
Corrected Total	1557.205	87			

R Squared = .577 (Adjusted R Squared = .416)

Table 7: Concentrations of the seven indicator PCBs in biota tissues and whole fish from Lagos lagoon

PCBs	PCBs in biota tissues (MEAN±SD) ng/g	PCBs in whole fish - Catfish (MEAN±SD)) ng/g	PCBs in whole fish – Tilapia (MEAN±SD)) ng/g	PCBs whole fish – Mullets (MEAN±SD)) ng/g
PCB 31/28	1.22±0.33	0.00	2.45±0.89	0.44±0.98
PCB 52	0.63±0.20	0.00	0.00	0.94±1.34
PCB 101	1.52±0.66	0.00	3.13±2.07	1.82±0.65
PCB 118	1.95±1.54	0.00	1.69±1.58	0.00
PCB153	3.44±2.91	0.00	8.79±8.42	0.54±1.20
PCB 138	2.10±2.05	0.00	4.72±4.44	0.00
PCB 180	1.57±1.23	0.72±0.98	4.35±2.11	0.56±0.77

In the wholefish there were no statistical significant differences in mean PCB concentrations with respect to fish type ($p = 0.112$, $df = 2$) and with respect to fish size ($p = 0.284$, $df = 4$). This result suggests a fairly constant source of PCBs exists for fish in Lagos lagoon, and also similar PCB bioaccumulation at different life stages. There were significant differences with respect to the PCBs ($p = 0.022$, $df = 7$). The most bioaccumulated PCB was PCB 153.

In the biota fillet tissues, there were significant differences in the mean concentrations of PCBs with respect to biota type ($P = 0.003$ and $df = 17$) as well as with respect to the different PCBs ($P = 0.000$ and $df = 7$), table 6. The Duncan table grouped the PCBs into two groups, with PCB17 forming the group with the highest concentrations (6.7142ng/g d. w.). Mean concentration of PCB 153 was high (3.44ng/g d. w.) compared to other PCBs that ranged from 0 .63 to 1.95ng/g d. w. (table 7).

3.5 Percent distribution of PCBs in different sample types

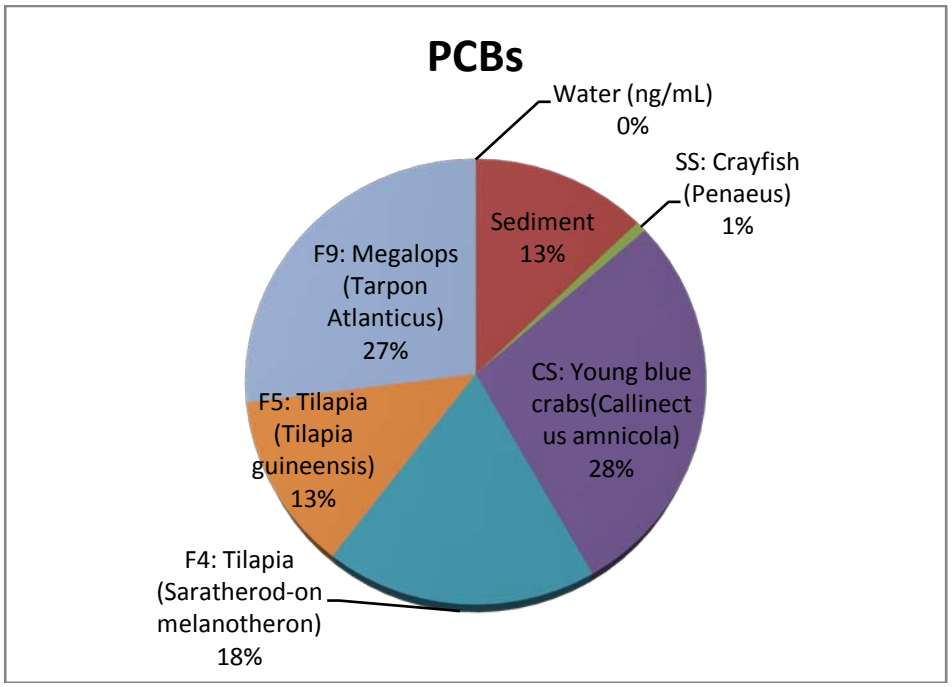

Fig. 7: Distribution of PCBs in different sample types

The young blue crabs had the highest percent distribution of PCBs (28%) in Lagos lagoon while crayfish had the lowest (1%) besides water which was not detected. Fig. 8 showed that the percent distribution of PCBs in the lagoon was highest in the biota, with young crabs reflecting 28%, megalops 27%, Tilapia 18%, while sediment distribution was just 13%. This distribution pattern reflected the high bioaccumulative property of the PCBs. The elevated concentrations of PCBs in tissues when compared to the sediment concentrations have also been reported by other authors. One of such studies was the assessment of the Avila Pier petroleum hydrocarbon contamination which reported the concentrations of PCBs exceeding 50 ng/g dry weight in sand crabs from beaches at Port San Luis Harbor and Avila, though PCBs were not detected in sediment samples collected from same beach [11].

3.6 Percent Distribution of PCBs in Fish and Invertebrates

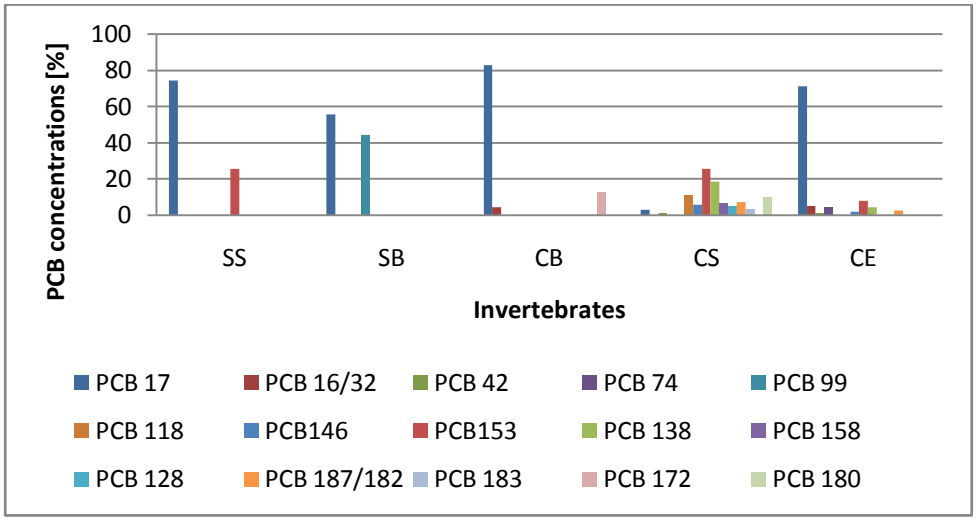

Fig. 8: Percent distribution of PCBs in invertebrates from Lagos lagoon

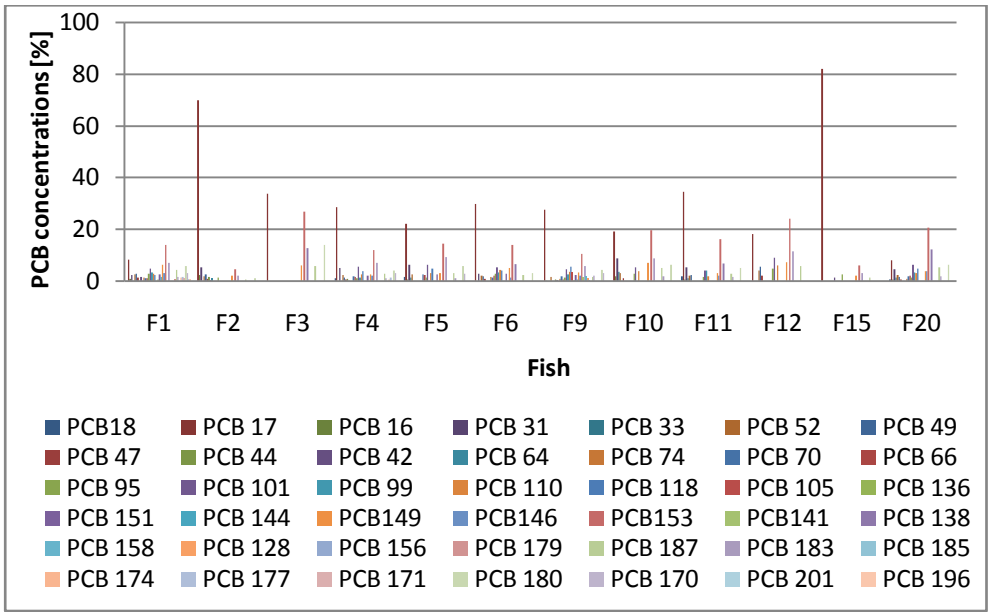

Fig. 9: Percent distribution of PCBs in fish from Lagos lagoon

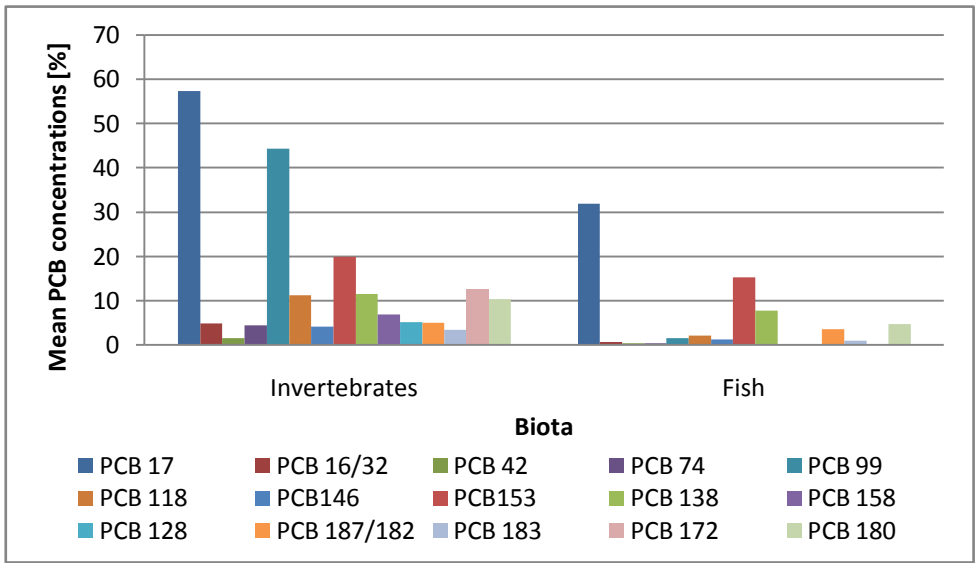

Fig. 10: Mean % PCBs in fish and invertebrates

More PCBs (41), as shown in Fig. 10, were bioaccumulated by the fish than the invertebrates (15 PCBs), but for reason of comparison between invertebrates and fish, the 15 PCBs were used as 100% total PCBs. Higher percentages of the PCBs were found in the invertebrates compared to those found in fish.

In our report PCB concentrations ranged from 0.199 to 20.249ng/g d. w. in fish, and from 0.301 to 28.301ng/g d. w. in invertebrates, while that of the sediments ranged from 0.054 to 8.986ng/g d. w. at same sampling sites. The result of elevated concentrations of PCBs in young crab tissues as reflected by the high % distribution in Fig. 8 suggests that this species may be a useful biological indicator for PCBs. Another report that among life stages of crabs and lipid weight-based concentrations of PCBs in young crabs were significantly higher than in older sand crabs [11]. Our findings compared favourably with Dugan's report as our sum PCBs (tables 2 and 3) in young crabs was 46.38ng/g d. w. and 2127.52ng/g lipid as compared to that of the matured crabs which was 6.41ng/g d. w. and 212.25ng/g lipid weight. As indicated in Fig. 9, PCB 17 was most dominant in the invertebrate samples with percent distribution ranging between 3.214 to 82.705% of the total PCB. Though PCB 17 (2,2'4 congener) is a low chlorinated PCB congener, the high bioaccumulation was favoured as a result of the lack of free adjacent meta-para positions on the rings [24]. In young crabs where many PCBs were bioaccumulated, PCB 153 was the most dominant representing 25.878 % of the total PCB, followed by PCB 138, PCB 118, PCB 180 which accounted for 18.538, 11.337 and 10.346 %

respectively. Here PCB 17 only accounted for 3.214% of the total PCBs in that sample.

In general, percent distribution of PCBs identified PCB 153 as the most dominant in the invertebrates from Lagos lagoon. This agreed with a Canadian study on herring gull which showed PCB 153 as one of the most strongly bioaccumulated PCBs [24]. The study on herring gall also showed that the congeners that were strongly bioaccumulative had one feature in common: they lacked free adjacent meta-para positions on the rings [24]. Amongst the congeners found in the invertebrates, PCB 153 is the only one that lacks free adjacent meta-para position on the ring. This is one of the reasons PCB 153 bioaccumulated most, even more than PCB 180 (having a free adjacent meta-para position on each of its two rings) which has higher chlorination (7 chlorine atoms) than PCB 153 (6 chlorine atoms). This also explained why PCBs 138 (having 6 chlorine atoms but one free adjacent meta-para position on the ring) bioaccumulated more than PCB 118 which has 5 chlorine atoms and one free adjacent meta-para position on the ring. Similar pattern was observed in all the fish samples, though the fish bioaccumulated much more PCBs than the invertebrates. This therefore suggested that persistence is related to the failure of P450 to metabolise some PCBs [24]. PCBs can act as inducers of P450 (metabolizing enzymes) and consequently accelerate the rate of their own metabolism which can also result in a number of toxic effects via activation. Induction of P450s by PCBs can increase the rate of activation of a number of carcinogens and mutagens, eg. PAHs. The presence of PCBs in the fish and invertebrates from Lagos lagoon, even though it did not exceed the FDA (US Food and Drug Administration) fish consumption action level for total PCBs (200 ug /Kg), could pose some risks by reason of its capacity to induce cytochrome P450. Higher PCBs are recalcitrant and therefore tend to be strongly bioaccumulated and bioconcentrated with movements along food chains. There could be magnification by several orders of magnitude with movement up the food chain. The levels of higher chlorinated PCBs are still undesirably high in predators – notably mammals and fish-eating birds at the top of marine food chains [10] & [25]. Which PCB had the highest %age in fish? Almost all the 42 PCBs found in the fish samples were found in agaza (F1) and the megalops (F9), making these two species the most contaminated with PCBs in the lagoon. Barracuda (F3) happened to be the least contaminated with the PCBs having bioaccumulated only 6 PCBs at very low concentrations to give sum PCBs of 3.338ng/g d. w. and 482.710ng/g lipid weight.

4. Conclusion

PCBs in the Lagos Lagoon environment have been evaluated for the first time. Sum PCBs of fish and invertebrates from Lagos Lagoon were lower than both the reference control level and the FDA food action level. Sum PCBs in sediments exceeded the interim marine sediment quality guidelines (ISQGs) at Okobaba, thus PCBs posed threats at this location. High bioaccumulation of PCBs by fish and invertebrates in the Lagos lagoon was influenced by chemical availability, bioavailabilty, lipid content of the biota, feeding habits of the biota, physiological characteristics of the biota, age of the biota, skin morphology, lack of adjacent meta-para positions on the PCB rings, and nonplanarity of PCBs amongst other factors. The PCBs bioaccumulated were predominantly nonplanar and refractory congeners. The importation, continued use, and unregulated disposal of used old PCB-containing products, which have negative impacts on the environment, are obviously still in common practice in Nigeria. In conclusion, PCBs presently pose risks in the Lagos lagoon marine environment, a very important natural resource.

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REFERENCES

1. Adeyemi, D., Ukpo, G., Anyakora, C., Unyimadu, J. P (2008) Organochlorine Pesticide Residues in Fish Samples from Lagos Lagoon, Nigeria. *American Journal of Environmental Sciences* 4 (6): 649-653, ISSN 1553-345X
2. Alani, R. A., Olayinka, K. O., and Alo, B. I. (2013). The Levels Of Persistent, Bioaccumulative, And Toxic (PBT) Organic Micropollutants Contamination Of Lagos Soils. *Journal of Environmental Chemistry and Ecotoxicology* Vol. 5(2), pp. 26-38.
3. Alani, R. A., Drouillard, K. G., Olayinka, K. O., and Alo, B. I (2012) Bioaccumulation of Polycyclic Aromatic Hydrocarbons (PAHs) in Fish and Invertebrates of Lagos Lagoon, Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences* 3 (2): 287-296.Alo,
4. B.I., Olayinka K.O, Oyeyiola, A., Oluseyi, T.O., Alani, R., and Abayomi, A., (2014) Studies and Transactions on Pollution Assessment of the Lagos Lagoon System, Nigeria in Salif Diop, Jean-Paul Barusseau, Cyr Descamps (Eds) *Estuaries of the*

World-The Land/Ocean Interactions in the Coastal Zone of West and Central Africa, Springer, Switzerland, 2014

5. ATSDR (Agency for Toxic Substances and Disease Registry) (2000) Toxicological Profile for Polychlorinated Biphenyls (Update). U.S. Department of Health and Human Services, Agency for Toxic Substance Disease Registry, Atlanta, GA. November.2000.
6. Birmingham, B., Gilman, A., Grant, D., Salminen, J., Boddington, M., Thorpe, B., Wile, I., Toft, P. and Armstrong, V. (1989) PCDD/PCDF multimedia exposure analysis for the Canadian population: detailed exposure estimation. *Chemosphere* 19(1–6):637–642.
7. CCME (1992) Canadian Water Quality Guidelines, prepared by the Task Force on Water Quality Guidelines of the Canadian Council of Ministers of the Environment, Eco-Health Branch, Ottawa .Ontario, Canada.
8. CEFAS (Centre for the Environment, Fisheries and Aquatic Sciences). (1997). Monitoring And Surveillance Of Non-Radioactive Contaminants In The Aquatic Environment And Activities Regulating The Disposal Of Wastes At Sea, 1994. *Aquatic Environment Monitoring Report No 47*, Centre for Environment, Fisheries and Aquaculture Science, Lowestoft.
9. Cole, S., Codling, I.D., Parr, W. and Zabel, T. (1999) Guidelines For Managing Water Quality Impacts Within UK European Marine Sites. Prepared by: WRc Swindon Frankland Road, Blagrove Swindon Wiltshire SN5 8YF, 13-109.
10. De Voogt, P. (1996). Ecotoxicology Of Chlorinated Aromatic Hydrocarbons. In Chlorinated Organic Micropollutants, No. 6 In Series on Issues in Environmental Science and Technology. R.E. Hester and R.M. Harrison (Eds.) *Royal Society of Chemistry* 89 112.
11. Dugan, J., Ichikawa, G., Stephenson, M., Crane, D., Mccall, J. & Regalado, K. (2005) Monitoring of Coastal Contaminants using Sand Crabs. Prepared for: Central Coast Regional Water Quality Control Board.
12. Fernandez-Salguero, P. M., Hilbert, D. M., Rudikoff, S. et al. (1996). Aryl-Hydrocarbon Receptor-Deficient Mice Are Resistant To 2,3,7,8-Tetrachlorodibenzo-P-Dioxin-Induced Toxicity. *Toxicology and Applied Pharmacology* 140, 173-179.
13. Fernie, K., Smits, J. & Bortolotti, G. E. A. (2001) Reproduction Success Of American Kestrels Exposed To Dietary PCBs. *Environmental Toxicology and Chemistry*, 20: 776-781.
14. Fitzgerald, E.F., Brix, K. A., Deres, D. A., Hwang, S. A., Bush, B., Lambert, G. L., and Tarbell, A. (1996) Polychlorinated Biphenyl (PCB) And Dichlorodiphenyl Dichloroethylene (DDE) Exposure

Among Native American Men From Contaminated Great Lakes Fish And Wildlife. *Toxicol. Ind. Health* 12(3–4):361–368.

15. Harwell, G R., VanMetre, P C., Wilson, J T., and Mahler, B J. (2003) Spatial Distribution and Trends in Trace Elements, Polycyclic Aromatic Hydrocarbons, Organochlorine Pesticides, and Polychlorinated Biphenyls in Lake Worth Sediment, Fort Worth, Texas. U.S. GEOLOGICAL SURVEY. Water- Resources Investigations Report 03–4269 In cooperation with the U.S. Air Force Austin, Texas
16. Jensen, S. (1972) The PCB Story. *Ambio* 1(4):123–131.
17. Klecka (2000) Evaluation of Persistence And Long-Range Transport Of Organic Chemicals In The Environment. SETAC, Pensacola Florida, 400p.
18. Lazar R, Edwards RC, Metcalfe CD, Metcalfe T, Gobas FAPC, Haffner GD (1992) A Simple, Novel Method For The Quantitative Analysis Of Coplanar (Non-Ortho Substituted Polychlorinated Biphenyls In Environmental Samples. *Chemosphere* 25:493–504.
19. Olojoba, A., Abu, A. and Okafor C. (2010) Nigeria-Polychlorinated Biphenyls (PCBs) Management Project. Report Number AC5412. PP 6.
20. Robertson, L. & Hansen, L. (2001) PCBs: Recent Advances In Environmental Toxicology And Health Effects, Kentucky University Press, Kentucky.2001
21. Tanabe, S., Hidaka, H. & Tatsukawa, R. (1983a). PCBs and Chlorinated Hydrocarbon Pesticides In Antarctic Atmosphere And Hydrosphere. *Chemosphere*, 12, 277-88.
22. UNEP (1999) Regional Overview Of Land-Based Sources And Activities Affecting The Coastal African Region. UNEP/GPA Coordination Office and West and East African Action Plan Regional Coordinating Unit.
23. Unyimadu JP, Udochu, A.O. 2002. Comparative Studies Of Organochlorine And PCBs In Fish From The Lagos Lagoon. *J. Agric. Biotech. Environ*. 4(1-2): 14-17.
24. Walker, C. H. (2009) Organic Pollutants. An Ecotoxicological Perspective., New York., CRC Press.
25. Walker, C. H. & Livingstone, D. (1992) Persistent Pollutants in Marine Ecosystems. A special publication of SETAC, Oxford, Pergamon Press.
26. Walker, C. H. and Johnston, G. O. (1989). Interactive Effects Of Pollutants At The Kinetic Level: Implications For Marine Environment. *Marine Environmental Research* 28, 221-225.
27. WHO (World Health Organization). (1992) Polychlorinated Biphenyls and Terphenyls. 2nd Ed. Environmental Health Criteria 140. Geneva: World Health Organization.

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PORE FILL AND LITHOLOGY DISCRIMINATION FROM CROSS-PLOTS OF ELASTIC ROCK PARAMETERS: AN EXAMPLE FROM THE ONSHORE NIGER DELTA BASIN, NIGERIA

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ABSTRACT

Cross-plots of elastic rock properties Lambda (λ, incompressibility), Mu (μ, rigidity) and Rho (ρ, density) and their combinations (λρ,μρ, λ/μ, etc.) were generated to determine which combination of attributes depict characteristics that can be used to identify specific lithologies and pore fluid types in an old producing oilfield within the onshore Niger Delta basin. Shear wave logs, which were not routinely collected were generated from P-wave logs, using the Castagna's equation. LambdaRho and MuRho logs were generated empirically while log editing and reconstruction was applied to correct for digitizing errors and depth shifts. The results show a distinct separation between brine and gas saturated lithologies by using either the Vp/Vs versus P-impedance or Vp versus Vs cross-plots. Oil filled sands were identified on the Ratio (λ/ρ)-Difference (λρ-μρ) cross-plot as having ratios less than one (<1). The cross plot of LambdaRho (λρ) versus MuRho (μρ) however distinguished gas and oil saturated sands from the regional wet trends. The results show that LambdaRho versus MuRho cross-plot is a better discriminator for oil and gas saturated sands in the area and could be evaluated on larger scales by cross plotting similar attributes from seismic volumes to identify other prospective oil bearing zones in areas away from wells.

* Keywords: Rock physics, Reservoir geophysics, Parameter estimation, Cross-plots

Introduction

Active exploration and production activities have been going on in the onshore Niger Delta Basin for over fifty years and production levels from most fields have continued to decline. However, renewed exploration interest in the basin could be revived through the discovery of bye-passed reservoirs in old oilfields using newer approaches. One of such approaches is the cross-plotting of elastic rock properties to determine which pair of attributes could serve as good hydrocarbon or lithology indicator within the onshore Niger Delta. Identifying these attributes would help in secondary exploration techniques (AVO and Seismic inversion (pre-stack and post-stack)) and reduce the lead time to the discovery of new reserves in mature fields. Proper identification of the correct pair of attributes from a producing well will enable seismic interpreters to look for similar patterns in a seismic volume by cross plotting similar attributes. Cross-plotting of appropriate pairs of attributes so that common lithologies and fluid types generally cluster together e.g. in AVO cross-plot space has become a straightforward approach for fluid and lithology prediction (Castagna and Smith, 1997; Dewar, 2001; Gray and Anderson, 2001; Pelletier, 2009; Chopra, et.al, 2003). Goodway (2001) demonstrated the use of derived elastic parameter cross-plots from wells for better petrophysical discrimination of rock properties and noted that various combinations of λ, μ, and ρ (e.g.$\lambda\rho$, $\mu\rho$, and λ/μ) show better separation of gas sands from brine sands and shales than P-impedance (I_p) and S-Impedance (I_s). In the Niger Delta basin, the viability of the Lambda-Mu-Rho technique and use of cross-plots in discriminating between hydrocarbons and various lithologies have been demonstrated for offshore areas by Omudu and Ebeniro (2005) and Ujuanbi et al., (2008). In this work, cross-plots of elastic rock parameters from a selected oil well located within the onshore part of the Niger Delta were evaluated to determine which pair of attributes constitutes better fluid and/or lithology indicators.

