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An Investigation of the Suitability of Drilling Fluids Formulation using Locally Sourced Materials

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***Abstract:** Based on the desire to contribute to local content initiative, laboratory investigations were carried out to determine the suitability of formulating drilling fluids using locally sourced materials. Locally sourced materials were used to formulate drilling mud and the properties evaluated and compared with those formulated using imported materials as well as the industry standard.*

While some of the drilling met the required industry standard, others need some minor treatments. Although, the drilling fluids formulated with imported materials tend be better, results showed that muds formulated using local materials compared favourably with the muds formulated using imported materials in terms of their compatibility with API mud weight, pH and viscosities specifications. The plots of viscosity against shear rates showed that increase in shear rate as well as decrease in the viscosities. Thus suggesting that the two mud systems have good hole cleaning properties hence they are good drilling fluids. Muds formulated using imported materials have higher viscosities. The Yield Point, Consistency Index, Yield Stress, Gel Strength and Marsh Funnel Viscosity results showed that they followed the same trends as the plastic viscosities. Muds formulated using local materials tends to age faster than muds formulated using imported materials. Therefore, for local muds samples to be used effectively, they should be given some little treatments.

***Keywords:** Local Content Initiative, Laboratory Investigations, Drilling Fluids, Industry Standard*

I. INTRODUCTION

Numerous authors have enumerated the importance of local content in the oil and gas sector. The objectives of Local Content Policies in the Oil and Gas Sector are laudable. The Local Content Act was enacted on April 22nd 2010. It provides a framework, for increased Nigerian participation in the Oil and Gas Industry. It prescribes minimum thresholds for Nigerian participation in activities within the industry through the utilization of Nigerian human and material resources and services in the upstream sector of the industry. This includes all activities, connected with the exploration, development, exploitation, transportation and sale of Nigerian crude oil and gas resources [1]–[3].

In order way, the term "local content" typically refers to the added value brought to a host country through the procurement of goods and services and local workforce development [4]. One of such goods or materials that can be sourced locally for use in oil field operations are the drilling fluids components.

According to . Neal [5]; Bourgoyne et al, [6]; Devereux [7]; Van [8] and IPIECA/OGP [9] drilling fluids are required to:

A. Remove cuttings from wellbore
B. Prevents formation fluid flow into the well
C. Maintain wellbore stability
D. Cools and lubricates the drill bit
E. Transmits hydraulic horsepower to the bit.

In addition to serving these functions, the drilling fluid should not:

1) Have detrimental properties to use of planned formation evaluation techniques,
2) Cause any adverse effects upon the formation penetrated,
3) Cause any corrosion of the drilling equipment and subsurface tubulars.

According to their basic material, drilling fluids are classified into liquids based, gases and the mixture of liquid and gas (Figure 1) [10]–[13]. The Drilling mud is made up of following components [14]–[16]:

a) *Base liquid:* Oil, fresh water, or salt water can be used as a base liquid in drilling muds, but oil and salt water are almost totally restricted to hydrocarbon drilling. Fresh water muds are used for geothermal drilling. Geothermal brine that is produced from nearby wells is sometimes used when drilling without returns.
b) *Active Solids:* Active solids are the clays and polymers added to the water to produce a colloidal suspension. They determine the viscosity of the mud and are known as viscosifiers.
c) *Inert Solids:* Inert solids are those added to the mud either by drilling (i.e., particles of the formation) or by using barite as a weighting material. These solids increase the density of the mud without appreciably affecting the viscosity.

Additives are added to mud to enhance its performance. Some common mud additives are Weighting Agents, Filtrate Reducers, Lubricants, Flocculants, Foaming Agents, Surface-active agent, Pipe-Freeing Agents, Alkalinity and pH Control additives, Bactericides, Calcium Reducers, Corrosion Inhibitors, Defoamers, Emulsifiers, Lost Circulation Materials, Shale-Control Inhibitors [6], [11], [13], [16].

Nigeria is a country blessed with valuable raw materials [17]. Although some of these local materials can be used in drilling fluid formulation; regrettably most of the drilling fluids components used in Nigerian Oil and Gas fields are imported.

Some researchers attempted to replace some the drilling fluid components with local materials, but not much have been done with the complete replacement the drilling fluid components with local materials. Thus, the purpose of this study was to determine the suitability formulating drilling fluids with locally sourced materials.

