

UNIVERSITY OF PORTHARCOURT

***“TAPPING THE UNTAPPED WEALTH IN OUR
BACKYARD: PATHWAY TO LOCAL CONTENT
DEVELOPMENT”***

An Inaugural Lecture

By

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DEDICATION

This lecture is dedicated to the memory of my late Father and Mother Mr Joel Amah and Orianu Joel through whose sacrifice and dedication to see me succeed, I was motivated to seek significance and purpose for living.

ACKNOWLEDGEMENT

I am deeply grateful to God for His Divine enablement and favour which has been the cornerstone of my success.

I am extremely thankful to God for the love and motivation I receive from my wife, Mrs Felicia Ogbonna, who, no doubt is the driving force behind my success. The desire to leave a better heritage for my children Onyinyechi, Chukwuemeka, Ngozi and Chinermere Ogbonna is the tonic that keeps me going.

I sincerely express my immense gratitude to Professor J.A Ajienka who inspired me to write. My Ph.D supervisor and teacher, Dr. S.E. Ovuru brought out the best in me, I appreciate him. I also wish to specially thank Professors E.N. Wami, I. L. Nwaogazie, M.O Onyekonwu, O. Akaranta and Mrs E.O. Nwachukwu, G.C. Ofunne for being part of the success story of my life.

Mr. E. Eguzoikpe, M. Egbete, B. Nwulu and a host of others from my clan that space will not allow me to mention, I cannot thank you enough for your love and contributions towards my success. Pastor Samuel James, you have been my spiritual anchor, I appreciate you.

I am equally grateful to my students and POCEMA Ltd staff who worked on different projects with me. For many not mentioned, I say a big **“thank you”** for being part of the success story of my life.

Most of the experience acquired would not have been possible but for Halliburton Energy Services who offered me rewarding employment for enhanced professionalism on Global Best Practices in fluid design and applications.

MY JOURNEY TO PROFESSORIAL RANK

In my childhood days, because of my love for books, my friends used to call me professor. Anyway, I never knew who a professor was. However, like most young men, when I came in contact with Professors in my undergraduate days and evaluated their financial status, there was no motivation to become one. I thought the oil Industry was the ultimate.

However, the turning point came when I met with professor Ajiienka in 2006 to introduce the NREP Certification programme at IPS. For the first time in my life, I saw a professor who was happy with himself, his job and his environment. I saw a professor well dressed, wearing very good shirt and shoes. Most lecturers I knew before now were always looking either frustrated, not happy with their profession and always complaining.

As I started interacting with him, he told me the story of how he left Shell to the University and told me that there was a place for me if I wanted to come. I got convinced that the University was a good place to make a career. In 2008, I decided to resign to join the University, however, I didn't ask what the salary was. I thought at worst, I will be given the salary I was paid in my last employment. Infact, I was one of the favoured staff in my previous employment, the company in addition to other incentives, nominated me to be among those who share in the profits at the end of the year and also granted me a percentage of the shares as an incentive to stay with them. However, the day I resigned, I lost all these benefits. Behold, when I opened the employment letter I thought the figure I saw was per month, but to my greatest dismay, it was per annum. How do I cope with my bills and dependants became a big

concern. What do I tell my family and friends? Thank God my wife supported my resignation, but for how long can she cope with this salary crisis? I knew I was in for trouble if nothing was done to remedy the new financial reality.

But when I looked at Professors Ajienka, Onyekonwu, Dosumu, I became confused and at the same time comforted. They were happy and not complaining. The biggest question in my heart was, could this be the total money they take home every month and yet they are comfortable and not complaining? It was obvious to me that the answer was “**NO**”. I had to take a closer look at their profile and discovered that among others the title “**PROFESSOR**” was attached to their names. I approached Professor Ajienka to find out what I needed to do to make progress and was told “**publish or perish**”.

Indeed, the heat was on, the money I got from my previous employer was depleting fast and financial crisis was looming, it was obvious that if I did not take a drastic step to **publish, I will perish**. I could no longer hold my peace, **like Esther of old I decided, if I perish, I perish**, it was time, God helping me to do all within my strength to publish.

I therefore hired a secretary, three research assistants and bought necessary equipment and set up a research lab and got consumed with research and publishing. I remembered flying to Abuja several times, hired hotel and did nothing but to write. By God’s grace within three years, I was able to publish over 60 papers in impact factor journals and wrote two books.

Thank God the efforts resulted to the privilege of standing before you today to declare what I am Professing. I am convinced that with passion and diligence, coupled with the grace of God, all things are possible.

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1.0 INTRODUCTION

“It is the glory of God to conceal a thing; but the honour of kings is to search out the matter” (Proverbs 25:2)

Man searched out Petroleum some million years ago and it plays vital roles in our way of life. How is this petroleum formed in the earth crust? How do we know where it exists and how can we bring it to the surface from the Subsurface? How is it processed into useful materials? These have been the gateway to many technological advancement.

Drilling, well completion, production enhancement and achieving optimum recovery require the use of several chemicals known as **oilfield chemicals**. Most of the chemicals currently being used in Nigeria for petroleum exploitation are imported, yet there are numerous natural resources in our backyard that can be processed and used for these operations (Ajienka et al., 2003, Joel, et al, 2009).

The Nigerian Content Act came into effect on 22nd of April, 2010 following the signing of the Bill into law by His Excellency Dr. Goodluck Ebele Jonathan establishing the Nigerian Content Development and Monitoring Board (NCDMB)(NCD ACT, 2010).

The board has commenced operations to realise the aspiration of the Federal Government of Nigeria to increase indigenous participation in the oil and gas industry, build local capacity, create linkages to other sectors of the national economy and boost industry contributions to the growth of our National Gross Domestic Product

Nigerian content is the quantum of composite value added or created in the Nigerian economy through the utilization of Nigerian human and material resources for the provision of

goods and services to the petroleum industry within acceptable quality, health, safety and environmental standards in order to stimulate the development of indigenous capability. Despite huge investments made by the Federal Government of Nigeria in the oil and gas sector of the economy, an average of \$10 billion USD per annum, its contribution to GDP growth had been minimal (Okolo, 2008, Afolabi, 2001). The drive of the Nigerian Content vision is to transform the oil and gas industry into the economic engine for job creation and national growth by developing in-country capacity and indigenous capabilities. One of the ways of creating jobs and actualizing the local content initiative is to ensure that some of the chemicals needed in the oil industry are produced in the country. Harnessing the local raw materials for petroleum exploitation is the main thrust of this inaugural lecture titled,

“Tapping the Untapped Wealth in our Backyard: Pathway to Local Content Development”.

1.1 THE ORIGIN OF PETROLEUM

The word “petroleum” is derived from the Latin words for “rock” (*Petra*) and “oil” (*oleum*), indicating that its origins lie within the rocks that make up the earth’s crust. The material of which a petroleum reservoir rock may be composed can range from very loose and unconsolidated sand to a very hard and dense sandstone, limestone, or dolomite. The grains may be bonded together with a number of materials, the most common of which are silica, calcite, or clay. Knowledge of the physical properties of the rock and the existing interaction between the hydrocarbon system and the formation is essential in understanding and evaluating the performance of a given

reservoir. Petroleum hydrocarbons are complex mixtures and exist in a range of physical forms — gas mixtures, oils ranging from thin to viscous, semi-solids and solids.

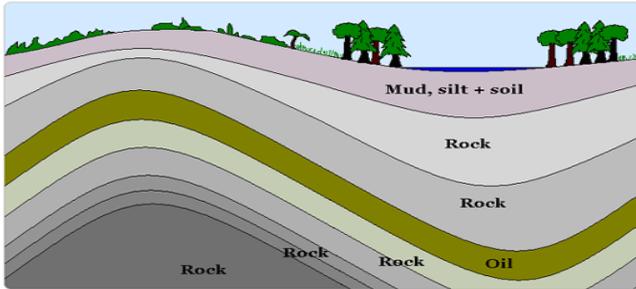


Fig-1.1: Formation of oil and Gas reservoir

Gases may be found alone or mixed with the oils. The simplest hydrocarbon is methane gas (CH_4). The more complex hydrocarbons have intricate structures, consisting of multiple carbon-hydrogen *rings* with carbon-hydrogen side chains. There are often traces of sulfur, nitrogen and other elements in the structure of the heavier hydrocarbons (Wami, 2006).

Reservoir hydrocarbons were created millions of years ago by the decomposition of plants and animals that died and drifted towards the bottom of ancient lakes, rivers and oceans. Much of these organic matters was decomposed in air (oxidized) and lost to the atmosphere, but some was buried before it decayed or was deposited in stagnant, oxygen-free water preventing oxidation. Over the ages, sand, mud and other sediments drifted down and compacted into rock. As these layers piled up, the organic matter was preserved in the sedimentary rocks. Eventually, the weight of the accumulated layers created pressure and heat that changed the organic

material into gas and oil. Sedimentary ‘source’ rocks include coal, shale and some limestone, which have a dark colour that comes from their rich organic content. Many sedimentary basins are gas-prone and produce primarily natural gas (CH₄).

At temperatures above 150°C and at lower depth, thermogenic gas is generated. This gas which is dry or wet gas can be trapped in underground reservoirs, often beneath an impermeable “cap” rock that prevents the gas from seeping upwards. In some gas reservoirs, high temperatures justify the heavier liquid hydrocarbons. When the gas is produced and the temperature drops, these hydrocarbons re-liquefy to form condensate. This fluid is almost pure gasoline and is also called natural gasoline. When recovered with other normal gaseous hydrocarbons – butane, propane and ethane, the condensate is called natural gas liquids (NGL). Hydrocarbon systems are classified on the basis of composition, gravity and gas-oil ratio. Crudes with H₂S content of less than 70ppm are considered sweet.

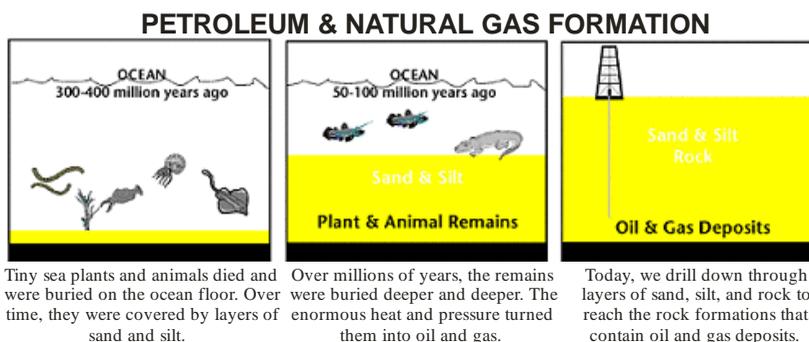


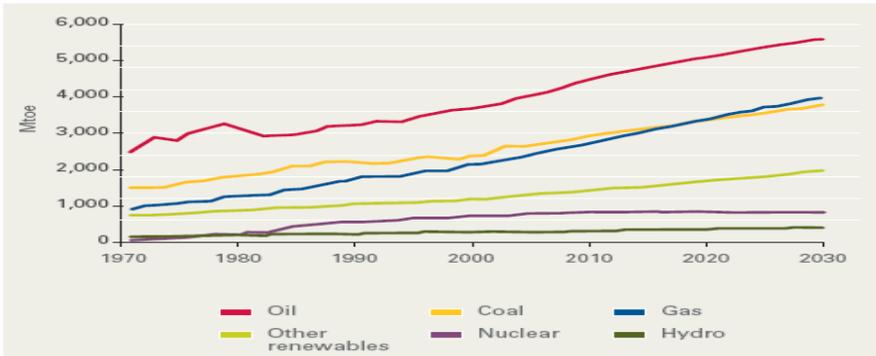
Fig 1.2: petroleum and natural gas formation

1.2 THE SEARCH IS ON

As hydrocarbons are being depleted from some formations, the search is on for greater reserves in difficult regions. Some wells are now drilled in more hostile downhole conditions, which include high temperature and high pressure in deep water terrain.



Figure 1.3: Offshore Development – New Frontier



Source: IEA, 2005

Fig 1.4: Global Energy Demand Curve

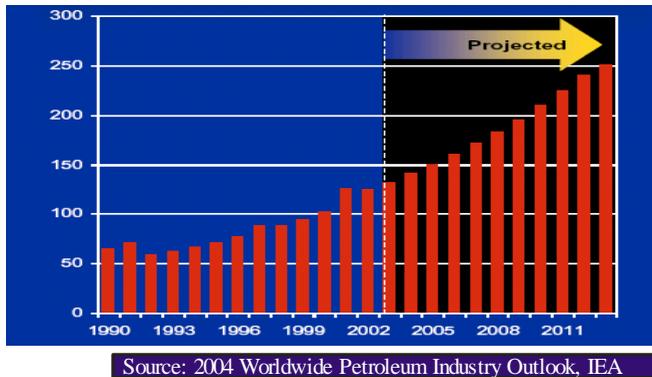


Fig 1.5: Petroleum Industry Capital Spending

1.3 EXPLORATION OPERATIONS

During oil exploration, a geophysicist will design and conduct a seismic survey. In seismic surveying, geophysicists use the same basic physical properties as the earthquake seismologists. Relatively low energy waves are mechanically generated and directed into the earth. Some of the energy is reflected back to the surface from the different layers of rock below the surface. The returning waves are detected with sensitive measuring devices that accurately record the strength of the wave and the time it has taken to travel through the various layers in the earth's crust and back to the surface. These recordings are then taken and, after various adjustments, done mostly by computers, transformed into visual images that give a picture of what the sub-surface of the earth is like beneath the seismic survey area. Although geophysicists cannot see directly beneath the ground, they can use seismic surveying to get a picture of the structure

and nature of the rock layers indirectly and predict where there is gas or oil accumulation.

1.4 DRILLING OPERATIONS

After the seismic survey, drilling activities commence. This is the application of science and technology to make a hole through the earth surface by using drilling bit in order to get to the pay zone or reservoir. Drilling is the only means to ascertain the presence of oil in the formation and produce reservoir fluid. It also provides a means of communicating with the reservoir or subsurface.

To recover oil and gas from the reservoirs, hole is drilled many hundreds of meters into the rock formation to capture them and bring them to the surface. Drilling for oil and gas, held many meters in underground reservoirs at enormous high pressure and temperature, is risky and demands carefulness. Pressure variations are closely monitored during drilling to prevent accident which could occur when unexpected abnormally high pressures are encountered in the subsurface. To control pressure, in the well during drilling and prevent blowouts, a mixture of clay, weighting materials, and chemicals with either water, oil or a mixture of oil and water, called drilling mud, is used. Pressure exerted by the weight of the drilling mud is maintained slightly higher than the hydrostatic pressure of the overlying water; this creates an overbalance, thus preventing fluids from the reservoir rock (formation fluids) entering the well prematurely.

If the pressure on the fluid in the subsurface rock is greater than the pressure on the drilling mud, underbalanced occurs, and the formation fluids (water, gas or oil) will flow out of the rock into the well. This often causes a phenomenon

called kick. If the kick is not controlled, blowout will occur. Blowout is the uncontrolled flow of formation fluids from the well to the surface; it is often violent, leading to explosion. Unless the kick is detected and corrected on time, it will usually lead to spindle top blow out.



Figure 1.6: Blow out

Rotary drilling rigs are used for almost all drilling done today. The hole is drilled by rotating a bit to which a downward force is applied. Generally, rotating the entire drill string, using a rotary table at the surface turns the bit and downward force is applied to the bit by using sections of heavy thick-walled pipe, called drill collars, in the drill string above the bit. The cuttings are separated from the drilling fluid at the surface. The main design features of marine rigs are portability and maximum water depth of operation.

1.5 DRILLING FLUID TECHNOLOGY

Many types of drilling fluids are used on a day to day basis. Some wells require that different types be used at different parts

in the hole, or that some types be used in combination with others. The various types of fluid generally fall into a few broad categories: (www.en.wikipedia.org/wiki/drilling_fluid, Jan 8, 2010).

The Drilling Engineer is concerned with the selection and maintenance of the best drilling fluid for the job. The drilling fluid is related either directly or indirectly to most drilling problems. If the drilling fluid does not perform adequately the functions listed below, it could become necessary to abandon the well. Also, the additives required to maintain the drilling fluid in good condition can be quite expensive. Drilling fluid cost often exceeds \$1 million on a single deep well in some areas. A drilling fluid specialist called a Mud Engineer frequently is kept on duty at all times to maintain the drilling fluid in good condition at the lowest possible cost (Baroid Training Manual, 1997).

1.6 MAIN FUNCTIONS OF DRILLING MUD (Baroid, 1997)

- a) Transport drilled cuttings and carvings to the surface
- b) Suspend drilled cuttings and caving-in the annulus when circulation is stopped
- c) Control subsurface pressure
- d) Cool and lubricate the bit and drill string
- e) Support the walls of the wellbore
- f) Help suspend the weight of the drill string and casing
- g) Transmit hydraulic energy
- h) Provide a medium for running wire-line logs
- i) Minimize formation damage
- j) Protect the drill string and casing from corrosion

1.7 TYPES OF DRILLING FLUID

a) Water-Based Mud (WBM) – Water-based drilling mud most commonly consists of bentonite clay (gel) with additives such as barium sulfate (barite), calcium carbonate (chalk) or hematite. Various thickeners are used to influence the viscosity of the fluid, e.g. Xanthan gum, guar gum, glycol, carboxymethylcellulose, polyanionic cellulose (PAC) or starch.

b) Oil-Based Mud (OBM): This can be a mud where the base fluid is a petroleum product such as diesel fuel. Oil-based muds are used for many reasons, some being increased lubricity, enhanced shale inhibition, and greater cleaning abilities with less viscosity. Oil-based muds also withstand greater heat without breaking down. The use of oil-based muds has special considerations. These include cost and environmental considerations.

c) Synthetic-Based Fluid (SBM). This is a mud where the base fluid is synthetic oil. This is most often used on offshore rigs because it has the properties of an oil-based fluid. This is important when men work with the fluid in an enclosed space such as an offshore drilling rig((ASME Shale Shaker Committee 2005, Gray et al,1980)

1.8 CEMENTING OPERATIONS

Cementing operation is an important operation in completion of oil and gas well. It involves the process of placing cement slurry between the casing and annulus in a well. The cement slurry placed at the total depth is subject to progressively increasing temperature from the time it is mixed on the surface and pumped into the well until the time the cement cures and return to static

condition. Cementing operation could be primary, remedial or plug (Halliburton cementing, 2003).