Location and Stratigraphic setting of the study area

The study area is located within the onshore Niger Delta basin (Fig. 1), which is a sedimentary basin composed of numerous complex regressive offlap sequences of clastic sediments. Sediment thickness in the basin ranges from 9000-12000 m. Short and Stauble (1967) identified three major lithofacies in the basin based on dominant environmental differences in which regressive sequences was clearly defined. The sedimentary environments are continental, transitional, and marine sequentially. A prograding delta (like the Niger Delta) will

have sediments from the different environments to be stratigraphically superimposed. The basal unit is the massive marine shales, the intermediate unit is the interbedded shallow marine and fluvial sands, silt and clay and top unit that caps the sequence with a massive continental sands. They are readily identifiable as three regional and diachronous formations, since the delta has been prograding uninterruptedly throughout the Tertiary. From the bottom to the top, the lithofacies are known as Akata Formation, Agbada Formation and the Benin Formation respectively (Fig. 2). Their ages range from the Eocene to the Recent.

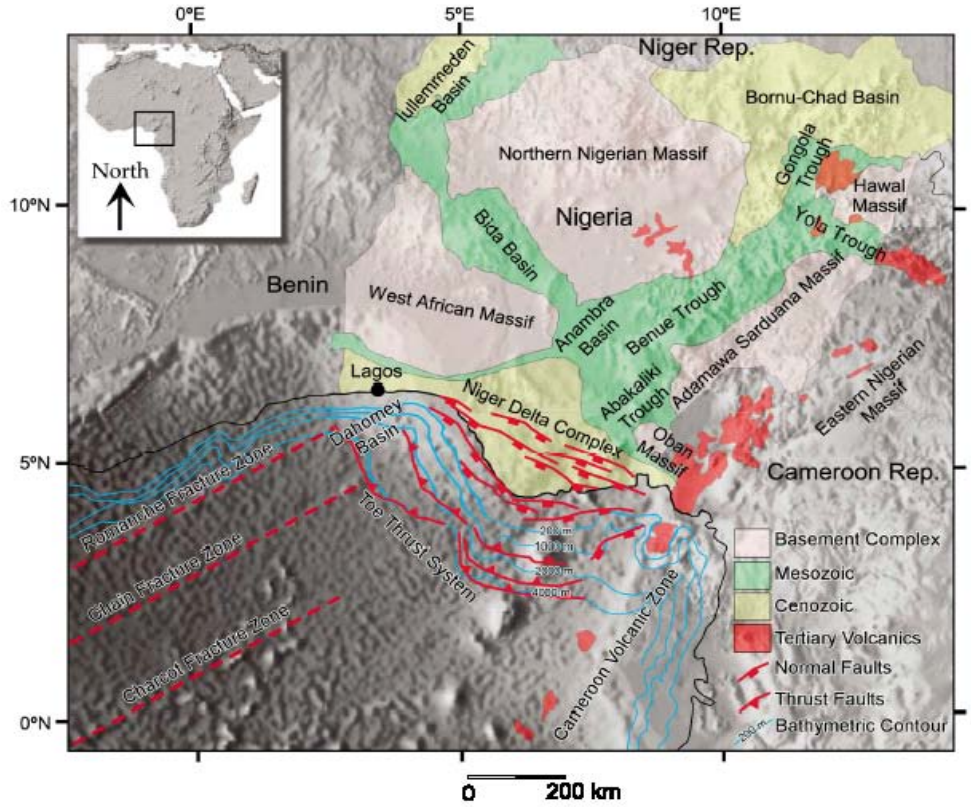

Fig. 1. Location map of the Niger Delta region showing the main sedimentary basins and tectonic features. The delta is bounded by the Cameroun volcanic zone, the Dahomey basin, and the 4000m (13,100ft) bathymetric contour. The regional geology is modified from Onuoha (1999). Topography and bathymetry are shown as shaded relief gray-scale image.

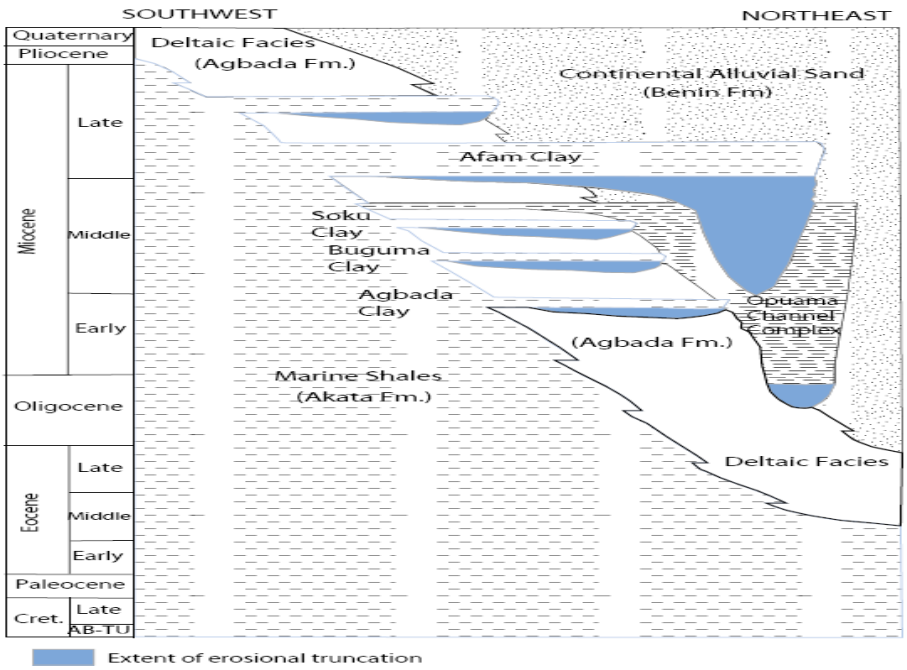

Fig. 2 Stratigraphic column showing the three formations of the Niger Delta (Shannon and Naylor, 1989; Doust and Omatsola, 1990; Tuttle et al., 1999)

Materials and Methods

The dataset for the present study includes a suite of well logs (density, sonic, resistivity, gamma ray and caliper) from a well in the selected field. The logs supplying information on interval transit times (Δt) and bulk density (ρ_b) and the other logs were carefully checked for quality and completeness prior to loading and subsequent use in cross-plotting. The well database was created using the Geoview module of the *Hampson Russell* software and Fig. 3 shows that the logs were of good quality. Shear wave logging is unfortunately not yet a routine activity in the area, so shear wave logs (Fig. 4) had to be generated from P-wave logs using the Castagna (ARCO) mudrock line relationship given by $Vp = 1.16Vs + 1360m/s$ (Castagna et al., 1985). The equation is accurate everywhere except in hydrocarbon filled zones. Fluid substitution (Fig. 5) using the Biot-Gassmann method was applied to obtain accurate readings over hydrocarbon bearing intervals. In practice, fluid substitution is performed by starting with compressional (Vp) and shear wave (Vs) velocities measured on rocks saturated with the *initial* pore fluid and then extracting the bulk and shear moduli, K and μ, using the equations below:

$$K = \rho\left(V_p^{\,2} - \frac{4}{3}V_s^{\,2}\right) \quad \text{and} \quad \mu = \rho V_s^{\,2} \tag{1}$$

and

$$\rho = \phi\rho_f + (1-\phi)\rho_0 \tag{2}$$

where ρ, ρ_f and ρ_0 are the densities of the rock, the pore filling phase (air or fluid), and the mineral phase respectively.
The bulk modulus of the rock saturated with the new pore fluid was calculated using equation 3 and the velocities reconstructed.

$$\frac{K_{sat}}{K_0 - K_{sat}} = \frac{K_{dry}}{K_0 - K_{sat}} + \frac{K_f}{\phi(K_0 - K_{sat})} \tag{3}$$

where ϕ is the porosity and K_0 and K_f are the bulk moduli of the mineral material and the pore fluid respectively.

The petrophysical parameters used for fluid substitution for the oil and gas zones are shown in Tables 1, 2 and 3.

Table 1. Petrophysical parameters for W9500 oil zone

S/N	PARAMETERS	VALUES
1	Fluid composition	Oil and Brine (2 phase)
2	Water saturation	0.24
3	Porosity	0.29
4	Top depth	9204ft
5	Bottom depth	9393ft
6	Oil Up To (OUT)	9205ft
7	Oil Down To (ODT)	9393ft
8	Calculated matrix density	2.60g/cc
9	Oil modulus	1.00GPa
10	Oil density	0.75g/cc
11	Matrix modulus	40GPa
12	Shear modulus	44GPa
13	Brine modulus	2.38GPa
14	Brine density	1.09g/cc

Table 2. Petrophysical parameters for Z1100 gas zone

S/N	PARAMETERS	VALUES
1	Fluid composition	Gas and Brine (2 phase)
2	Water saturation	0.04
3	Porosity	0.26
4	Top depth	10905ft
5	Bottom depth	10975ft
6	Gas Up To (GUT)	10905ft
7	Gas Down To (GDT)	10975ft
8	Calculated matrix density	2.623g/cc
9	Gas modulus	0.021GPa
10	Gas density	0.1g/cc
11	Matrix modulus	40GPa
12	Shear modulus	44GPa
13	Brine modulus	2.38GPa
14	Brine density	1.09g/cc

Table 3. Petrophysical parameters for Z1200 gas zone

S/N	PARAMETERS	VALUES
1	Fluid composition	Gas and Brine (2 phase)
2	Water saturation	0.1
3	Porosity	0.23
4	Top depth	10905ft
5	Bottom depth	11111ft
6	Gas Up To (GUT)	10975ft
7	Gas Down To (GDT)	11111ft
8	Calculated matrix density	2.623g/cc
9	Gas modulus	0.021GPa
10	Gas density	0.1g/cc
11	Matrix modulus	40GPa
12	Shear modulus	44GPa
13	Brine modulus	2.38GPa
14	Brine density	1.09g/cc

The logs of elastic rock parameters (e.g. Lambda(λ), Mu(μ) and their

combinations (e.g. LambdaRho and MuRho) were derived from other logs using the relations below:

$$\text{LambdaRho} = \lambda\rho = Z_P^{\,2} - cZ_s^{\,2} \quad (4)$$

and

$$\text{MuRho} = \mu\rho = Z_s^{\,2} \quad (5)$$

where Zp, Zs and ρ represents P-impedance, S-Impedance and Density respectively and c = multiplier constant ($2.0 \leq c \leq 2.5$)

Several reservoir zones of interest (well tops) were chosen for the well and documented for the purpose of this study (e.g. W9500, Z1100, Z1200, etc.). Cross plots of elastic rock properties Lambda (λ), Mu (μ), and Rho (ρ) from logs and their combinations (λρ, μρ, λ/μ, etc.) were generated to determine what combination of attributes depicts characteristics that can be used to discriminate between the different lithologies and pore fluids.

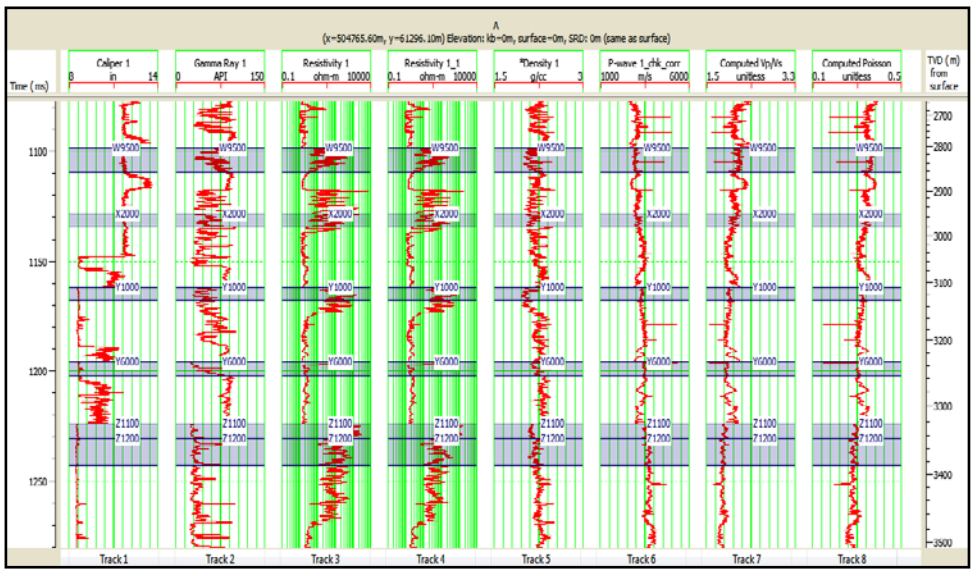

Fig. 3. Log panel for well A before fluid substitution

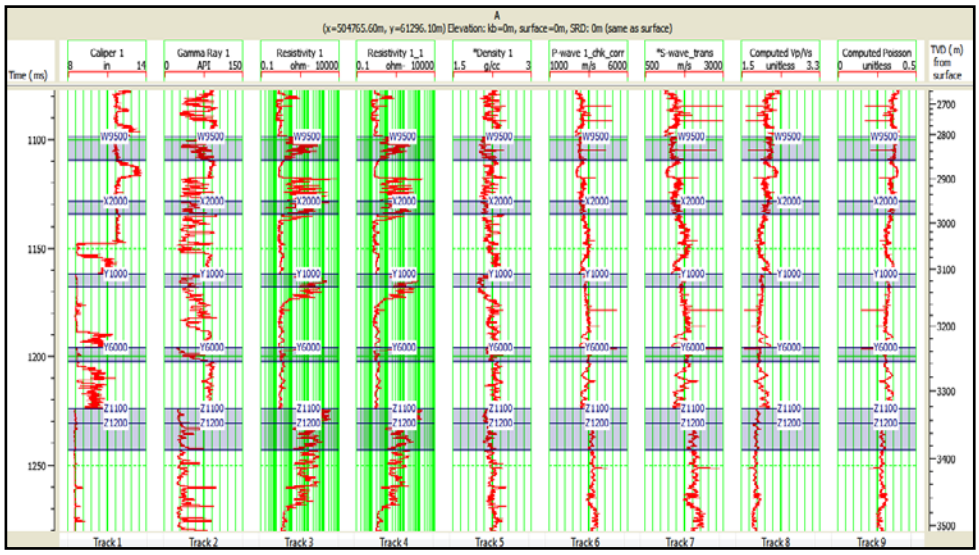

Fig. 4. Log panel for well A showing the generated S-wave log (track 7)

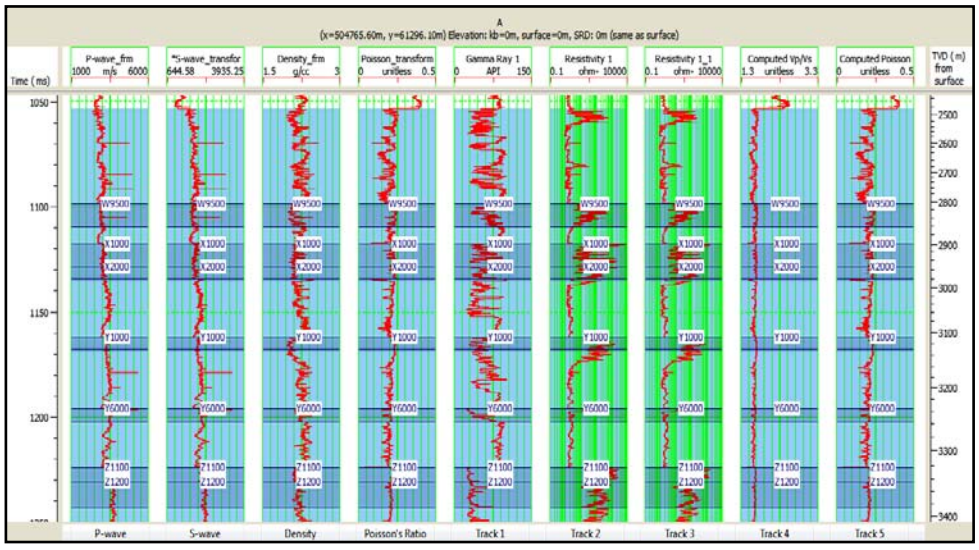

Fig. 5. Final logs after fluid substitution. Note the reduction in V_p/V_s and Poisson ratio as a result of replacing brine with oil and gas respectively.

RESULTS

The results are presented as cross plots of several rock parameters from the well as shown below

Cross plot of P-wave (V_p) log versus Measured depth

The cross plot (Fig. 6) was used to show the variation in the velocity of P- waves across the study area. The velocity of P-waves is given by

$$V_P = \sqrt{\frac{K + \frac{4}{3}\mu}{\rho}}$$

Where k, the bulk modulus is a measure of the incompressibility of the material through which the waves travel and ρ is the density of the material.

If all the other parameters remain constant, an increase in density would lead to a reduction in the velocity of P-waves in the propagating medium. This, however is not usually the case because an increase in density with depth is usually accompanied by a proportionate increase in the bulk and rigidity moduli of the rocks, leading to an increase of the velocity of P-waves (V_p) with depth. The P-wave velocity (V_p) is faster in sands in the upper and lower sections of the well while the middle section shows a progressive increase in V_p in shales. The switch have been attributed to greater compaction in shales with respect to sand, leading to increased density and higher acoustic impedance.

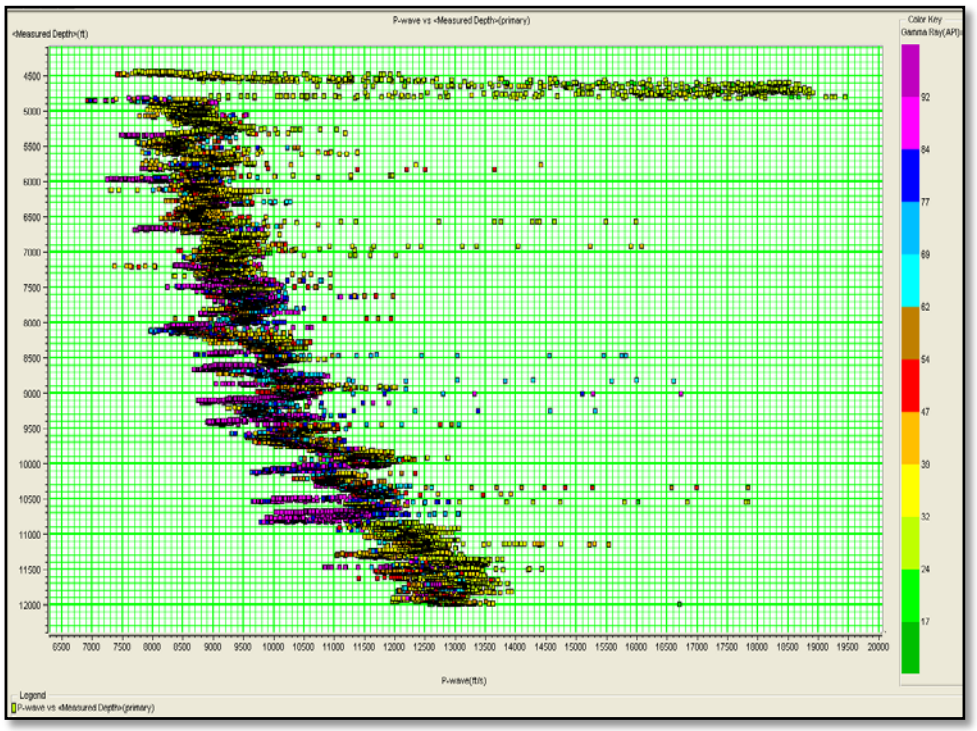

Fig. 6. Crossplot display of P- wave versus Measured depth for Well A. Trend shows an increase in V_p with depth.

Cross plot of S-wave (V_s) log versus Measured depth

The cross plot of measured depth and shear wave (S-wave) velocities was used to evaluate the variation in the speed of S-waves across the study area. The predicted shear wave trend for Well A in the study area is shown in Fig. 7 . The velocity of shear waves in any medium is given by

$$V_S = \sqrt{\frac{\mu}{\rho}}$$

Where μ, the rigidity modulus is a measure of the resistance of the material to shearing stress and ρ is the density. The equation above indicates that if all other parameters remain constant, an increase in density will reduce the velocity of S-wave. On the other hand, an increase in the density of the formation is often followed by symmetrically larger increases in rigidity of the rock. For example, an increase in density which sediments undergo when they are buried, compressed, cemented and lithified coincides with even a greater increase of the material's rigidity. This creates a balanced effect and leads to an increase in the speed of shear waves with depth. The trend is reflected in this cross plot, which shows a progressive increase in the velocity of shear waves across the study area.

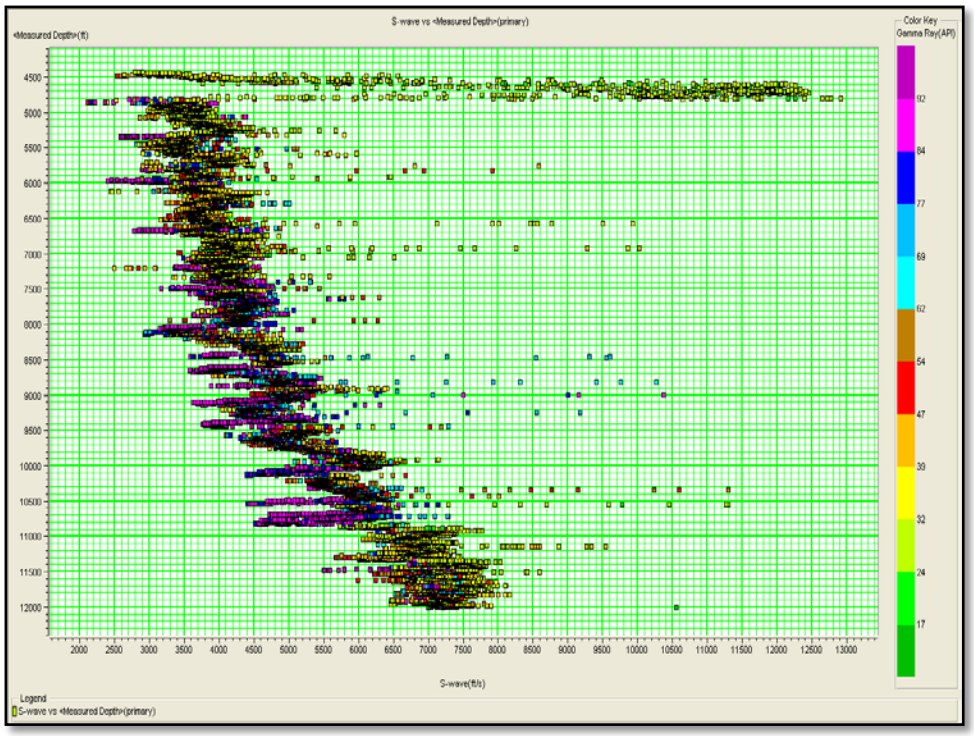

Fig. 7. Crossplot display of S- wave versus Measured depth for Well A. Trend shows an increase in V_s with depth.

Cross plot of P- Impedance (V_p*ρ) versus Measured Depth

The cross plot (Fig. 8) shows an increase in the value of acoustic impedance with depth in the study area. This was attributed to compaction due to overburden pressure as a result of increasing depth of burial. The variation of acoustic impedance in shales and sands was shown in a gamma ray colour coded (to discriminate sands from shales) cross plot which depicts the sands within the shallow and deeper sections as having higher impedance than the surrounding shales. The reverse was the case in the middle section where shales have higher acoustic impedance than sands. The switch in acoustic impedance in the sands and shales within the middle section was attributed to increased compaction in the shales which resulted to higher density and overpressure conditions and increased P-wave velocity (V_p).