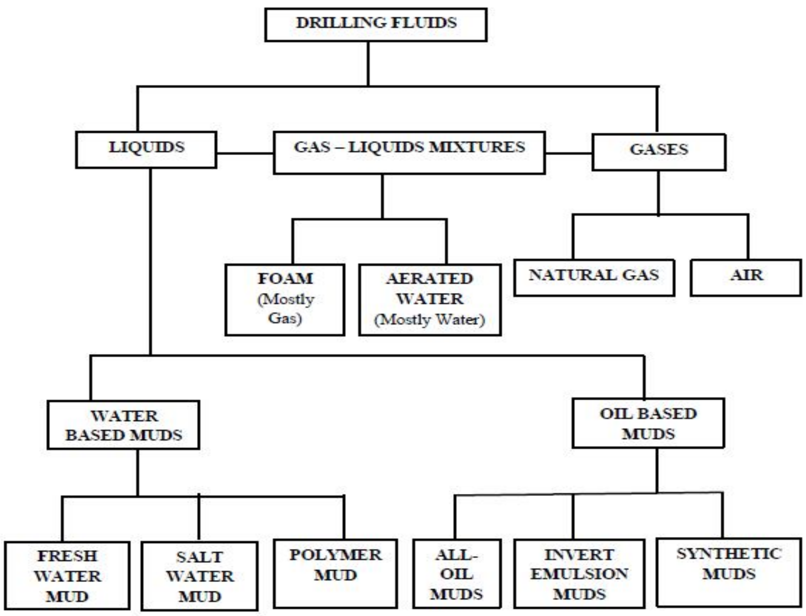

Figure 1: Simplified classification of drilling fluids

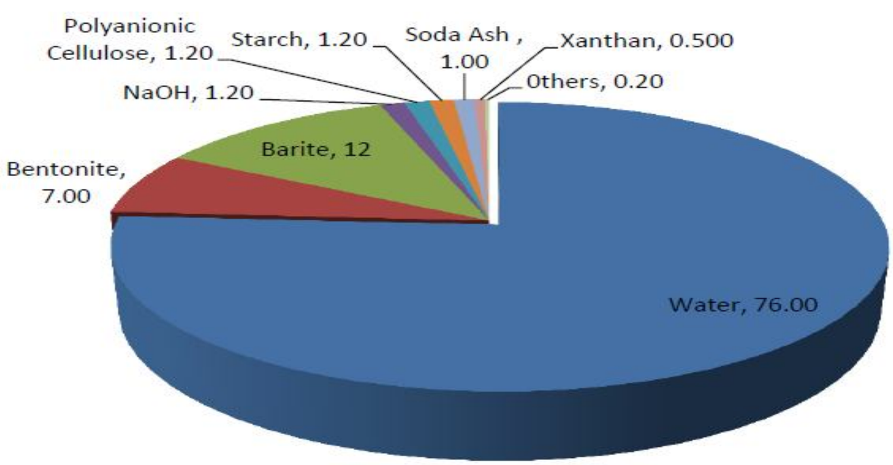

Figure 2: Composition of a typical water based drilling mud (%) [13].

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II. MATERIALS AND METHODS

A. Materials

The materials include the drilling mud materials, and the apparatus as well as the equipment that were used for the formulation and testing of the drilling fluids.

1) *Drilling Mud Materials:* The drilling mud materials used are shown in table 1. All the local materials were sourced from the Niger Delta.

Table 1: Drilling Mud Materials

Local Materials	Imported Materials	Remarks
Irri clay	Bentonite clay	Viscosity, Gel and Filtrate Control agents
Nigerian Iron oxides	Barite	weighting materials
Cassava starch and cellulose	CMC, Industrial Starch	viscosifiers.
Ashes from Burnt calyx corolla of palm fruits	Caustic Soda and Salts	pH control agents / Thinning agents

2) *Equipment /Apparatus Used:* The major mud properties testing equipment and apparatus are shown in table 2;

Table 2: Mud Properties and Major Testing Equipment

MUD PROPERTIES TESTS	MAJOR EQUIPMENT
Mud Weight	Baroid Mud Balance Model 140
Viscosity	Fann Viscometer (rheometer), Model 35 FANN®
Gel Strength	Fann Viscometer (rheometer), Model 35 FANN®
pH	Universal pH indicators, pH meter-Hach Model H260
Filtrate Rate and Mud Cake Thickness	Filter Press (API LTLP Model 300 and HTHP Model MB, 4 Unit, Vernier Caliper

Other include Thermometer, Spatula, Sieve, Manual Mortar grinder, Cutting mills SM 100, Jaw Crushers BB 50, Muffle furnace BST/MF/900; Electric multi mixer (Fann® Model 9B), Measuring cup, Filter paper, Beakers, Flasks, and Sample containers, Pulverizer, tin grater, sieve, spatula, digital weighing machine, Beakers, Flasks, containers, Stop-watch, Graduated cylinders (10mL, 25mL, 50mL and 100mL), steel plate.