1.9 PRIMARY CEMENTING

Primary cementing is the cementing operation performed immediately after the casing has been run down hole. This is accomplished by pumping cement slurry down the entire length of casing, out the bottom joint, and up into the annular space. The cement is then allowed to set before drilling is resumed or well is completed (Haut *et al.*, 1980). The main objectives of primary cementing are to seal the annulus and to obtain zonal isolation. The latter is accomplished if cement in the annulus prevents the flow of formation fluids (Suman *et al.*, 1977). For zonal isolation to be achieved all drill cuttings and drilling fluid must be removed from the annulus and replaced by cement slurry. Cement slurry must then undergo hydration, changing from the liquid to the solid phase and developing properties to prevent flow of formation fluids and to support the casing. The cement sheath should also be able to withstand different operations such as stimulation, perforation, production, and intervention during the life of the well (Smith, 1987). Cement slurry used in the oil industry consists mainly of cement, additives, and water. The various types of cements and additives depend on the end application. The primary cementing process bonds the pipe to the wall of the hole and prevents communication of fluids in the well bore from one zone to another. The three main functions of the cement are isolation, protection, and support.

1.10 CASING PROGRAM

Holes are usually drilled in sections and cased. The four basic casings that are used as the well gets deeper are (Haut *et al.*, 1980, Halliburton Cementing, 2003).

- Conductor Casing
- Surface Casing
- Intermediate Casing
- Production Casing
- Production Liners

After each casing is placed, it must be cemented into place using cement slurry (a mixture of cement, water and additives). The duration of each cement job is put into consideration, so that the wait on cement time (time to wait for cement to set, before drilling commences) is taken note of, so that proper drilling planning is carried out. The cementing materials like the guide shoe, the float collars, scratchers, centralizers and wiper plugs are taken into consideration. Preflushes and spacer fluids are also looked into for proper isolation of drilling fluid from cement (Bowman *et al.*, 1988).

Remedial cementing describes cementing operations which are performed to remedy an undesirable condition in a well.

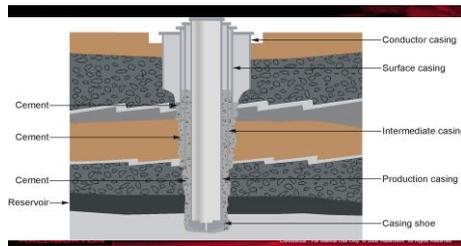


Fig.1-8: Casing types in cementing operations

1.11 STIMULATION OPERATIONS

Oil well stimulation is the general term used to describe a variety of operations performed on a well to improve its productivity. After an oil or gas well has been drilled, the wellbore pressure reduces below the oil or gas bearing formation pressure. The higher formation pressure forces the oil or gas to the wellbore, where it then goes to the surface. Sometimes, the flow of oil or gas (well production or productivity) might be too small. If the reservoir does contain enough oil or gas to make it commercially viable, then the problem of the low productivity may be formation damage near the wellbore caused during the drilling and well completion process or may be the formation has a low permeability (ability to allow flow). In either case, the flow of the oil or gas needs to be stimulated. Natural production tendencies for wells are for the oil production rates (and reservoir pressure) to be at its highest at initial production, and fall-off considerably as the well is produced. Typically, one finds oil rates declining as water production increases, driving up operations costs while revenue shrinks (HAL WORLD, 2002). This scenario continues until the well fails and/or becomes uneconomic to operate or repair. Stimulation operations can be focused solely on the wellbore or on the reservoir; it can be conducted on old wells and new wells alike; and it can be designed for remedial purposes or for enhanced production.

1.12 MAIN TYPES OF STIMULATION OPERATIONS

Well stimulation techniques are applied on a regular basis to enhance productivity and maximize recovery in oil and gas wells. Its main two types of operations are matrix acidization and hydraulic fracturing (Nevito, 2006). Among these

techniques, matrix acidizing is probably the most widely performed job because of its relative low cost, compared to hydraulic fracturing. The acidizing process leads to increased economic reserves, improving the ultimate recovery in both sandstone and carbonate reservoirs.

1.13 MATRIX ACIDIZING

Matrix acidizing consists of injecting an acid solution into the formation, at a pressure below the fracture pressure to dissolve some of the minerals present in the rock with the primary objective of removing damage near the wellbore, hence restoring the natural permeability and greatly improving well productivity (Aboud *et al*, 2007). Most acidizing treatments(Gdanski,2009) can be categorized into: (a) wellbore cleanout, (b) removal of damage from a sandstone formation by matrix acidizing, (c) improvement of production from carbonate formations by matrix acidizing, and (d) improvement of production from carbonate formations by fracture acidizing. A fundamental requirement for successful wellbore cleanout is that the material be acid soluble. If a well is plugged with an acid soluble scale such as carbonate scale, then acid can be very effective at removing the scale and restoring production. Acid will not dissolve paraffin deposits, which are not acid soluble. Acid can be very effective at removing iron scales such as iron sulfide. With proper fluid selection, design, and execution, matrix acidizing can be applied successfully to stimulate high-temperature oil & gas wells and geothermal wells. These types of wells have some common features, but they also have significant differences (e.g., completions, mineralogy, formation fluids and formation flow) that influence stimulation designs and fluid choices.

1.14 HYDRAULIC FRACTURING

Hydraulic fracturing is a technique used to create fractures that extend from the well bore into rock or coal formations. These fractures allow the oil or gas to flow more easily from the rock pores, where the oil or gas is trapped, to the production well (Mitchell,2001). Hydraulic fracturing involves literally breaking or fracturing a portion of the surrounding strata, by injecting a specialized fluid into the wellbore directed at the face of the geologic formation at pressures sufficient to initiate and extend a fracture in the formation (i.e. above the minimum in situ rock stress,Economides,2000, Gidley, *et al*,1989, Yew,1997).

Thus, the purpose of the fracturing fluid generally is two-fold: (1) to create or extend an existing fracture through high-pressure introduction into the geologic formation of interest; and (2) to simultaneously deliver the proppant into the fracture void space so that the proppant can create a permanent channel through which the hydrocarbon can flow to the wellbore(Banks,1996).

2.0 THE LABORATORY AS A FULCRUM IN OIL FIELD CHEMICAL DESIGN AND APPLICATIONS.

The petroleum industry relies on lab results to make critical decisions in;

- Exploration
- Drilling
- Cementing
- Production, etc



2.1 DRILLING FLUID LABORATORY TESTING

Regular monitoring and interpretation of the changes in the drilling fluid are necessary to identify problems in drilling operations. Drilling fluid properties determined from routine field testing can be used as qualitative and quantitative guides for controlling drilling fluid performance. The API has recommended standard methods of conducting field and laboratory tests for drilling fluids and detailed procedures may be found in the API publication, "Recommended Practice: Standard Procedure for Field Testing Water-Based (Oil-Based) Drilling Fluids," API RP 13B-1, 13B-2 and supplements (13I for Laboratory Testing Drilling Fluids. The following tests are conducted among others for drilling and cementing.

- a) Mud weight
- b) Rheology
- c) Fluid loss
- d) Free fluid
- e) Thickening Time
- f) Compressive strength
- g) Compatibility tests

2.1.1 MUD WEIGHT (DENSITY)

Formation pressures are contained by the hydrostatic pressure of the drilling fluid. Hydrostatic pressure is a function of depth and mud density. Mud weight is determined with a mud balance which consists of a cup with lid mounted at the end of a graduated arm (fig-2.1).



Fig-2.1: Pressurized mud balance

2.1.2 RHEOLOGY MEASUREMENT

Mud rheological properties are obtained from a direct-reading using the viscometer (fig-2.3). It provides readings that are easily converted to the rheological parameter's plastic viscosity and yield point.



Fig-2.3: Fann Viscometer

2.1.3 FLUID LOSS DETERMINATION

The filtration or wall-building property of a mud is determined by means of a filter press (fig-2.4). The test consists of determining the rate at which fluid is forced through the filter paper. The test is run under specified conditions of time, temperature and pressure.

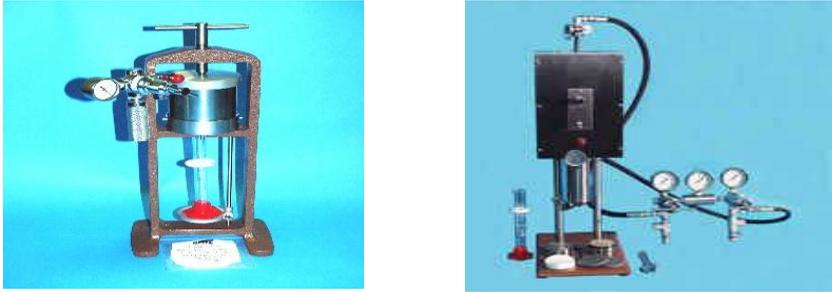


Fig-2.4: Low and HPHT Filtration cell

2.1.4 RETORT

The Retort (fig-2.5) provides a method for measuring the percentage (%) of oil and water, and for estimating both suspended and dissolved solids contained in a sample of water-based or oil-based muds and cuttings.



Fig-2.5: Retort

2.2 CEMENTING LAB TESTING

Cementing of oil well is a capital intensive project; hence, the importance of a good design cannot be overemphasized. A poor design can be very costly in the life of any well. Therefore, before cement slurry is pumped into a well a variety of laboratory tests are conducted to assist in predicting the performance and behavior of the slurry as it is pumped and after its placement (Joel, 2010). Designing and testing for a cost-effective recipe at simulated down-hole conditions for different wells pose a big challenge for a beginner. The initial effort for every test is to conduct pilot test with lab samples of materials to be used for the planed job. However, before actual job execution, confirmatory tests are performed with representative samples of cement, additives and mix water as supplied from the rig. Before cement slurry can be designed and tested properly, the temperature it will be exposed to must be determined. Tests are conducted as per recommended and Best Practices, in line with American Petroleum Institute (API) specification (API, 1990, 1997, 2000)

2.2.1 BLENDING OF CEMENT SLURRY

In order to obtain a homogeneous mixture, the additives, water and cement must be blended at a specified speed before testing. This is used using the constant speed mixer.



Fig 2.8: Constant Speed Mixer

2.2.2 ELECTRONIC BALANCES

It precisely measures the weight of cement and additives used to perform a cement test.



Fig 2.9 Electronic Balance

2.2.3 FREE FLUID AND SEDIMENTATION

The separation of water from slurry, once it has been placed, can lead to channel formation and gas migration problems - particularly in deviated wells. The free-water test is designed to simulate this using a 250 ml graduated cylinder in which slurry is left to stand for two hours under simulated wellbore conditions. The volume of water collected after this period is expressed as a percentage by volume. For deviated wellbores, a more critical test is to incline the column at 45 degrees.

2.2.4 THICKENING TIME

The High Temperature/High Pressure Consistometer (HPHT) is used to measure cement slurry viscosity or consistency under simulated well pressure and temperature conditions. Its primary function is to determine the maximum available pumping time of a cement slurry before the slurry reaches an unpumpable consistency prior to setting. While designed for cement slurries, the effects of pressure, time, and temperature can also be observed for other fluids, emulsions, dispersions or slurries under static or dynamic conditions.



Fig 2.11a: HPHT Consistometer



Fig 2.11b: Slurry Cup.

2.2.5 ATMOSPHERIC CONSISTOMETER

The atmospheric Consistometer is used extensively in oil well cement testing applications as pre-conditioning cement slurry prior to other tests, e.g., fluid loss, free water, or rheological testing. The slurry sample should be conditioned for 20 minutes at specified test temperature not greater than 190 deg F in an atmospheric consistometer at atmospheric pressure before measurements are taken.



Fig 2.12: Atmospheric Consistometer

2.2.6 FLUID LOSS

This instrument measures the fluid loss of fluids such as cement slurry and drilling muds. After conditioning the slurry at bottom hole circulating temperature (BHCT) for at least 20 minutes, the slurry is placed in the fluid loss cell and 1000 psi differential pressure is applied across the 325-mesh screen (Fig 2.13)

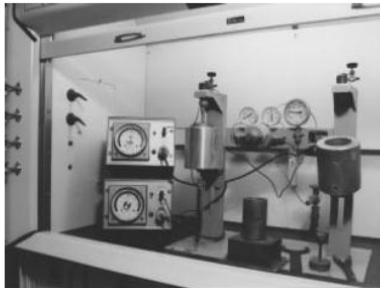


Fig 2.13: Static Fluid Loss Cell

2.2.7 COMPRESSIVE STRENGTH

The pressure it takes to crush the set cement is measured in this test. This test indicates how the cement sheath will withstand the differential pressures in the well. The slurry samples are cured at

bottom-hole temperatures and pressures and the results reported in psi. The compressive strength can be measured using either the autoclave system or the ultrasonic cement analyzer (UCA) as shown in fig 2.14a and fig2.14b respectively.



Fig 2.14a: Autoclave system Fig2.14b Ultra Sonic Cement analyzer

2.3 ESTABLISHMENT OF POCEMA LTD AND ITS CAPABILITIES

Pollution Control and Environmental Management (POCEMA) LTD provides integrated Services to the Industry, Commercial enterprise, and public agencies in Nigeria. Guided by Worldwide Standards and Best Practices, we devote our Resources and Skills to provide dependable Quality Services in Environmental Management, laboratory Services and Engineering applications.



Fig 2.15: POCEMA LTD PORT HARCOURT OFFICE

2.3.1 RESEARCH LAB AND LOCAL CONTENT DEVELOPMENT

In order to enhance my research capabilities in the field of drilling fluid systems (cementing, mud and production enhancement) and environment, a research lab with associated equipment as applicable and research team for development of local content capacity was established.



TEAM OF LAB ANALYSTS DURING ANALYTICAL TESTING

3.0 ADDITIVES: THE BLOOD IN DRILLING AND COMPLETION FLUIDS FORMULATION

Drilling, cementing and production enhancement are among the major operations in petroleum exploitation and production. These operations require the use of chemicals to achieve the goals. The various chemicals/additives and their functions are

shown in Tables 3.1 – 3.12(Baroid, 1997).Almost all the additives are imported presently in the country.

Table 3.1: Weighting Materials

S/N	Description	Primary function
1	Barite (SG 4.2) Barium Sulfate	For increasing density
2	Hematite (SG 5.0) Iron Oxide	For increasing density
3	Calcium Carbonate	Acid soluble weighting and bridging agent for increasing density

Table 3.2: Viscosifier

S/N	Description	Primary function
1	Bentonite	Viscosity and filtration control
2	Attapulgit	Viscosity in salt water muds
3	Guar gum	Viscosity and fluid – loss control in low solids muds
4	Hydroxyl ethyl Cellulose	Viscosity in brine work-over/completion fluid and water-base muds.

Table 3.3: Dispersants/Deflocculants

S/N	Description	Primary function
1	Lignite	Thinner, emulsifier and fluid-loss control
2	Chrome Lignite	High temperature thinner, emulsifier and fluid-loss

Table 3.4: Fluid-Loss Control Agents

S/N	Description	Primary function
1	Preserved polysaccharide	Non-fermenting starch for fluid-loss control, viscosity and shale stabilization in salt water and fresh water muds.
2	Sodium Carboxymethyl Cellulose (CMC)	Fluid-loss control and Viscosifier
3	Polyanionic Cellulose (PAC) Premium grade	Fluid – loss control and Viscosifier
4	Derived starch	Fluid –loss control and Viscosifier for reservoir drill-in fluid systems

Table 3.5: Shale Stabilizers

S/N	Description	Primary function
1	Surfactant/polymer blend	Proprietary shale and gumbo control additives
2	Sulfonated asphalt	Shale stabilizer, fluid-loss control and lubricant
3	Polyglycol, water-base system	Shale stabilizer, fluid-loss control and lubricant
4	Blown asphalt	Oil dispersible shale stabilizer and lubricants

Table 3.6: Lubricants, Emulsifiers and Surfactants

S/N	Description	Primary function
1	Low-toxicity lubricant	Low-toxicity lubricant for water base muds
2	Drilling detergent	Surface tension reducer to prevent baleing, drop sand and emulsify oil
3	Low-toxicity stuck pipe soaking fluid	Environmentally acceptable stick pipe liberator – spotting fluids
4	Liquid defoamer	All purpose defoamer for water-base mud

Table 3.7: Corrosion Inhibitors

S/N	Description	Primary function
1	Water dispersible filming amine	Corrosion inhibitor for fresh water-base muds and packer fluids
2	Scale inhibitor	Tubular goods scale inhibitor in drilling and completion fluids
3	Biocide	Bactericide
4	Oxygen Scavenger	Removes oxygen from water-base muds

Table 3.8: Lost-Circulation Materials

S/N	Description	Primary function
1	Nut shells	Granular lost – circulation material
2	Mica	Flake for seepage losses and prevention
3	Shredded cedar fibre	Fibrous for general loss of return
4	Cellulose fibres	Cellulose fibres for lost circulation and sweeps in oil-base muds

Table 3.9: Common Chemicals

S/N	Description	Primary function
1	Sodium hydroxide (NaOH)	pH control in water-base muds
2	Sodium bicarbonate (NaHCO ₃)	Calcium precipitant and pH reducer in cement contaminated muds
3	Sodium Chloride (NaCl)	Saturated salt muds, work-over/completion fluids and resistivity control
4	Sodium carbonate (Na ₂ CO ₃)	Calcium precipitant in lower pH muds
5	Calcium Hydroxide (Ca(OH) ₂)	Calcium source and increasing pH
6	Sodium tetraphosphate (Na ₆ P ₄ O ₁₃)	Thinner in low pH muds and calcium sequestering agent
7	Calcium Sulfate (CaSO ₄ ·2H ₂ O)	Calcium source at a neutral pH
8	Potassium Carbonate	Potassium source in inhibitive potassium muds

Table 3.10: Cement Accelerators

S/N	Description	Primary function
1	CAL-SEAL(Calcium sulfate hemihydrates)	Used to reduce thickening time in cement
2	CaCl ₂ (Calcium chloride)	Used to reduce thickening time in cement
3	NaCl (Sodium Chloride)	Used to reduce thickening time in cement
4	KCl (Potassium Chloride)	Used to reduce thickening time in cement

Table 3.11: Strength Retrogression

S/N	Description	Primary function
1.	Micro Fly ash	Used to stop strength retrogression
2.	Micro-sand	Used to stop strength retrogression
3.	Silica sand	Used to stop strength retrogression
4.	Silica flour	Used to stop strength retrogression

Table 3.12: Work-over and Completion Fluid Products

S/N	Description	Primary function
1.	Potassium formate (KCHO ₂)	Reduces formation damage in situations where formation waters contain high concentration of bicarbonate and sulfate ions.
2.	Sodium Bromide (NaBr)	Used to eliminate potential of formation damage from the precipitation of carbonate, bicarbonate or sulfate compounds associated with using calcium base brines where formation waters contain high concentrations of bicarbonate and sulfate ions.
3.	Sodium formate (NaCHO ₂)	Reduces formation damage in situations where formation waters contain high concentrations of bicarbonate and sulfate ions.
4.	Zinc Bromide/ Calcium Bromide	Can be blended with CaCl ₂ /CaBr ₂ brines to formulate and control the density of various fluids blends. Provides hydration and migration prevention of swelling clays and can be used as packer fluids.
5.	Hydrochloric acid	pH adjuster and cleaning scale.