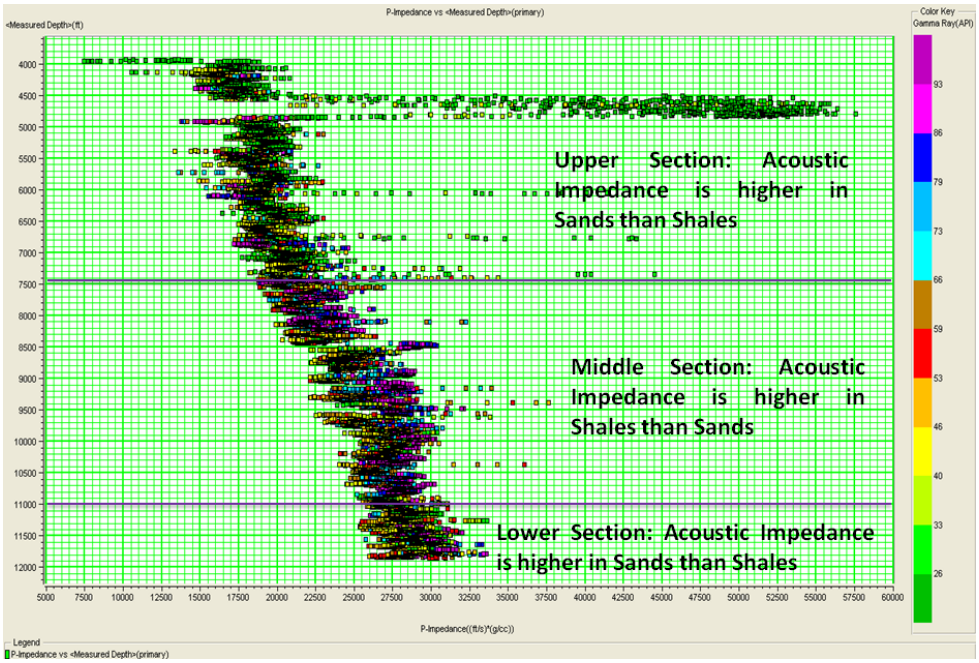

Fig. 8. Cross plot of P-impedance versus measured depth (colour coded with gamma ray log) showing the variation in Acoustic Impedance values in the study area. Blue tones represent shales while golden tones represent sand

Cross-plot of Vp/Vs ratio versus P-Impedance

Fig. 9 shows a gamma ray colour coded cross-plot of Vp/Vs ratio versus P-impedance for well A. The sands are clearly shown to have lower acoustic impedances (<45 API) than the shales (>62 API). The cross-plot distinguished a cluster of points which deviated from the regional wet trend. The anomalous data points (coloured polygon) was identified

in an attribute cross-section from the Well and lies within a depth range of 10904 – 10975 ft (≈3323-3345 meters) (Fig. 10). The zone correlates well with one of the identified key horizons in well A (the Z1100 gas sand reservoir zone) and has a Vp/Vs ratio value of about 1.7, a value adjudged by previous researchers (e.g. Potter et al., 1996) to depict good quality sand reservoir. The low Vp/Vs ratio was attributed to a decrease in the velocity of the shear waves (Vs) with shaliness and could serve as a good diagnostic indicator of clean reservoir sand in the area.

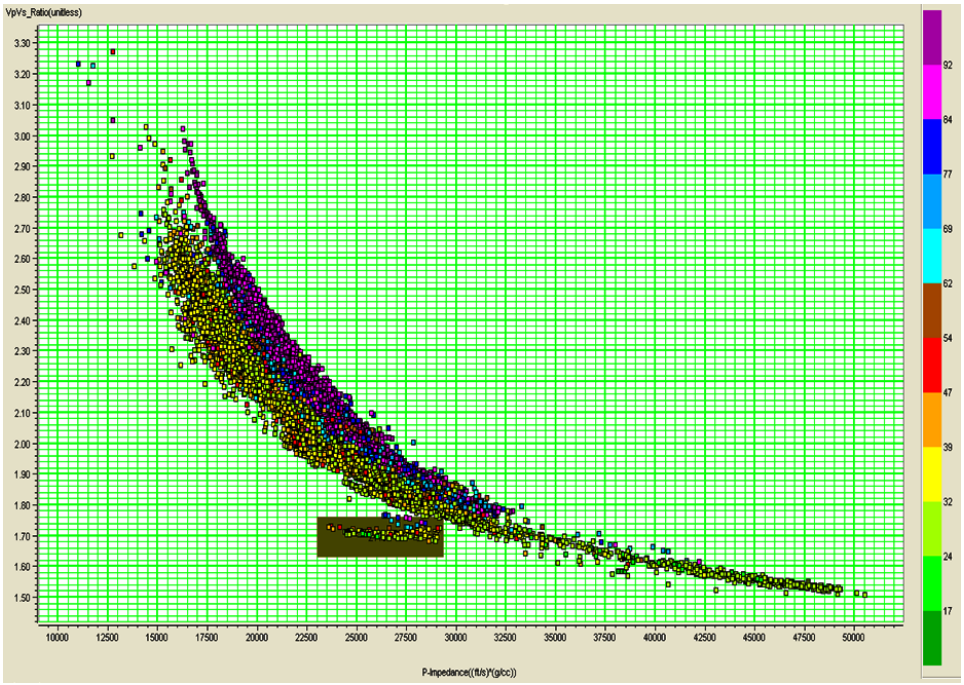

Fig. 9. Cross-plot of Vp/Vs ratio versus P-Impedance for Well A, showing a cluster of points outside the background wet trends

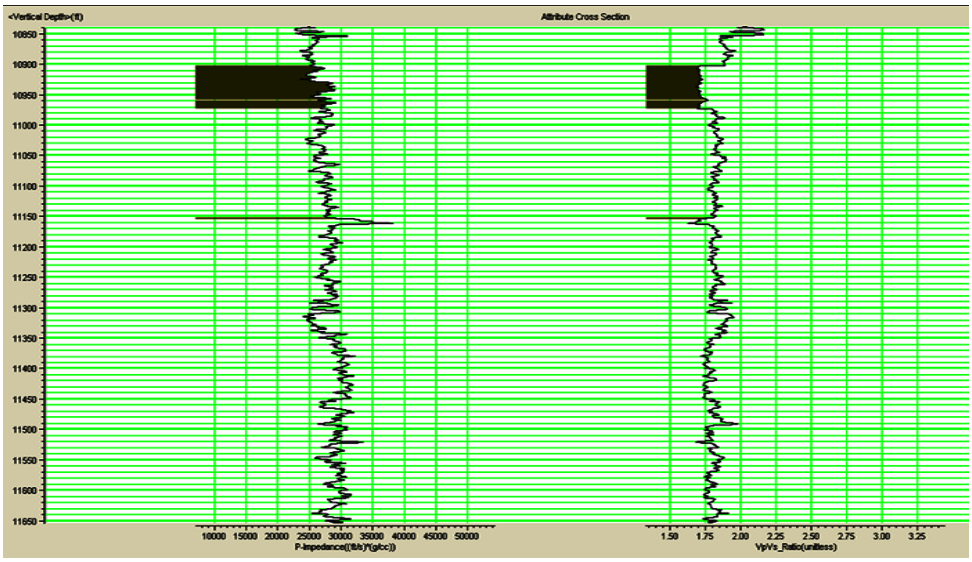

Fig.10. Attribute cross sectional display of Vp/Vs versus impedance showing the position of the deviated cluster points in well A. The zone corresponds to the Z1100 gas reservoir interval (10905-10975ft)

P-wave velocity (Vp) versus S-wave velocity (Vs)

The anomalous data points in the V_p versus V_s cross-plot lie below the mudrock line (Fig.11) and according to Goodway (2001) some of the rock types that lie off the mudrock line are expectedly gas saturated sandstones or carbonates and igneous rocks. In the study area, the stratigraphic column is subdivided into three units. The basal unit is the massive marine shales (Akata Formation), the intermediate unit is the interbedded shallow marine and fluvial sands, silt and clay (Agbada Formation) and top unit that caps the sequence with a massive continental sands (Benin Formation) and because of the absence of carbonates or igneous rocks, the anomalous data points could only be due to hydrocarbon saturation in sandstones. The attribute cross section (Fig. 11) shows that the anomalous data points represents the Z1100 gas sands.

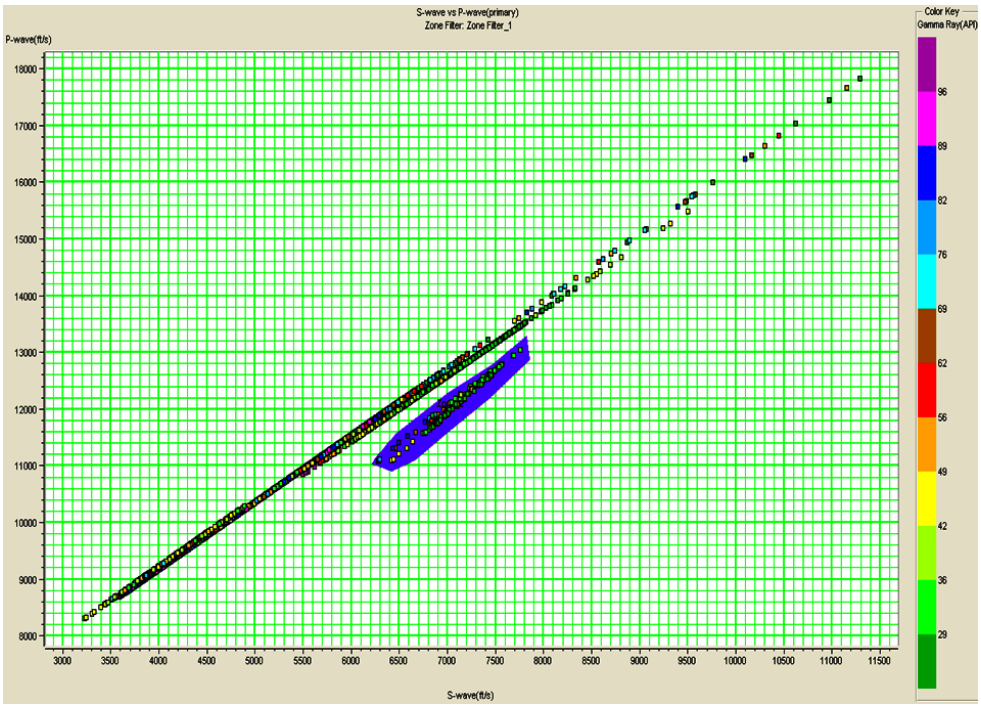

Fig. 10. Vp versus Vs cross-plot display showing deviations (coloured zone) from the wet background trend.

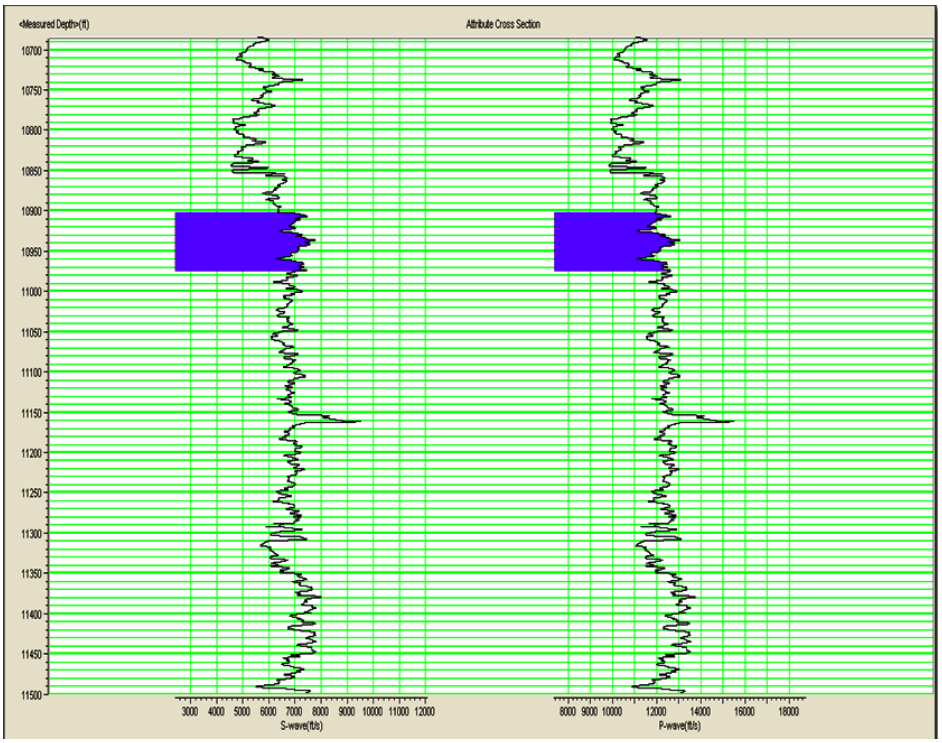

Fig.11. Vp versus Vs attribute cross section display showing the anomalous zone. The zone corresponds to the Z1100 gas sands.

Lambda/Mu versus LambdaRho - MuRho (Ratio - Difference Crossplot)

Goodway, 2001 have shown that the ratio between incompressibility (λ) and rigidity (μ) can serve as a tool for discriminating lithology and detection of fluids from a Lamé parameter standpoint. The Lambda/Mu versus LambdaRho - MuRho, also known as the Ratio-Difference cross-plot was used to determine if this attribute could be used to identify hydrocarbon bearing sands within the study area. Fig. 12 shows the cross-plot and analysis of the plot shows that oil filled sands were identified as having ratios less than or equal to one. Fig.13 shows the depth interval corresponding to the coloured area. The zone corresponds to horizons that was picked over oil bearing intervals (e.g. Z1500 and Y1500) and demonstrates the usefulness of this attribute in delineating oil sands in wells.

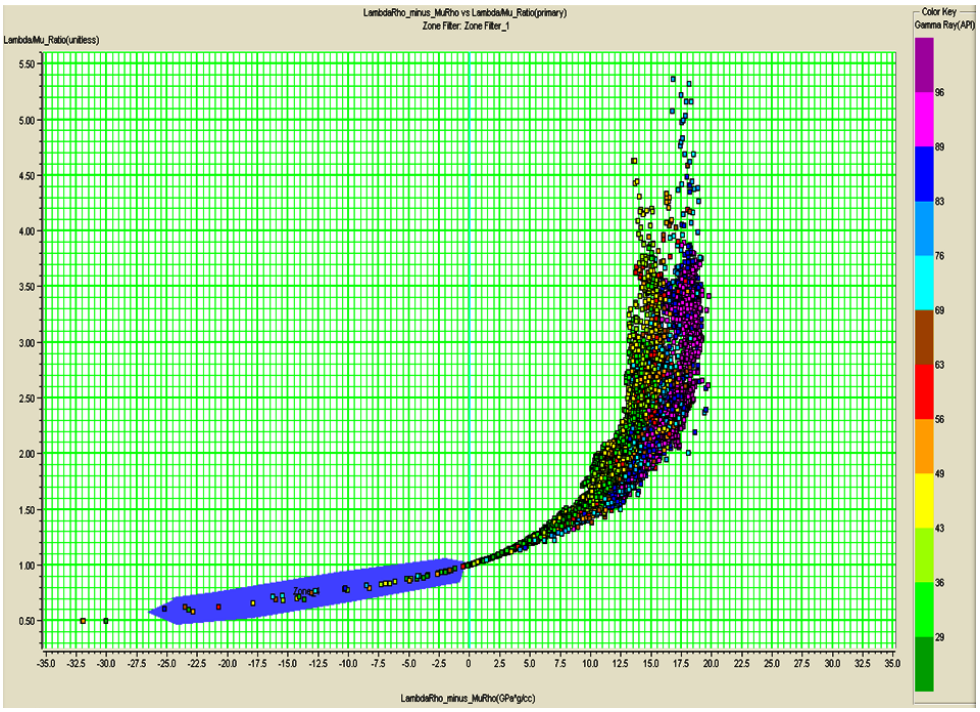

Fig.12. Ratio Difference crossplot display for Well A showing the off-trend data points (coloured polygon)

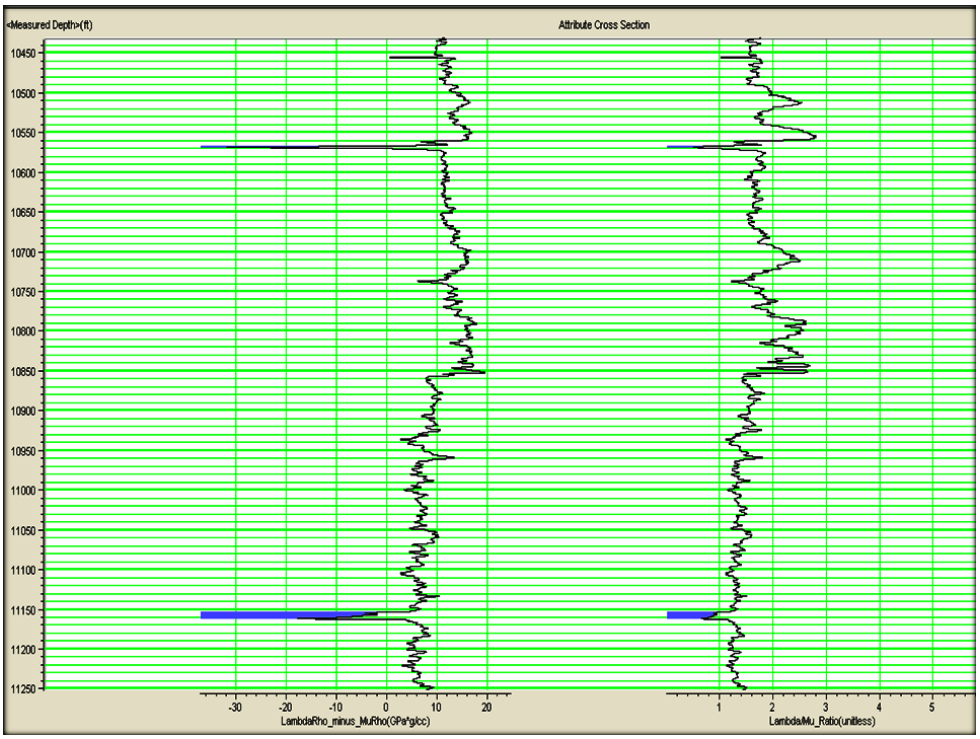

Fig. 13. Ratio difference cross plot showing the depth in Well A with Ratios (Lambda/Mu) less than one. The highlighted (Blue) areas from top to bottom represents Z1500 (1114- 11161ft) and Y1500 (10273-10319ft) oil sands respectively.

MuRho versus LambdaRho

This cross-plot demonstrated the robustness of the Lambda-Mu-Rho in differentiating fluids and lithologies within the study area. LambdaRho is a sensitive indicator of water or hydrocarbon saturation and MuRho is used to map pure rock fabric or lithology. Clearly, the different clusters are more separated in the LambdaRho versus MuRho crossplot (Fig.14) than in the Vp/Vs versus acoustic impedance cross-plot (Fig.9). Gas sands, for example, would exhibit low values of LambdaRho and high values of MuRho. The anomalous data points show that the orange zone corresponds to the Z1100 gas sands while the blue zones corresponds to the W9500, Z1700 and Z1900 oil sands respectively (Fig.15). Hence, an improved identification of the reservoir zones is possible by the enhanced separation of lithologies and fluids from the LambdaRho versus MuRho cross-plot.

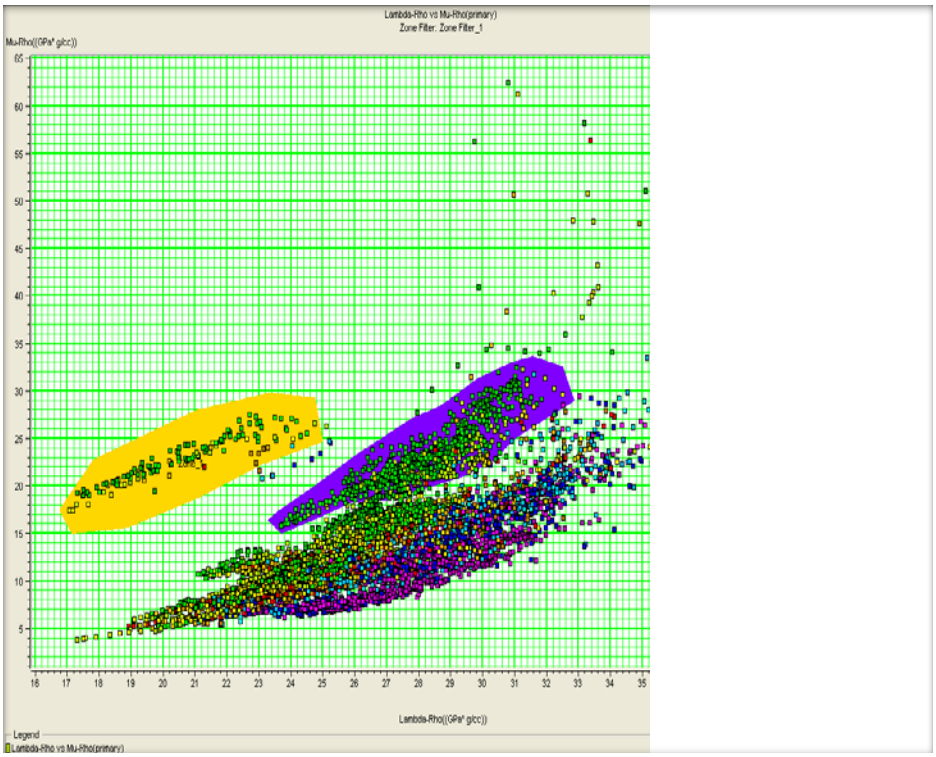

Fig. 14. Gamma ray colour coded cross-plot display of MuRho versus LambdaRho. Two anomalous cluster of points, demarcated by orange and purple polygons are evident from the plot.

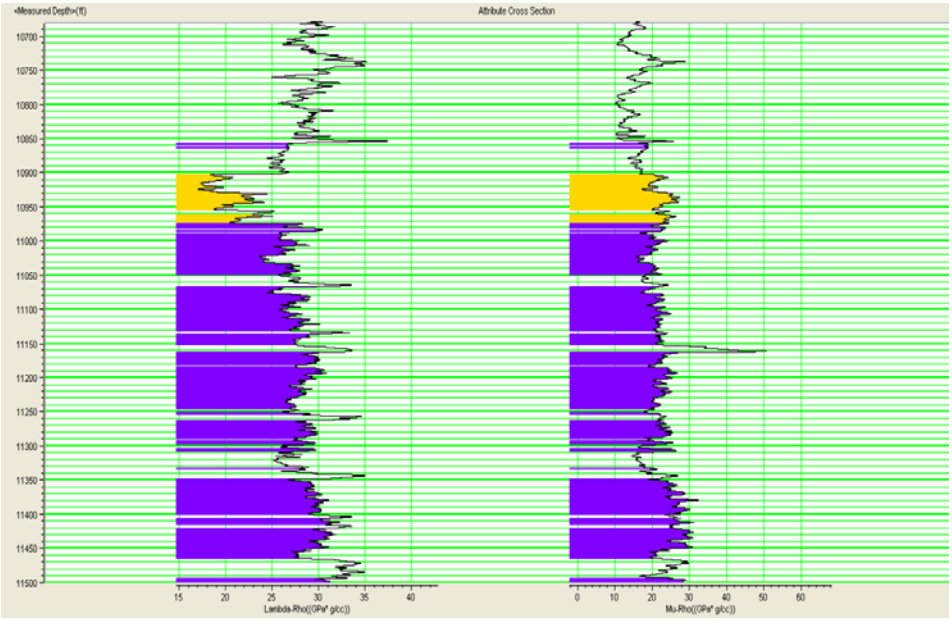

Fig.15. Attribute cross section display of MuRho versus LambdaRho. The orange zone corresponds to the Z1100 gas sands while the blue zones correspond to the W9500, Z1700 and Z1900 oil sands respectively

Conclusion

The cross-plot of various rock properties obtained from the well log show a separation or clustering of data according to lithology and/or fluid fills. In the well data studied from the Niger Delta basin, there was a distinct separation between brine and gas saturated lithologies by using either Vp/Vs versus P-impedance or Vp versus Vs cross-plots. Oil filled sands were identified on the Ratio (λ/ρ)-Difference ($\lambda\rho$-$\mu\rho$) cross plot as having ratios less than one. The cross-plot of LambdaRho ($\lambda\rho$) versus MuRho ($\mu\rho$) however distinguished gas saturated and oil saturated sands from the regional wet trends. This implies that the LambdaRho ($\lambda\rho$) versus MuRho ($\mu\rho$) cross-plot is a better indicator of fluids and lithology within the studied field in the Niger Delta Basin. In line with the results obtained by Omudu and Ebeniro (2005) and Ujuanbi et. al. (2008), the present results further demonstrate the use of rock physics parameters as pore fluid and lithology indicators in the Niger Delta basin.

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REFERENCES

Castagna J. P., Batzle M. L. and Eastwood R. L. 1985. Relationships between compressional-wave and shear-wave velocities in clastic silicate rocks: *Geophysics*, 50, 571-581.

Castagna J. P. and Smith S. W. 1997. Principles of AVO cross-plotting: *The Leading Edge*,

Chopra S., Alexeev V. and Xu Y. 2003. Successful AVO cross-plotting: *CSEG Recorder*, Pp. 5-11.