B. Methods

1) *Preparations Local Samples*

a) *Preparation Of Cassava Starch and Cellulose:* Cassava cellulose is a starch extracted from cassava root, in preparation of "Cassava cellulose" from cassava, cassava are uprooted from the cassava root, then peeled with a cutlass and washed with clean water to remove earth particles. They are then grated with "tin grater", the grated cassava was then collected in a sack and then pressure pressed to extract the starch and cellulose. They were then oven dried at 75^0C until a constant weight is obtained. The dried cellulose was then grinded to smaller particles with the aid of manual grinder and then sieved with a standard test sieve (212 microns – Screen Mesh 70) to fine powdery form.

b) *Production Ashes From Burnt Calyx Corolla of Palm Fruits:* The palm fruit was gently removed from the bunch, and the bunch was cut into smaller bits. The materials were placed in steel plate (plate weight 56.2g). It was then oven dried at 110^0C until a constant weight is obtained. The dried calyx corolla was burnt into ashes inside a clean steel plate. The sample was sieved (filtered) using a U.S standard mesh sieve of 212 microns – Screen Mesh.

c) *Preparation of Local Iron Oxide Sample:* The iron oxide was placed inside the steel plate and then oven at 75^0C until a constant weight is obtained. The dried iron oxide pulverized and sieved using a U.S standard mesh sieve of 212 microns – Screen Mesh.

d) *Preparation of Local Clay Sample:* The local clay used in this study was obtained from Emu Unor in Ndokwa West Local Government Area of Delta. It was oven dried at 75^0C until a constant weight is obtained. It was then pulverized and sieved using a sieve size of 212micron.

2) *Preparations Imported Samples:* Imported samples were obtained from drilling company and were prepared in accordance with the industry standard [18].

3) *Formulation of Drilling Muds:* The laboratory preparation of a medium water based mud was performed to acceptable international standard (API) preparation procedures. Two water based muds were formulated.

a) *Formulation of Drilling Muds Using local Materials:* The local clay was collected and then weighed with same range of 21g for 12(twelve) sample and then poured into a mud mixer can. 350ml of distilled water was measured out with the help of a graduated cylinder beaker and turned into the mud mixer can. It was then stirred vigorously with the aid of the blender for ten (10) minutes for the clay to mix properly and then test was carried out on it. All other local additives were added concentrations as shown in Table 3.

b) *Formulation of Drilling Muds Imported Materials:* The imported bentonite was collected and then weighed with same range of 21g for 12(twelve) sample and then poured into a mud mixer can. 350ml of distilled water was measured out with the help of a graduated cylinder beaker and turned into the mud mixer can. It was then stirred vigorously with the aid of the blender for ten (10) minutes for the clay to mix properly and then test was carried out on it. All other imported additives were added at different concentrations as shown in Table 3.

Table 3: Drilling Fluid Formulations

LOCAL COMPONENTS OF THE DRILLING FLUID	FORMULATIONS			IMPORTED COMPONENTS OF THE DRILLING FLUID	FORMULATIONS		
	Formulation 1	Formulation 2	Formulation 3		Formulation 1	Formulation 2	Formulation 3
Water (mL)	350	350	350	Water (mL)	350	350	350
Local clay (g)	21	21	21	Bentonite (g)	21	21	21
Nigerian Iron Oxide (g)	1	2	3	Barite (g)	1	2	3
Cassava starch and cellulose (g)	1	2	3	Carboxy- methyl cellulose (CMC) (g)	1	2	3
Ashes from Burnt calyx corolla of palm fruits (g)	0.1	0.2	0.3	Sodium Hydroxide (g)	0.1	0.2	0.3

4) *Drilling Mud Properties Determination and Comparative Study:* Experimental mud properties test were carried in accordance with the API Recommended Practice, ANSI/API [18]. The following test were carried out on the drilling muds formulated with local materials and drilling muds formulated with imported materials to determine mud properties of interest and compared.

a) Mud weight tests – mud weight

b) Mud rheological tests - Plastic viscosity (PV), Yield point (YP), Gel strength, Apparent viscosity (AV), Consistency index (K), Yield stress (YS), Flow index (n), Tau(τ),

c) Gel strength tests - Gel Strength, (10 secs.) and Gel Strength, (10 mins.)

d) Filtration test- Fluid loss

e) Mud pH tests.

f) Sand content tests.