3.1 CEMENT COMPOSITIONS AND TYPES

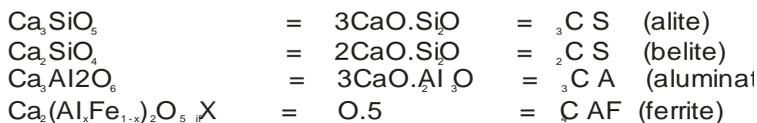
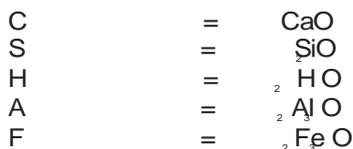
Portland Cements are used for well cementing throughout the world (DiLullo, *et al.*, 1994). They are manufactured by combining limestone (calcium carbonate) and clay (silicon oxides + aluminum oxides + iron oxides) in about a 2:1 ratio and then heating to a temperature of 2,600 to 3,000 °F (1426 to 1648 °C). The mixture is heated to initiate chemical reactions between the limestone and clay. Several products form as result of these reactions, and the combined mixture is called cement clinker. The cement typically encountered is in powder form, which is made by pulverizing and grinding the clinker.

The limestone / clay reactions lead to the formation of four major products that comprise four distinct crystalline phases: alite, belite, aluminate, and ferrite. The alite phase is composed primarily of tricalcium silicate (C_3S); it makes up 50% to 70% of a typical cement clinker. Belite consist primarily of dicalcium silicate (C_2S) and makes up 15 to 30% of a typical clinker. The aluminate and ferrite phases are composed primarily of tricalcium aluminate (C_3A) and tetra-calcium aluminoferrite (C_4AF) and typically constitute 5 to 10% and 5 to 15% of a clinker, respectively (Young and Hansen, 1987; Bogue, 1955).

The oil industry purchases cements manufactured in accordance with API classifications. These have been published annually by the American Petroleum Institute since 1954, when the first national standards on cements for use in wells were issued. These specifications are reviewed annually and revised according to the needs of the oil industry. The different classes of API cements for use at down-hole temperatures and pressures are defined and listed in the *API Standards 10A*, dated January 1, 1995, Smith, 1987, Standard specifications, 1990).

Cement slurry used in the oil industry consists mainly of cement, additives, and water. The various types of cements and additives depend on the end application. Portland cement is the material of choice for about 99% of all primary cement treatments. Several types of cement are manufactured for oil-well use. The American Petroleum Institute (API) has set standards for oil well cements. The common types of API cements are API class A, API class C, API class G, and API class H. The chemistry of each of these grades is similar, but the quality control is most stringent for API classes G and H. Cement reacts with water and produces a product that is hard which provides zonal isolation. The more finely ground the material, the larger the surface area and the quicker the reaction. Therefore, API class C is the fastest setting and the highest early strength cement of the group, while API class H is the slowest setting of the group. Hydration reaction is accelerated thermally, so at higher temperatures, cement will take less time to set.

3.1.1 CEMENT CHEMISTRY SHORTHAND



Oilwell cements, which can have either moderate sulfate resistance (MSR) or high sulfate resistance (HSR), are

commonly used. These cements generally differ from construction cements in the following ways.

- Some sulfate resistance is required because the cement might have prolonged exposure to sulfate-containing formation waters (frequently encountered in oilwell drilling and completion operations). Sulfate resistance in oilwell cements is achieved by lowering the C_3A content to 8% or less for MSR cements, and 3% or less for HSR cements.

- C_3S content is generally lower.
- C_2S content is generally higher.
- Iron-rich phases are generally higher.
- Free lime and alkali sulfates contents are generally lower.

Hydration and performance

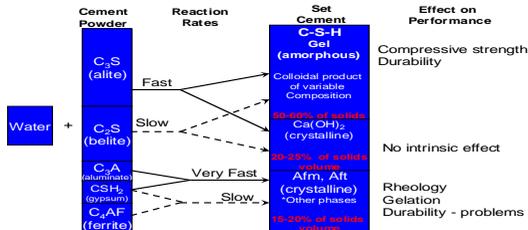
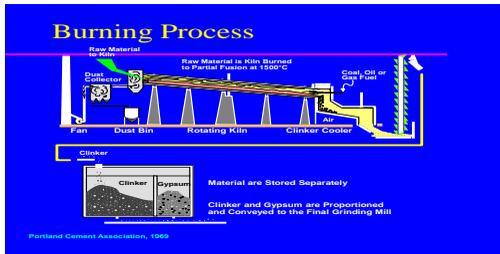


Fig 3.1: Hydration and performance mechanism



Fig 3.2: Mining of Raw materials for cement



Clinkering zone

Fig 3.3: cement production processing

3.2 CEMENT ADDITIVES

Cement additives have been developed to allow the use of Portland cement in many different oil and gas well applications. Cement additives development has been ongoing for decades. These additives make obtaining required performance properties relatively easy. Typical additive classifications are listed below (American Petroleum Institute, 1990).

a) Accelerators – Reaction rate enhancers. Accelerators are used to shorten the set time of cement slurries. They do not increase the ultimate compressive strength of cement but do increase the rate of strength development. Accelerators are used at low temperatures to reduce time waiting on cement (WOC). The most common accelerator is calcium chloride, commonly used at 3% or less by weight cement.

Others are:

- i. Sodium Chloride.
- ii. Seawater.
- iii. Econolite.

b) *Retarders* -Retarders are used to increase the set time of cement. They do not decrease the ultimate compressive strength of cement but do slow the rate of strength of development. The most common retarders are natural lignosulfonates and sugars. The newest retarders are made from various synthetic compounds.

c) *Light weight additives* - Many formations will not support long cement columns of high density slurries, sometimes these slurries weights need to be reduced to protect formations that have low fracture gradient or for economics purposes. To reduce the weight of cement slurries, water can be added as well as low specific – gravity solids. Bentonite is one of the most commonly used lightweight additives, (Haut *et al.*, 1980). Water is the cheapest material that can be added to cement. The problem is that the slurry will become too thin and the cement will settle and have free water. To prevent this problem, extenders (thickeners) such as bentonite or sodium silicate are added.

d) *Dispersants* – Reduce slurry consistency. These are used to reduce the viscosity of cement slurry. They are useful in designing high density slurries and also tend to improve fluid-loss control.

e) *Stability agents* – Preventing slurry from settling or having free water develop. Even with extenders, at elevated temperatures slurry may bleed water or settle. Therefore, special additives are required in small quantities to aid in slurry stability. Because these additives do not increase the viscosity of

the slurry excessively at surface conditions, they allow easy mixing.

f) *Heavy weight additives* – The main purpose of heavy weight additives is to restrain high formation pressures. Heavy weight additives are used to obtain slurry densities up to 20 lb/gal. They have a low water requirement and have a uniform particles size range from batch to batch. Heavyweight additives are chemically inert and compatible with other additives. The most common materials used for weighting cements are (Wilson, et al., 1987)

- i. Hematite (iron ore).
- ii. Barite (more common in drilling fluids).
- iii. Ottawa sand.
- iv. Salt.

g) *Anti – foam agents* – Surfactants that alter surface tension. Many additives cause foaming problems, but if slurry foams badly, the mixing centrifugal pump will air lock and mixing must be stopped. The most common anti-foam agents are polyglycols; silicones are used sometimes.

h) *Fluid-loss additives-permeability plugging additives* - Fluid-loss additives reduce the rate at which water from cement is forced in permeable formations when a positive differential pressure exists in the permeable formation. Fluid-loss additives are normally polymers such as cellulose, polyvinyl alcohol, polyalkanolamines and liquid latex. Most Fluid-loss additives increase the slurry viscosity, although some retard it to some degree.

3.3 CLAY CHEMISTRY

Thus, an understanding of clay chemistry is important in the selection of a drilling fluid system and borehole stability.

The gelling and swelling qualities of clays impart colloidal properties to drilling mud that make them different from viscous liquids such as honey or lubricating oil. The actual clays range from those that swell and hydrate very highly to those that do so only slightly (Grim, 1980). The rheological and filtration properties of drilling fluids depend on the size, shape and molecular structure of the particles suspended therein. Interaction between opposite charges influences the viscosity of the clay mud at low flow velocities, and is responsible for the formation of a reversible gel structure when the mud is at rest (Marshall, 1949). The performance of some clay can be greatly improved by chemical treatment (beneficiating) enhances the sample. Most reservoir sandstones also contain some clay minerals. These may react with the fluids that contact them in such a way as to completely block the formation. Therefore, the structures and reactions of clays are important in the design of fluids that may be in contact with the producing zone. Clays play a significant role in drilling fluids, particularly in water base fluids. They may be added intentionally to control the viscous flow properties and to provide the colloidal properties required for filtrate loss control, or they may build up through drilling of formations in which they predominate. Commercial clays such as bentonite and attapulgite are purposely added to enhance drilling fluid properties. However, since the combination of formation clays and commercial clays frequently leads to too much viscosity, a large group of chemicals, including those described as “mud conditioning chemicals”, are added to control the viscous properties. A full understanding of

the chemistry of those chemicals and the clays will enable operating personnel to have a better grasp on the measure taken to control the fluid properties (George, Darley and Walter, 1980).

3.4 AVAILABILITY OF RAW MATERIALS FOR OILFIELD CHEMICALS IN NIGERIA

Studies from Raw materials Research and Development Commission, reports from the Nigerian Mining Corporation, and other international industry accounts have established the existence of bentonite clay reserves of over 700million tones in the country with the largest single deposit at Afuze in Edo State holding 70-80 million tons of Bentonite. Beneficiated Bentonite clay from Edo State has been found to be useful for oilfield applications (Ajienka et al. 2003, Joel et al, 2009). Also, previous studies of Bentonite deposits at locations in Delta State include samples from Oburudu-Bamadi Local Government Area (LGA), Ofoni-Sagbama LGA, Ughewughe (Okuwara)-Ughelli LGA, Ughewughe (Osokpo)-Ughelli LGA, Uvweru-Ughelli LGA, and Oto-Edo-Ughelli LGA.

However, virtually none of the companies listed in the directory as oilfield chemical suppliers in Nigeria actually source production chemicals or any of the raw materials used in the formation of production chemicals from within the country. Though the state that they ‘manufacture’ these chemicals, companies with ‘blending facilities’ in which none of the materials used in the mixing are local raw materials can hardly be called local manufacturing companies. The sooner local manufacturers and researchers get involved in the oilfield chemical business the better (Babbo, 2009).

3.4.1 Raw Materials Information in Nigeria: States and their Natural Resources

ABIA STATE	Iron-ore	GOMBE STATE		Limestone	Phosphate
Gold	Lead/Zinc	Gemstone	KWARA STATE	Oil/Gas	Potash
Lead/Zinc	Limestone	Gypsum	Cassiterite		Silica Sand
Limestone	Marble		Columbite	OSUN STATE	Salt
Oil/Gas	Salt	IMO STATE	Feldspar	Columbite	
Salt		Gypsum	Gold		TARABA STATE
	BORNO STATE	Lead/Zinc	Iron-ore	Gold	Lead/Zinc
ABUJA	Bentonite	Lignite	Marble	Granite	Kaolin
Cassiterite	Clay	Limestone	Talc	Talc	
Clay	Diatomite	Marcasite	Tantalite	Tantalite	YOBE STATE
Dolomite	Gypsum	Oil/Gas		Tourmaline	Soda Ash
Gold	Hydro-carbon	Phosphate	LAGOS STATE		Tintomite
Lead/Zinc	Kaolin	Salt	Bitumen	OYO STATE	
Marble	Limestone		Clay	Aqua Marine	ZAMFARA STATE
Tentalite		JIGAWA STATE	Glass-Sand	Cassiterite	Coal
	C/RIVER STATE	Butyres		Clay	Gold
ADAMAWA STATE	Berytes		NASSARAWA STATE	Dolomite	
Bentonite	Lead/Zinc	KADUNA STATE	Amethyst (Topaz Garnet)	Gemstone	
Gypsum	Lignite	Amethyst	Barytes	Gold	
Kaolin	Limestone	Aqua Marine	Beryl	Kaolin	
netite	Manganese	Asbestos	Cassirite	Marble	
	Oil/Gas	Clay	Chalcopyrite	Sillimonite	
AKWA IBOM STATE	Salt	Flospers	Clay	Talc	
Clay	Uranium	Gemstones	Columbite	Tantalite	
Lead/Zinc		Gold	Cooking Coal		
Lignite	DELTA STATE	Graphite	Dolomite/marble	PLATEAU STATE	
Limestone	Clay	Kaolin	Feldspar	Barytes	
Oil/Gas	Glass-Sand	Kyanite	Galena	Bauxite	
Salt	Gypsum	Mica Rock Crystal	Iron-ore	Bentonite	
Uranium	Iron-ore	Ruby	Limenite	Bismuth	
	Kaolin	Sapphire	Mica	Cassiterite	
ANAMBRA STATE	Lignite	Sihnite	Salt	Clay	
Clay	Marble	Surpentinite	Sapphire	Coal	
Glass-Sand	Oil/Gas	Tentalime	Talc	Emerald	
Gypsum		Topaz	Tantalite	Fluoride	
Iron-ore	EBONYI STATE	Tournmaline	Tournmaline	Gemstone	
Lead/Zinc	Gold		Quartz	Granite	
Lignite	Lead/Zinc	KANO STATE	Zireon	Iron-ore	
Limestone	Salt	Cassiterite		Kaolin	
Phosphate		Copper	NIGER STATE	Lead/Zinc	
Salt	EDO STATE	Gemstone	Gold	Marble	
	Bitumen	Glass-sand	Lead/Zinc	Moloybdenite	
BAYELSA STATE	Clay	Lead/Zinc	Talc	Phrochlor	
Clay	Dolomite Phosphate	Pyrochinnre		Salt	
Gypsum	Glass-Sand	Tantalite	OGUN STATE	Tantalite/Columbite	
Lead/Zinc	Gold		Bitumen	Tin	
Lignite	Gypsum	KATSINA STATE	Clay	Wolfgram	
Limestone	Iron-ore	Kaolin	Feldspar		
Manganese	Lignite	Marble	Gemstone	RIVERS STATE	
Oil/Gas	Limestone	Salt	Kaolin	Clay	
Uranium	Marble		Limestone	Glass-sand	
	Oil/Gas	KEBBI STATE	Phosphate	Lignite	

BAUCHI STATE		Gold		Marle	
Amethyst (Violet)	EKITI STATE		ONDO STATE	Oil/Gas	
Gypsum	Feldspar	KOGI STATE	Bitumen		
Lead/Zinc	Granite	Coal	Clay	SOKOTO STATE	
Uranium	Kaolin	Dolomite	Cola	Clay	
	Syenite	Feldspar	Dimension Stones	Flakes	
BENUUE STATE	Tatium	Gypsum	Feldspar	Gold	
Berytes		Iron-ore	Gemstone	Granite	
Clay	ENUGU STATE	Kaolin	Glass-sand	Gypsum	
Coal	Coal	Marble	Granite	Kaolin	
Gemstone	Lead/Zinc	Talc	Gypsum	Laterite	
Gypsum	Limestone	Tantalite	Kaolin	Limestone	

4.1 MY CONTRIBUTIONS TO OIL FIELD CHEMICALS DEVELOPMENT AND APPLICATION

4.1.1 Comparative study of local cement with imported class “G” cement for cementing of oil wells in Nigeria(Joel,1999,Joel, 2009)

All Oil Companies involved in cementing of oil and gas wells in Nigeria use imported cement in the cementing operations. Cementing of oil well is a capital intensive project and the cost of getting the imported cement is quite enormous in terms of foreign exchange.

The purpose of this project was to determine the suitability of locally manufactured cement as a substitute for imported oil-well cement.

Four cement types were used namely:

- a) Class “G” cement (marked Norcem) representative of imported cement that has been used to successfully execute cement jobs in the country.
- b) Elephant (representative sample of locally manufactured cement)
- c) Eagle (locally manufactured sample)
- d) Burham (locally manufactured sample)

A series of laboratory tests were performed to evaluate the performance on thickening time, compressive strength, free fluid, and rheological properties among others. All tests were conducted in line with the specification for materials and testing for Well Cements (API, 1990, API *Specification 10A* 1995 and API, 1997). Six experimental conditions were investigated; the testing conditions are specified as highlighted in table 4.1.

Table 4. 1: Experimental conditions (Joel, 1999)

TEST CONDITIONS	20" CSG JOB (TAIL) T1	13-3/8" CSG JOB (LEAD) T2	9-5/8" CSG JOB (MAIN) T3	9-5/8" CSG JOB (MAIN) T4	SQUEEZE DESIGN (MAIN) T5	PLUG DESIGN (MAIN) T6
BHST (°F)	95	137	154	195	190	230
BHCT (°F)	84	105	125	140	160	192
DEPT (FEET)	1400	4500	5700	4500	9591	12462
GRADIENT (°F/100FT)	1.05	1.26	1.3	1.46	1.2	1.2
PRESSURE (PSI)	1150	2700	4683	4900	7880	10368
SL.WT (PPG)	15.8	11.5	15.8	15.0	15.8	16.0
S.YIELD (FT ³ /SK)	1.15	2.89	1.3	1.29	1.20	1.15
GEL % BWOC		4.0				
ANTIFOAMER GAL/SK)	0.02	0.02	0.02	0.02	0.02	0.02
FRESH WATER GAL/SK	4.98	-	4.25	5.97	3.67	
CaCl ₂ %BWOC	1.0	-	-			
FLUID LOSS AGENT % BWOC		-	0.70	0.80	0.50	0.70
DISPERSANT %BWOC	-	-	0.30	0.10	0.50	0.40
RETARDER (GAL/Sk)	-	-	0.05	0.05	0.02	0.07
GAS CONTROL (%BWOC)					0.65	0.65

Test results are shown in the tables below and discussion given as applicable.