Onuoha, K. M. (1999): Structural features of Nigeria's coastal margin: an assessment based on age data from wells. *Journal of African Earth Sciences*, vol. 29(3), 485 – 499.

Dewar J. 2001. Rock Physics for the rest of us- an informal discussion: *CSEG Recorder*, Pp. 42-49.

Doust H. and Omatsola E. 1990. Niger Delta, *in*, Edwards, J. D., and Santogrossi, P. A., eds., Divergent/passive Margin Basins, AAPG Memoir 48: Tulsa, *American Association of Petroleum Geologists*, Pp. 239-248.

Goodway 2001. AVO and Lamé constants for Rock parameterization and fluid detection: *CSEG Recorder*, 26, Pp.39-60.

Gray F.D. and Andersen E.C. 2001. The application of AVO and inversion to the estimation of rock properties: *CSEG Recorder*, 26, Pp. 36-39

Omudu L.M. and Ebeniro J.O. 2005. Cross-plotting of rock properties for fluid discrimination using well data in offshore Niger Delta: *Nigerian Journal of Physics*, Vol. 17, Pp. 16-20.

Pelletier H. 2009. AVO Crossplotting II: Examining Vp/Vs behaviour: CSPG, CSEG, CWLS convention, Calgary, Alberta, Canada, Pp. 105-110.

Potter, C.C, Miller, S.L.M, and Margrave, G, 1996. Formation elastic parameters and synthetic P-P and P-S seismograms for the Blackfoot field: *CREWES Research Report*, volume 8; pp. 37(1) - 37(17).

Shannon P. M. and Naylor N. 1989. Petroleum Basin Studies: London, Graham and Trotman Limited, p 153-169.

Short K.C. and Stauble A.J. 1967. Outline of the Geology of the Niger Delta, *AAPG Bulletin*, Pp. 761-777.

Tuttle M. L. W., Charpentier R. R. and Brownfield M. E.1999. The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa: USGS Open-File Report 99-50-H, Pp. 1-70.

Ujuanbi O. Okolie J.C. and Jegede S.I. 2008. Lambda-Mu-Rho techniques as a viable tool for litho- fluid discrimination- the Niger Delta example: *International Journal of Physical Sciences*, Vol. 2(7), Pp. 173-176.

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QUALITY CONTROL AND *IN VITRO* BIOEQUIVALENCE STUDIES ON CONVENTIONAL CARBAMAZEPINE TABLETS IN NIGERIA MARKET

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ABSTRACT.

Carbamazepine is primarily indicated for partial and tonic-clonic seizures and for the treatment of trigeminal neuralgia. This study aims at assessing the quality and the interchangeability of the various brands of carbamazepine tablets in Nigeria market through in vitro bioequivalency studies. The physicochemical parameters of five brands of conventional carbamazepine tablets marketed in Nigeria were assessed through the evaluation of their active ingredients, uniformity of tablet weight, tablet thickness, friability, hardness, disintegration and dissolution studies according to established procedures. The disintegration time and dissolution rate were determined in simulated gastric fluid (SGF) and simulated intestinal fluid (SIF) without enzymes. The concepts of dissolution efficiency (DE), predicted availability equivalence (PAE), difference (f_1) and similarity (f_2) factors were employed in the assessment of the bioequivalency of the drug products based on their dissolution profiles. Results showed that all the brands passed the active ingredient, hardness and weight uniformity tests while 80% passed the friability test. All the products passed the disintegration time test while 80% passed the dissolution rate test in

Keywords: Pharmaceuticals: Bioequivalence study, carbamazepine tablets, interchangeability of drug products.

at least one of the two media (SGF and SIF). Based on their dissolution profile analysis using the different models, only one brand was considered equivalent and interchangeable with the reference brand. The present study has concluded that though most of the conventional carbamazepine tablet brands in Nigeria drug market complied with the quality control specifications, only a few brands are likely to be bioequivalent with the reference brand. In vivo studies are however, advocated to confirm these findings.

Introduction

Lack of adequate facilities for the routine analysis and poor control of drug products especially in developing countries such as Nigeria encourage the wide circulation of fake and substandard drugs in such countries. In addition, the high level of poverty in such countries encourages the proliferation of multisource generic drug products. The marketing of multisource drug products with the view of improving health care delivery through competitive pricing has its attendant problem of doubts about their quality and interchangeability [1]. Variable clinical responses to drugs presented as generics and batch-to-batch inconsistencies have been reported [2]. There is need therefore to perform quality control analysis of every drug product as part of post marketing surveillance to ensure the quality, efficacy and safety of the drug product to the patients. Drugs having more than three generic products also require analysis for their biopharmaceutical and chemical equivalency. There have been reports of several such studies on a number of drug products marketed in Nigeria [3-6]. Conventional carbamazepine tablet is considered ideal for such analysis as it is commonly used and it has many generic brands marketed in Nigeria.

Carbamazepine (CBZ), designated as 5H-dibenzo [b,f]azepine 5-carboxamide, is considered a primary drug for the treatment of partial and tonic-clonic seizures and also used for the treatment of trigeminal neuralgia [7]. The drug is characterized by slow and irregular gastrointestinal absorption due to its low water solubility [8]. Both conventional and sustained release forms of the CBZ tablets are marketed in Nigeria and the drug is sold under various trade names by different pharmaceutical companies. The present study assesses the quality control parameters and possibility of inter-changeability of some of the conventional CBZ tablets in Nigeria market based on their *in vitro* bioequivalence studies.

Materials and methods

Five brands of conventional CBZ tablets containing 200 mg of CBZ were purchased from pharmacy shops in different parts of Nigeria. They were coded as CBZ A, CBZ B, CBZ C, CBZ D and CBZ E. Samples

were stored as they were obtained and in the conditions specified by the manufacturers prior to their essay. All the reagents and chemicals were of analytical grade.

Preparation of reagents

Simulated intestinal fluid without enzyme (SIF) was prepared by dissolving 40 g of sodium hydroxide and 34 g of potassium phosphate monobasic in 2 L of distilled water and then diluting to volume in a 5-L volumetric flask [9-10]. Simulated gastric fluid without enzyme (SGF) was prepared by adding 43 mL of concentrated hydrochloric acid to 2 L of distilled water in a 5-L volumetric flask, then 500 mL of 2% sodium chloride solution was added, and the solution was diluted to volume [9-10].

Assay of active CBZ

In order to determine the standard calibration curve of CBZ, a stock solution of 100 µg/ml was prepared in distilled water to which was added 1% sodium lauryl sulfate [11-12]. Then dilutions were made to prepare a series of solutions containing CBZ in different concentrations. In these solutions absorbance values at 287 nm (λ_{max}) were determined UV spectrophotometrically (Jenway 6505, England) by plotting the concentration values (x) versus absorbance (y). A calibration curve and the regression equation of CBZ were hence determined. The amount of CBZ in each tablet brand was determined by dissolving samples of crushed CBZ tablets (n = 20, taking the amount equivalent to the weight of one tablet) from each brand in distilled water to which was added 1% sodium lauryl sulfate and the absorbance taken as above. The CBZ amount in each tablet was calculated using the equation for the calibration curve.

Tablet hardness test

Ten (10) tablets were randomly selected from each brand of CBZ. The hardness of each tablet selected was determined using a hardness tester (Monsanto).

Thickness test

Ten (10) tablets were randomly selected from each brand of CBZ. The thickness of each tablet was determined using a vernier caliper.

Weight uniformity

Each tablet (n=20) belonging to each brand was weighed with an electronic balance (OHAUS). The mean weight as well as the deviations of the individual tablet from the mean weight was calculated.

Friability test

Ten (10) tablets from each brand were weighed together and put into the friabilitor (Roche Friabilitor). The tablets were rotated at 25 rpm for 4 min and weighed again. The friability percentage was calculated for each brand from Eq. 1 [6]:

Disintegration test

Six (6) tablets were selected at random from each brand. One tablet was placed in each of the six tubes contained in each unit of the Erweka multiple unit disintegrating apparatus. The disintegrating media were 900 ml each of SGF and SIF maintained at 37 ± 1°C. The time taken for each tablet to completely breakdown to particles and pass through the wire mesh was determined.

Dissolution study

The dissolution rate studies on CBZ tablets were carried out according to the basket method using the USP XXII dissolution apparatus type I (Electrolab, Mumbai, India) at a stirring rate of 100 rpm [13]. The dissolution media were 600 ml each of SGF and SIF each thermostated at 37 ± 1°C. For each dissolution media, one tablet from each brand was randomly selected and the dissolution profile assessed by withdrawing the sample solution at definite time intervals for one hour (5, 10, 20, 30, 40, 50 and 60 min). This was assayed spectrophotometrically as described previously. The percentage of cumulative CBZ amount released from the tablets was calculated thus (Eq. 2):

where A is the amount of drug released (mg) calculated from the standard calibration plot and B (200 mg) is the label claim of each brand of CBZ [6].

Comparison of the dissolution profiles

Concept of AUC, DE and PAE

In order to assess the pharmaceutical equivalence of the different brands of CBZ tablets, the concepts of AUC (area under the curve), DE (dissolution efficiency) and PAE (predicted availability efficiency) were used. AUC was calculated using the trapezoid rule (Eq. 3) [5-6]……. (Eq. 3),

where and refer to the concentration and time for the n^{th} sample.

DE and PAE were calculated from the following relations (Eq. 4 and 5) [4-6]: …… (Eq. 4);

(Eq. 5);

DE_t and AUC_t refer to dissolution efficiency and AUC at time, t, respectively while AUC_{total} refers to the AUC over the entire release period. AUC_b and AUC_{inv} refer to AUC of a brand and AUC of the reference (innovator) brand respectively.

Concept of similarity and difference factors

Two fit factors that compare the dissolution profile of a pair of drug products were further applied to the dissolution data. These fit factors directly compare the difference between percent drug dissolved per unit time for a test and a reference product. The fit factors are denoted as difference (f_1) and similarity (f_2) factors and are defined by Eq. 6 and 7 respectively:

where n is the number of dissolution sample times and R_t and T_t are the individual or mean percent dissolved at each time point, t, for the reference and test dissolution profile respectively [11-12].

Statistical analysis

Data were plotted and evaluated using a statistical package program (Microsoft Excel & SPSS 16.0). The weight uniformity was analyzed with simple statistics (percentage deviation) while the dissolution profiles were analyzed with difference factor (f_1), similarity factor (f_2) and some other approaches such as area under the curve (AUC), dissolution efficiency (DE) and predicted availability efficiency (PAE) as stated above. The results are expressed as Mean ± SEM (standard error in mean).

Results

Assay of active drug

The results of active drug content (Table I) show that active ingredient ranged from 93.49% (CBZ C) to 99.02% (CBZ E). According to the compendia specifications, the contents of CBZ tablets should not be less than 92.0% and not more than 108.0% of the labeled amount of active drug [11-12]. Results show that all the brands complied with this specification.

Table I. Quality control parameters of the brands of the conventional CBZ tablets marketed in Nigeria

Tablet brand	Hardness (kg/cm^2)	Thickness (cm)	Active drug (%)	Weight uniformity (mg)[a]	% Friability	Disintegration Time (s)	
						SGF	SIF
CBZ A	7.05±1.20	0.369±0.01	98.99	280.55(3.20%)	0.075	22.43	30.88
CBZ B	5.95±1.23	0.350±0.02	93.49	300.62(2.45%)	0.067	78.99	26.79
CBZ C	5.31±0.87	0.336±0.12	93.62	301.45(2.32%)	0.067	1.22	1.20
CBZ D	7.54±2.34	0.443±0.14	95.07	318.05(3.01%)	1.038	17.08	13.87
CBZ E	7.95±1.56	0.409±0.21	99.02	258.85(4.00%)	0.233	1.32	2.18

a: for the weight uniformity values, the data in parenthesis refer to the highest value of the % deviation of individual tablet from the mean weight. Data are expressed as Mean± SEM

Hardness test

For a satisfactory tablet, hardness should be between 4 and 8 kg/cm^2 [12, 14-15,]; thus a force of about 4 kg/cm^2 is considered the minimum requirement for a satisfactory tablet. The results in Table I show that all the commercial CBZ tablet brands complied with the hardness test with results ranging from 5.31 to 7.95 kg/cm^2.

Thickness

The mean thickness for the various brands ranged from 0.336±0.12 to 0.409±0.21. The standard error in mean (SEM) was quite low in each brand (0.1-0.21), indicating little variations of tablet thickness (Table I).

Weight uniformity

According to the USP [16], weight of the individual tablet should not exceed 7.5% of the average weight if the average weight is between 130 and 324 mg. From Table I, the mean weight of the various brands of CBZ varied from 258.85 to 318.05 mg. All the brands complied with the official requirement as none of the tablets in any of the brands deviated by more than 7.5%.

Friability test

The friability values ranged from 0.067 (CBZ B and CBZ C) to 1.038 (CBZ D). The compendia specification is that friability value should not be greater than 1% [17-18]. From Table I, it is seen that all brands except CBZ D (CBZ D represents 20% of the entire brands) passed the friability test.

Disintegration test

The results of the disintegration test of the tablets in the two pH media (SGF and SIF) show that CBZ C disintegrated within the shortest time in both media (1.22 s and 1.20 s respectively) followed by CBZ E and CBZ D while CBZ B and A disintegrated much more slowly than others (Table I). For uncoated tablet, the maximum limit for disintegration is 30 min [19]. Based on this specification all the brands passed the test in at least one of the dissolution media.

Dissolution studies

The dissolution profile of the drug products in both dissolution media shows that brands CBZ B, CBZ D and CBZ E had the 75% or more of their drugs dissolved after 60 min in SGF (Figure 1) while brands CBZ C, CBZ D and CBZ E produced 75% dissolution within this time in SIF

(Figure 2). According to the official specification [6], drug dissolved for all conventional CBZ tablets should be at least 75% of the labeled amount in the given time (60 min). In both media, CBZ E released the maximum amount of drug (88.91%), and CBZ A showed the lowest drug release (52.80%) and also failed the dissolution test in both dissolution media (CBZ A represents 20% of the entire brands). CBZ E was then considered the reference product.

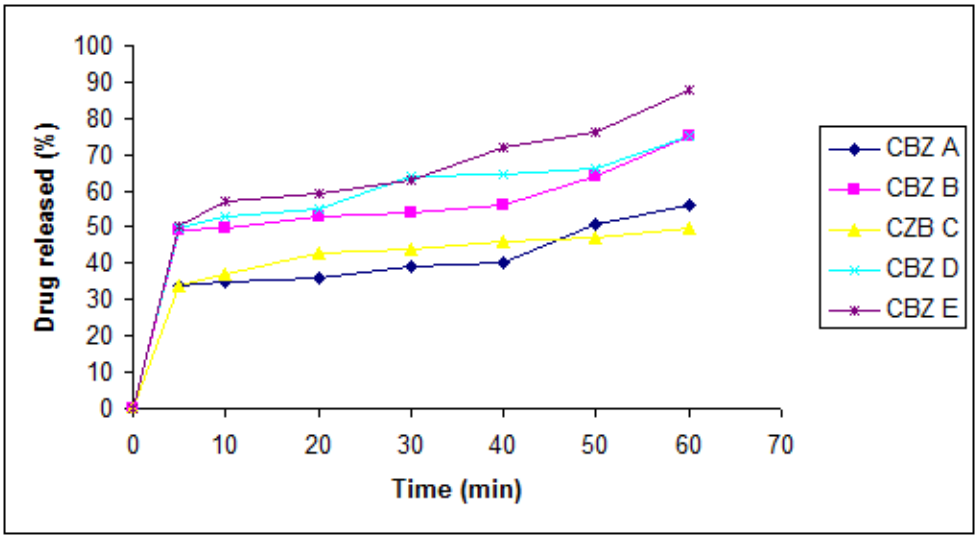

Figure 1: Dissolution profile from SGF of the various brands of CBZ tablets in Nigeria market

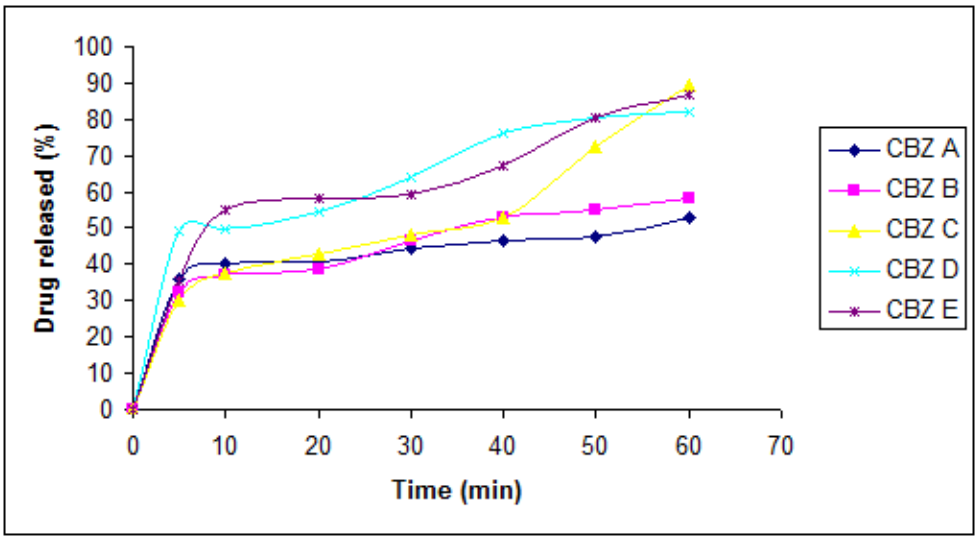

Figure 2: Dissolution profile from SIF of the various brands of CBZ tablets in Nigeria market

Comparison of the dissolution profiles

Concept of AUC, DE and PAE

Table II shows the dissolution parameters of the various brands of CBZ based on the concept of AUC, DE and PAE. The AUC ranged from 79.62 (µg/ml.h) (CBZ A in SGF) to 124.36 (µg/ml.h) (CBZ E in SGF). CBZ D is predicted to have produced the highest dissolution (PAE of 91.80% in SGF and 102.78% in SIF) among the other brands (CBZ A-D) when compared to the reference brand (CBZ E). The percentage difference between the test brand and reference brand (Diff %) in both media ranged from 0.38 to 1.66%.

Table II: Dissolution parameters of various brands of CBZ tablets marketed in Nigeria from different dissolution media

Brand	SGF				SIF			
	AUC (µg/ml.h)	DE_{30} (%)	Diff (%)	PAE (%)	AUC (µg/ml.h)	DE_{30} (%)	Diff (%)	PAE (%)
A	79.62	16.05	0.76	64.02	81.41	17.79	1.66	68.38
B	105.26	17.27	0.46	84.64	108.17	13.39	2.74	90.85
C	81.23	18.24	1.43	65.32	98.37	15.70	0.43	82.62
D	114.16	17.78	0.97	91.80	122.37	16.51	0.38	102.78
E	124.36	16.81	0.00	100.00	119.06	16.13	0.00	100.00

DE_{30}=dissolution efficiency at 30 min; Diff=difference between the DE_{30} of the reference brand (E) and the test brand

Concept of similarity and difference factors
The dissolution parameters of the various brands of CBZ based on the concept of similarity and difference factors are presented in Table III. Only CBZ D has f_1 value between 0 and 15 and f_2 value between 50 and 100 in both media.

Table III. Difference (f_1) and similarity (f_2) factors for the brands of CBZ tablets dissolved in SGF and SIF

Brand	SGF		SIF	
	f_1	f_2	f_1	f_2
CBZ A	37.84	29.31	30.99	32.50
CBZ B	14.30	48.42	27.44	35.98
CBZ C	31.14	31.30	16.76	46.35
CBZ D	08.57	56.61	09.26	57.01
CBZ E	-	-	-	-

Discussion

The quality of a drug product determines the efficacy and in most cases the safety of the product. For a tablet to be considered of good quality, the tablets should fulfill certain criteria: the tablet should include the correct dose of the drug (evaluated by the weight uniformity and active drug tests), the tablet should show sufficient mechanical strength to withstand fracture and erosion during manufacturing and handling (evaluated by the hardness and friability tests), the drug should be released from the tablet in a controlled and reproducible way (evaluated by the disintegration and dissolution tests), the appearance of the tablet should be elegant and its weight, size and appearance should be consistent (evaluated by visual observation, weight variation, thickness and diameter of the tablet) and the tablet should be packed in a safe manner. Some of these specifications (hardness, friability, active ingredient, weight uniformity, disintegration and dissolution tests) are official tests with compendia specifications.

Thus a good product is expected to comply with the various specifications especially the official specifications. The results of the present investigation showed that all the brands of CBZ passed the various tests except friability test (which was failed by CBZ D) and dissolution test (which was failed by CBZ A). Friability is a very important tablet evaluation parameter as during manufacturing and handling, tablets are subjected to stresses from collision and tablet sliding towards one another and other solid surfaces, which can result in the removal of small fragments and particles from the tablet surface. The result will be progressive reduction in weight and change in appearance. Friability not only indicates the ability of the tablets to crumble but also detects incipient capping or lamination of the tablets.

Thus one (CBZ D) of the five brands may not likely withstand the stresses involved during transportation or handling. Manufacturing procedure and the composition of the tablet excipients could be responsible for the failure of the brand. Perhaps friability may not be as important as the release of the drug in the body. For the drug to be fully available for absorption, the tablet must first disintegrate and discharge the drug to the body fluid for dissolution. In the present study, assessment of the release profile of the tablets was made *in vitro* in both simulated intestinal fluid (alkaline) and gastric fluid (acidic) to predict their *in vivo* release pattern in both intestine and gastric fluids. Some of the brands were observed to have disintegrated rapidly in both fluids, though still complying with the specifications. Rapid disintegration could be as a result of the nature or quantity of disintegrants used or it could be due to the method of manufacture [20]. The result of dissolution tests showed that CBZ A was the only brand that failed the dissolution test in both media; this brand also could not disintegrate in SIF within 30 min.

Most of the brands disintegrated rapidly but released their active drug slowly. Initial burst release from the matrix could possibly be attributed to the nature of the formulation excipients. Penetration of solvent molecule could be hindered probably due to the hydrophobic coating on the drug particle leading to the slow release for a prolonged period [21]. Thus the slower penetration of dissolution medium in tablet matrices could be due to the lipophilicity of hydrophobic substances [22]. The hardness of the tablet could markedly affect the release rate of drug [23]. Usually, an increase in hardness of a tablet is accompanied by a decrease in release rate, due to a decrease in porosity of the tablet [24]. Besides the hydrophobicity of the formulation excipients and the hardness of the tablets, other factors that can determine the disintegration and dissolution rate of a tablet include particle size of drug substance, solubility of the drug, type and amount of disintegrant, binder and lubricant, and manufacturing method (compactness of the granulation and compression force used in tableting). CBZ is a poorly soluble drug and this factor could have retarded the release of some of the products. CBZ E, however, complied with all the specifications possibly because good manufacturing practices were observed both in the formulation of the product and during production.

Though the dissolution of the tablets within the stipulated time is very important, comparison of the various brands for equivalency is as well vital in order to determine the interchangeability of the brands. It has been reported that the exchange of one marketed brand of CBZ for another caused seizures and the occurrence of side effects [12, 25]. Dissolution profile is commonly employed in such comparison of the

drug products having similar active ingredients. Dissolution testing of drug products plays an important role as a quality control tool to monitor batch-to-batch consistency of drug release from a dosage form and as an *in vitro* surrogate for *in vivo* performance [10, 26]. For the purpose of dissolution profile comparison in the present study, CBZ E was considered the reference brand having produced the highest drug release within the stipulated time while others are considered the test brands. Also several models were employed to assess the similarity of the various brands of CBZ tablets based on their dissolution profile. Dissolution efficiency (DE) is the area under the dissolution curve within a time range (t_1 - t_2) expressed as a percentage of the dissolution curve at maximum dissolution (y_{100}) over the same time frame [27-28]. From Table II, none of the DE_{30} values of the test products differed from that of the reference brand (in the two media) by more than 10%. It has been reported that the reference and the test product could be said to be equivalent if the difference between their dissolution efficiencies is within appropriate limits (± 10% is often used) [27, 29]. This suggests that all the brands were equivalent and hence interchangeable. However, the values of PAE (Table II) indicate that among the test products (CBZ A-D), CBZ D produced the highest dissolution (102.78%) than others followed by CBZ B. This was seen in both dissolution media. The implication of the PAE is to express the relative ease of release and predictive release pattern of the drugs *in vivo* [26]. Thus the PAE data seem to suggest that only CBZ D is bioequivalent with the reference brand since the PAE of CBZ D is close to that of CBZ E (100%) despite the fact that DE_{30} has suggested that all are bioequivalent and interchangeable as discussed above.