The tests were carried out in accordance with the procedures described by Baroid, [19]; Amoco, [20]; Baker Hughes, [21]; Baroid and Halliburton [22]; Baker Hughes [23] and ANSI/API, [15].

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III.RESULT AND DISCUSSIONS

A. Mud density /Mud weight

Except for the formulation 1 (Local), Muds formulated using local materials compared favourably with the muds formulated using imported materials in terms of their compatibility with API mud weight specification ranges of 8.60 - 9.60 Ib/gal (Figure 3).

Aging effects: The results showed initial slight gained in weight (Day 1 to Day 2) due to absorption of moisture by the some of the deliquescent materials used in the formulation as time increases. This is followed by slight loses in weights due to aging effects (Day 2 to Day 3) by evaporation and degradation of the mud components.

The comparative study of the weights of muds formulated using local materials with muds formulated using imported materials showed that the local materials performs fairly well. Thus the locally sourced Iron oxide can be used in placed of imported Barite as weighting materials.

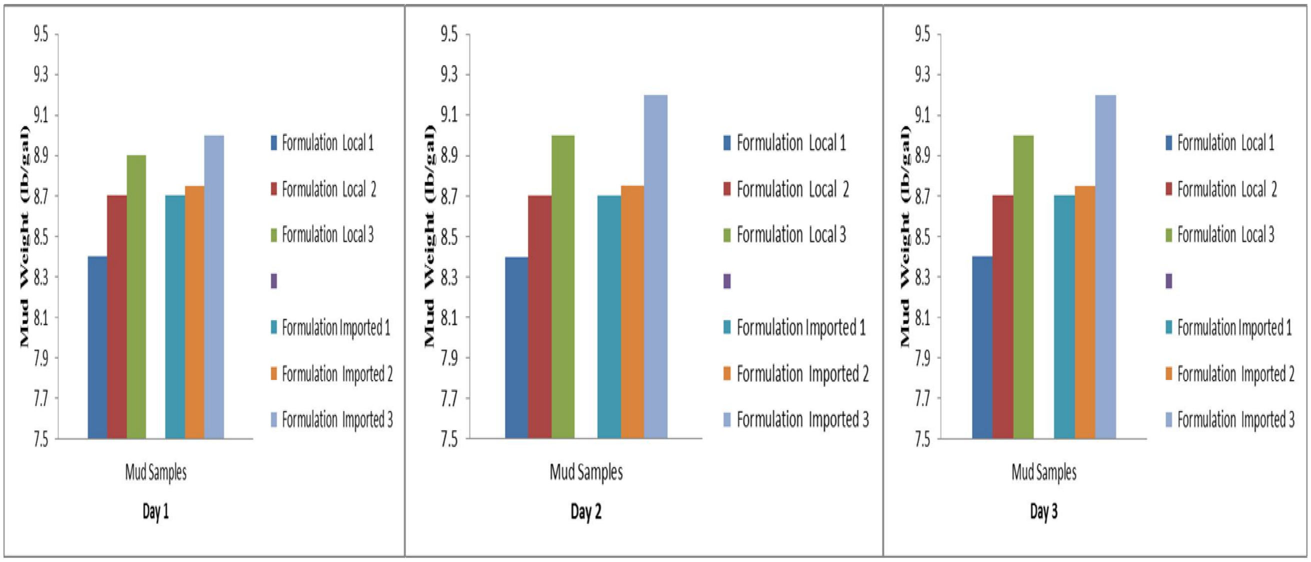

Figure 3: Comparison of mud weight of muds formulated from local and imported materials

B. Rheological Properties

The rheological properties determined during this study include Plastic Viscosity, Apparent Viscosity, Yield Point, Flow Index, Consistency Index, Yield Stress, and Marsh Funnel Viscosity. The rheological properties are very important in determining the Cuttings carrying index (CCI) and Cuttings suspending index (CSI).

Figure 4 showed the relationship between shear stress and shear rate that indicate non-Newtonian fluids patterns. These curves showed an initial high stress after which there was a less stress with increasing shear. The plots of viscosity against shear rates further showed that increase in shear rate as well as decrease in the viscosities. Thus suggesting that the two mud systems have good hole cleaning properties hence they are good drilling fluids.