Table 4.2: Thickening time profile

CEMENT	T1	T2	T3	T4	T5	T6
NORCEM	3:15	5:00	4:50	4:00	5:00	3:40
ELEPHANT	2:50	6:00	3:00	2:44	4:10	1:00
EAGLE	3:20	3:03	1:10	2:20	2:10	1:50
BURHAM	2:10	5:10	3:10	3:00	3:10	2:26

Table 4.3: Fluid loss profile

CEMENT	T3	T4	T5	T6
NORCEM	75	70	20	40
ELEPHANT	40	58	ND	ND
EAGLE	106	158	10	26
BURHAM	46	143	15	11

Table 4.4: Compressive strength profile

CEMENT	T1	T2	T3	T4	T5	T6
NORCEM	3050	0	5500	2750	4900	2576
ELEPHANT	2675	0	1600	2000	4250	4100
EAGLE	3500	0	4250	3200	4250	3750
BURHAM	2800	0	2850	2000	1600	2550

Table 4.5: PV profile

CEMENT	T1	T2	T3	T4	T5	T6
NORCEM	52.5	18	75	36	180	180
ELEPHANT	30	6	78	55.5	ND	ND
EAGLE	54	13.5	97.5	75	228	175.5
BURHAM	66	6	52.5	31.5	102	142.5

Table 4.6: YP profile

CEMENT	T1	T2	T3	T4	T5	T6
NORCEM	38.5	62	5	2	50	50
ELEPHANT	42	65	12	8.5	ND	ND
EAGLE	75	48.5	37.5	155	29	94.5
BURHAM	89	36	29.5	45.5	4	62.5

Tests were conducted using the same test equipment and experimental conditions as shown in **Table 4. 1**. In almost all the tests, the foreign cement (Norcem) appeared to pump longer than the local cement (**Table 4. 2**). The implication is that for deeper wells with higher temperatures, more retarder concentrations are needed to bring up the thickening time results of local cements to the level of the imported cement. However, for shallower wells, we need less accelerator concentration to shorten the thickening time.

In most of the tests conducted with only few exceptions, test results indicated that the local cements exhibited better fluid-loss control tendencies. This implies that to achieve a reasonable fluid-loss control at higher temperatures using the local cements, we need less concentration of fluid loss additives (**Table 4.3**).

Test results revealed that the compressive strength obtained with the local cements compared favorably with that of the imported cement. In all the tests conducted with the different local cement samples, the minimum requirements for compressive strength as applicable were met. However, the compressive strength obtained showed that tests with the foreign cement sample appeared higher in most of the tests (**Table 4.4**).

Test results indicated that results from all the local cement samples showed no settling tendencies of the slurries when allowed static for two hours. There was no significant difference in the free fluid results for all the samples tested.

The rheological values obtained from the local cement samples compared favorably with that of the imported cement. The basic reason for determination of rheological properties is to predict plastic viscosity and yield point values. With the exception of elephant cement which exhibited a thermal shock phenomenon at higher temperatures (160 and 192^oF), no abnormal gellation was observed in other rheological investigations with the local cements. In order to avoid this thermal shock tendencies observed using Elephant cement sample, it is imperative that the slurry be heated gradually from room temperature to test temperature when running the atmospheric Consistometer. The PV and YP values obtained from the rheological deductions with the local cement compared favorably with that of the imported cement. In almost all the test, the values of the PV and YP evaluated showed that the slurries were pumpable (**Table 4.5-6**).

The following conclusions can be drawn about the use of local cement in oil and gas exploitation

- Locally manufactured cement could be used as a substitute for imported cements in cementing of gas

and oil wells; however, premature gellation and non-reproducibility of test results were phenomenal at higher temperatures.

- Results with local cement compare favourably with the imported cement
- Implementation of the local substitute in the cementing of oil wells will bring savings in foreign exchange and expansion of operations of local cement industries.
- This will lead to enhanced home based technology and research development efforts.
- Research findings implementation will create Job opportunities to local industries and more employment for nationals.

4.1.2 Enhancing utilization of local cement as an alternative source of oil and gas well cement—a case study on Dangote and Elephant cements (Mfonnom, Puyate and Joel 2009)

Major concerns with the use of locally produced construction cement in oil- and gas- well cementing among others include:

- Poor quality control and rapid gellation of slurries
- Loss of slurry integrity caused by reactive nature of cement making them unsuitable for use at the elevated temperature (often experienced in oil and gas wells)
- Susceptibility of locally manufactured cements to sulphate attack and eventual deterioration
- Unpredictable thickening time

To overcome the problems detailed above, a service company developed and tested a product that allows non-API specification local cements to be used in oilwell cementing designs and application. This product is commonly referred to as universal cement system (UCS) additive. In the majority of cements tested worldwide, UCS additive has allowed the formulation of consistent slurry recipes with locally manufactured cements at concentrations that make it economically desirable (Hunter *et al.*, 2002). The UCS additive can counteract the differences often seen between different batches of locally manufactured cement, reduce the high gellation effects, impart chemical resistance, and allow their use at temperatures up to 250°F. In addition, long-term testing has shown that UCS additive improves the sulphate resistance of cements. UCS additive at 1.0% showed resistance to sulphate attack similar to that of a Class G oilwell cement (Carole, 2000)

Table 4.7—Technical Results Comparison of 18 5/8-in. Casing Tail

Job Type	Tail		
Test type	18 5/8-in. casing	18 5/8-in. casing	18 5/8-in. casing
BHST, °F	126	126	126
BHCT, °F	100	100	100
BHP, psi	2,300	2,300	2,300
Heat-up time, min	25	25	25
Additives	<i>Dangote</i>	<i>Elephant</i>	<i>Dyckerhoff</i>
WG-17™ agent, %bwoc	.05	.05	.05
HR@-5 retarder, %bwoc	.15	.15	.15
UCS additive, %bwoc	1	1	1
D-AIR 3000L™ anti-foaming agent, gal/sk	.02	.02	.02
Slurry weight, lbm/gal	15.8	15.8	15.8
Water requirement, gal/sk	4.98	4.98	4.98
Mixing fluid, gal/sk	5	5	5
Yield, cu. ft/sk	1.16	1.16	1.16
Thickening time	—	—	—
30Bc, hrs:min	04:24	04:59	06:19
50Bc, hrs:min	04.49	05:07	06:50
70Bc, hrs:min	05:06	05:16	07:31
Rheologies, 80°F	—	—	—
300 rpm, cp	88	30	40
200 rpm, cp	65	25	30
100 rpm, cp	39	14	19
6 rpm, cp	15	3	6
3 rpm, cp	12	2	4
PV, cp	73.5	24	31.5
YP, lbf/100ft ²	14.5	6	8.5
Rheologies, BHCT	—	—	—
300 rpm, cp	86	24	86
200 rpm, cp	63	20	70
100 rpm, cp	38	11	53
6 rpm, cp	9	2	28
3 rpm, cp	5	1	22
PV, cp	72	19.5	49.5
YP, lbf/100ft ²	14	4.5	36.5
comp. strength	—	—	—
12 Hours, psi	1,176	782	1,147
24 Hours, psi	2,285	1,501	2,307
Fluid loss, cc/30min	ND	ND	ND
Free fluid at 90°, %	0.64	0	1.28

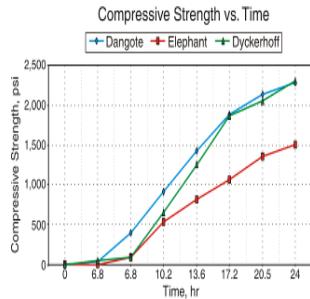
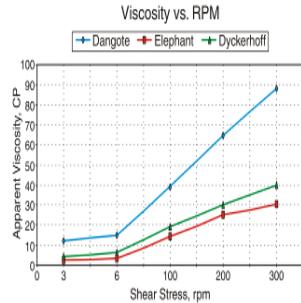
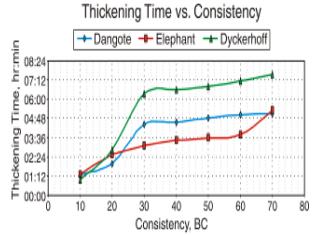


Fig 4.1: 18 5/8-in. casing tail charts.

Table 4.8—Technical Results Comparison of 9 5/8-in. Casing Lead

Job Type	Lead	Lead	Lead
Test type	9 5/8-in. casing	9 5/8-in. casing	9 5/8-in. casing
BHST, °F	194	194	194
BHCT, °F	156	156	156
BHP, psi	9,400	9,400	9,400
Heat-up time, min	66	66	66
Additives	Dangote	Elephant	Dyckerhoff
BENTONITE, %bwoc	2.5	2.5	2.5
WG-17™ agent, %bwoc	0.15	0.15	0.15
HR@-5 retarder, %bwoc	0.15	0.15	0.15
UCS additive, %bwoc	1	1	—
D-AIR 3000L™ anti-foaming agent, gal/sk	0.02	0.02	0.02
Slurry weight, lbm/gal	12.5	12.5	12.5
Water requirement, gal/sk	12.07	12.07	12.07
Mixing fluid, gal/sk	12.09	12.09	12.09
Yield, cu. ft/sk	2.12	2.12	2.12
Thickening time	—	—	—
30Bc, hrs:min	07:40	10:00	02:39
50Bc, hrs:min	08:09	10:20	02:47
70Bc, hrs:min	08:29	10:31	02:52
Rheologies, 80°F	—	—	—
300 rpm, cp	20	22	30
200 rpm, cp	16	18	25
100 rpm, cp	10	12	20
6 rpm, cp	3	5	11
3 rpm, cp	2	3	10
PV, cp	15	38	15
YP, lbf/100ft ²	5	7	15
Rheologies, BHCT	—	—	—
300 rpm, cp	18	16	50
200 rpm, cp	14	14	46
100 rpm, cp	9	9	40
6 rpm, cp	3	4	12
3 rpm, cp	2	2	10
PV, cp	13.5	10.5	15
YP, lbf/100ft ²	4.5	5.5	25
comp. strength	—	—	—
12 Hours, psi	321	197	244
24 Hours, psi	566	302	492
Fluid loss, cc/30min	ND	ND	ND
Free fluid at 90°, %	2.8	0.62	3.6

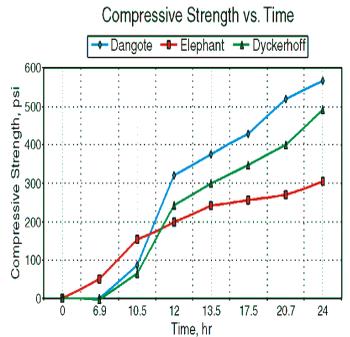
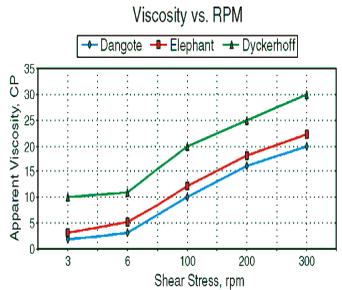
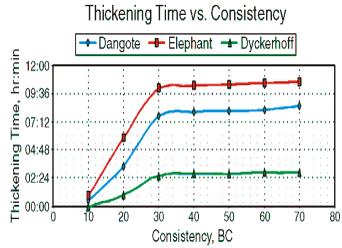


Fig 4.2: 9 5/8-in. casing lead charts.

Technically, all slurries developed using Dangote cement show similar and better properties than Dyckerhoff slurries. The inclusion of UCS additive at uniform concentration allowed the Dangote and Elephant cement to be used for all hole sections under the condition they contain the properties of the Dyckerhoff equivalents.

Locally produced cement, especially Dangote cement, proved to have properties suitable for application in oilwell cementing operations, in terms of fluid loss, thickening time, compressive strength, and free water, when tested at atmospheric temperatures and pressures that simulated reservoir conditions.

The addition of UCS additive enhanced the performance of the local cement and help to:

- Enhance compressive strength
- Control fluid loss
- Control rheology
- Impart chemical resistance and prevent sulfate
- Control premature gellation

By working in conjunction with local cement manufactures, operators can help ensure local cement maintains consistency. Using local cement can improve logistics and reduce the cost of cementing offshore wells in Nigeria by eliminating the need for importation from Europe. Working with local materials and local manufacturers can provide a valuable economic contribution to a region and strengthen ties to local communities (Mfonnom, Joel and Puyate 2009).

The use of local cement has been deployed in Nigeria especially for SPDC operations with great success. A total of 33 wells were cemented in place from 2001 to 2004 by Halliburton for Shell EA using the additives to optimize the locally manufactured construction cement.

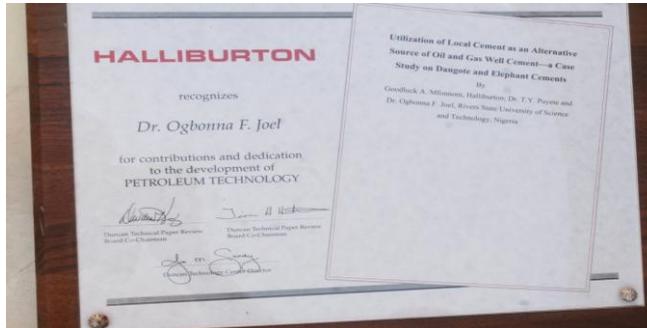


Fig 4.3: Award from the project.

4.1.3 Performance evaluation of local Bentonite with imported sample for utilization in oil field operations in Nigeria (Joel and Nwokoye, 2010).

NATURAL BENTONITE CLAYS

Bentonite is highly colloidal clay, which hydrates in water and greatly increases viscosity. Bentonite is a widely distributed, abundant mineral resource of major industrial importance for an enormous variety of uses (Ampian, 1985). The special properties of bentonite are an ability to form thixotropic gels with water, an ability to absorb large quantities of water with an accompanying increase in volume of as much as 12–15 times its dry bulk, and a high cation exchange capacity. The gelling and swelling qualities of clays impart colloidal properties to drilling

mud that make them different from viscous liquids such as honey or lubricating oil. The actual clays range from those that swell and hydrate very highly to those that do so only slightly (Grim, 1980). Sodium montmorillonite and calcium montmorillonite are the two major forms of bentonite. Some of the best deposits of sodium montmorillonite are found in Wyoming and a little over into South Dakota, Sodium (Grim, 1953).

Montmorillonite is the preferred clay for oilfield use because it yields the most viscosity. The ability to take up water affects the utilization and commercial value of Bentonite (Grim, 1968; Parker, 1988).

The performance of some clay can be greatly improved by chemical treatment (beneficiating) and such treatment is regularly given the natural mud made while drilling (George, Darley and Walter, 1980).

Among others, it is added to fresh water mud to increase hole cleaning capability, reduce filtration into permeable formation, form a thin filter cake of low permeability and promote hole stability. It is also used as a lightweight additive in cement slurry design. However, up till date in Nigeria, the bentonite in use in oil field operations had been imported. Attempts to use the local bentonite had yielded little or no result because of its low yield and inability to meet up API specification.

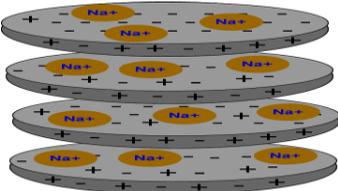


Fig 4.4: Aggregated State

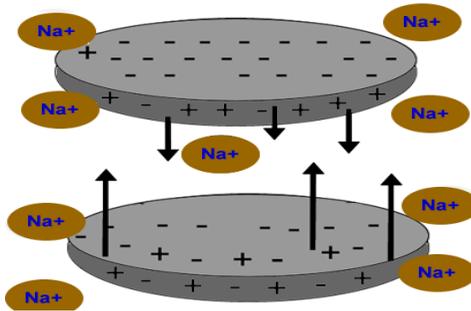


Fig 4.5: Hydrated Clay

BENTONITE HYDRATION MECHANISM

- The surfaces of clays contain hydroxyl and oxygen groups which form hydrogen bonds to water molecules.
- When the clay is exposed to water, the water is ionically attracted to the clay platelets.
- It begins to build up layers of water around the individual platelets.
- Eventually the layers of water will be thick enough to actually break the bond between the sodium ions and the clay platelets.
- The platelets are free to float about, and the maximum amount of surface area is exposed, which allows for maximum viscosity.
- Calcium has a stronger bond than sodium and it is a larger molecule.
- Sodium montmorillonite is the preferred clay for oilfield use because it yields the most viscosity.
- For this reason, calcium montmorillonite has to have polymers added to achieve similar viscosity to sodium montmorillonite.

- These polymer treated clays are known as "beneficiated" bentonite.

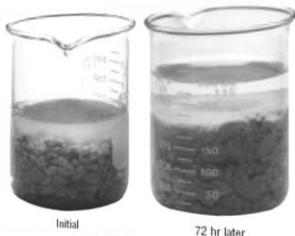


Fig 4.6a: Hydration of Local Bentonite



Fig 4.6b Hydration of Imported Bentonite

COMPOSITIONS OF BENTONITE CLAYS

Table 4.9: API Specification Result (API Spec 13 A, 2004)

S/N	RHEOLOGICAL PROPERTIES	
1.	Ø600 RPM	30 Min.
2.	Yield Point /Plastic Viscosity	3 Max.

Table 4.10: Chemical Analysis of Local and Imported Bentonite

S/N	Parameter	Imported Bentonite	Local Bentonite
1	Na (ppm)	240,000	2700
2	Mg (ppm)	90	140
3	Fe (ppm)	21	96
4	Ca (ppm)	300	2400

Results from chemical analysis for both the imported and local Bentonite indicated that Nigerian Bentonite is predominately Calcium based exchangeable cation while

imported is sodium. This accounts why the imported is a high yield grade with very high hydration capabilities. In order to make the Nigerian Bentonite meet API specification and be effective in oil well operations, there is utmost need for beneficiation.