To further compare the dissolution profiles of the brands, a model independent approach of difference factor (f_1) and similarity factor (f_2) was employed to assess the equivalency and hence the interchangeability of the products. Besides, it has been reported that no single comparison approach is widely accepted to determine similarity of dissolution profiles [27, 31]. Similarity factor (f_2) has been adopted by FDA and the European Agency for the Evaluation of Medicinal Products (EMEA) by the Committee for Proprietary Medicinal Products (CPMP) as a criterion to compare the similarity of two or more dissolution profiles [32, 33]. Though the difference and similarity factors have been criticized by formulation scientists and analysts as being biased and a conservative estimate which does not take into account the dissolution differences within the reference product and the test product batches and which is insensitive to the shapes of the dissolution profiles [27, 34], these factors are still valid and give clear indication of the similarity of the products. According to these guides, generally f_1 values vary between 0-15 and f_2 values vary between 50 and 100, and both ensure sameness or equivalence of the

curves [11]. The present result showed that only one brand, CBZ D, has f_1 value between 0 and 15 and f_2 value between 50 and 100 in both media. Thus from the analysis above, only brand CBZ D out of four test brands (CBZ A-CBZ D, representing 25% of the four test brands) could be considered to be equivalent and possibly interchangeable with the reference brand (CBZ E). This is in agreement with our earlier observation using the concept of PAE above. Such dissimilarities in terms of the dissolution profiles of CBZ tablet brands have been observed in independent studies carried out on CBZ tablets marketed in Turkey (one out of three test brands were not equivalent with the reference brand) [11] and India (two out of three test brands were not equivalent with the reference brand) [12]. The implication of this observation is that prescribers of such drugs have to be careful in interchanging one product of CBZ tablet with another as all may not produce similar therapeutic effects.

Conclusion

This study has shown that not all the various brands of carbamazepine tablets marketed in Nigeria meet up with the compendia specifications of quality. Also not all the brands are interchangeable, indicating that they may not show the same therapeutic effectiveness even though they are all labeled 200 mg carbamazepine. However, larger sample size and *in vivo* studies are needed to confirm this observation. The present research has further confirmed the widely held belief that chemical equivalence is not a guarantee of bioequivalence.

REFERENCES

1. Olaniyi A A, Babalola C P, Oladehinde F O, & Adegoke A O (2001). Towards Better Quality Assurance of Drugs. Proceedings of the 4th National Workshop, Department of Pharmaceutical Chemistry, University of Ibadan, Ibadan, Nigeria, pp 59–60.

2. Troy D E (2001). *Remington:The Science and Practice of Pharmacy*, 20th ed., Lippincott Williams & Wilkins: Philadelphia, pp 473–474.

3. Osadebe P O, Akabogu A (2004). Assessment of quality control parameters and interchangeability of multisourced metformin hydrochloride tablets marketed in Nigeria. *Bolletino Chimico Farmaceutico*. 143 (4):170–173.

4. Nwodo N, Uzochukwu I, & Omeje E O (2007). Quality control assessment and the possibility of

interchangeability between multisourced norfloxacin tablets marketed in Nigeria. *Scientific Research and Essay*. 2 (8): 348-352.

5. Okorie N H, Umerie S C, Uzochukwu S C, Nwobi S C, & Osadebe P O (2011). Quality control assessment of five brands of ketoconazole tablets marketed in Nigeria. *Nigerian Journal of Pharmaceutical Research*. 9(1):15-22.

6. Osadebe P O, Uzor P F, & Enwereji P O (2011).Quality Control and Interchangeability of

Multisourced Lisinopril Tablets Marketed in Nigeria. *African Journal of Pharmaceutical Research and Development*. 3(1): 71-76.

7. McNamara J O (2001). Drugs Effective in the Therapy of the Epilepsies in *Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 10th ed., eds Hardman J G, Limbird L E (McGraw-Hill, New York), pp 533–534**.**

8. Filipovic-Grcic J, Perissutti B, Moneghini M, Voinovich D, Martinac A, & Jalsenjak I (2003). Spray-dried carbamazepine loaded chitosan and HPMC microspheres: preparation and characterisation. *Journal of Pharmacy and Pharmacology*. 55(7): 921-931.

9. Jantratid E, Janssen N, Reppas C, & Dressman J B (2008). Dissolution media simulating conditions in the proximal human gastrointestinal tract: an update. *Pharmaceutical Research*. 25 (7): 1663–1676.

10. Awofisayo S O, Awofisayo O A, Eyen N, & Udoh I E (2010). Comparative Assessment of the Quality Control Measurements of Multisource Ofloxacin Tablets Marketed in Nigeria. *Dissolution Technologies*. May 2010: 20-25.

11. Çomoğlu T, & Gönűl N (2005). Quality Control Studies on Conventional Carbamazepine Tablets Available on the Turkish Drug Market. *Turkish Journal of Medical Science*. 35: 217-221.

12. Ghosal K, Ranu S, Billah M, Mondal S, & Hoque M (2012). Quality Control Studies on Conventional Carbamazepine Tablets Available in the Indian Drug Market. *Dissolution Technologies*. Feb 2012: 36-39.

13. British Pharmacopoeia (2001). The Stationery Office, London, pp 1005-1183.

14. Parrot E L, & Saski W (1971). Solid Pharmaceuticals. *Experimental Pharmaceutical Technology*, 3rd ed, Burgess Publishing Co., Minneapolis, MN, pp 58–106.

15. Allen L V, Popovich N G, & Ansel H C (2004). *Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems*, 8th ed, Lippincott Williams & Wilkins, Philadelphia, p. 236.

16. The United States Pharmacopeia and National Formulary USP 28–NF 23 (2005). The United States

Pharmacopeial Convention, Inc., Rockville, pp 341– 2670.

17. Moore J W, & Flanner H H (1996). Mathematical comparison of dissolution profiles. *Pharmaceutical Technology*. 20 (6): 64–70.

18. Ofoefule S I (2002). A Textbook of Pharmaceutical Technology and Industrial Pharmacy, Samakin, Lagos, Nigeria, pp 57-66.

19. Babalola C P (2001). Bioavailability/Bioequivalence (BA/BE) Assessment in Towards Better quality assurance of Drug in the 3rd Millennium, 1st edn, eds Olaniyi A A, Babalol C P, Oladeinde F O and Adegeko A O (Omoadade Printing Press, Ibadan, Nigeria), p 79.

20. Olaniyi A A (2005). Principles of Drug Quality Assurance and Pharmaceutical Analysis, Musoro Publishers, Ibadan, Nigeria, pp 4 - 414.

21. Yonezava Y, Ishida S, & Sunanda S (2001). Release from or through a wax matrix system I: basic release properties of the wax matrix system. *Chemical and Pharmaceutical Bulletin.* 49:1448-1451.

22. Hamdani J, Moes A J, & Amighi K (2002). Development and evaluation of prolonged release pellets obtained by the melt pelletization process. *International Journal of Pharmacy*. 245: 167–177.

23. Capan Y (1965). Influence of technological factors on formulation of sustained release tablets. *Drug Development and Industrial Pharmacy*. 15: 927-956.

24. Katikaneni P R, Upadrashta S M, Neau S H, & Mitra A K (1995). Ethylcellulose matrix controlled release tablets of a water-soluble drug. *International Journal of Pharmacy*. 123: 119-125.

25. Olling M, Mensinga T T, Barends D M, Groen C, Lake O A, & Meulenbelt J (1999). Bioavailability of carbamazepine from four different products and the occurrence of side effects. *Biopharmaceuticals and Drug Disposition*. 20 (1): 19–28.

26. Dressman J B, Amidon G L, Reppas C, & Shah V P (1998). Dissolution testing as a prognostic tool for oral drug absorption: immediate release dosage forms. *Pharmaceutical Research.* 15 (1): 11–22.

27. Ngwuluka N C, Lawal K, Olorunfemi P O, & Ochekpe N A (2009). Post-market *in vitro* bioequivalence study of six brands of ciprofloxacin

tablets/caplets in Jos, Nigeria. *Scientific Research and Essay*. 4 (4): 298-305.

28. Costa P, & Sousa Lobo JM (2001). Modeling and comparison of dissolution profiles. *European Journal of Pharmaceutical Sciences*. 13(2): 123-133.

29. Anderson N H, Bauer M, Boussac N, Khan-Malek R, Munden P, & Sardaro M (1998). An evaluation of fit factors and dissolution efficiency for the comparison of *in vitro* dissolution profiles. *Journal of Pharmaceutical and Biomedical Analysis*. 17 (4-5): 811-822.

30. Sweetman S C (2002). *Martindale*: *The Complete Drug Reference*, 33rd ed, Pharmaceutical Press, London.

31. Polli J E, Rekhi S G, Augsburger L L, & Shah V P (1997). Methods to compare dissolution profiles and a rationale for wide dissolution specifications for metoprolol tartrate tablets. *Journal of Pharmaceutical Sciences*. 86 (6): 690-700.

32. US Food and Drug Administration, Center for Drug Evaluation and Research (1997). Guidance for industry: Dissolution testing of immediate release solid oral dosage forms, Available at: http://www.fda.gov/cder/Guidance/1713bp1.pdf.

33. US Food and Drug Administration, Center for Drug Evaluation and Research (2000). Guidance for Industry - waiver of *in vivo* bioavailability and bioequivalence studies for immediate-release solid oral dosage forms based on a biopharmaceutics classification system, Available at: http://www.fda.gov/cder/guidance/3618fnl.pdf.

34. Shah V P, Tsong Y, Sathe P, & Liu J (1998). *In vitro* Dissolution Profile Comparison-Statistics and Analysis of the Similarity Factor, f2. *Pharmaceutical Research*. 15 (6): 889-896.

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SUITABILITY OF OKHUEN WOOD (*BRACHISTEGIA NIGERICA*) AND RECYCLED LOW DENSITY POLYETHYLENE FOR COMPOSITE BOARD MANUFACTURE

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ABSTRACT

Particleboard has been made out of wood-based fibers bound together using formaldehyde resin. One of the major challenges associated with wood-based particleboard is the use of formaldehyde resin that is volatile. The aim of this study was to investigate the suitability of wood particles and recycled low density polyethylene (RLDPE) as a raw material for composite board manufacturing. Two different sets of composites board were produced (i.e 60:40%, 50:50%, ratio of the wood particles to RLDPE binder) at particles sizes of 420µm and 1000µm respectively. The microstructure, physical (density, thickness swelling (TS), water absorption (WA)), and mechanical (modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB)) properties of the particleboards were determined. The results show that the WA and TS values were moderate, the MOR met the minimum requirements of the European standards of 16-18MPa for general purpose application. All the composite boards produced had IB higher than the requirement. Hence Okhuen wood sawdust and RLDPE can be used as a substitute for wood- formaldehyde based particleboard for general purpose applications.

* Keywords: Wood, Recycled low density polyethylene, Physical and mechanical Properties

1.0 Introduction

Environmentally friendly or 'green' building materials are becoming more widely used as our society becomes aware of harmful consequences associated with the use of standard practices in industrial production. These materials are nontoxic and are made from renewable or recyclable resources. They produce little or no off gassing due to absence of urea-formaldehyde and are generally recyclable [1].

One of the common materials used in building construction is particleboard, which serves numerous functions. Particleboard is commonly used for cabinetry, tabletops, shelving, wall and floor panels, doors, furniture, and other non-structural architectural applications. Particleboard was initially introduced in the 1940s in Germany and the United States. It has undergone significant growth in production since the 1960s and, due to its low manufacturing cost, is still in the forefront of construction design today [2-3].

Traditionally, particleboard has been made out of wood-based fibers bound together using a formaldehyde resin. The desired thickness is achieved by using a hot press that forms the board into sheets[4]. Particleboard has a homogenous structure and can be manufactured in different sizes, thicknesses, densities and grades for numerous uses, making it a desirable material with which to work [5]. One of the major challenges associated with wood-based particleboard is the use of formaldehyde resin. Formaldehyde is a volatile, colorless gas with a strong odor that is commonly used in industrial processes, particularly in manufacturing building materials [6].

Pressed wood products, such as wood-based particleboard and medium density fiberboard, are made using adhesive resins containing urea-formaldehyde. Off-gassing levels are at their highest when the products are new, with emissions tapering off as they age.

Exposure to formaldehyde in concentrations greater than 0.1 parts per million (ppm) can cause nasal and throat congestions, burning eyes, or headaches as well as increasing the risk of developing cancer[6].

Some previous studies of the work of wood based particleboard composites include: Nourbakhsh *et al* [7] who explored the use of recycled HDPE for production of wood fiber composites. The results of the experiment conducted to evaluate the possibility of utilizing RHDPE in composites manufacturing indicated that wood fiber (Poplar -populous deltoids)/Recycled high density polyethylene (RHDPE)

composite met minimum requirements with the exception of physical and mechanical properties of panel.

Shebani *et al* [8] studied the effect of wood species on the mechanical and thermal properties of wood-Linear low-density polyethylene (LLDPE) composite. Significant differences were found between the wood species in terms of both chemical composition and wood fiber length distribution. They found that the use of acacia resulted in wood polymer composite (WPC) with superior mechanical properties and thermal stability compared with the other species, due to its higher cellulose and lignin contents and a favourable wood fiber length distribution; however, acacia composite also showed a higher water absorption rate due to the higher cellulose content.

Nadir *et al* [9] studied the physical and mechanical properties of WPC panel made from various mixtures of rubber wood fiber (Havea brasiliensis) and polypropylene (PP). They concluded that water resistance of the panels was negatively influenced by increasing wood fibre content up till 60wt% but the decrease was not significant. The modulus of elasticity of the panels increased with increase in fibre content from 40 to 50 wt% and then decreased as the fibre content reached 60wt%. Internal bond strength and screw withdrawal declined with the increase in fibre content from 40wt% to 60wt%.

Najafi *et al* [10] investigated the effect of load and plastic type on creep behaviour of wood sawdust/HDPE (high density polyethylene) composite. Wood sawdust/HDPE composite panels were made from virgin and recycled HDPE and wood sawdust at 40% by weight HDPE loadings. Results indicated that the composites containing virgin HDPE exhibited higher creep deflection and by increasing the recycled HDPE content the creep deflection decreased in all load levels. At high levels of load, the behaviour of composites was distinctly non-linear in character.

Talavera *et al* [11] studied the effect of production variables on bending properties, water absorption and thickness swelling of bagasse/plastic composite boards. They concluded that Modulus of Rupture (MOR) and bending modulus of elasticity (MOE) increased proportionally with press temperature and press time. An increase of the bagasse content was found to have a positive effect only on the bending MOE and increase in pressure had a negative effect on both bending strength and MOE. Water absorption and thickness swelling were reduced significantly by an increase in temperature and pressing time, whereas variation of pressure did not have any influence on these board properties.

Pornnapa Kasemsiri et al [12] investigated the properties of experimentally manufactured wood polymer composites based on benzoxazine resin (BA - a) and cashew nut shell liquid (CNSL) copolymer. They observed that Bisphenol A benzoxazine resin mixed with cashew nut shell liquid was a good binder for natural fiber and that the addition of cashew nut shell liquid and eastern red cedar particles effectively reduced the curing temperature and activation energy of benzoxazine resin. Water absorption and thickness swelling of the wood composites at various particle contents were relatively low.

Hashim et al [13] studied and examined the suitability of producing binderless particle board from oil palm biomass. They concluded that oil palm biomass waste is a suitable material for the production of binderless particle board composites panels. All the parts of oil palm had poor water absorption and thickness swelling properties and that panel made from the bark and leaves had poor MOR and IB strength.

Hashim et al [14] investigated some physical and mechanical properties of experimental particle boards manufactured from different parts of oil palm including bark, leaves, fronds and trunk consisting of mid-part and core-part using phenol formaldehyde adhesive. Two types of panels with target densities of 0.80 and 1.0 g/cm^3 were manufactured using pressure levels of 5 and 12MPa respectively. Both types of panels were pressed at temperature of 180^{o}C for 20 minutes. They found that density and pressure levels have influence on the overall properties of the panels. It was also noted that the panels satisfied modulus of rupture (MOR) characteristics for particle board types 13 and 8 listed in the Japanese Standard. All panels met the internal bond (IB) strength requirement for type 8 except panels made from leaves manufactured at a target density of 1.0g/cm^2 and pressed at 12MPa. The boards did not satisfy the thickness swelling requirements. They concluded that parts of oil palm could have potential to manufacture exterior panels with acceptable strength properties.

Ye *et al* [15] studied and compared the properties of dry-formed medium density fibreboard (MDF) made from renewable biomass (wheat and soybean straw) and those from conventional softwood fiber. They evaluated the modulus of elasticity, modulus of rupture, internal bond strength, thickness swelling and screw holding capacity of MDF. They observed from their results that soybean straw was comparable to wheat straw in terms of both mechanical and water resistance properties and that water resistance of MDF decreased drastically with increasing straw fiber content.

Osarenmwinda and Nwachukwu [16] manufactured composite material from sawdust and palm kernel shell at different formulations of

sawdust/palm kernel shell of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50 using urea formaldehyde at 20wt% of oven weight. Physical and mechanical properties were said to be enhanced with 50:50 formulation being the superior one and had the following values: yield strength (4.47N/mm^2), ultimate tensile strength (7.75N/mm^2), modulus of elasticity (2603N/mm^2), modulus of rupture (16.67N/mm^2) internal bond strength (0.54N/mm^2) thickness swelling (10.30%), water absorption (18.90%) and density (996.18Kg/m^3).

Based on this background this present study is looking at the potential utilization of Okhuen (Brachistegia nigerica) wood type and recycled low density polyethylene (RLDPE) in composite production as a substitute to formaldehyde resin bounded wood particleboard. Finally, information based on utilization of waste polythene bags (water sachets) and waste wood of Okhuen wood composite boards manufacture are not available, hence the need for this research work [17]

2.0 Materials and Methods

2.1 Materials

The sawdust of Okhuen wood (*Brachistegia nigerica*) used in this work was obtained directly from sawmill in Benin, Nigeria. Waste polythene bags (empty sachet water bags) of the same kind and type were collected from Nnamdi Azikwe University Awka, Nigeria premises, washed with clean water and dried.

2.2 Equipment

Equipment used in this research were: digital weighing machine, drying oven, vernier calliper, set of sieves, hydraulic press model No PUJI200E, Euerpac universal material testing machine, Hounsfield Tensometer, two roll mill, pulverizing machine and Scanning Electron Microscope (SEM).

2.3 Methods

The particle size analysis of the sawdust particles was carried out in accordance with BS1377:1990 [15]. 100g of the particles was placed unto a set of sieves arranged in descending order of fineness and shaken for 15 minutes which is the recommended time to achieve complete classification. The sawdust particles of 1000μm and 420μm were used in this study. The oven dried sawdust with moisture content of less than 6% and waste polythene bag particulates were weighed for each formulation. They were melt blended (compounded) in a two roll mill mixer model No 5183 supplied by Reliable Rubber and Plastic Machinery Company U.S.A at College of Chemical and Leather Technology (CHEL TECH) Zaria, Nigeria. The temperature of the two

roll mill was set at 130^0C during the compounding process. Two different sets of composites board were compounded (i.e 60:40%, 50:50%, ratio of the wood particles to LDPE binder) at particles sizes of 420µm and 1000µm each. The photograph of the compounded sample is shown in Figure 1.

Metal moulds were used in the production of the composite board samples. Each mold had a cavity to accommodate the composite board samples. The dimensions and shapes of cavities were made according to the size and shape of the samples as per ASTM Standard D 638-90 for tensile testing[17] and ASTM Standard D 790-97 for flexural testing[18].

After compounding, the compounded samples were poured into the fabricated mould. The inside surface of the mould was coated with oil to avoid adhesion of the mixture and to allow easy removal of the composite sample. Compression moulding of the mixture was done using 40-ton electrical heated hydraulic press supplied by Moore Birmingham U.K, serial No.D288. The composites were produced at a temperature of 160^oC, time of 7minutes and pressure of 40kg/cm^2. At the end of each press cycle, the samples were removed from the mould after cooling at room temperature. Figure 2 show the photograph of the produced composites boards after removal from the mould.

Figure 2: Photograph of the produced composites boards

Scanning Electron Microscopy (SEM) observations of the composite boards were made with a JEOL electron microscope (SEM) JEOL JSM-6480 LV. The samples were fractured after cooling in liquid nitrogen and the freshly fractured surfaces were coated with thin layer of Gold (Au) for elimination of charge effects in the microscope

The basic method of determining the density of the composite samples was by measuring the mass and volume of the sample used. A clean sample is weighed accurately in air using a laboratory balance and then suspended in water. The weight of the sample when suspended in water was determined and the volume of the sample was determined from the effect of displacement by water (Archimedes Principle). The density of the sample was then estimated from the equation [19].

$$\text{Density} = \frac{Mass}{Volume} \qquad (1)$$

The samples with dimension 50□50□4mm were used to examine water absorption behaviour (ASTM 570-98). The samples were immersed in deionised water at 23°C and taken out of water after 24h immersion. Excess water on the surface was removed by blotting with (tissue paper. Wet measurement of length, thickness and weight were recorded immediately. These measurements were used with the initial measurements to calculate water absorption. The amount of water absorbed W_c was calculated as follows [20].

$$W_c(\%) = \frac{w_1 - w_0}{w_0} \times 1 \quad (2)$$

Where w_0 and w_1 are weights of the specimen before and after immersion in water respectively.

Thickness Swelling (TS) was calculated as follows

$$T(\%) = \frac{t_e - t_0}{t_0} \times 1 \quad (3)$$

Where t_e is the thickness of the sample after immersion, t_0 is the thickness of the sample before immersion. At least four specimens for each sample were used.

Prior to mechanical testing, the samples were conditioned at constant room temperature and 65% relative humidity (RH) in accordance to *BS EN 319:1993[21].*

Tensile strength measurement of samples was determined using Hounsfield Tensometer W3179. The crosshead speed during the test-was 3mm/min. Five (5) specimens from each sample were tested. The specimen was loaded using self-aligning, self tightening grip that distributes the force evenly over the grip surface and did not allow slipping. The load was applied continuously throughout the test at a uniform rate of motion of the moveable crosshead of the testing machine. The maximum tensile stress was calculated in accordance with the equation [17].

$$R_T = \frac{P_{max}}{b\,d} \quad (4)$$

Where b = width of reduced cross- section of the specimen measured in dry condition in mm, d = thickness of the specimen measured in dry condition, P_{max} = maximum tensile load (N), R_t = maximum tensile stress (MPa)

Flexural tests were performed using universal testing machine ENERPAC model No PUJ1200E equipped with a 500kg load cell, after conditioning at 25°C, in accordance with ASTM S790 standard. A three point bending configuration was used with specimen nominal dimension of 150×50×4mm^3 and a span of 96mm. The load was applied continuously throughout the test at a uniform rate 3mm/min. The modulus of rupture, apparent modulus of elasticity were calculated for each specimen in accordance with the following equation [18].

$$R_b = \frac{3P_{max}L}{2b\,d^2} \quad - \quad - \quad - \quad - \quad - \quad - \quad (5)$$

Where b = width of specimen measured in dry condition (mm), d= thick of specimen (mm), L = length of span in mm, P_{max} = maximum load (N), $\frac{\Delta p}{\Delta y}$ = Slope of the straight line portion of the load deflection curve (N/mm).

The internal bond (IB) tests were conducted on samples cut from the experimental board and tested according to ASTM D10376a. The tensile strength perpendicular to the surface was determined using five conditioned specimen of 50□50 mm□4mn from each composite board. Loading blocks of steel 50mm square and 25mm in thickness. The specimen was stressed by separation of the heads of the testing machine until failure occurred. Rapture load (p_s) was determined and internal bond strength was calculated using the following formula [21].

$$IB = \frac{P_{max}}{a\,b} \quad - \quad - \quad - \quad - \quad - \quad - \quad (6)$$

Where a = width of the specimen measured in dry condition (mm), b = length of the specimen (mm), P_{max} = maximum load (N), IB = internal bond strength (MPa)

3.0 Results and Discussion

3.1 Morphology Studies of the Composite Boards

The morphologies of the two composites boards by SEM are shown in Figure 3 for 1000µm sawdust/polythene composite board and Figure 4 for 425µm sawdust/polythene composite board. The microstructure reveals that there are small discontinuities and a reasonably uniform distribution of particles and the resin. The microstructure clearly shows that, when wood particles were added to the recycled LDPE resin binder, morphological changes in structure took place. The microstructures reveal that there is reasonable uniform distribution of wood particles and recycled LDPE binder indicating that the bonding is fairly good. The bonding was achieved due to the compounding of wood particles and the recycled LDPE binder in a two roll mill. In Figure 3 however, due to big particle size and smaller surface area, the sawdust

become unevenly distributed through the binder. Thus the reduced dispersion of sawdust led to weak interfacial bonding which might have resulted in small void spaces and cavities which consequently lowered the mechanical properties of the composite board.