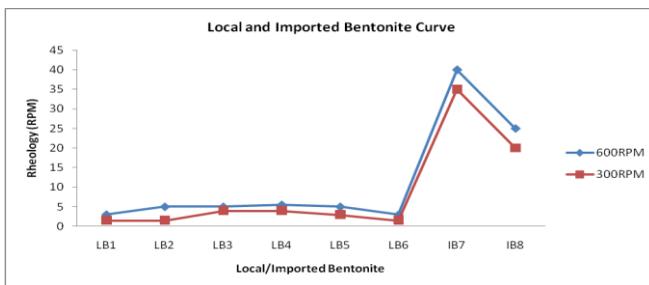


Fig 4.7: Local (LB1 – LB6) and Imported (IB7 – IB8) Bentonite Curve

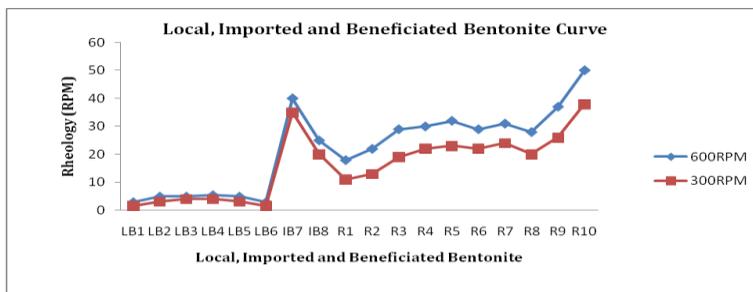


Fig4.8: Local (LB1–LB6), Imported (IB7–IB8) and Beneficiated (R1-R10) Bentonite Curve

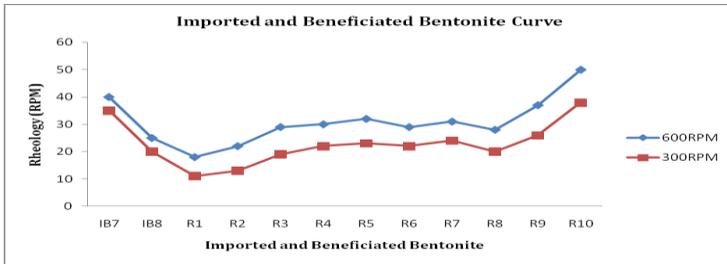


Fig 4.9: Imported (IB7 – IB8) and Beneficiated (R1 – R10) Bentonite Curve

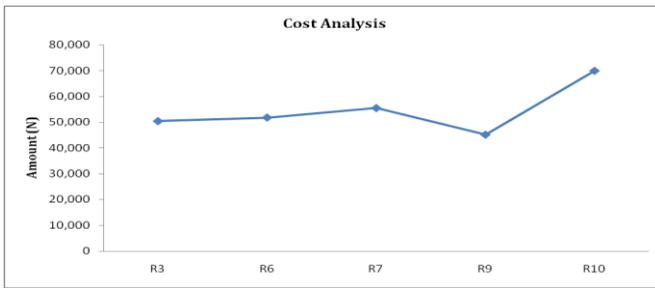


Fig4.10: Cost Analysis of Different Additives of Beneficiated (R3-R9) and Imported (R10) Bentonite

Table 4.9 indicates the acceptable specification for a good quality Bentonite. It is imperative that before any sample is used for job execution, the QA/QC must be determined to ensure the results are within acceptable range as specified by API.

Table 4.10 details the chemical analysis of both local and imported Bentonite. Test results indicated that the local sample had concentration of Na^+ (2,700ppm), Mg^{2+} (140ppm), Fe^{2+} (96ppm) and Ca^{2+} (2,400ppm) respectively, while the imported sample had Na^+ (240,000ppm), Mg^{2+} (90ppm), Fe^{2+} (21ppm) and Ca^{2+} (300ppm) respectively.

The low yield exhibited by the local Bentonite could be attributed to low Na^+ concentration compared to the higher concentration seen in the imported sample. Higher content of Na^+ in Bentonite clay has been found to enhance hydration process while high calcium content inhibits hydration capabilities of Bentonite.

Variation in exchangeable cations affects the maximum amount of water uptake and swelling capabilities of Bentonite, these are greatest with sodium and least with potassium, magnesium and calcium.

Fig4.7 indicates test results of rheological properties of imported Bentonite result are within acceptable range as specified by API. Fig 4.8 details the result of rheological properties of non-beneficiated local Bentonite. All the six samples tested indicated that none met the minimum API specification. In order to enhance the performance of the local Bentonite and bring it up to API specification, there is utmost need for beneficiation. Fig 4.9 details the result of the rheological properties of the beneficiated sample. As could be seen some of the additives were not affected in improving the yielding capabilities of the local Bentonite. With some additives, the minimum API specification was obtained. The higher the value of the additives added, the higher the rheological value, however cost considerations might be a limiting factor.

Fig 4.10, gives the trend in the cost analysis between the beneficiated local sample and imported ones. Though the cost for some of the beneficiated samples appear to be a little higher, the comparative advantage of local content realization and enhancement of home- based technology should outweigh cost considerations.

It is cost effective to utilize the local Bentonite, though the cost for deploying the local beneficiated samples may appear to be a little higher in some cases, the comparative advantage of local content realization and enhancement of home- based technology should outweigh cost consideration.

This will no doubt provide a significant logistical improvement, home-base technological advancement, and substantial cost-savings and help meet up with local content aspirations.

Right now in collaboration with Association of Miners and Processors of Barite (AMAPOB), we are setting up a plant to go into commercial production of local beneficiated Bentonite.

4.1.4 Evaluation of suitability of local silica sand as alternative for imported silica sand for utilization in Nigeria oil and gas industry (Joel and Iseghohi, 2009).

Cementing of high temperature wells poses a big challenge and requires special considerations in slurry design applications. Among others, the problem of strength retrogression encountered during the life of the well if special additives are not added to the slurry design is critical. For twelve months or more, after cement has set, it continues to hydrate and consequently develop in strength. After this time, it maintains the strength that it has attained except if it is attacked by agents of erosion. Cement will attain maximum strength after one fortnight is exposed to temperatures exceeding 230°F. After these first two weeks, the strength slowly starts to decrease. This process of cement losing its strength is known as strength retrogression. Structural changes and loss of water are the agents of cement degradation. When cement is set, it contains a

complex calcium silicate hydrate called tobermorite. At temperatures around 250°F, tobermorite is converted to a weak porous structure which causes strength retrogression (Diamond, 1983). The rates at which these changes occur depend upon temperature. Silica flour or silica sand is commonly used to prevent strength retrogression by modifying the hydration chemistry, and it can be used with all classes of Portland cement. The addition of 30 to 40% silica is usually adequate to provide strength stability while maintaining good permeability characteristics when static temperature in the zone exceeds 230°F (API, 2000).

It is obvious that almost all of the additives used in Nigeria for oil well operations, including silica sand are imported. However, it is imperative to note that this material is in commercial quantity in Nigeria. This project was undertaken to determine the suitability of local silica sand as alternative for imported silica sand for utilization in Nigerian oil and gas industry.

A series of laboratory tests were performed to evaluate the performance on thickening time, compressive strength, free fluid, and rheological properties among others. All tests were conducted in line with the specification for materials and testing for Well Cements (API, 1990, *API Specification 10A* 1995 and API, 1997).

Thickening Time: Test results (table4.11) indicated that the thickening time results with the local silica (1-4) within experimental error compared favourably with the imported silica. Three out of the four samples of the local silica tested pumped longer than that of the imported silica (fig4.9). Such deviations are expected in course of testing samples from different batches.

Table4.11: Slurry Composition / Test Data Sheet

Slurry	Unit	Imported Silica	Local Silica 1	Local Silica 2	Local Silica 3	Local Silica 4
BHST	°F	284	284	284	284	284
BHCT	°F	234	234	234	234	234
BHP	psi	9600	9600	9600	9600	9600
CEMENT BRAND		Dyckerhoff	Dyckerhoff	Dyckerhoff	Dyckerhoff	Dyckerhoff
Fluid Loss 1	%Bwoc	0.6	0.6	0.6	0.6	0.6
Fluid Loss 2	%Bwoc	0.7	0.7	0.7	0.7	0.7
Retarder 1	L/Ton	10	10	10	10	10
Retarder 2	L/Ton	20	20	20	20	20
Silica	%Bwoc	35	35	35	35	35
Anti- foam	L/Ton	1.78	1.78	1.78	1.78	1.78
Freshwater	L/Ton	527.5	527.5	527.5	527.5	527.5
Slurry Wt.	KG/L	1.9	1.9	1.9	1.9	1.9
Yield	CuFt/Sk	100.78	100.78	100.78	100.78	100.78
Rheology	°F	190	190	190	190	190
300	CP	142	190	142	192	146
200	CP	102	137	103	140	103
100	CP	58	80	57	77	60
6	CP	5	5	4	5	4
3	CP	3	2	2	2	2
PV	CP	126	165	127.5	172.5	129
YP	LB/100 Ft ²	16	25	14.5	19.5	17
Fluid Loss	CC'S/30 Min	32	38	40	40	38
Thickening Time	BC	5:47	6:19	6:20	6:16	5:26

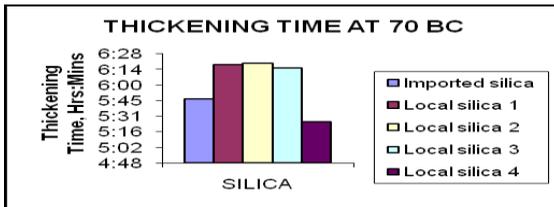


Fig 4.11: Thickening Time at 70 BC

Fluid Loss: The fluid loss results (table4.11) indicated that the fluid loss results with the local silica (1-4) compared favourably with result of the imported silica. All the four samples of the local silica tested had fluid loss values higher than the imported silica (fig4.11). This might be due to differences in particle size between the imported and local silica.



Fig 4. 12: Fluid Loss per 30Minutes

Compressive Strength: Test results indicated that the imported silica developed early strength compared to the local silica. 12hours strength for imported silica was (3214psi) as against (996psi for local silica 1, 827psi for local silica 2 and 1609psi for local silica 3). Though the strength for the local silica samples were lower at 12hours, the strength attained the minimum range of 500psi required to commence drilling within the 12hours period. It is imperative to note that during 24-72hours period, the compressive strength attained by the local silica compared favourably with the values of the imported silica (fig4.12)

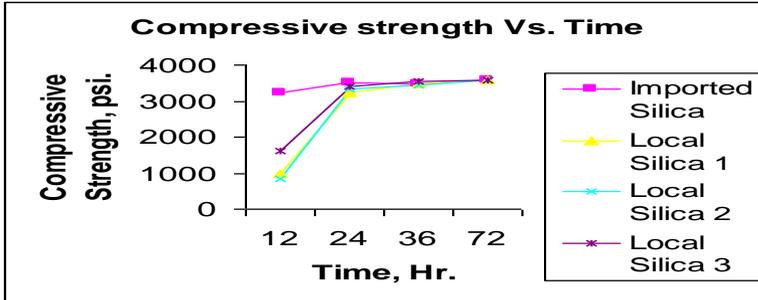


Fig 4.13: Compressive Strength versus Time

Rheological Test: From (table4.12), samples 1 and 3 of the local silica showed higher rheological values especially for the 300rpm and 200rpm readings. Samples 2 and 4 rheological values of the local silica compared favourably with the imported silica. However, the differences in the rheological values do not pose a concern since there was no mixability problem.

Research results therefore indicated that:

- Local silica has proven to be suitable for HPHT Oil wells in Nigeria.
- Results with local silica compares favourably with the imported silica.
- It is important to work closely with the local silica manufacturer/researchers to improve the quality of product.
- Using local silica can improve logistics and reduce the cost of cementing wells.
- Using local silica provides a valuable economic contribution to the country and enhances local content aspiration.

The local silica local has been deployed in Nigeria for high temperature, high pressure wells with huge success. This has resulted in cost savings by oil companies; breakthrough in home based technology in line with local capacity and capability development, a step towards realizing the Nigerian vision 2020.

4.1.5 Investigation of local polymer (cassava starches) as a substitute for imported sample in viscosity and fluid loss control of water based drilling mud(Ademiluyi, Joel and Kazeem)

Starch is the second most abundant biomass found in nature, next to cellulose (Herman Katopo *et al.*, 2002). It consists of two major components namely amylose and amylopectin (Wing, 1988). Starch is usually used in the technology of drilling fluids in modified forms due to its solubility in water. Starch materials are predominantly used as effective protective colloids decreasing the filtration of practically all kinds of water dispersing drilling fluids with the impact on the kind of used salt and additionally increasing the viscosity of drilling fluids. This starch action is caused by its swelling and increasing of its volume due to free water absorption. At the same time we can observe the decrease of filtration and the increase of rheological properties of drilling fluids. Swelled starch becomes a component of filtrating deposit to form polymer-clayey mixture. This mixture decreases the permeability of this deposit and reduces negative action of filtrate on sectors of borehole without drill pipe. There is a possibility of controlling the permeability of filtration deposit by proper utilization of starch constituents and their mixture with Bentonite and other polymers (Chatterji, *et al.*, 1981, Joel, *et al.*, 2010).

The amylose component of starch controls the gelling behaviour since gelling is the result of re-association of the linear chain molecules. The abundance in hydroxyl groups in the starch molecules impart hydrophilic properties to the polymer and thus its potential to disperse in water.

Different types of polymers and chemicals are used by the petroleum industry to design some drilling muds to meet some functional requirements such as appropriate mud rheology, density, fluid loss control property etc. (Amanullah *et al.*, 1997). Amanullah and Long (2004) developed several corn-based starches using local resources to study their suitability to use as drilling fluid additive. Okumo and Isehunwa (2007) studied the prediction of the viscosity of a water-base mud treated with cassava starch and potash at varying temperatures using factorial design. The work of Ikegwu *et al.*, 2009 shows that variations were observed in the functional properties of the starch samples of about 13 cassava cultivars studied.

Comparative study of local polymer (cassava) with an imported type in controlling viscosity and fluid loss in water-based mud was investigated in this study. Five different cassava starches were tested as viscosifiers and fluid loss control additives in water based mud and compared with Barazan D, an imported sample.

Test results are indicated in Fig 4.14 to 18 and discussions highlighted as reflected as applicable in the discussion section.

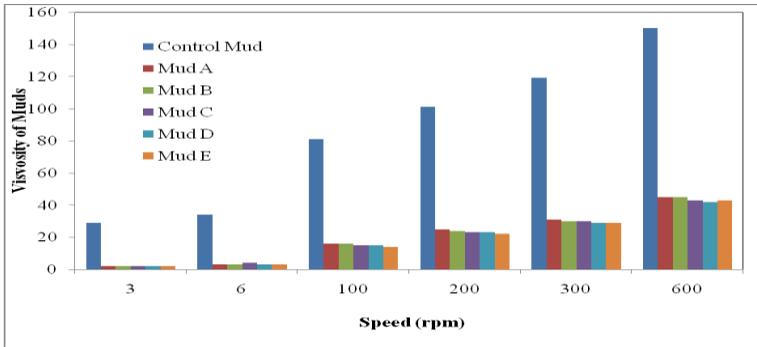


Fig 4.14: Viscosity of drilling fluids in (Cp) at different speed before aging at 80°F.

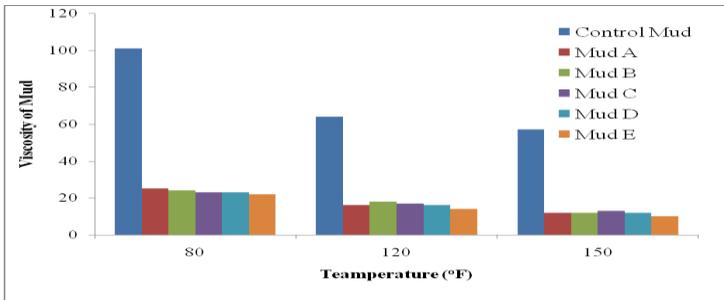


Fig 4.15: Viscosity of drilling fluids in (Cp) at different speed after aging at 80°F.

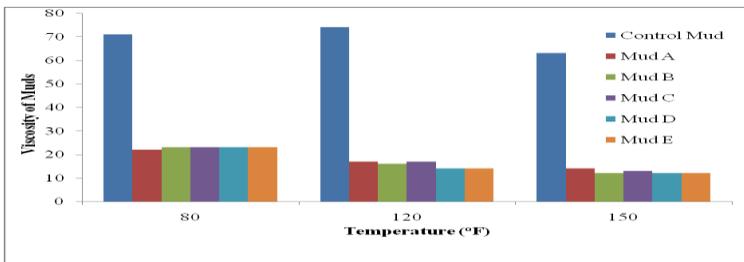


Fig 4.16: Viscosity of drilling fluids at different temperatures after aging (at 200rpm).

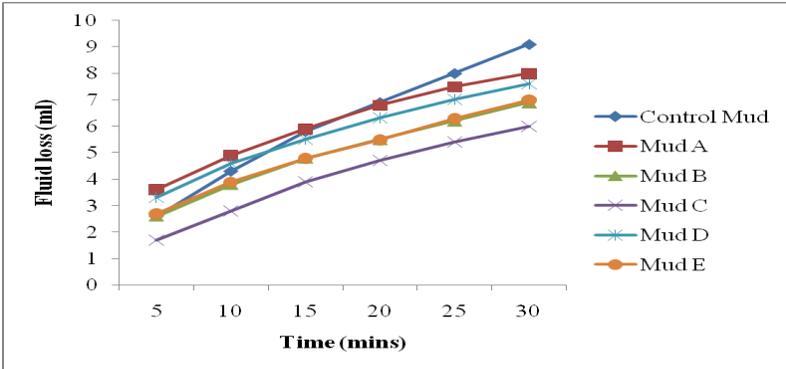


Fig 4.17: Fluid loss with time before aging at 80°F.

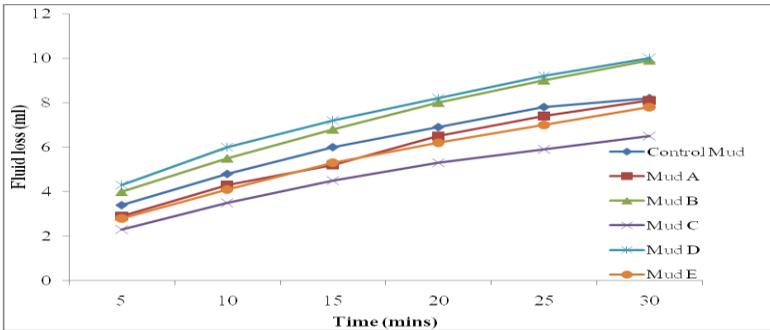


Fig 4.18: Fluid loss with time after aging at 80°F.

The viscosity of the drilling fluids tested at different speed before aging at 80°F is presented in Fig4.14. Generally, the viscosity increased with speed for both the drilling fluid formulated using the imported polymer and local cassava. The viscosity of the the drilling fluid produced using the imported polymer was significantly higher than that produced from local samples. This could be attributed to the variation of the constituents between the imported sample and local ones. Amanullah and Long Yu (2004) reported that the short

branching chains in the amylopectin are the main crystalline component in granular starch. Variation in the amount of amylose and amylopectin in a starch changes the behaviour of the starch. The amylose component of starch controls the gelling behaviour since gelling is the result of re-association of the linear chain molecules. Amylopectin is usually larger in size. The large size and the branched nature of amylopectin reduce the mobility of the polymer and their orientation in an aqueous environment. Amylose content of **cassava** increases the **water absorption capacity** and affects hydration (Eke *et al.*, 2010). The viscosities of the drilling fluids produced from local starches (Mud A to E) vary slightly due to differences in amylose content of cassava starches used. The abundance in hydroxyl groups in the starch molecules impart hydrophilic properties to the polymer and thus its potential to disperse in water (Amanullah *et al.*, 1997).

The effects of temperature on the viscosity of the formulated muds at different temperature and tested at 200rpm before and after aging are presented in Fig4.14 and 16. Test results from the rheological values indicated that the higher the temperature, the lower the rheological values respectively. This is in line with previous work that higher temperature results in thinning effect (Joel, *et al.*, 2010).

The fluid loss control potentials before and after aging was determined for the control sample and other samples prepared using the local starch and results indicated in Fig4.17 and 18 respectively. The fluid loss of the control sample and other samples prepared using the local starch increased with increase in time. Test results indicated that there was significant difference in the fluid loss Figures before and after aging especially for the imported sample. This shows that aging

enhance the hydration process for the samples that have higher amylose content and higher water absorption capacity. Therefore, this could be the reason why mud C and the control sample had lower fluid loss than other local samples. Eke *et al.*, (2010) reported similarly that amylose content of **cassava** increases the **water absorption capacity**. Previous study by Chatterji, *et al.*, 1981, indicated a decrease of filtration with increase in rheological properties of drilling fluids.

Research Findings indicated that:

- Local starch could be used as a substitute for imported sample to control viscosity and fluid loss in water based drilling muds.
- Samples with highest amylose content and high water absorption capacity produced drilling fluid with higher viscosity and lower fluid loss.
- Further research on this on better quality control efforts to obtain reproducible results with local samples will open up a new market for non-food use of starches from cassava.
- It is also hoped that this work will open new market for non-food use of starches from cassava and thus expected to provide economic benefit to Nigerian farmers and a way forward to actualize vision 20-2020 agenda.

4.1.6 Development of antifoam additive for cementing and gelling agents for pipeline de-oiling and pigging operations (Ensta/Pocema Tech bulletin, 2012).

POCEMA in collaboration with ENSTA has developed:

- A fit for purpose antifoam additive for both conventional and gas wells.
- Gelling agents for pipeline de-oiling and pigging.

These products have been applied successfully for field applications in Nigeria.

4.2 My Contributions to Design and Applications of Oilfield Fluid Systems for Drilling, Cementing and Production Enhancement Operations

Have handled about 3000 drilling and cementing projects. The projects were for most of the oil companies that are operating in Nigeria(Chevron, Texaco, Total, SPDC, Conoil, Agip, Mobil, Addax, Snepco). Job and slurry design ranged from surface casing, intermediate and production casing jobs for land, swamp and offshore locations with low temperature and high temperature wells with gas migration potentials. Job designs and execution were highly successful with high service quality delivery.

Also about 500 stimulation/production enhancement fluids design was undertaken. The scope ranged from matrix acidizing ,gravel pack and hydraulic fracturing jobs. Laboratory design and testing focused on gel hydration, break test, sand settling, scale analysis among others.

Among the research and papers published in these areas include.

4.2.1. The Secondary Effects of Lingo sulfonate Cement Retarder on Cement Slurry Properties (Joel, 2009).

4.2.2. Performance Evaluation of Low Density Bentonite and Econolite Cement Slurries (Joel and Ujile, 2009).

4.2.3 Identification Of Formation Scales And Designing of Compatible Matrix Acidizing Fluid Systems(Joel and Ajienka, 2009).

4.2.4. Overview of Raw Materials for Oil Field Chemicals and Nigerian Content Development. (Joel and Ajienka, 2009; Joel and Ujile, 2011).

4.2.5 Performance Evaluation of Spacer Formulation for Efficient Mud Removal and Better Cement Bond (Joel and Ujile, 2010).

4.2.6 Modeling of Cement Thickening time at high Temperatures with different retarder concentrations (Joel and Umeokafor, 2010).

4.2.7 Evaluating the Performance of Cement Slurry properties at low temperature. (Joel and Ujile, 2010):

4.2.8. Special Consideration in Designing of Cement Slurry for HPHT Oil and Gas Wells(Joel and Ikiensikimama, 2010).

4.2.9 Comparative Study of Lignosulfonates and Synthetic Retarders on Cement Thickening Time and Compressive Strength (Joel and Anyanwu, 2011).

4.2.10. Modeling of Compressive Strength of Cement Slurry at Different Slurry Weights and Temperatures (Joel and Ademiluyi, 2011):

- 4.2.11. Foam Cementing Design and Application: A cure for low gradient-associated problems in deepwater operations in the Gulf of Guinea** (Joel and Oyetade, 2011)
- 4.2.12. Advances in Mud Design and Challenges in HPHT Wells** (Woha, Joel and Oriji, 2011).
- 4.2.13. Challenges and Remedy for Cementing of HPHT Wells in Nigerian Operation** (Joel and Shado, 2011).
- 4.2.14. Modeling of Rheological Properties of Drilling Fluids for Ultra High Temperature (HPHT) oil and Gas Wells** (Oriji, Joel and Dosumu, 2011).
- 4.2.15. Causes and Preventive Management of Scale Formation in Oilfield Systems** (Joel, Adesanya and Ajienka, 2011).
- 4.2.16. Modeling Gel Break-Time in Gravel Pack Fluids as a Function of Breaker and Activator Concentrations with Temperature** (Akonye and Joel, 2012).
- 4.2.17. Effect of Cement Contamination on Some properties of Drilling Mud** (Joel, Ndubuisi and IKeh, 2012).
- 4.2.18. Evaluation of Effect of Different Concentrations of Shale on Rheological Properties of Water-based Mud** (Joel, Durueke and Nwokoye, 2012)
- 4.2.19. Accurate Estimation of Equivalent Circulating Density during High Pressure High Temperature (HPHT) Drilling Operations** (Ataga, Joel and Oriji, 2012).

4.2.20: Identification of Formation Scale and Modeling of Treatment Fluid (Azeta, Joel and Kinigoma, 2012):

4.2.21: Effect of KCl on Rheological Properties Of Shale Contaminated Water - Based Mud (WBM)(Joel, Durueke and Nwokoye,2012)

4.2.22. Modeling Break Time on Gravel Pack Fluid at Different Breaker Concentrations and Temperatures (Joel, Ademiluyi and Iyalla (2009).

4.2.23. Evaluating the performance of fracturing fluid for break time at different temperatures and breaker concentrations(Joel and Ajienka (2009)

Generally speaking, creating a fracture in a hydrocarbon-bearing formation requires a complex suite of materials. In the case of conventional fracturing treatments, four or five principal components are required: (1) a carrier fluid (usually water or brine), (2) a polymer, (3) a cross-linker, (4) a proppant, and (5) optionally a breaker.

The challenge in gravel pack and fracturing job execution is to design an economical fluid that easily and safely transports the required proppant into the fracture. The fluid must then break and be recovered from the fracture, allowing the proppant pack to produce unimpeded by the placement fluid. The effect of gel breakers on 60lbs/Mgals gravel pack fluid system at test temperatures of 168°F and 178°F with breaker concentrations of 10gal/Mgal respectively was investigated. Tests conducted among others were, gel hydration and gel break tests.

Table4.13: Gel Formulation for 60lbs/Mgal

S/N	CHEMICAL	CONCENTRATION
1.	Fresh Water (Mix Water)	1000gal/Mgal
2.	Biocide-1(short time)	0.15lb/gal
3.	Biocide-2(long time)	0.15lb/Mgal
4.	Gelling agent	60lb/Mgal
5.	Iron reducing agent	8lbs/Mgal
6.	pH adjuster	20lbs/Mgal
7.	KCL (Clay stabilizer)	3%
8.	Gel Breaker	10gal/Mgal



Hydrated gel



crossed linked gel

Table 4.14: Break Test for 60lbs/Mgal Gel with 10 gal/Mgal Breakers @ 168°F:

TIME (MINS)	300 rpm (cp)	200 rpm (cp)	100 rpm (cp)	6 rpm (cp)	3 rpm (cp)
0	50	46	36	24	20
30	46	42	34	22	18
60	44	40	32	20	16
90	42	38	30	18	14
120	40	36	30	16	14
150	40	36	30	16	12
180	38	34	30	14	12
210	36	32	28	14	12
240	34	30	26	14	12
270	32	28	24	14	12
300	30	26	22	14	10
330	28	24	18	12	10
360	26	22	16	12	10
390	24	20	14	10	8
420	22	18	12	8	6
450	18	14	10	6	4
480	16	14	10	6	4
510	14	12	8	4	2
540	12	10	6	4	2
590	10	8	6	4	2

BREAK TIME: 09:30 HRS: MIN

Table 4.15: Break Test for 60LBS/MGAL Gel with 10 gal/Mgal Breaker @ 178°F

TIME (MINS)	300 rpm (cp)	200 rpm (cp)	100 rpm (cp)	6 rpm (cp)	3 rpm (cp)
0	50	46	36	24	20
30	46	42	34	22	18
60	42	38	32	20	16
90	40	36	30	18	14
120	38	34	30	16	12
150	36	32	28	14	12
180	34	30	24	12	10
210	32	28	22	10	8
240	30	26	20	14	10
270	24	20	14	10	8
300	18	14	12	8	6
330	14	12	8	6	4
360	12	10	8	4	2
390	10	8	4	2	2

BREAK TIME: 06:30 HRS: MIN

The Gel hydration is pH sensitive and the various chemicals must follow a sequence to ensure proper gel hydration. Before adding the salt, the water must be brought down to a pH of (2-3). This is to ensure that the iron in the water does not precipitate as well as to avoid the formation of fish eyes when the salt is added. After dissolving the salt, the mixture must be raised to a pH of 7-8. The gelling material (HEC) hydrates in basic medium.

The gel is considered broken when viscosity of 10cp or less is obtained for 300rpm dial reading of Fann Viscometer. At a temperature of 168°F, the break-time for 10gal/Mgal breaker was 9hours: 30mins and at 178°F with same breaker

concentration, the break-time was 6hours: 30mins. Test results with lower temperature and breaker concentrations respectively had longer break time than test at higher temperature and concentration of breaker (**Tables 4.14-.15**).

Test results indicated that break time is a function of temperature and breaker concentration, at a higher temperature and breaker concentration respectively, the gel break were faster and vice-versa .The work established a fluid system with optimum sand transport and break time at different temperatures.

The fluid system as indicated in this project had been successfully implemented in the field for gravel pack operations in the Niger Delta of Nigeria.

4.3. MY CONTRIBUTIONS TO EVALUATION OF ECO-TOXICITY OF CHEMICALS

With thousands of chemical compounds and elements being discharged into the environment daily from oil industry related activities, there is potential threat from effluents that contain a number of seemingly harmless chemical products that could have deleterious or indeed synergistic effect with one another when mixed.

The purpose of the study is to investigate the effects of different concentrations of chemicals on aquatic organisms in order to find out when these concentrations reach dangerous levels. The practical approach adopted in this work will result in a better understanding of the concept and basic methods of effluent toxicity testing which is an invaluable tool used to protect one of our most precious resources—clean water. Test results validated the age long theory that “**the most important**

factor that determines the effect of any substance is the dose-time relationship”.

Toxicology is the study of the adverse effect of chemicals or physical agents on living organisms. Because of the boundary conditions that create a bottle neck in determining the adverse effect of these chemicals, the most effective method to gauge effluent toxicity is to perform an effluent toxicity test that uses aquatic organisms as indicators of toxicity. A small, developing organism is an ideal model system for testing effluent toxicity. The developing organism exhibits rapid growth and sensitivity to the toxic material. Such tests are used in laboratories to ascertain the concentration of an effluent, usually expressed as a percent volume, which is lethal to 50% of the test organisms that are subjected to the effluent for a predetermined time period. This value is expressed as the Lethal Concentration 50 or the LC₅₀.

The chemical analysis of an effluent cannot by itself predict its potential toxic effect. Many toxic pollutants cannot be detected by commonly available chemical analysis methods. The toxicity of many chemicals is unknown even when they can be detected. Different chemicals combined together in the same effluent can have unknown additive effects even when the toxicity of each individual chemical is well-known (Randall, 1999; Joel and Amajuoyi, 2009).

Toxicity tests are used to evaluate the concentrations of the chemical and the duration of exposure required to produce the criterion effect. Apparently, aquatic toxicity tests are used in detecting and evaluating the potential toxicological effects of chemicals (Okpokwasili and Odokuma, 1994) on aquatic organisms (Franklin, 1973). Toxicity tests became desirable in chemical quality evaluations as a consequence of the inability of

the physical and chemical tests alone to sufficiently assess the potential effect on aquatic biota (Powell *et al.*, 1985). Furthermore, chemicals which by themselves would have been harmless may cause deleterious/synergistic effects by interacting in the general milieu of contaminated waters (Kingham, 1981). Our environment has been continuously subjected to the upstream activities of numerous petroleum based Industries. In most cases, the aquatic environments are the ultimate receivers of spill and other discharges. Most petroleum industries utilize various types of chemicals, which include low toxicity base oil, oil based mud system, drilling fluid, dispersants (Oyemo, 1986), and other chemicals as measure of drilling, reclamation and remediation.

The effect of any substance is dependent on a number of factors. The most important factor is the dose-time relationship. Dose is the quantity of a substance that a surface, plant, or animal is exposed to. Time means how often the exposure occurs. Thus, the dose- time relationship is how much of the substance is involved and how often the exposure to the substance occurs. This relationship gives rise to two different types of toxicity studies that applicators must know and understand. They are acute and chronic toxicity studies (Dede and Dogara, 2004; Dede, *et al.*, 2002).

Fresh water fish *Tilapia guineensis* were collected from Mmiri azu ulo at Ohanso village near Akwete in Abia State. The fish were caught using nets at spring tide and were immediately transferred into 10L coolers containing the habitat water (APHA, 1998,DPR 2002). Juveniles were collected because of their small size and sensitivity to toxicants.



Fig4.19: Fresh water fish, *Tilapia guineensis*

Brackish water juvenile shrimp, *Palaemonetes africanus* were collected from the brackish water at Eagle Island Waterside, Port Harcourt. Juvenile shrimps were collected with the aid of sieves of appropriate mesh size during spring tide. They were transferred into 10L coolers containing the habitat water (APHA, 1998).



Fig 4.20: Brackish water shrimp, *Palaemonetes africanus*

ACCLIMATIZATION

All test organisms were first acclimatized for ten days at room temperature $28 \pm 2^{\circ}\text{C}$. They were acclimatized in dark glass tanks in which air (oxygen) was continuously bubbled into, through an aerator. They were also fed with fish feed obtained from the Institute of Fisheries at Aluu near University of Port

Harcourt during the period of analysis. The water in the acclimatization units was replaced with the fresh water from the organism's habitat daily. There was controlled lighting system, as 12hours of light and 12hours of darkness was employed.



Fig 4.21: Accimatization of Test Organisms with an Aerator Pump

Selection of Test Organism:

Twenty test organisms of fairly equal size were randomly caught with a hand net from acclimatization tanks and carefully transferred into the test vessel. The organisms were not touched with hand during the selection so as to avoid stress due to handling. Only healthy and active test organisms were selected.

Test Medium:

Five different concentrations of the test sample (10mg/l, 100mg/l, 1000mg/l, 10, 000mg/l) were prepared using habitat water of the particular organism as diluent. This followed after a preliminary range finding test. Similar concentrations of crude oil (Bonny light), crude oil and test sample mixture (1:1), and a reference chemical, sodium lauryl sulphate (SLS) were also prepared using habitat water of the particular organism. . The corresponding aliquots were added to the test vessels

constructed of glass. The aliquots were first stirred for 5mins and subsequently at 8 hourly intervals.



Fig 4.22: Laboratory Personnel undertaking Aeration of Test Vessels during Testing Period

Twenty test organisms were used in each concentration. Healthy, active test organisms were carefully introduced into bioassay vessels representing different concentrations. Controls containing dilution water, and twenty test organisms were prepared without the toxicant and this served as the control. Each of the test concentrations was labeled appropriately. After each day, the media were replaced with fresh one. Dead organisms were also removed at the end of each exposure period. This was done to avoid contamination of live organisms by bacteria from dead decaying organisms. Mortality was recorded at 4, 8, 24, 48, 72 and 96 hour exposure periods (Finney, 1978 and Sprague, 1973).

RANGE FINDING TEST:

Range Finding Test was carried out to establish a preliminary working range by obtaining the least concentration that gives no effect and the minimum concentration that gives 100% death.

Test design incorporated multiple, widely spaced concentrations with single replicates. Exposure times were 4hr., 8hr., 24hr., and 48hr.