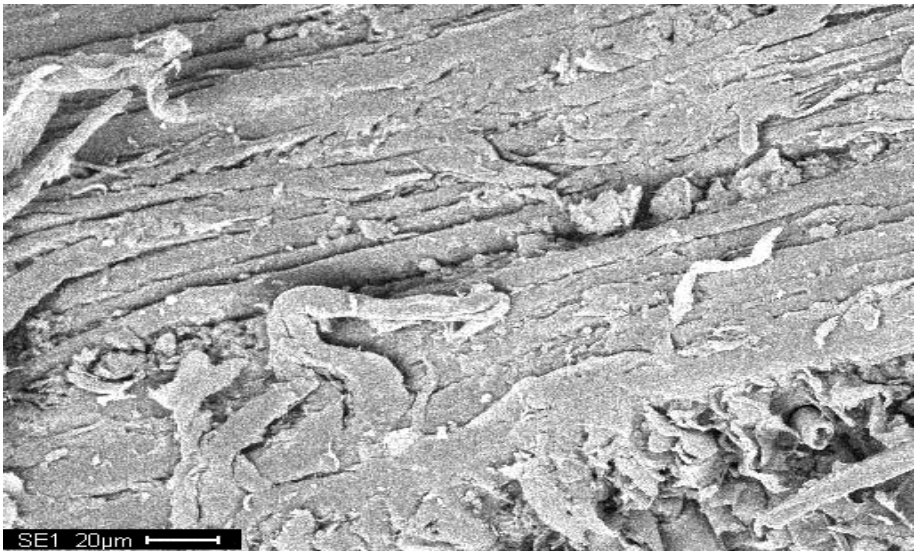

Figure 3 : 1000µm sawdust particles size/ polythene composite

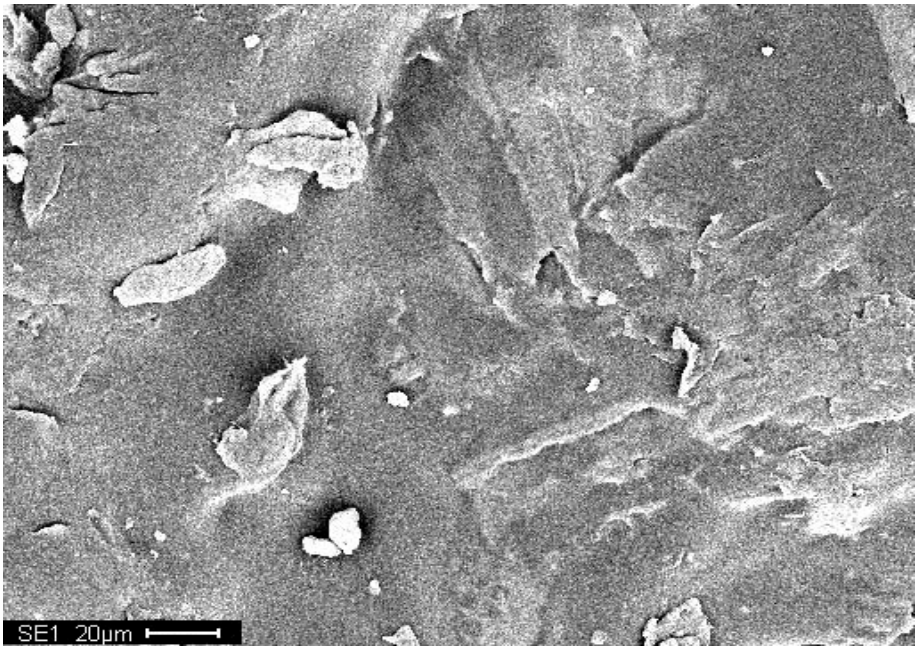

Figure 4 : 425µm sawdust particles size/ polythene composite

In Figure 4, the interfacial bonding between sawdust and binder was much better when compared to the micrograph in Figure 3. The improvement might be due to bigger surface area associated with

smaller particle size of sawdust that resulted in better wetting of sawdust by resin binder.

3.2 Physical and Mechanical Propeerties

The results of the physical and mechanical test are shown in Table 1. The density profile of a board is dependent on theparticle configuration, moisture distribution in the mat, hot press temperature and rate of closing, resin reactivity and the compressive strength of the particles [13]. The board density ranges from 0.74 to 0.80 (Table 1).

TABLE 1: PROPERTY OF OKHUEN WOOD SAWDUST/POLYTHENE COMPOSITE BOARD

Board type (optimum board)	Density g/cm^3	Bending properties (MPa)		Water Absorption (WA) and thickness swelling (TS)		Tensile strength MPa	Internal bond 1B N/mm^2
		MOR	MOE	WA 24h (%) WA(%)	TS(%)		
420µm particle 60 sawdust/40 RLPPE	0.74	16.21	1232	8.67	5.43	13.90	0.52
420µm particles 50 sawdust/ 50 RLDPE	0.80	17.23	1121	6.76	3.64	13.99	0.61
1000µm particles 60 sawdust/40 RLDE	0.79	13.182	1187	16.34	7.13	12.31	0.45
1000µm particles 50 sawdust/50 RLDPE	0.75	16.32	1005	14.25	6.13	12.94	0.54
Standard value	0.85	14 - 18	1200-1400	25-60	15-25	10-14	0.4

From Table 1, the water absorption and thickness swelling of the different boards manufactured vary from 6.76% to 16.34% and 3.64 to 7.13% respectively with the lowest value corresponding to the board with a (50wt%) plastic content. These values are clearly superior to that obtained for a conventional wood particle board of similar density and thickness [23]. They also compare favourably with those reported by Nouebakhist *et al* [7] for wood/High-density polyethylene composites. At 50% plastic, distribution of the plastic component among the wood sawdust particles covered a large surface area of the hygroscopic wood component ensuring better surface protection of lignocellulosic particles, water absorption and thickness swelling levels are reduced and moisture resistance of the wood-plastic composite boards improved. The composite with 60wt% sawdust has high water absorption and thickness swelling. This may be due to the fact that a larger share of the particle surface is insufficiently bonded and protected by the plastic component, and the greater connectivity between particles allows for easier moisture intrusion.

The bigger size particles of 1000μm with 50w% or 60wt% sawdust have higher water absorption and thickness swelling. The moisture absorption in composites is mainly due to the presence of lumens, pores and hydrogen bonding sites in the wood fiber, the gaps and flaws at the interfaces, and the micro cracks in the matrix found during the compounding process [9]. The larger the particles size of sawdust the higher the water absorption. This can be explained in two ways (i) lager particles lead to greater hydrophilic exposure surfaces (ii) poor adhesion between wood particles and the binder generates void spaces around the wood particles. The maximum thickness swelling as a result of 24hour water immersion according to EN 312-3 was 15%. All the boards produced met the requirement as stated in EN Standards [22].

Modulus of elasticity (MOE) of the different boards manufactured varies from 1,005-1232MPa (Table 1), the lowest values corresponding to the boards with a high (50%) plastic content. MOE is slightly lower than that reported for conventional board product of wood polypropylene composites [4]. The relationship of the wood content with MOE is directly proportional, that is, an increase in the content of wood material causes an increase in MOE whereas MOR decreases proportionally. Such an inverse behaviour of bending strength and modulus of elasticity as a result of the lignocellulosic material content was already reported by other authors such as Simonsen[23], Rowell *et al* [24], and Stark and Rowlands [25]. This is interpreted in such a way that the lignocellulosic material only acts as filler without an appreciable capacity to reinforce the polymer matrix in the composite board[4]. Spring back effect as a result of cooling the boards out of

press with temperature still above the plastic melting point may have affected stiffness more than bending strength.

From the Table 1, the bending strength (MOR) of the different board types manufactured varies from 13.18MPa to 17.23MPa. The MOR is well within the minimum requirements (16-18MPa) stipulated in EN 312-3[22] for general purpose flat-press particle board of up to 13mm thickness, and above those for medium density particleboard (11-16.5MPa). The MOR is lower than MOR of conventional sheathing grade plywood (20.7-48.3MPa) sheathing grade oriented strand board (20.7-27.6), medium density fiber board (24MPa), and standard hardboard (31MPa) as reported by [22].

The tensile strength of the composites decreased slightly as the sawdust loading increased. The same is true for particle size. The bigger sawdust particle sizes (1000μm) have lesser tensile strength. This may be as a result of poor interfacial bonding created among hydrophilic sawdust and hydrophobic binder with consequent problems such as small void spaces and de-bonding in the composite.

From Table 1, composites with high sawdust content possess low internal bonding strength. Wood fibre/particle is a kind of stiff organic material, so adding sawdust could decrease the internal bonding strength of composite. The decrease in the internal bonding strength is likely due to decrease of the amount of binding between plastic, as the adhesive decreases. Based on EN312-3[22] standards for general purpose application, the internal bond (IB) strength requirements are 0.4MPa and 0.24MPa. All the composite boards met these requirements.

4.0 Conclusion

From the above results and discussions the following conclusions are made:

(i) This research work shows the successful fabrication of Okhuen wood sawdust/polythene composite boards by simple compressive moulding technique is attainable.

(ii) Composites made with waste polythene sachet (water sachets) exhibited lower water absorption. when compared with those of EN 317-1993

(iii) All the composite boards produced met the MOR and MOE requirements for interior fittings including furniture and for general uses according to EN 312-3 standards. They also satisfied the Japanese industrial standards JIS A-5908 Type 8 and Type 13 minimum requirement for MOR which are 8.0 MPa and 13 MPa

respectively and for IB strength which are 0.15 N/mm^2 and 0.2N/mm^2 for type 8 and type 13 respectively

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REFERENCES

1. Au, K.C., Gertjejansen, R.O., 1989. Influence of wafer thickness and resin spread on the properties of paper Birch waferboard. Forest Prod. J. 39 (4), 47_ 50.
2. Kalayciog˘lu, H., Nemli, G., 1997. Properties of structural particleboard prepared from the bark of Pinus brutia. Proceedings of the XI World Forestry Congress. 13_ 22 October 1997, Antalya, Turkey, p. 50.
3. Khristova, P., Yussifou, N., Gabir, S., Glavche, I., Osman, Z., 1998. Particleboards from sunflower stalks and tannin modified UF resin. Cell. Chem. Technol. 32, 327_ 337.
4. Youngquist, J.A, Myers, G.E., Muehi, J.M., Krzysik, A.M., Clemons, C.M. 1993. Composite from Recycled wood and plastics. Final Report for U.S. Environmental Protection Agency, Project # 1AG-DW-12934608-2 USDA, Forest service, Forest products laboratory, Madison WI
5. Viswanathan, R., Gothandapani, L. And Kailappan, R. (2000). Water Absorption and Swelling Characteristics of Coir Pith Particle Board, *Bioresource Technology,* 71(1):93 – 94.
6. Singha, S. Amar., Vijay Kumar Thakur., 2009. Study of mechanical properties of urea formaldehyde thermoset reinforced by pine needle powder. Peer reviewed article Bio resources 4 (1) pp 292 – 308.
7. Nourbakhsh, A., Ashori, A. 2009. Preparation and properties of wood plastic composites made of Recycled High-density polyethylene. Journal of composite materials, vol. 43(8) pp 877-882.
8. Shebani, A.N, and Reenen, A.J.V. 2009. Effect of wood species on the mechanical and thermal properties of wood-linear low density polyethylene composites. Journal of composite materials vol. 43(11) pp. 1305-1318.
9. Nadir Ayrilmis and Songklod Jarusombuti (2011). Flat pressed wood plastic composite as an Alternative to conventional wood-based panels. Journal of composite materials, Vol. 45(1) pp 103-112
10. Najafi Abdollah and Najafi Kazemi Saeed .2008. Effect of load levels and plastic type on creep behavior of wood sawdust/HDPE

composite. Journal of reinforced plastic and composite vol. 00(00) pp 1-9.

11. Talavera, Fuentes, F.J. Guzman, Silva J.A., Richter H.G., Duenas, Sanjuan R., Quirarte Ramos J. (2007). Effect of production variables on bending properties, water absorption and thickness swelling of bagasse/plastic composite boards. Industrial Crops and products 26 pp 1-7.
12. Pornwapa kasemsiri, Salim Hiziroghu, Sarawul Rimdusit 2011. Properties of Wood Polymer Composites from Eastern red cedar particles reinforced with bensonxazine resin/cashew nut shell liquid copolymer, composites; part A 42 pp1454 – 1462.
13. Hashim Rokiah, Said Norafizah, Lamaming Junidah, Baskaran Mohana, Sulaiman Othaman, Sato Masatoshi, Hiziroglu Salim, Sugimoto Tomoko. 2011. Influences of press temperature on the properties of binderless particleboard made from oil palm trunk. Materials and Design 32 pp 2520 – 2525.
14. Hashim Rokiah, Wan Noor Aidawati Wan Nadhari., Othman Sulaiman., Salim Hiziroglu., Masatoshi Sato., Fumilo Kawamura., Tay Guan Seng., Tomoko Sugimoto and Ryohei Tanaka. 2010. Evaluation of some properties of exterior particleboard made from oil palm biomass. Journal of Composite materials: vol. 45 (16) pp1659 – 1665.
15. Ye Philip X., James Julson., Monlin Kuo., Al Womac., Deland Myers. 2007. Properties of Medium Density Fiberboards Made from Renewable Biomass. Bioresource Technology: 98 pp1077 – 1084.
16. Osarenmwinda, J. O. Nwachukwu, J. C. 2010. Development of Composite Materials from Agricultural waste. International Journal of Engineering Research in Africa Vol. 3 pp42 – 48.
17. Atuanya, C. U. 2013, The Use of Polyethylene Bags as Binder in the Manufacture of Wood Composite, Ph.D Thesis, University of Benin, Benin City, Nigeria.
18. ASTM Standard D 638-90 (2003) Standard test method for tensile properties of plastics. West Conshohocken ASTM internationals
19. ASTM Standard D 790-97 (2010) Standard test method for flexural properties of plastics. West Conshohocken ASTM internationals
20. BSI. 2003. *BS EN 312:2003: Particleboards. Specifications*. The British Standards Institution, London.
21. BSI(British StandardsInstitution). 1993a. *BS EN 317:1993: Particleboards and Fibreboards—Determination of Swelling in Thickness after Immersion in Water*. The British Standards Institution, London.

22. BSI. 1993c. *BS EN 319:1993: Particleboards and fibreboards—Determination of Tensile Strength Perpendicular to the Plane of the Board*. The British Standards Institution, London.
23. EN 312-3, 1996. Particleboards-specifications-part 3: requirements for boards for interior fitments (including furniture) for use in dry conditions. European Standardization Committee, Brussels
24. Simosen, J., 2004 Wood-plastic Composite: defining the interphase. Oneline at htt//woodscience orgonstate. edu/faculty/simonsen/index.htm (consulted September 08 2005).
25. Rowell, R.M., sanadi, A., Jacobson, R., canfield,D., 1999. Utilization of natural fibers in plastic composites: problem and opportunities, In, L., A, carvalho X., F., Frollini, E. (Eds), hignocellusic plastic composites, pp. 23-51
26. Stark, NM., Rowlands, RE.,(2003) Effect of wood fiber characteristics on mechanical properties of wood/polypropylene composites; 35(2):167-74.

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HIGH SALT-TASTE THRESHOLD IS A GOOD, 10-YEAR PREDICTOR OF ESSENTIAL HYPERTENSION IN A RURAL COMMUNITY COHORT OF YOUNG ADULT AND MIDDLE-AGED NIGERIANS.

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ABSTRACT:

Background: *One of the controversies still lingering in medicine today is whether there is a connection and, if so, what kind exists between salt-taste threshold and essential hypertension. The current, prospective study was designed with a view to modestly contributing towards the resolution of this controversy.*

Methods and Results: *In this 10-year prospective, rural community-based, cohort study thresholds for salt-taste detection, blood pressures and the body mass index (BMI) were measured in healthy, normotensive subjects at entry in 2002. During the follow-up period the participants were being screened for any subsequent occurrence of hypertension. The cohort consisted of 309 participants (130 males and 179 females) of mean age 36.71 ± 8.3 years (± SD). Fifty-five (17.8%) of the participants had high entry thresholds for salt-taste detection out of whom 43 (78.2%) subsequently became hypertensive during the 10-year follow-up period. The crude positive and negative predictive values for hypertension of high salt-taste threshold were 78.2% and 98.0% respectively. These values did not change significantly after a further*

* Key Words: Salt-taste threshold, Hypertension, Prediction.

analysis was done to adjust for the confounding effects of age, sex and obesity on the blood pressure measurements (p>0.05 for each).

Conclusion: *These findings suggest that high salt-taste threshold is a good, independent 10-year predictor of essential hypertension in young adult and middle-aged Nigerians. There is, however, a need for further independent confirmation.*

Introduction

Hypertension is the most prevalent non-communicable disease and the single most common cause of cardiovascular morbidity and mortality world-wide, with the prevalence reported to be rising globally [1,2]. Although the identification of hypertension as a disease condition dates back to 2600 B.C. when the ancient Chinese used the pulse character to diagnose the condition [3] the etiopathogenesis of essential hypertension is still froth with knowledge gaps. Hypertension is a heterogeneous disorder which needs pre-morbid commencement of personalized, preventive interventions aimed at postponing the disease onset or avoiding it completely [4]. Whereas lifestyle, dietary, genetic, racial, environmental and other factors are clearly associated with essential hypertension all attempts at fitting various combinations of these factors into an accurate disease prediction model have largely been unsuccessful [5]. This constitutes a stumbling block against knowing with reasonable precision when and in whom hypertension will eventually develop. This knowledge is critical to both patients and their care-givers for a personalized, pre-morbid planning and targeting of interventions. There is, therefore, an urgent need for better markers that will add more value to the existing prediction models of essential hypertension.

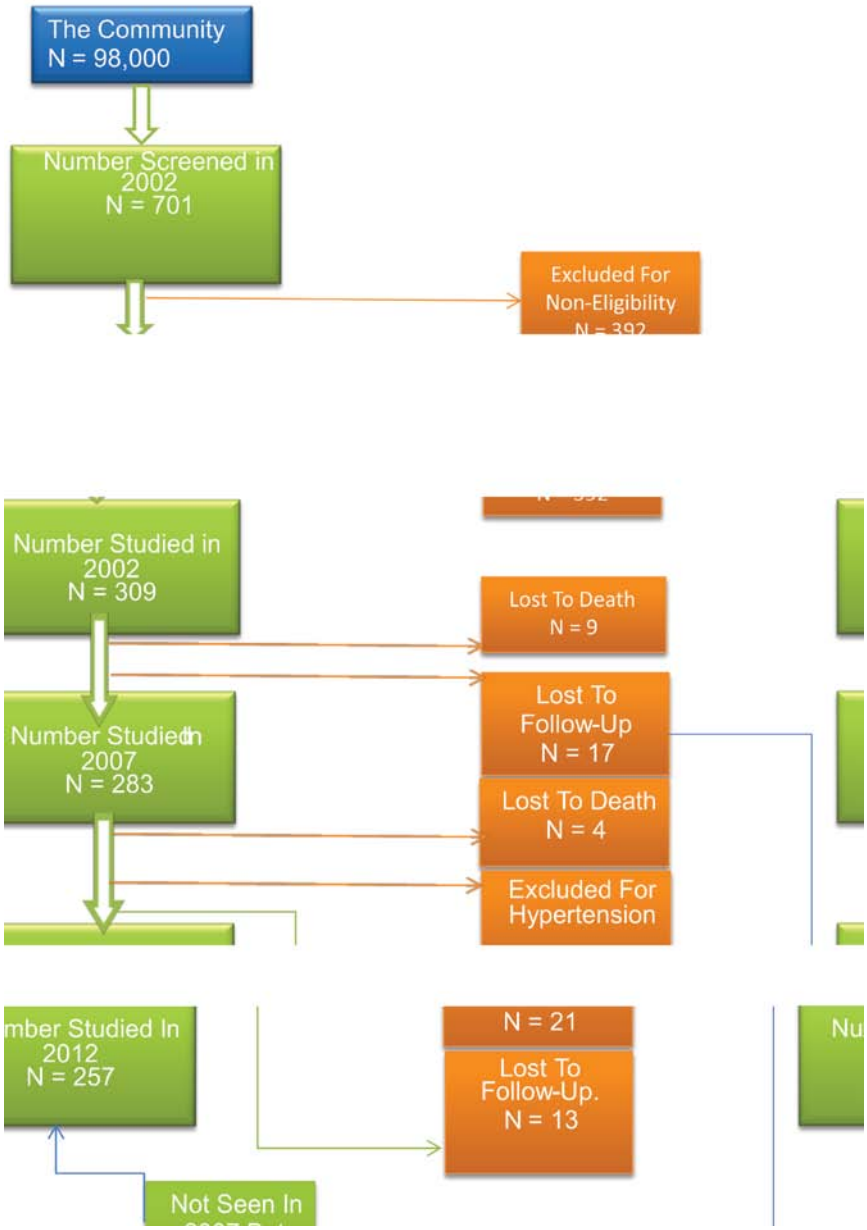
The association between high salt intake and essential hypertension is well established. Some studies have associated high threshold for salt-taste detection with increased quantity of sodium chloride intake [6, 7, 8, 9, 10, 11]. Whether this association further translates to a causal relationship to essential hypertension has, however, remained a subject of intense controversy [12]. A further complication is, in fact, introduced by the observation that old age, a physiological process, as well as some pathological states can also alter the threshold for salt-taste perception [13, 14, 15, 16]. Whereas some previous studies have related high salt-taste threshold to hypertension [17, 18, 19, 20] others have failed to show such a relationship [21, 22, 23, 24]. The cross-sectional designs of most of the studies as well as other methodological flaws have all been blamed for this confusion [12]. The current prospective, cohort study was designed to use the threshold for salt-taste detection as a one-factor prediction model for essential

hypertension and to compare the model's performance indicators with those of the multiple risk-factor models currently in use. The essence is to clarify whether or not high salt-taste threshold possibly has a causal relationship to essential hypertension.

Methods:

The study community

The current study was carried out in Ukana, a rural, agrarian community in Udi Local Government Area of Enugu State in South-Eastern Nigeria. The community was selected for this study because members of our research team had participated in two previous health outreach programs for the community. The terrain was, therefore, not new to us and we had access to enough useful demographic and health data about the community to enable us plan for and design the current study. It was observed from the data kindly made available to us by Grassroots Healthcare Foundation (GHF), the non-profit organization sponsoring the medical missions to the community, that young people in Ukana were not probably as affected by rural-urban migration as those in many other rural communities in Nigeria [25]. From the age distribution and patterns of hypertension prevalence rates in Ukana obtained from the available GHF documents it was considered that enough participants for the needed sample size could be recruited during the course of a two day mission to the community. One of the investigators (AUM) hails from the community and he facilitated contacts within the community and helped ensure the high level of co-operation the team enjoyed throughout the study. Ukana is a small, close-knit community with a population of about 98,000 (2006 Nigerian census figure). It is located on top of one of the Udi Hills and on longitude 7^{o} 24' 46" E and latitude 6^{o} 30' 22" N. About 60% of the inhabitants are subsistence farmers growing mainly cassava, maize, yams, plantain and bananas. The community has one primary school, one secondary school and one health center. The community has a traditional ruler, the "Igwe", who works with a cabinet comprising of several hamlet chiefs. There is also the Town Union of which members are elected representatives, one from every hamlet. The Town Union has executive and over-sight powers in all development projects in the community and it has the responsibility of co-coordinating the frequent medical missions to the community in liaison with GHF.



The Study Sample Size

The sample size was determined using the following formula for estimating an incidence rate with specified relative precision as applied to one-sample cohort studies [26]:

$n = \{Z_{1-\alpha/2} / \varepsilon)^2$

The relative precision (ε) applied in the sample size computation for the current study was 20%. A design effect of 2 was also applied since the participants were not selected by simple random sampling. A minimum sample size of 194 participants was, therefore, to be followed up in

order to observe an incidence of hypertension to within 20% of its true population value with 95% confidence. A provision of 20% attrition rate was also made and this brought the required minimum sample size to 233. However, all the 309 qualified persons seen during the sampling period were enrolled as per the study protocol.

Study Procedure.

The study was approved by the Ethics Committee of University of Nigeria Teaching Hospital, UNTH, Enugu prior to the commencement. The approval to incorporate the current study into the medical missions to the community was given by the sponsors, the GHF, and permissions were also obtained from the traditional ruler of the community as well as from the community's Development Union leaders. Finally, informed consent was obtained from each of the participants. The initial survey was carried out in March 2002 during a free medical mission to the community. A structured, interviewer-administered questionnaire was used to obtain the following information: age, sex, address, names of parents, highest education, occupation as well as any family history of hypertension or diabetes. Blood pressure and fundoscopic examinations were also done on each person while salt-taste detection thresholds were determined using different strengths of sodium chloride solutions.