Test results of analysis of test chemical, test chemical and crude oil (1:1) mixture, crude oil alone and a reference chemical (SLS) alone and range finding test of the test chemical were indicated below:

Table 4.16: Some Physicochemical Characteristics of Two Dilution Water Types

PARAMETER	FRESHWATER	BRACKISH WATER
pH	5.50	7.20
TEMPERATURE (°C)	26.1	25.4
CONDUCTIVITY (mg/l)	158	3999
DISSOLVED OXYGEN (mg/l)	6.0	7.0
SALINITY (mg/l)	97.35	1359
ALKALINITY (mg/l)	17.1	1333.8
HARDNESS (mg/l)	20	80
TDS (mg/l)	29	2000

Table 4.17: Dose-time effect of test chemical and crude oil for Freshwater Habitat

Concentrations (m)	% Mortality				
	10	100	1000	10000	100000
4 Hours	0	0	0	10	100
24 Hours	0	0	5	80	100
48 Hours	0	15	15	100	100
96 Hours	0	20	20	100	100

Table 4.18: Dose-time effect of test chemical and crude oil for Brackish

water Habitat

	% Mortality				
Concentrations (mg/l)	10	100	1000	10000	100000
4 Hours	0	0	25	80	100
24 Hours	0	50	100	100	100
48 Hours	0	50	100	100	100
96 Hours	0	55	100	100	100

Table 4.19: Dose-Time Effect of Crude Oil Only for Freshwater Habitat

	% Mortality				
Concentrations (mg/l)	10	100	1000	10000	100000
4 Hours	0	0	0	0	100
24 Hours	0	0	5	65	100
48 Hours	10	10	30	100	100
96 Hours	20	25	45	100	100

Table 4.20: Dose-Time Effect of Crude Oil Only for Brackish water Habitat

	% Mortality				
Concentrations (mg/l)	10	100	1000	10000	100000
4 Hours	0	55	90	95	100
24 Hours	0	80	100	100	100
48 Hours	0	90	100	100	100
96 Hours	0	95	100	100	100

Table 4.21: Dose-Time Effect of SLS Only for Fresh water Habitat

	% Mortality				
Concentrations (mg/l)	10	100	1000	10000	100000
4 Hours	0	0	0	0	0
24 Hours	0	0	0	0	0
48 Hours	0	0	0	0	0
96 Hours	0	0	0	0	0

Table 4.22: Dose-Time Effect of SLS Only for Brackish water Habitat

Concentrations (mg/l)	% Mortality				
	10	100	1000	10000	100000
4 Hours	0	0	0	0	100
24 Hours	0	0	0	100	100
48 Hours	0	0	0	100	100
96 Hours	0	15	25	100	100

- The range finding test of the test chemical alone produced no deleterious effect on the organisms for fresh aquatic habitats as no death was recorded with respect to time.
- Dose-time synergistic effect of the test chemical and crude oil on the receiving water body resulted to increase in mortality rate of the organisms for both freshwater and brackish water habitat (**Table 4.17-.18**).
- Dose - time effect indicated that the brackish water juvenile shrimp, *Palaemonetes africanus* were more sensitive to the mixture of test chemical and crude oil (**Table4.18**). Hence, at 4Hr interval, more deaths were recorded for the brackish water organisms. This could be attributed to the physicochemical constituents of the receiving environment (**Table4.16**).

The acute toxicity test results indicated that the freshwater was less sensitive than the brackish water environments to the test chemical when applied alone (**table4.21 and 4.22**).

The physicochemical constituents of the receiving environment also played a major role in determining the mortality rate of the aquatic organisms. The mortality rate was higher in the brackish water habitat than the fresh water habitat in all the concentrations tested.

The semi- static bioassay affirmed that the higher the concentration of the test chemical and crude oil with time, the higher the % mortality recorded.

This research work will make for a better understanding of the concept of basic methods of chemical toxicity testing and as well has validated the age long theory that “the most important factor that determines the effect of any substance is the dose – time relationship.

4.4 MY CONTRIBUTIONS IN ENVIRONMENTAL RESEARCH RELATED TO MANAGEMENT OF PETROLEUM INDUSTRY OPERATIONS

4.4.1 Effective remediation of drilling waste using solidification process

At the inception of oil exploitation activities in Nigeria, little emphasis was placed on the safety of the operational environment. This was made manifest in the indiscriminate disposal of drilling wastes (sludge) such as drilling mud, cuttings and fluids and other effluents into un-engineered pits without any form of treatment. This insensitive act has caused serious pollution of the environment with its associated health hazards to man and animals.

Used oil and drill cuttings applied to land, through percolation and run-off into ground and surface waters, poses an environmental hazard. It may also render the soil unproductive, depending upon the rate of application and characteristics of the soil surface and subsequently contaminate groundwater supplies (Mueller Associates Inc. 1987). In this wise, not only the quality of soil is affected, but also plants and the living beings

that rely on these plants. The groundwater quality could be affected as well; thus the safety of drinking water could become a serious problem. Heavy metals, such as lead, cadmium, arsenic, chromium in the oil can accumulate in soil. Thus inhibiting the growth of plants on this contaminated soil. When people eat the food made of these plants, the heavy metals can accumulate in our bodies causing poisoning of the body systems.

Thus treatment or remediation has been the panacea. Literature review process reveals that a variety of treatment methods have been tried in a bid to convert toxic liquids and sludge/ cuttings into harmless solid material (Ifeadi, 1986). However, solidification is been conceived as a veritable technique of contending with the nuisance of oil sludge. In the solidification mechanism, contaminants are physically bond within a stabilized mass and chemical reactions are induced between the stabilizing agents and the contaminants, thus reducing their mobility and toxicity of the hazardous constituents.

The use of solidification in the treatment of hazardous waste is not a cakewalk; the environmental engineers need a proper understanding of the process in order to choose the most effective solutions to their particular applications (Bolsing, 1994). It is against the backdrop that project examines the effectiveness of solidification in the remediation of sludge polluted solid phase.

Site investigation was conducted to determine the extent of soil contamination. Pilot test was therefore undertaken to determine the composition of the sludge and thereby design an optimum ratio of the sludge and stabilizing reagent to transform

the material so that the hazardous constituents are in their least mobile or toxic form.

DESIGN CONCEPT:

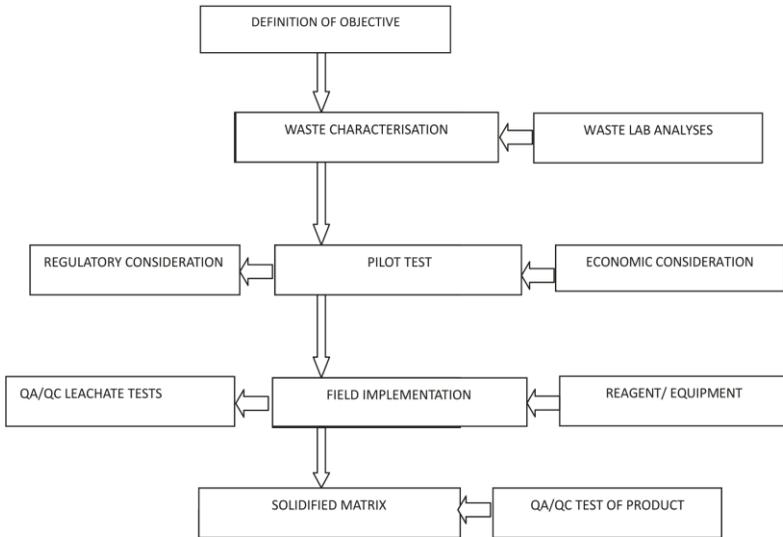


Fig 4.23: Preliminary Design Concept

The following were undertaken in course of field job execution (Joel and Akinde, 2010).

- Collected samples and obtained initial lab test analysis of sludge to have an idea of the composition of the sludge stream.
- Conducted pilot tests to determine the most cost-effective and optimum combinations for the

solidification/stabilization agents that will meet the design objectives.

- Conducted additional lab analysis for the recommended package in order to determine the effectiveness of the treatment /remediation design.
- The laboratory testing programs provided the basic guidance for planning the field job and execution.

EFFECTIVENESS OF TREATMENT

The effectiveness of any treatment procedure is of course defined by the residues of contaminant that remained after such treatment. Such definition may be in terms of percentage of contaminant removed or as a residual concentration. Before embarking on a plant design, a full appraisal of the chemical process options and their relative efficacies must be made from underlying theoretical principles. This will provide the basis for establishing the processes likely to be most effective; but best procedure in terms of result and cost will only be found by experimental trial, and this may extend into full scale design (Sittig, 1981).

The results of the tests conducted are presented in tables 4.19 and 4.20 respectively below:

Table 4.23: Comparison between Sludge Result and Solidified Sample Result

PARAMETER	OIL/GREASE	BARIUM	REMARK
SLUDGE SAMPLE	200mg/l	517.2mg/l	Not Acceptable
SOLIDIFIED SAMPLE	40mg/l	1.235mg/l	Acceptable

Table 4.24: Results of Physicochemical Parameters

S/N	PARAMETERS	UNIT	A	B	DPR LIMIT	REMARKS
1.	COMPRESSIVE STRENGTH	PSI	194 @ 6 Days	582 @ 6 Days	>20	ACCEPTABLE
2.	PERMEABILITY	cm/sec	3.2×10^{-7}	3.77×10^{-8}	$\leq 1 \times 10^{-6}$	ACCEPTABLE
3.	WET/DRY DURABILITY	Cycles to failure	Wt variation was constant after 10 cycles	Wt. variation was constant after 10 cycles	≥ 10	ACCEPTABLE
4.	MOISTURE CONTENT	%	6.4	3.4	≤ 50	ACCEPTABLE
5.	pH		6.85	6.80	6.5-9.0	ACCEPTABLE
6.	ELECTRICAL CONDUCTIVITY	mmhos/cm	2.121	2.717	8	ACCEPTABLE
7.	SAR		6.46	3.43	12	ACCEPTABLE
8.	OIL & GREASE	mg/l	68.8	59.4	100	ACCEPTABLE
9.	CHLORIDES	mg/l	725	740	5000	ACCEPTABLE
10.	ARSENIC	mg/l	0.035	<0.001	5	ACCEPTABLE
11.	BARIUM	mg/l	1.235	0.896	100	ACCEPTABLE
12.	CADMIUM	mg/l	<0.001	<0.001	1	ACCEPTABLE
13.	CHROMIUM (TOTAL)	mg/l	0.28	0.11	5	ACCEPTABLE
14.	LEAD	mg/l	0.15	0.09	5	ACCEPTABLE
15.	MERCURY	mg/l	<0.001	<0.001	0.2	ACCEPTABLE
16.	SELENIUM	mg/l	0.096	0.129	1	ACCEPTABLE
17.	SILVER	mg/l	0.036	0.024	5	ACCEPTABLE
18.	ZINC	mg/l	3.90	3.80	50	ACCEPTABLE



Fig4.25a: Sludge sample from Pit conducted before solidification.



Fig4.25b: Series of pilot tests before recommendation.



Fig4.25c: Sample after solidification



Fig4.25d: Stabilized/solidified sample used for leachate and compressive strength tests.



Fig4.25e: Sample after field job execution and solidification

Test results (Table4.23) of original sludge composition indicated that among other parameters, oil and grease as well as barium had values above limits specified by regulatory agencies. This validated findings from previous work on sludge pits which showed that oil dump sites typically contain toxicants concentrations that pose a hazard to human health and the environment. However, a prudent design for effective treatment technique could provide a means of stabilizing the sludge and reduce the contaminants so that the hazardous constituents are in their least mobile and toxic form.

As evident in test results (Table 4.24), the treatment adopted was able to reduce the contaminants (oil and grease and barium) to acceptable level. Moreover, an unconfined compressive strength of more than 500psi at five days was obtained.

The field job execution arising from laboratory pilot test recommendation was successful. The physicochemical parameters, heavy metals and compressive strength (Table4.19) showed that solidified blocks obtained (Fig4.25a to 25e) can safely be disposed in landfill without health and environmental hazards.

Test results indicated that the oil and grease concentration from the original sludge sample was reduced from 200mg/l to 40mg/l, Barium was also reduced from 517.2mg/l to 1.235mg/l after solidification and unconfined compressive strength of over 500psi in 6days was obtained. Field job execution using laboratory pilot test specification resulted in solidified blocks using the sludge and cement as a binding agent. All test results after treatment were within the acceptable limit specified by the regulatory body (Nigerian Department of Petroleum Resources) for landfill disposal.

Solidification process, therefore, could be used as effective remediation technique for oil/sludge polluted soils.

4.4.2 CREATING WEALTH FROM WASTE: CASE OF USED OIL MANAGEMENT IN NIGERIA

Oil is a potential hazardous material capable of contaminating soil, underground and surface water. One litre of oil released into the environment can pollute 41,500,000 litres of fresh water enough to supply 50 people for a whole year. In Nigeria, little, if any data are available in the country on the quantities of used oil being generated, handling and disposal practices. A study of using recycling of used lube-oil as method of pollution control was conducted. This was done by first conducting analysis of used lubricating oil from different vehicles. In the course of this investigation, used lubricating oil was subjected to different treatment methods and characteristic parameters were determined for both used and treated oils and compared with characteristic parameters of typical commercial unused lubricating oil. Experimental results indicated that result from the use of glass beads was more feasible, has low operating potential hazards and most effective in pollutant reduction compared with others. Comparative study of Nigeria used oil management system with USA was undertaken and way forward recommended. This project was undertaken to proffer solution on how to efficiently manage used oil in the country for profitable and environmental sustainability. For effective implementation, pro-active Government policies need to focus attention on the demand side of the regulation. Generators and collectors should be paid for used oil supplied for processing; this will encourage active participation and make for a win-win business. Feasibility study showed that it is cost effective and

profitable to invest in this project and the country stands to conserve over one hundred billion naira per annum if implemented (Joel and Ovuru (2000), Joel (2002), Joel (2004), Joel and Ovuru (2009), Joel and Mmom (2009)).

MOTIVATION FOR RESEARCH

- Nigeria is about the 6th largest producer of Crude oil in the World and in recent times averages about 600,000,000 litres yearly of total consumption of lubricating oil.
- Significant quantities of these used lube oil are wastefully disposed in the country by means, which pollute the water, land and air, and in turn endanger the public health.
- Research have shown that recycling of used lube oil is a desirable method of controlling pollution and helps to protect the environment, demonstrates a commitment to proper waste management and lessens the demand on our natural resources
- Effective used Oil management in the country will help to meet up with the long-term challenge to manage all materials to minimize waste, conserve resources, and enhance economic opportunities and make for sustainable development.

RECYCLING OF USED OIL

- Therefore, recycling of used oil entails acquisition and processing of oil that has become unsuitable for its intended use in order to regain useful material.
- In this recycling process, a number of stages are possible depending on original source of the used oil, the level of contamination, and the sophistication of the technology utilized
- It is not “waste oil”, but it is a recoverable, recyclable resource. Oil doesn’t wear out; it just gets dirty.

- Used Lube oil can be re-refined into lubricating oil that is equal in quality to lubricating oil made from crude oil. Used oil include engine, turbine or gear lubricating oils, Hydraulic transmission fluid, metal working fluids used in cutting, grinding, machining, rolling, stamping and coating.
- In general, the earlier in the life of a lubricant that it is exposed to recycling technology, the easier the job and the better the results.
- Among the commonly used physical methods are settling, filtration, centrifugation, and in some cases, thermal processing for removal of light ends and water.

RECYCLING TECHNOLOGIES IN ADVANCED COUNTRIES

- The re-refining industry is not new; it is a well proven technology. It has been in existence since the early 1900s in Europe, where the primary impetus for recovery and reclamation was the low supply of local crude oil and the high cost of imported crude oil. In the United States, the re-refining of used oil dates back to the World War 1, when
 - Re-refined oil was successfully used in military aircraft. With renewed interest during World war 11, the industry prospered and grew rapidly during the 1940s and 1950s.
 - By 1960, the industry contained approximately 150 re-refineries producing about 300 million gal of re-refined oil or almost 18% of the U.S. lubricating needs
 - Already, market demand has increased significantly. The 1993 presidential executive order mandated federal procurement of re-refined lube oil, with a minimum used oil content of 25%.

- This definitely will be a step in the right direction for Nigeria to follow.

PROPOSED USED LUBE OIL MANAGEMENT SYSTEM IN NIGERIA

According to National Database petroleum products consumption, the total domestic consumption of lubricating oils in 1996 was 364, 106,000 liters (PPMC, 1990 - 2004). Unfortunately, there is no record of how the used lube oil was managed. This would be attributed to the unstructured nature of disposal and lack of governmental regulation requiring dissemination of the data on used oil collection, handling and disposal practices.

As shown in (Fig4.23) the system encompasses the flows of used oil, ranging from generation, through collection and processing, to end-use. In general, the system shows that used oil generated by automotive and industrial generators is either dumped or used on site, or gathered by collectors, who then act as suppliers to reclaiming facilities or fuel oil dealers.

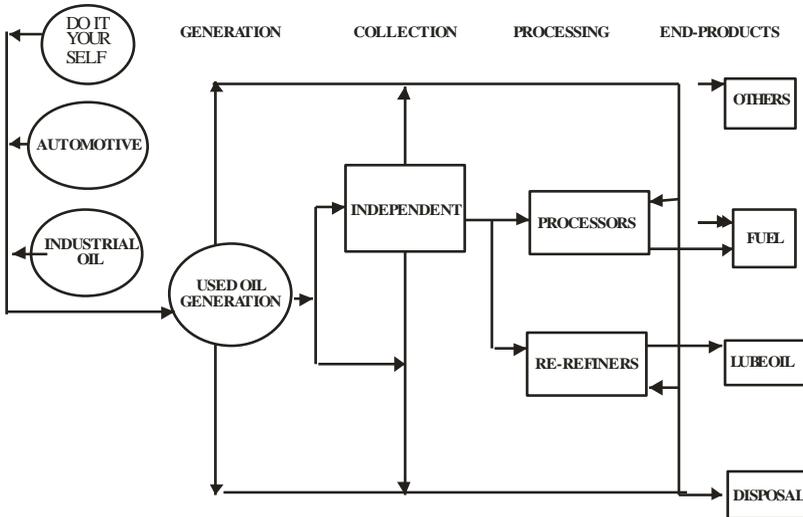


Fig 4.26: Proposed Used Lube Oil Management System in Nigeria:

- Service stations or collection centres should be established through approved agents to collect the used oil from generators and in turn hand over to processors.
- A good number of them should be government and industry sponsored.
- Generators and Collectors should be paid for used oil supplied for processing; this will encourage active participation and make for a win-win business
- Research findings have shown that recycling of used lube oil is desirable method of controlling pollution of the environment, demonstrates a commitment to proper waste management, reduction in the demand on our natural resources and enhance economic opportunities.