The community was then re-visited in March and April 2007 and finally in April and May 2012. During each of these visits the same subjects that had been recruited in 2002 were recalled or traced and the same parameters reassessed. The materials and techniques used during all the assessments were the same. All those involved in the data collection had received adequate training and demonstrated sufficient knowledge and skill about their particular assignments before the study began. As per protocol all the subjects who came out for the free medical outreach in March 2002 were examined but apparently healthy individuals aged from 21 years to 60 years were recruited into the study. The exclusion criteria were: (a) no consent, (b) Hypertension or participants already on anti-hypertensive drugs or had hypertensive retinal changes and (c) diabetes mellitus. The age limits were set in order to exclude minors and to eliminate the potentially biasing effect of the gustatory changes known to be associated with ageing [13]. A requirement in the protocol was that participants, once found to be hypertensive, would be referred for treatment and would be excluded thence from further participation. This latter decision was made to obviate the potentially biasing effect of anti-hypertensive drugs, some of which have been shown to lower salt-taste threshold [27].

Clinical Data Collection Procedure

Weights and heights were determined with a Seca 700 weighing scale fitted with a stadiometer (Seca, Hamburg, Germany). The body mass index (BMI) was calculated based on a method that has been described in detail elsewhere [28]. Blood pressure was measured using mercury sphygmomanometers fitted with adult-size cuffs (Accoson, Essex, England). The first and fifth Korotkoff sounds were used to determine systolic and diastolic blood pressures, respectively. The blood pressures were taken after the participants had rested for at least 15 minutes. They were taken from both arms with the participants in a sitting position and the average reading recorded. The examination of the participants' ocular fundi was carried out exclusively by one of the authors (BIE), who is an ophthalmologist. The mean arterial pressure (MAP) was calculated using the formula (2 x diastolic blood pressure + systolic blood pressure)/3 as it is conventionally done. Hypertension was defined as systolic blood pressure≥ 140 mmHg and / or diastolic blood pressure≥ 90 mmHg as measured on at least two different occasions with or without hypertensive retinal changes; while generalized obesity was taken as BMI≥ 30 Kg/m ^{2}. The patients were given the dates to return to the same venue for subsequent follow-up studies and the dates were normally publicized in advance with the aid of the numerous media of native communication, including the use of the "community crier" who went round the community at night to make announcements, striking his metal gong first to draw attention. Every effort was made by the team to trace defaulters and to assess them once traced.

Procedure for determining the thresholds of gustatory salt recognition:

For the salt-taste detection threshold tests 0.02M, 0.03M, 0.04M, 0.05M, 0.06M, 0.07M, 0.08M and 0.09M solutions of sodium chloride (table salt) were prepared in distilled water. Each concentration of the salt solutions mentioned above was stored in a separate container and had a dedicated pipette of 88.9mm in length with a bulb at the 5.1mm-end while the open end is 1.3mm in diameter and has a slightly curved tip. The 8 different sodium chloride solution strengths were each manned by a different, trained tester and neither the testers nor the participants knew what was in the solution.

The testers were stationed in a row of 8 stations, with each station having a jar containing a different strength of the test solution. The participants were made to move along from one station to the other, starting from the station with the lowest concentration of test solution to the highest. There was a time-keeper who signaled the end of each phase of the testing and the beginning of the next. This arrangement was found the fastest and most error-free during the prior test-runs.

The containers of the salt solutions were the same and were randomly coded A to H in order to avoid bias. At each testing point the participants first rinsed their mouths with distilled water. Then 3 drops of the test solution were dropped on the tip of the participant's tongue with the pipette. The participant then smacked the mouth and was asked to report whether he or she had perceived any taste and, if so, what the substance tasted was. The tester recorded the response, rinsed the participant's mouth again with distilled water, waited for another 30 seconds and then directed the participant to the next, test station. The lowest solution strength at which the participants first showed correct perception and cognition of salt was taken as the threshold for salt-taste detection.

Pre-testing of the procedure for ascertaining the threshold for salt-taste detection.

Before the study started the same strengths of sodium chloride solutions were set-up and 5 different medical student volunteers went round eight test stations and were tested for salt-taste detection thresholds in a way that simulated the field arrangement. Each of the students was tested 10 times within two days in exactly the same way. The testers swapped stations each time the students went through each round in order to minimize bias. The intra-individual coefficient of variation (CV%) was computed for each student with respect to the measured thresholds of salt-taste detection to assess the consistency of the method. The resultant CV% ranged from 0% in 4 of the students to 7.71% in only one of them.

Statistical analysis:

The data analysis was carried out using Epi Info 2002 statistical software [29] and Sigma Stat Version 3.5 [30]. The data were first subjected to normality testing using quantal-quantal plots for visual assessment and then, sequentially, using the Shapiro-Wilk normality test for quantitative estimation before the data analysis. Continuous data were stated as Mean ± Standard Deviation (±SD) and analyzed using two-tailed, unpaired Student t-test for two-group data comparisons while one-way analysis of variance (One-way ANOVA) was used for comparisons across more than two data groups. Proportions were stated as per cent (%) and compared using Fisher's exact test. The relationships between variables were investigated using Spearman's non-parametric regression coefficients (r_s) and simple linear regression coefficients (r) as appropriate for non-continuous and continuous variables respectively. Analysis of covariance (ANCOVA) was performed in order to control for the confounding effects of age, sex and BMI on the systolic and diastolic blood pressures of the participants.

Results:

Figure 1 shows a schematic presentation of the participants flow. A total of 701 persons aged 15 years and above who turned up for the GHF's free healthcare screening and treatment in Ukana in March 2002 were tested for salt-taste detection thresholds following which 309 who satisfied all the entry criteria were recruited. Nine of the participants had died by 2007 while 17 (5.5%) were not seen, leaving 283 whose data were obtained. In 2012 the number of participants studied was 257 after the following were excluded: 21(6.8%) who were diagnosed with hypertension in 2007, 4 (1.3%) who had died and 13 (4.2%) who were lost to follow-up and all efforts to trace them failed. Twelve (3.9%) out of the 17 who were not seen in 2007 reported back in 2012 and were re-admitted into the study.

Table 1 A comparison of the study variables among the participants as measured in 2002, 2007 and 2012.

PARAMETER	2002 (MEAN ± SD) N = 309	2007 (MEAN ± SD) N = 283	2012(MEAN ± SD) N= 257	P-VALUE
Height (m)	1.57 ± 0.1	1.58 ± 0.1	1.59 ± 0.1	=0.0683^{ns}
Weight (Kg)	51.23 ± 10.6	53.07 ± 12.0	56.22 ± 13.7	< 0.0001^{a}
BMI (Kg/m^2)	22.43 ± 7.1	23.68 ± 8.4	26.89 ± 9.2	<0.0001^{a}
Systolic Blood Pressure (mmHg)	123.21 ± 19.8	125.60 ± 20.3	128.38 ± 23.7	< 0.0001^{a}
diastolic Blood Pressure (mmHg)	78.44 ± 11.6	81.51 ± 12.4	85.91 ± 13.0	< 0.0001^{a}
MAP (mmHg)	88.92±22.4	94.30±23.10	99.1±24.3	<0.0001^{a}
Threshold for salt-taste recognition (Molarity)	0.049 ± 0.02	0.051 ± 0.02	0.049 ± 0.02	=0.9913^{ns}

N = Number of subjects
SD = Standard deviation
MAP = Mean arterial pressure
^{ns} = Not statistically significant ($p>0.05$)
^{a} = Statistically very highly significant ($p<0.001$)
Analysis was by One-way ANOVA

For the 701 screened the mean threshold for salt-taste detection found was 0.051M and the 95% confidence limits were 0.037M and 0.059M. The upper limit of 0.059M was assumed to be the upper limit of normal for the study population and so the threshold of 0.06M was used as the cut-off point for the current study. Out of the 309 participants there were 130 males and 179 females, giving a male: female ratio of 0.7:1. Family history of hypertension was established in 43 (13.9%) of the participants while 7 (2.3%) had a family history of diabetes mellitus. The mean age (± SD) of the cohort at entry was 36.71 ± 8.3 years.

Table 1 shows the parameter differences observed among the participants from baseline in 2002, through 2007 to 2012. It was found that BMI and MAP but not threshold for salt-taste detection increased significantly from 2002 to 1012 ($p \leq 0.026$). The cohort's mean threshold for salt-taste detection at entry was 0.048 ± 0.02M. The relationship of the baseline salt-taste detection thresholds with each of the other parameters measured at baseline was further examined using Spearman's rank correlation analysis. Thresholds of salt-taste detection at baseline correlated positively with the baseline systolic blood pressure ($r_s = 0.66$, $p < 0.0001$), diastolic blood pressure ($r_s = 0.58$, $p < 0.001$), MAP ($r_s = 69$, $p < 0.0001$) and BMI ($r_s = 0.55$, $p < 0.0001$). The correlation with age among the participants was, however, not statistically significant ($r_s = 0.17$, $p = 0.0973$). Fifty-five (17.8%) of the participants had high baseline thresholds for salt-taste detection (above 0.06M) while the rest had thresholds below this limit. There was no significant sex difference in the threshold for salt-taste detection at entry (0.047 ± 0.02M Vs. 0.048 ± 0.02M for males and females respectively; $t=0.351$, $df=307$, $p = 0.726$). The number of participants found with hypertension in 2007 was 21 (7.4%) and in 2012 the new cases observed were 28 (10.5%). The overall incidence of hypertension among the cohort during the 10-year period of the study was 49 (16.1%), giving an average yearly incidence of 1.6%. Although there was no statistically significant sex difference observed in the incidence of hypertension (13.8% for males Vs. 17.3% for females; $p =0.44$, by Fisher's exact test) significantly more females were obese (5.4% for the males Vs. 18.9% for the females; $p = 0.001$ by Fisher's exact test). Overall, the MAP increased significantly from 2002 to 2012 ($p < 0.0001$ for each). Forty-three out of the 49 participants who subsequently developed hypertension had entry thresholds for salt-taste detection of > 0.06M while 6 had thresholds within the normal range. However, the participants with family history of hypertension had higher baseline thresholds 0.058 ± 0.02M compared with those without such history 0.047 ± 0.02M ($t=3.650$, $df=307$, $p = 0.0003$)

The height and weight of the participants at entry were 1.57 ± 0.1m and 51.23 ± 10.6 Kg respectively and the entry BMI was 22.43 ± 7.1

Kg/m^2. The overall entry prevalence of obesity was 41 (13.3%). Seventeen (34.7%) of the participants with baseline obesity became hypertensive. Over the period from 2002 to 2012 the BMI was observed to have significantly increased ($p < 0.0001$). Overall, there was a positive correlation found between BMI and MAP ($r = 0.61$, $p < 0.0001$). The crude positive and negative predictive values of baseline high salt-taste threshold for hypertension among the cohort were 78.2% and 97.6% respectively with a crude sensitivity of 87.8%. The values were re-calculated after controlling for the confounding effects of age, sex and BMI on the systolic and diastolic blood pressures of the participants. The age-, sex- and BMI-adjusted incidence of hypertension among the cohort was 37 (12.0%) while the adjusted positive and negative predictive values obtained were 65.5% and 99.6% respectively, with a sensitivity of 100%. These adjusted values did not differ significantly from their corresponding crude values ($p = 0.203$ and $p = 0.122$ for the positive and negative predictive values respectively; by Fisher's exact tests).

Discussion:

Hypertension is the most prevalent non-communicable disease and the single most common cause of cardiovascular morbidity and mortality world-wide [1, 2]. The prevalence of hypertension is rising globally [2] and a recent, rural community-based survey in South-Eastern Nigeria reported a prevalence rate of 46.4% [31].

There is a relationship between increased sodium load and hypertension, which leads to vascular and renal injury [32]. Some studies have related the amount of salt consumed by an individual to the level of his or her salt-taste threshold, suggesting that salt-taste threshold may be a good index of sodium intake [6, 7, 8, 9, 10, 11]. However, disorders of taste have been shown to occur in the course of many diseases [14, 15, 16]. Patients suffering from hypertension have been shown to have increased salt-taste threshold [6, 17, 18, 19, 20]. However, whether the hypertension-related change in salt-taste threshold is causal to or a consequence of the elevated blood pressure has remained unclear [12]. The results of the various studies, most of which are either cross-sectional or short-term longitudinal observations, have been inconclusive [12]. The current prospective, community-based, 10-year study was aimed at elucidating the nature of this relationship, if any, between high salt-taste threshold and future hypertension.

The subject of sodium toxicity was debated for a long time. In 1982 Campese and colleagues [33] demonstrated that a subset of patients with essential hypertension have impaired ability to suppress plasma norepinephrine during high sodium intake, suggesting that such

patients have hyperactivity of the sympathetic nervous system. Subsequently, Skraba et al [34] proposed in 1986 that inherited salt sensitivity in humans was the cause of essential hypertension. These observations led to efforts at elucidating the determinants of salt preference in humans. Experiments in rats showed that the principal mechanism for transduction of the salty taste involves passage of sodium through a specific ion channel, the epithelial sodium channel or ENaC, in the apical membrane of receptor cells which is blocked by amiloride [35]. However, this experimental finding in rats does not appear to bear out in a similar fashion in humans. While some studies have shown that the application of amiloride to the dorsal tongue epithelium can reduce the saltiness of sodium chloride in humans [36, 37] others could not substantiate that finding [38]. Although salt-taste threshold has been shown in some studies to be a good index of sodium chloride intake [6, 7, 8, 9, 10, 11] this was not so in others [21, 22, 23, 24]. Genetic, environmental, racial and age-related influences on salt-taste threshold as well as inconsistencies in study designs have all been invoked as possible explanations for the conflicting findings [24]. In the current study the participants were fairly homogeneous with respect to race and socio-cultural environment. The proportion found with high salt-taste threshold (high threshold for salt-taste detection) at entry was less than a quarter. Although there is a paucity of information about other population prevalence rates available to us for comparison, the mean value of salt-taste detection threshold that we found compares well with those previously reported among normotensive subjects in Western and Northern parts of Nigeria respectively [6, 18]. While the existence of a genetic link with respect to some taste modalities is being unraveled that for salt taste is still less well characterized in humans [39].

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The yearly incidence rates of hypertension have variously been reported but generally within the range of 3% to 18% depending on the age, gender, ethnicity, and body size of the population studied [2, 5]. In this 10-year study the yearly incidence rate we observed is low compared with the global situation. Part of the explanation for this could be that our participants were within the young adult and middle age groups while the highest prevalence of hypertension is found among the elderly, as shown in a recent survey of a rural community close to Ukana [31]. The global increase in the prevalence rates of hypertension is thought to be related to the coincident, noticeable rises in the amount of salt consumed [40] and in the increasing prevalence of obesity, among others [41]. In this study the prevalence of obesity found was low compared with what has been reported from some other parts of Nigeria [42]. This suggests that the contribution of obesity towards the prevalence of hypertension in this study population may be relatively small. A possible explanation for the low prevalence of

obesity found may be the high level of physical activity demanded by the participants' usual long trek to and from their distant farms and the physically-demanding, crude implements and methods they use in farming. The challenge of developing accurate prediction models for the future occurrence of diseases has been a daunting one for medicine [5]. The recent developments in genomics, proteomics and metabolomics have raised the hope for individualized disease prevention, diagnosis and treatment [43, 44]. However, the clinical application of these techniques in hypertension is still limited by non-universal availability and prohibitive cost of the technology as well as by the polygenic inheritance and variable phenotypic expression of hypertension, among others [43, 44]. The fore-going underscore the need to continue the search for the "magic bullet" genetic or other markers of the disease.

To this end several statistical models have been ingenuously derived for the prediction of essential hypertension based on the known risk factors for the condition [5]. The major ones include age, sex, race, smoking habits, family history of hypertension, lipoprotein A, triglyceride, uric acid, total cholesterol, and body mass index (BMI). [45,46]. In a recent study the performances of nine different models fitting the above risk factors as independent variables (multiple risk-factors models) were compared for predictive accuracy for hypertension [5]. The predictive performance of salt-taste threshold as a one-factor model as used in the current study appears to compare favorably with those of the afore-cited, multiple risk-factors models. The high salt-taste threshold model may have the further advantage of simplicity, not requiring the complicated computer calculations characterizing the multiple risk-factors models [5]. During pregnancy the precise prediction of an individual's proneness to develop hypertension is pressing for the early prevention of pre-eclampsia / eclampsia [47]. Although high salt-taste threshold as a prediction model for gestational hypertension has not been examined, to the best of our knowledge, the need for an examination of its utility in this situation appears compelling.

In conclusion, the findings suggest that high salt-taste threshold may be a good, 10-year predictor of essential hypertension among healthy, young adult and middle-aged rural Nigerians, independently of age, sex and BMI. These results, however, have to be interpreted with caution since the study itself is population-restricted, the sample size small and the overall effect of the dropouts on the study outcome is also uncertain.

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REFERENCES

1. Kearney PM, Whelton M, Reynolds K, Whelton PK, He J, Worldwide prevalence of hypertension: a systematic review, *Journal of Hypertension*, 2004; 22(1): 11–19,
2. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J, Global burden of hypertension: analysis of worldwide data, *The Lancet* 2005;365(9455), 217–223
3. Nei Ching Yellow Emperor's Classic of Internal Medicine. Books 2-9, published between 2698 and 2598 B.C.
4. Magometschnigg D, Schnögl H. [Individualized therapy of hypertension. The Austrian Professional Group of Clinical Pharmacology]. *Wien Med Wochenschr*.1995;145(15-16):349-352.
5. Ture M, Kurt I, Kurum AT, Ozdamar K. Comparing classification techniques for predicting essential hypertension. *Expert Systems with Applications* 2005; 29: 583–588.
6. Azinge EC, Sofola OA, Silva BO. Relationship between salt intake, salt-taste threshold and blood pressure in Nigerians. *West Afr J Med* 2011;30(5):373-376.

7. Mattes RD. Assessing salt taste preference and its relationship with dietary sodium intake in humans. In: Solms J, Booth DA, Pangborn RM, Raunhardt 0, eds. Food acceptance and nutrition. New York: Academic Press, 1987:129-42.17.
8. Shepherd R, Farleigh CA, Land DG. The relationship between salt intake and preferences for different salt levels in soup. *Appetite* 1984;5:281-190.
9. Shepherd R, Farleigh CA. Preferences, attitudes and personality as determinants of salt intake. *Hum Nutr Appl Nutr* 1986;40A:195-208\
10. Chan MM-Y, Garey JO, Levine B, McRae JE, Terpenning I. Moderate dietary salt reduction and salt taste perception of normotensive individuals with family history of hypertension. *Nutr Res* l985;5: 1309-1319.
11. Shepherd R, Farleigh CA, Land DG. Preference and sensitivity to salt taste as determinants of salt-intake. *Appetite* 1984;5:l87-97.
12. Arguelles J, Díaz JJ, Málaga I, Perillan C, Costales M, Vijande M. Sodium taste threshold in children and its relationship to blood pressure. *Brazilian Journal of Medical and Biological Research* 2007;40**:** 721-726.
13. Grzegorczyk PB, Jones SW, Mistretta CM. Age-Related Differences in Salt Taste Acuity, *J Gerontol* 1979;34 (6): 834-840.
14. Wen XY. Salt taste sensitivity, physical activity and gastric cancer. *Asian Pac J Cancer Prev* 2010;11(6):1473-1477.
15. Szalay C, Abrahám I, Papp S, Takács G, Lukáts B, Gáti A, Karádi Z. Taste reactivity deficit in anorexia nervosa. *Psychiatry Clin Neurosci* 2010;64(4):403-7.
16. Henkin RI, Solomon DH. Salt-taste threshold in adrenal insufficiency in man. *J Clin Endocrinol Metab.*1962;22:856-858.
17. Mattes RD. The taste for salt in humans. *Am J. Clin. Nutr*,1997; 65: 692S-697S.
18. Okoro EO, Uroghide GE, Jolayemi ET. Salt taste sensitivity and blood pressure in adolescent school children in southern Nigeria. *East Afr Med J* 1998 Apr;75(4):199-203.
19. Isezuo SA, Saidu Y, Anas S, Tambuwal BU, Bilbis LS. Salt taste perception and relationship with blood pressure in type 2 diabetics. *Journal of Human Hypertension* 2008;22: 432-434.
20. Rabin M, Poli de Figueiredo CE, Wagner MB, Antonello IC. Salt taste sensitivity threshold and exercise-induced hypertension. *Appetite* 2009;52(3):609-613

21. Fischer ME, Cruickshanks KJ, Pinto A, Schubert CR, Klein BE, Klein R, Nieto FJ, Pankow JS, Snyder DJ, Keating BJ. Intensity of Salt Taste and Prevalence of Hypertension Are Not Related in the Beaver Dam Offspring Study. *Chemosens Percept* 2012;5(2):139-145
22. Mattes RD. Salt taste and hypertension: a critical review of the literature. *J Chronic Dis.* 1984;37(3):195-208.
23. Campuzano Martín SH, Díaz Martín JJ, Perillán Méndez C, Argüelles Luis J, Vijande Vázquez M, Málaga Guerrero S. [Salt intake profile and blood pressure in cystic fibrosis]. *An Pediatr (Barc)* 2009;70(5):418-423.
24. Mattes RD. The taste for salt in humans. Am J Clin Nutr. 1997;65(2 Suppl):692S-697S.
25. Johnnie PB. Rural-urban migration in Nigeria: consequences on housing, health-care and employment. Migr World Mag. 1988;16(3):22-29.
26. Lwanga SK, Lemoshow S. Sample size determination in health studies: A practical manual. World Health Organization, Geneva, Switzerland, Mcmillam/Clays, 1991 pp12
27. Sulibursk a J, Duda G, Pupek-Musialik D. The influence of hypotensive drugs on the taste sensitivity in patients with primary hypertension, *Acta Poloniae Pharmaceutica - Drug Research* 2012; 69(1): 121-127.
28. Garrows JS, Webster J. Quetelets index (wt/Ht2) as a measure of fatness. *International J. Obesity* 1985; 9:147 – 153
29. Epi Info 2002. Centers for Disease Control and Prevention 1600 Clifton Rd. Atlanta, GA 30333, USA.
30. Sigma Stat. Aspire Software International 20448 Charter Oak Drive Ashburn, VA 20147
31. Onwubere BJ, Ejim EC, Okafor CI, Emehel A, Mbah AU, Onyia U, Mendis S. Pattern of Blood Pressure Indices among the Residents of a Rural Community in South East Nigeria. *Int J Hypertens*. 2011; doi:10.1155/2011/308687.
32. Wilcox C. Dietary Salt Intake for Patients with Hypertension or Kidney Disease. In: Mitch WE, Ikizler TA, editors. Handbook of Nutrition and the Kidney. 6. Philadelphia: Lippincott Williams & Wilkins; 2009. pp. 233–242.
33. Campese VM, Romoff MS, Levitan D, Saglikes Y, Friedler RM, Massry SG. Abnormal relationship between sodium intake and sympathetic nervous system activity in salt-sensitive patients with essential hypertension. *Kidney Int* 1982;21(2):371-8.
34. Skrabal F, Hamberger L, Ledochowski M. Inherited salt sensitivity in normotensive humans as a cause of essential hypertension: a new concept. *J Cardiovasc Pharmacol* 1984;6 (Suppl 1):S215-S223.

35. Heck GL, Mierson S, DeSimone JA. Salt taste transduction occurs through an amiloride-sensitive sodium transport pathway. *Science* 1984:223:403-405.
36. Schiffman SS, Lockhead E, Maes FW. Amilonide reduces the taste intensity of Na and Lıı salts and sweeteners. *Proc NatI Acad Sci U S A* 1983:80:6136-40.
37. Desor IA, Finn I. Effects of amiloride on salt taste in humans. *Chem Senses* I989:14:793-803.
38. Formaker BK, Hill DL. An analysis of residual NaCI taste response after amiloride. *Am J Physiol* l988;255:1002-1007.
39. Newcomb RD, Xia M, Reed D. Heritable differences in chemosensory ability among humans. *Flavour* 2012,1:9 doi:10,1186/2044-7248-1-9.
40. Battarbee HD, Meneely GR. The toxicity of salt. *CRC Crit Rev Toxicol* 1978; 5(4):355-376.
41. Lauer RM, Filer Li, Reiter MA, Clarke WR. Blood pressure, salt preference, salt threshold, and relative weight. *Am J Dis Child* 1976; 130:493-497.
42. Akpa MR, Mato CN. Obesity in Nigeria: Current trends and management. *Nigerian Medical Practitione* 2008;54(1):11-15.
43. Williams RR. Will gene markers predict hypertension? *Hypertension* 1989;14: 610–613.
44. Williams RR, Hunt SC, Hassted, SJ. Current knowledge regarding the genetics of human hypertension. *Journal of Hypertension* 1989;**7**(Suppl. 6), 8.
45. Nakanishi N, Li W, Fukuda H., Takatorige T, Suzuki K, Tatara K. Multiple risk factor clustering and risk of hypertension in Japanese male office workers. *Industrial Health* 2003; 41, 327–331.
46. Jo, I., Ahn, Y., Lee, J., Shin, K. R., Lee, H. K., & Shin, C. Prevalence, awareness, treatment, control and risk factors of hypertension in Korea: The Ansan study. *Journal of Hypertension* 2001;19(9), 1523–1532.
47. Thadhani RI, Johnson RJ, Karumanchi SA. Hypertension during pregnancy: a disorder begging for pathophysiological support. *Hypertension*. 2005;46(6):1250-1251.