For effective implementation and optimization of the Used Lube Oil Management System in Nigeria, the following are recommended:

- Set up collection Centers in almost all the state capitals and major cities.
- Set up processing Centers in three zones namely Kaduna, Port Harcourt and Lagos.
- Kaduna to serve as processing centre for collected used lube oil from the Northern Zone and part to be supplied to the Kaduna refinery for re-refining.
- Port Harcourt to serve as a processing centre for used Lube oil collected from the Eastern Zone. This could be accomplished by establishing lubricants blending facilities.
- Lagos to serve as a processing centre for used oil collected from the Western Zone, moreover a re-refining plant to be established in Lagos.

4.5 MY OTHER CONTRIBUTIONS OF RESEARCH AND PUBLISHED WORK RELATED TO SUSTAINABLE ENVIRONMENTAL MANAGEMENT AND POLLUTION CONTROL

- 4.5.1 **Effects of nutrient and aeration on the remediation of crude oil polluted solid phase environment** (Wami, Rotifa and Joel,2009).
- 4.5.2 **Determination of Selected Physico-chemical Parameters and Heavy Metals in a Drilling Cutting Dump Site** (Joel and Amajuoyi, 2009).

- 4.5.3 **Modeling of Rate Constant for Biotransformation of Oil Contaminated Solid Phase Environment**, (Wami, Rotifa and Joel, 2009).
- 4.5.4 **Determination of Some Physico-chemical and Microbiological Characteristics of Sewage Samples from Domestic, House-Boat and Offshore Facilities Discharge Points**(Joel,Nwokoye and Akinde, 2009).
- 4.5.5 **Assessment of the Levels of Soil and Water Pollutants at an Oil Pipeline Spillage Site in the Niger Delta, Nigeria** (Joel, and Sunday2009).
- 4.5.6 **Evaluation of Acute Toxicity Effects of Iron on the Brackish water Shrimp- *Palaemonetes africanus***, Int. J. Natural & Appl Sci., 3(3) 198-203(Joel and Amajuoyi,2009).
- 4.5.7 **Comparative study of the acute toxicity of kerosene, crude oil and diesel on a brackish water shrimp- JNSChE, vol. 25(1&2) 86-93**(Joel, Nwokoye and Amajuoyi,2010):
- 4.5.8 **Evaluation of physico-chemical and metal levels from Gulf of Guinea offshore location** (Joel and Akinde, 2009; Joel and Akinde, 2012)
- 4.5.9 **Characterization of formation water constituents and fresh water dilution effect- a case study of Niger delta, Nigerian land rig location**(Joel, Amajuoyi and Nwokoye, 2010).

4.5.10 Treatment and disposal of oil contaminated soil using (TDU)(Agbor and Joel, 2010).

4.5.11 Green Economy: Wake-up call for the government and oil Industries in Nigeria (Joel and Olajide, 2012)

4.5.12 Evaluating Waste Management in Nigeria: The Gaps and Way Forward) (Mkpaoro and Joel, 2012)

4.6 MY CONTRIBUTIONS IN TRAINING AND CERTIFICATION

The drive towards environmental sustainability has become a big issue and there is increasingly stringent legislation and concern by organizations to achieve sound environmental performance by controlling the impact of their activities products or services on the environment. Holistic approach in our environmental education that will make for win-win and manage the industry, technology and environment as allies instead of foes is needed. Advancing Environmental training upward and carrying all stakeholders along is crucial in attaining sound environmental management (Joel, 2007; Joel and Mmom, 2009).

There is need for training and retraining as a process of acquiring new skills required for development and transformation of a people to face challenges of their new roles. Apprenticeship programs had been identified as a tool for updating the old skills, acquiring new competences and improving understanding of basic principles of environmental management (Joel and Ugbebor, 2011). There are a lot of hazards associated with operations in the oil industry operation.

These hazards are multi-dimensional, and range from mechanical, chemical, biological, radioactive, and environmental among others. It is therefore imperative that organization must exhibit due diligence and efficient training programmes to identify, assess, and control these hazards as early as possible and implement action plans to minimize or eliminate the environmental impacts.

For more than eight years , have been African Regional Representative for National Registry of Environmental Professional (NREP, USA).

Through my effort as African Regional Representative for National Registry of Environmental (NREP,USA), about 700 candidates have been certified as Environmental professionals and laboratory technologists. Institute of petroleum Studies, Centre of Occupational Health, Safety and Environment, Centre of Geosciences and SSLT students of Uniport are beneficiaries among others.

**SPECIAL AWARD TO DISTINGUISHED NREP
GLOBAL PROFESSIONALS**



Fig 4.27a: Students of Institute of Petroleum Studies, Uniport after their training session in the lab



Fig 4.27b Special training/ certification session for SSLT Students from Uniport



Fig 4.28: A cross section of students taking the NREP Certification Exams, in Abuja, Nigeria, May, 2008.

INTERNATIONAL AWARDS OF EXCELLENCE



4.7 OTHER NOTABLE ACCOMPLISHMENTS

- a) Designed and set up cold testing of cement slurries for deep water operations
- b) Developed 10 liquid additives for offshore operations cement operations for Halliburton
- c) Consultant and trainer to NNPC
- d) Undertake waste management for NNPC

- e) Consultant and trainer to many companies on environmental management, drilling, cementing and production enhancement fluid designs and applications
- f) Managing Consultant and researcher on oil field chemicals to company's local producers.

5.0 CHALLENGES TOWARDS EFFECTIVE UTILIZATION OF LOCAL RAW MATERIALS AND IMPLEMENTATION OF LOCAL CONTENT

The challenges facing utilization of local materials and effective implementation of local content include among others

a) Lack of synergy between the academia and the industry

For effective local content drive that will make for home based technology, and win-win efforts, the industry and academia must come together and decide on what chemicals to research on. The present situation where there is lack of synergy between the universities and industry is a big set back towards fulfilling the local content implementation dream.

b) Lack of funding for research and development

No meaningful technological breakthrough can be realized without commitment to research and development. The funding of the research and development is not given consideration by the government and other stakeholders. Our laboratories and research centers have ceased to function; this in no small measure has affected actualizing the local content initiative.

c) Poor quality products

The oil industry is a high risk venture. The use of sub-standard products poses a big problem in the drilling and completion operations. Most of the locally made materials have poor quality and are inconsistent in performance. There is poor Quality control/quality assurance (QA/QC) efforts and the materials cannot perform as expected. This, therefore, creates doubt on the ability of the local products to compete with imported ones. To restore confidence in the mind of the operators, stringent QA/QC efforts and efficient production processes must be put in place to address these concerns.

d) Lack of patronage for local made materials

Most operators and the majority of people have poor perception of locally made materials. Despite efforts to enhance the quality of locally made chemicals, most local investors who have taken great pains to develop products end up in frustration and hardly break-even because of lack of patronage and poor perception of the materials.

e) Poor communication network on progress

What one finds instead, are individual research workers in various locations scratching the surface in personally-funded research projects in order to make enough publications for promotion. This type of research which lacks co-ordination can hardly lead to meaningful development and progress.

5.1 ON GOING RESEARCH AND LOOK AHEAD

- a) Upgrading of Local Cement (Class A) to oil field(class G) cement standard
- b) Performance evaluation of local Bentonite for higher temperature operations for drilling and cementing operations
- c) Comparative study of local Barite with imported Barite for alternative use for drilling operations in Nigeria.
- d) Environmental and operational benefits of using synthetic mud as against oil-based/water-based mud.
- e) Study on efficient waste management of drilling and production waste streams
- f) Evaluation of Acute and Long –Term Toxicity Effect of selected Oil-well Chemicals on Aquatic Organisms and environment
- g) Developing of green chemicals for deployment in Nigerian oil operations
- h) Working with local producers of oil field chemicals to enhance their research capabilities and help them produce high quality products
- i) Establish a QA/QC Centre in collaboration with NCDMB to act as a clearing house and advisor to local manufacturers of oil field chemicals to make Uniport a research and Centre of excellence in oil field chemicals development.
- j) Liaising with other experts in the University to undertake a collaborative research that will provide a holistic answer to drilling, cementing, production/enhanced oil recovery operations.

- k) Partner with industry and investors to commercial products and deploy in field operations for the chemicals not yet introduced into the market.

5.2 CONCLUSION AND RECOMMENDATIONS

- a) Nigerian content is the quantum of composite value added or created in the Nigerian economy through the utilization of Nigerian human and material resources for the provision of goods and services to the petroleum industry within acceptable quality, health, safety and environmental standards in order to stimulate the development of indigenous capability
- b) One of the ways of creating jobs and actualizing the local content initiative is to ensure that some of the chemicals needed in the oil industry are produced in the country. We cannot talk of local content if all the chemicals we utilise are imported
- c) Almost all the chemicals in-use in oil field operations presently are imported, sad enough, most of these chemicals are available locally in commercial quantities, and could be sourced for use in oil field operations.
- d) Identification and utilization of local raw materials in drilling fluids, well completion and oilfield production chemicals will enhance Nigerian content development and stop capital flight

- e) Synergy among all the stakeholders and creation of enabling environment is a panacea for local content development of oil field chemicals.
- f) Efficient research efforts in raw material development will create Job opportunities to local industries and create more employment for nationals and enhance home base technology and research efforts
- g) The starting point of the local content policy drive with respect to raw material utilization will be to encourage and fund in-country researchers and manufacturers on local raw material development. This will be a win-win for the researchers and the oil industry, and definitely will create multiplier effect.
- h) A government sponsored chemical industrial complex needs to be set up to produce basic chemicals like caustic soda, soda ash, ammonia, sulphuric acid, etc. as they possess the potential not just to affect the oil industry but other sectors of the economy.

Vice Chancellor Sir, in my modest assessment of my stewardship and in the wisdom of the Senate to make me a Professor of the hidden treasure “Petroleum”, I will affirm that so far so good, I have paid my dues: I have provided bread on the table of many by being employer of labour, I have searched out the untapped wealth in our backyard, the “chemicals” and converted them to wealth and contributed to local content development, I have brought honour to the university through international awards and provided succor to students by offering

my company for industrial training. I have carried the gown to town and provided answers through consultancy to companies. What is more, I have been able to pay myself the wages the system could not pay me when I came in 2008; indeed, ***I am fulfilled and determined to do more.***

However, my concern today is that a lot of people are not aware of the untapped wealth in our backyard, which is the pathway to technological and local content development.

MAY THE good Lord open our eyes to the hidden riches in our backyard!!!!!!!!!!!!!!!, so that we do not perish in the midst of plenty

And god opened her eyes, and she saw a well of water; and she went, and filled the bottle with water, and gave the lad drink (gen 21:19)

Vice Chancellor Sir, may I then conclude this lecture by saying that there is enough for everyone to share, there is a hidden treasure in our backyard that can make this country great and achieve technological and local content breakthrough. The University of Port Harcourt will truly become an entrepreneur University if we reward performance adequately and engage in collaborative research on oilfield chemicals for local content development.

Thank you for your attention and God bless you.

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7.0 CITATION ON PROFESSOR JOEL, OGBONNA FRIDAY



B.Tech (RSUST), M.Sc (Benin), Ph.D (RSUST)

African Regional Representative for National Registry of Environmental Professional (NREP, USA).

The Vice Chancellor, Deputy Vice Chancellor (Administration), Deputy Vice Chancellor (Academics), Deputy Vice Chancellor (Research and Development), The Librarian, The Registrar, The Bursar, Provost of college of graduate School, Provost College of Medicine, Provosts of colleges, Deans of Schools of Graduate Studies, Deans of Faculties, Heads of Departments, Distinguished Professors and Colleagues, Ladies and Gentlemen.

I crave your indulgence to savour this particular honour and privilege to read the citation of our....Inaugural Lecturer, Professor Ogbonna Friday Joel of the Department of Petroleum and Gas Engineering.

Education

Born some few decades ago in Oberete Ibeme in Abia State, our lecturer started his education at Obete Ukwu Primary School, Ibeme Imo State in 1971. After his first School Leaving Certificate obtained in 1974 his next move was to Boys' Secondary School, Eziukwu, Aba, where in 1979 he obtained O level certificates GCE and WASC. Professor Ogbonna Joel then proceeded to the Rivers State University of Science and Technology in 1982 where he bagged a Bachelor of Technology in Chemical and Petro-Chemical Engineering degree (2nd Class Upper Division) in 1987. One may note that our Lecturer took the then Dean's Prize as the best graduating student of that set of 1987.

It was at this point Mr. Vice Chancellor that his long running romance with the oil and gas industry started. First of all he got engaged with laboratory operations in Halliburton – a world class oil servicing company. The comparative advantage he had over his peers (a fat salary and prestige) in no way doused his other blossoming love affair with higher academic pursuits. And so, he enrolled in the University of Benin in 1997 and later bagged a Master of Science degree in Engineering Management in 1999. His enthusiasm for still higher academic excellence was rewarded in 2003 with a PhD in Chemical/Petrochemical Engineering from the Rivers State University of Science and Technology. Then he really got married to research and development of human and natural resources in the field of laboratory technology with bias to petroleum engineering and environmental management.

Research experience

Since then our lecturer has had remarkably rewarding stints with some of the best oil and gas research laboratories in the world. Professor Ogbonna's research interests have been in drilling, cementing/stimulation fluid systems in addition to environmental management and pollution control. Such laboratories like the Duncan/Lafayette and Houston Laboratories of the Halliburton

Research Centre in USA and Environmental Technology training for the oil and gas industry – imperial college, London have played hosts to Prof. Ogbonna.

It is not out of place here to say that his background in these institutions obviously turned Engr. Joel Ogbonna into an enduringly active and productive academic-cum-industrialist par excellence.

Since he joined services of the University of Port Harcourt in 2008, “prolific” is not enough to describe his prowess in academia. With 15 local and international academic awards and honours on record; 74 publications in peer-reviewed international and national journals and proceedings (**within 3 years**), two academic textbooks; 19 local and international conferences attended; between 1995 and 2008 he had up to 42 certified on-the-job training sessions, three manuals and seven technical reports, you will agree with me that our lecturer has indeed had a productive career.

His devotion to duty, despite his very tight schedule as a dedicated lecturer, has seen him supervise many B. Sc, post HND, PGDPT and M. Sc./M. Eng students, and has certified over 700 candidates for Associate Environmental Professionals and Registered Environmental Specialists/Managers (as the African Regional Rep of the National Registry of Environmental Professionals NREP USA). Moreover, Mr. Vice Chancellor Sir, Professor Joel has been a Visiting/Industry Lecturer for Institute of Petroleum Studies, Uniport, Rivers State University of Science and Technology as well as University of the Witwatersrand, Johannesburg respectively. This has led to what one may describe as a high flying rise in his career as an academic.

Working Experience

As a young man Professor Ogbonna has been a Clerical Officer 1980-1981 with Obioma Ngwa Local Government area, Mgboko; Bank Clerk with First Bank Nigeria (1981-1982); Industrial Trainee in many companies including Gas Producers Nig Ltd PH, West African Glass Industry, Halliburton Ltd and Lever Brothers Ltd Aba between

1984 and 1986. After his mandatory youth service in Alari High School, Ogun State in 1988 he joined Alkem Nigeria Ltd Lagos between 1989 and 1990.

Engineer Ogbonna joined the University of Port Harcourt in 2008 at the Senior Lecturer level and was elevated to the coveted chair of Professor in 2011.

Industry Experience

In the industry, he has held many positions of trust in Halliburton including:

- Principal Scientist 2001-2002
- Technical Professional Manager 2002-2006
- Scientific Advisor 2006 – 2008
- Laboratory Trainee 1991 – 1999
- Laboratory Technologist/Chemist 1992-1998
- Managing Consultant and Environmental Advisor for POCEMA Ltd 2003

Administrative Experience

- While Professor Ogbonna is currently the Assistant Director of IPS Uniport (2010-date), he is also member Board of Trustees for Oil and Gas Trainers Association of Nigeria (OGTAN) (2009);
- Member University-Industry Partnership Committee (2010-date); Examiner, Petroleum Technology Development Fund (PTDF). Team member, Halliburton Global Laboratory Best Practices. (2003 – 2008)
- Team member, Halliburton Nigeria environmental and quality service delivery (2004)
- Member, Department of Petroleum and Gas DTLC Committee (2009)
- Member, COREN visitation readiness review team (2009)

- Deputy Director – Centre for Occupational Health, Safety and Env. IPS. Uniport (2010-
- Acting Director – Emerald Energy Institute (2013-)
- Zonal Leader – Deeper Life Bible Church.

Professional Membership/Certification

1. Member Nigerian Society of Chemical Engineers(MNSChE)- (2000)
2. Member Nigerian Society of Engineers(MNSE)-(2000)
3. Member Society of Petroleum Engineers(MSPE)-(2000)
4. Registered Environmental Professional(REP, NREP, USA)-(2001)
5. Member World Safety Organization (WSO), (2002)
6. Certified Safety Specialist(Environment Safety & Health (WSO) (2002)
7. Registered Professional Chemical Engineer with COREN-(2003)
8. Registered Environmental Manager(REM, NREP, USA)-(2005)
9. Member Nigerian Environmental Society(MNES)-(2007)
10. Registered Environmental Auditor(REA, NREP, USA)-(2008)

Professor Ogbonna Joel is also fully married to his lovely wife Mrs. Felicia Ogbonna and has prolifically produced four children Onyinyechi (18yrs), Chukwuemeka (16yrs), Ngozi (14yrs), and Chinemere (12yrs) whom we suppose has put a stamp of finality on this productive process.

Mr. Vice Chancellor Sir, Distinguished Ladies and Gentlemen, today we shall listen to the lecture entitled

“TAPPING THE UNTAPPED WEALTH IN OUR BACKYARD: PATHWAY TO LOCAL CONTENT DEVELOPMENT”

from a man

- ◆ who bestrides the academia and the industry, a Nigerian who dons the gown and goes to “town”
- ◆ *Member Society of Petroleum Engineers MSPE, Member Nigerian Society of Engineers MNSE, COREN certified Engineer, Member*

*Nigerian Society of Chemical Engineers MNSChE, Member,
World Safety Organisation WSO,*

- ◆ *Member Nigerian Environmental Society MNES, and Listed in the Marquis who is who in Science and Engineering -- the first Nigerian Technology Manager and Scientific Advisor in Halliburton Company.*
- ◆ *An educator, a technologist, an industrialist, a former banker, a former clerical officer, an Administrator, an academic and a family man*
- ◆ *A professor of Petroleum Engineering, Mr. VC Sir, Ladies and gentlemen, may I humbly introduce to you the inaugural lecturer Professor Ogbonna Friday Joel!!*

By

**Professor Gordian Obute
Orator**