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OCULAR DYNAMICS OF BOLUS INGESTION OF PALM WINE AMONG VISUALLY ACTIVE VOLUNTEERS

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Sponsored by P.O. Okonkwo FAS

ABSTRACT

Palm wine is a milky white effervescence fluid or sap obtained from palm tree (Elaeis guineensis) and is widely consumed among the various ethnic nationalities in Nigeria. The effect of bolus ingestion of 600ml, Palm wine, was undertaken so as to determine its ocular dynamics in healthy volunteers. Results showed that bolus ingestion of palm wine produced effects on general body physiology in which the functions of the eye were affected. Results further showed that the NPC decreased from 10.5cm to 8.5cm (19.1% fall), the AA changed from 8.0D to 9.0D or 12.5% rise, while the distant lateral phoria changed from ortho position to two esoposition or 30% increase, and the mean phoria moved from 6-exo to 4-exo or 33.3% decrease. Furthermore, the IOP dropped from an initial value of 17.5mmHg to 13.5mmHg (22.9%) fall at the end of the study. The pupil diameter demonstrated slight miosis which was still within normal range. Results also showed that the VA at near remained unchanged while the distant VA increased by 9.9% and the AC/A ratio decreased from an initial value of 3.75 to a final value of 2.75 or 26.7% fall.

We conclude that a single clear binocular vision is dependent or the perfect coordination of the convergence and accommodative mechanisms and any slight change in the balance as induced by palm wine intake

* Key Words: Biology, *Elaeis guineensis,* Human vision, ocular.

will disrupt the equilibrium effect on visual functions hence the accompanying diplopia, blurred vision or vision impairment.

Introduction

Palm wine is the general name for the natural alcoholic food drink or beverage obtained from spontaneous fermentation of the sap of palm tree (*Elaeis guineensis*) [1,2]. and can be defined as a suspension of micro-organisms in fermenting palm sap[3]. It is a source of income in the rural areas, is milky in appearance when fresh, containing about 11.5% of total sugar including glucose (0.15%), fructose (9.5%) and raffinose (0.05%), the protein content is about 0.1% while the specific gravity is 1.02 [4]. The estimated alcohol content of palm wine varies from 2.3% when fresh to 5.1% when fermented [5], the sugars and the alcoholic constituents of palm wine vary with stages of fermentation[5].

Earlier, other workers described palm wine as alcoholic food beverage consumed in large quantities throughout the tropics and is a whitish coloured liquid produced by natural fermentation of palm sap [6,7] .

Palm wine is consumed in fresh state as a milky white effervescence fluid. The effervescence is as a result of fermentation process going on within the mixture, which occurs as a result of enzymatic activities of comensal micro-organisms resident on the palm sap. These micro-organisms have been attributed to yeast and bacteria[3] while other workers attribute the milky flocculent appearance of palm wine to be due to its high contents of yeast [2].

Palm wine is a refreshing social food beverage, widely distributed, drunk without regulation or prescription, and enjoyed in many parts of the tropics – Africa, Asia, South America, India and Brazil [5,8] .

Palm wine is held in high esteem by the Igbos of South-East- Nigeria who celebrate the food beverage during festivals, meetings, marriage ceremonies and other social activities. For instance, it is presented by the Igbos as mark of respect, appreciation and friendship, it can also be used in peace missions between individuals and groups. It plays an important role as an extracting solvent in ethnomedicine or folk medicine practice, while in some instances, its decoction has been used as remedy for small pox and measles [3].

The nutritional values of *E. guineensis* is very high as it serves as a rich dietary source of vitamins B complex and C, sucrose and glucose[2].
Alcohol causes blurred vision, difficulty focusing and double vision. Short term effects also include dry eye, redness or tunnel vision, which

is the result of decreased sensitivity of peripheral vision i.e inability to register objects in the main field of view[9].

The purpose of this study is to investigate the ocular dynamics or kinematics following bolus or acute ingestion of palm wine, on visually active volunteers, because the food beverage is consumed by the local people without prescription or restriction. This is in continuation of our efforts in investigating the effects of local food spices on the ocular system and adnexa.

Materials and methods

Palm wine was tapped using a special laboratory stoppered glass flask supplied by the Department of Optometry, and was used fresh (within 12hrs) without any additive or preservative. For purposes of consistency, only one source of palm wine was used i.e those obtained from the University town of Uturu in Abia State. There was no prior extraction and the food beverage was drunk whole by the volunteers. Ten healthy male emmetropic adult volunteers whose ages ranged between 30 and 35yrs (mean 32.5±1.5) and body weight 60-65kg were screened and selected from those attending the University Optometry Clinic. This study was approved by the College Ethical Committee and informed verbal consent of the participants were obtained. The protocol for the study was explained to each participant and those not willing to comply were excluded. Subjects on any form of medication, oral or topical or smokers were also disallowed from participating in the study.

Each volunteer was interviewed separately and information on sociodemographic data, medical history obtained. Each volunteer was further subjected to screening, ocular and visual examinations by the Optometrist to ensure ocular health i.e refractive errors or ocular pathologies which might introduce errors in the study. Additionally, each volunteer had a normal near point of convergence (NPC) of 8 – 10cm before the study.

Subjects had initial measurements of the pupil size, visual acuity (VA) at far and near, near point of convergence (NPC), habitual phoria at far and near, the amplitude of accommodation (AA) and tonometry using Schiotz tonometer before commencement of protocol so as to establish their initial values. Furthermore, each volunteer or subject served as his own control. Only male subjects or volunteers were used in order to ensure compliance.

Thereafter 600ml of fresh palm wine was administered to each volunteer as a bolus over a period of 5min after which the above visual parameters and functions were re-assessed every 10min for the next 60min in order to establish the effects of palm wine on them. The

subjects were allowed 20min so that the effects of might be felt on ocular tissues because preliminary studies have shown that the effect of acute ingestion of palm wine had quick on-set of action in the ocular system[9].

Differences between the initial values of the visual parameter or function and those observed after palm wine ingestion were regarded as the effect of palm wine on the particular visual parameter or function.

Measurements

(a) The pupil size (pupil diameter, PD) was measured in millimeters using the pupil distance rulers. Readings were taken at three different positions and the mean calculated.

(b) The near point of convergence (NPC) was measured with the subject fixating at the tip of a pencil positioned initially at 10cm, then adjusted towards the subject until the subject reports diplopia. The distance between the position of doubling and the central plane of the subject was measured with a meter rule in centimeter to give the NPC.

(c) The visual acuity (VA) was measured for near and far respectively using the standard illuminated Snellen optotypes at appropriate measuring distance (0.4m for near and 6m for far, respectively).

(d) The phoria was measured using the phoropter, and for the distant phoria, the subject was asked to fixate at the far Snellen chart placed at 6m. Then a 15 prism diopters base-in was introduced on the right eye while 6 prism diopters base-out was introduced on the left eye. The chart will appear double. The 15 prism diopters base-in was gradually reduced until there was vertical alignment of the chart. The amount of prism diopters obtained was recorded as the phoria value. For near phoria, the procedure was repeated at a distance of 0.4m.

(e) The amplitude of accommodation (AA) was accomplished using the minus lens to the blur method. The amount of lens added to the blur point plus + 2.50 to compensate for the reduced target gave the AA in diopter.

(f) The intraocular pressure (IOP) was measured using the Schiotz tonometer with a weight of 5.5g and the value read from the accompanying table and the value recorded in mmHg.

The inter-pupillary distance ruler was used for the measurement of the pupil diameter while the meter rule was used for the NPC. The Snellen distance chart and the reduced snellen chart were used for the measurement of VA and the habitual phoria. The Schiotz tonometer and 0.4% xylocaine solution were used in the determination of the intraocular pressure (IOP).

Statistical Analysis

Statistical analysis was done using the students "t" test. Results are expressed as mean ± SEM for six experiments and differences were considered significant at $p > 0.01$.

Results

The ocular effects of palm wine manifested 20 min after ingestion reaching maximum in 30-40 min and declined, and by the end of one hr, the ocular effects had virtually disappeared and the visual functions returned to normal.

The pupil diameter (PD) showed a slight decrease in size from a mean initial value of (3.0±0.1) to 2.8±0.2 mm (0.2mm change) or 7.1% constriction, miotic effect in 40 min and by 60 min the miosis has vanished (Fig 1.).

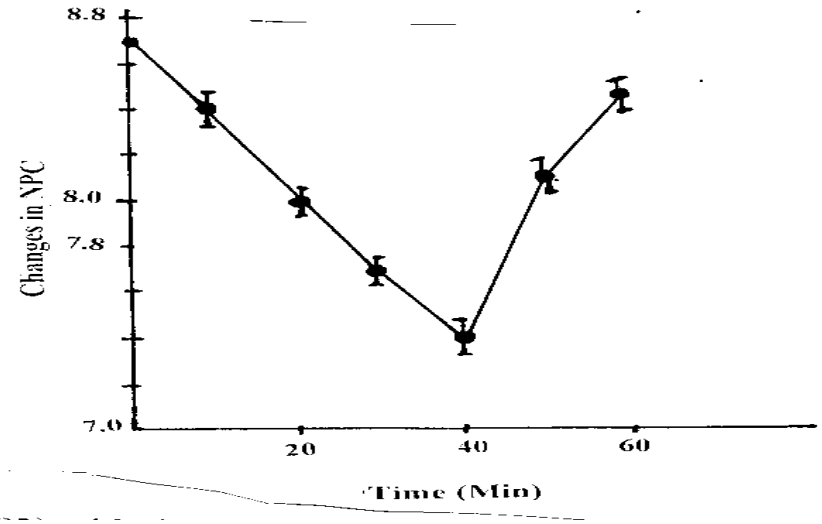

Fig 1: Changes in pupil diameter (PD) with time following bolus ingestion of *E. guineensis* (600 ml).

At the beginning of the study, each volunteer had normal near point of convergence (NPC) of 8 – 10cm or a mean value of (8.4±0.5)cm and following bolus ingestion of the value dropped to a mean value of

(7.4±0.4)cm or 11.9% fall in 20 min before returning to normal in 60 min (Fig. 2).

Fig 2: Variation in NPC with time following bolus ingestion of *E. guineensis* (600 ml).

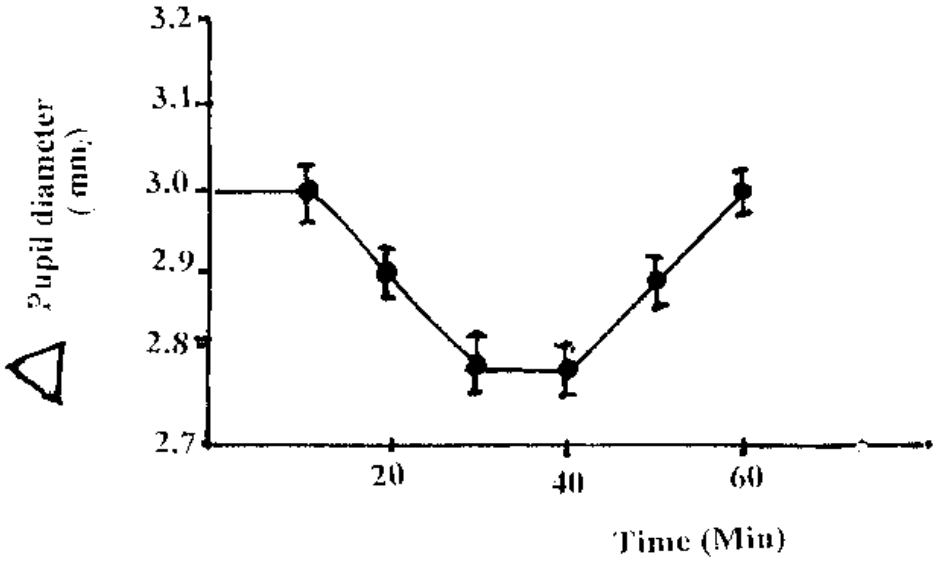

Fig 2: Variation in NPC with time following bolus ingestion of E. guineensis (600 ml).

Palm wine has no effect on the visual acuity (VA) at near as the value remained unchanged in all the subjects throughout the study. However, the VA at far increased from an initial mean value of 1.42 to 1.56 or 9.9% increase within 40 min before returning to normal in 60min. On the other hand, amplitude of accommodation (AA) showed a slight positive shift from an initial mean value of (8.09±0.1)D to (8.71±0.2)D in 40 min or 7.7% increase.

The accommodative convergence/accommodation (AC/A) ratio of the subjects had initial mean value of 3.75 before the study, and following ingestion of *Elaeis guineensis*, the AC/A ratio dropped sharply within 40min to 2.75 (26.7%) fall before returning to normal in 60 min.

Palm wine intake reduced the intraocular pressure (IOP) from the base line value of 15.6±1.5 mmHg (OD) and 17.0±1.6 (OS) to 11.65 ± 1.1 mmHg (OD) and 13.43 ± 1.2 mmHg (OS) or 23% OD and 21% (OS) reduction respectively in time dependent manner, and the fall was persistent and continuous.

Discussion

Previous studies have shown that local food spices which are consumed in their natural and original state without prescription, affect ocular dynamics and kinetics variously. For example, *Solanum melongena* [10], *Xylopia aethiopica*[11] , *Afromomum meleguata*[12], *Cola nitida*[13] , *Garcinia cola*[14], etc, and in the present study, results obtained have shown that palm wine, a local food beverage has demonstrated measurable and detectable effects on the ocular dynamics and adnexa, such as miosis, NPC, AA, AC/A ratio and IOP, producing pupillary constriction (miosis), a reduction in NPC, increasing the VA at far, decreased AC/A ratio, a fall intraocular pressure and a slight increase in AA, all synergizing to impair vision.

The pupil size which demonstrated slight constriction (7.1%) was still within normal range but the slight miosis was sufficient to afftect binocular vision, hence the diplopia. The NPC which dropped by 4.8% was still within normal range of 8 – 10cm and the individual can still read but the miosis and the accompanying diplopia will mar the exercise.

Due to strong association between accommodation and convergence, an individual with normal AA, NPC and lateral phoria both at far and near will maintain clear single binocular vision. It follows that any deviation or defect in AA will lead to blurring of vision and a reduction in NPC will result in diplopia [15] , and this accounts for the irregular visual acts experienced by the volunteers following the ingestion of palm wine.

Palm wine stimulates the parasympathetic system which produces such effects as miosis, increase in AA and NPC which will in turn elicit diplopia. The pinpoint pupil will reduce the amount light reaching the retina and the accompanying blurring of vision is pathognomonic of palm wine effect on the eye.

The VA at near remained unchanged while the distant VA increased by 9.9% and because the near VA did not change, will augument the slight change in NPC and will thus allow near work to be done, which in effect will tend to overcome the slight miosis produced by *E. guineensis*.

The AC/A ratio dropped by 26.7% in 40 min while the IOP maintained a sustained fall, which will be enough to produce palliative effects on glaucomatous patients since palm wine has diuretic effect.

REFERENCES

1. Aaron I. The oil palm in Malaysia, Kuala Lumpor Malaysia, Ministry of Agriculture and Cooperative p.16
2. Eze MO, and Ogan AU Sugar at unfermented sap and the wine, from oil palm *Elaeis guineensis* tree. Plant food for Human Nutrition 1987, 31, 121 – 128.
3. Okafor N. (1978) Microbiology and Biochemistry of oil palm, Adv. Appl. Microb. 24:193 – 200
4. Eluwa MA, Ekere EE, Ekanem TB, Akpantah AO, Igiri AO (2009): Effect of beer and palm wine on the histology of the foetal kidney of Wistar rats. Internet J of Toxiology Vol. 6 No 2.
5. Bassir O. (1962) Microbiology and Biochemistry of oil palm wine Advanced Applied Microbiology 43, 159-161.
6. Uzogara SG, Agu LN, Uzogara EO (1990). A review of traditional fermented food condiments and beverages in Nigeria, Their benefits and possible problems, Ecos, Food Nutrient 24: 267 – 288.
7. Uzochukwu BU, Balogh EE. Ngoddy P.O. (1991) Standard pure culture inoculum at natural and fermented palm: Nig. J. Micro 9:67 – 77
8. Van-Pee W and Swings JG (1971) Chemical and Microbiological studies on Congolese palm wine *Elaeis guineensis*. East Africa Agric J. 36: 311-314.
9. Miyao M, Ishikawa H, Ito M, Teo PC, Furuta M, Ishigaki M (1994): Effect of low dose alcohol on dynamic visual acuity. Percept mot Skills 78:963-967.
10. Igwe S.A, Akunyili DN and Ogbogu C (2003): Effect of *Solanum melongena* (garden egg) on some visual functions of visually active Igbos of Nigeria. J. Ethnopharmacology 86: 135 – 138.
11. Igwe SA, Afonne JC, Ghasi SI (2003): Ocular dynamics of systemic aqeuous extracts of *Xylopia aethiopica* (African guinea pepper) seeds on visually active volunteers. J. Ethnopharmacology 86: 139 – 141.
12. Igwe S.A, Emeruwa IC, Modie JA, (1999): Ocular toxicity of *Afromomum melegueta* (alligator paper) on healthy Igbos of Nigeria. J. Ethnopharmacology 65: 203 – 206.
13. Igwe S.A, Akunyili DN, Ikonne EU (2006): Ocular effects of acute ingestion of *Cola nitida* (Linn) on healthy adult volunteers. S. African Optometry 66: 19 – 23.
14. Igwe SA, Akunyili DN, Igwe PC, Ikonne EU (2006): Ocular dynamics of *Garcinia cola* (Heckel) on healthy volunteers following bolus ingestion S. African Optometry 66:24-29
15. Cooper SO. and Duckman F.E (1978) Problems concerning convergence, Trans Am Ophthal 68: 10-16.

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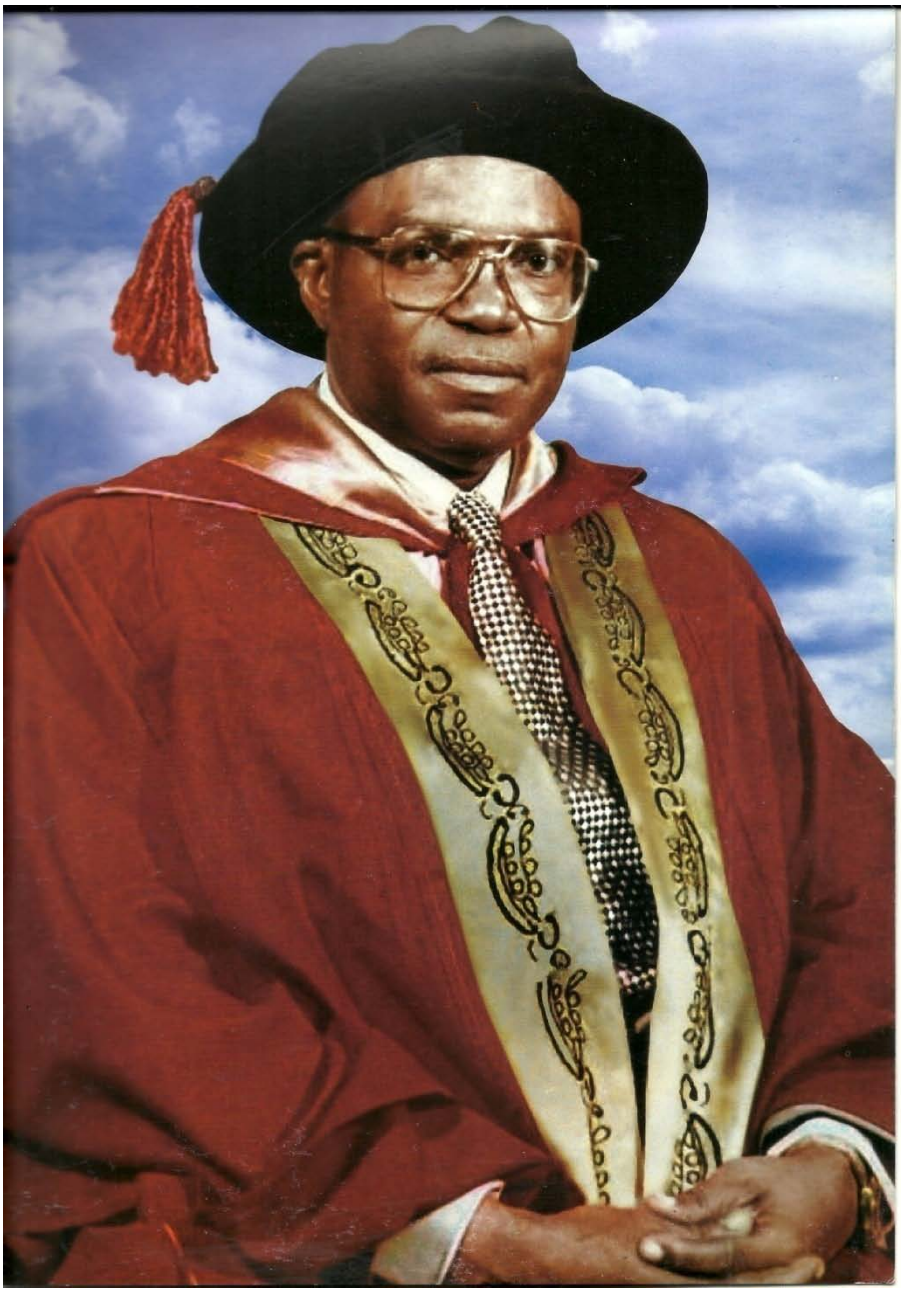
OBITUARY

Emeritus Professor Chukwuedu Nwokolo. 1921-2014. FAS, FRCP, FWACP, FACP, DSc (Hon).NNOM, OFR.

Emeritus Professor Chuwuedu Nwokolo has passed to the great beyond. He started his illustrious career at the Government College Umuahia (1934-1939). He proceeded to Yaba Higher College to study Medicine (1940-1946). He was one of the few selected by Sir Samuel Manuwa to undergo housemanship at the then new University College Hospital Ibadan (UCH). He served under Professor Alexander Brown before proceeding to the United Kingdom to obtain the LRCP in record time and shortly after passed the MRCP examination, the second Nigerian to pass that examination at the time. He was awarded FRCP (Edinburgh) in 1961) He served briefly in the then Eastern Nigeria Medical Services before settling at UCH as Consultant Physician. In 1962, he spent a year on a Rockefeller Fellowship at Mayo clinic in Minnesota USA. Returning to UCH, he set up the Gastroenterology unit. During the Civil War (1967-1970) he was the leader of the Medical team for Refugees. At the end of the war in1971, he and his colleagues from Ibadan set up the Medical School in Enugu. As Professor and Dean, he took delight in workshops on the Art of Teaching for Consultants, using lecturers from English and Education departments. He always gave the lecture on "Teaching by the Bedside". As Chairman of the Nigerian Institute for Medical Research, he steered the institution to award grants to young biomedical scientists. He was at various times, the Chairman of the Board Of University of Calabar Teaching Hospital and Chairman of Council and Pro-chancellor Ahmadu Bello University, Zaria.

Although his contribution in teaching, administration and patient care were outstanding, it is his scientific investigative skill that catapults him above other physicians of his time. Quite early in his career, he described the prevalence of Haemoglobin C on contiguous shores of the River Niger and the epidemiology of *Paragonimus tuberlateralis* in Nigeria and the Cameroons. He was the first to describe Endomyocardial Fibrosis and propose a mechanism for Juvenile Pancreatitis Syndrome. He saw that aflatoxicosis was one of the causative factors in hepato-cellular carcinoma. He saw five patients with onchocerciasis and traced their infection to flies breeding in rivers cascading from the Udi hills. His textbooks and chapters in books are phenomenal. His numerous findings were published in *Nature*, *Lancet* and other high impact journals. In his later years, he focussed on sickle cell disease. He had devised a battery- operated genotype machine, ideal for screening in rural communities, with hope of eliminating the disease with voluntary counselling. It is not a wonder that he was elected Fellow of the Nigeria Academy of Science (FAS), awarded the medal of the National Order of Merit(NNOM) and National Honour(OFR). He received DSc (Hons) from Universities of Ibadan and Maidugri.

Nwokolo had developed a friendship with Adamu Chiroma, who was an archaeologist digging with Shaw at the Nri-Igboukwu sites near Awka, in the early 1960s. The bronze



artefacts were dated to 700 AD. Despite his Anglophile habits (black suit and tie at all times), he came to admit that Africans were using sophisticated tools before the Normans brought civilisation to feudal England. His friendship with the super perm secretary brought the two families (North and South) together.

Tributes have poured in from all over the world from admirers, relatives and colleagues. Emeritus Professors Ogunlesi FAS, Anmalu FAS , and Pounder among others sent glowing tributes. Emeritus Professor Nwokolo is survived by his wife Njideka and seven children. His eldest son is a Professor of Gastroentology.