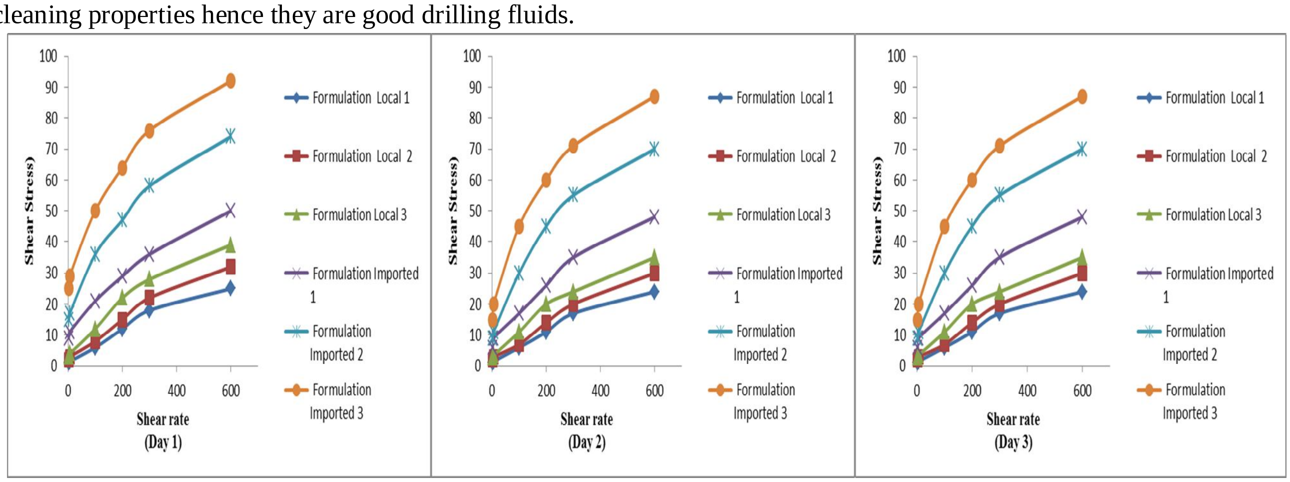

Figure 4: Shear rate versus Shear stress plots for muds formulated from local and imported materials

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1) *Plastic and Apparent Viscosities:* Figure 5 and 6 showed that drilling fluids formulated with lower materials have lower viscosities compared to those formulated with imported materials. Drilling fluid with low viscosity have good prospect for drilling in the sense that their low viscosity will offer less resistance to fluid flow and therefore would lead to a turbulent flow at low pump pressure which would result in good hole cleaning.

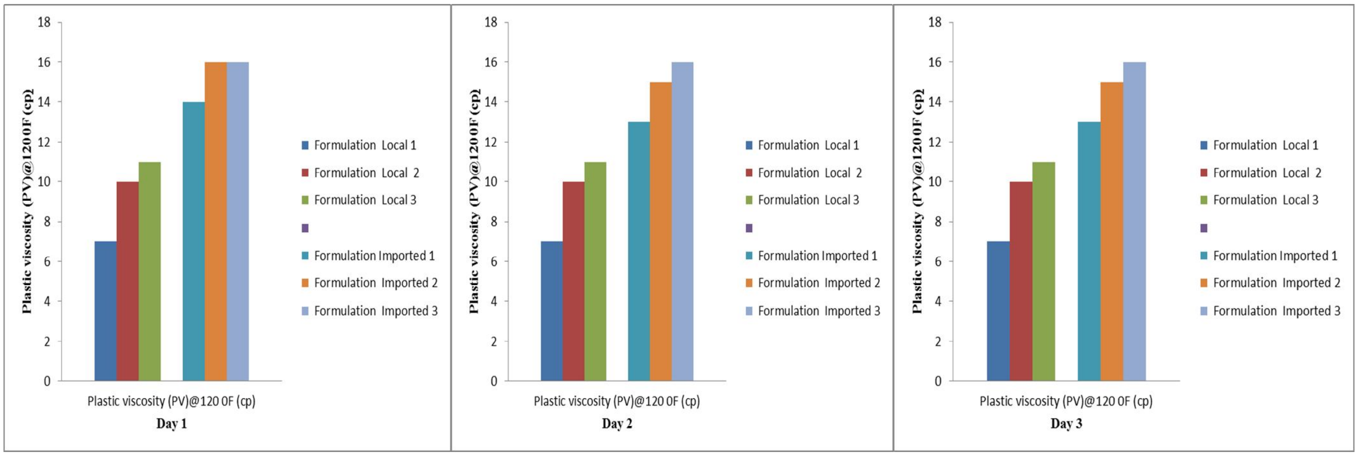

Figure 5: Comparison of the Plastic viscosity (PV)@120 ^{0}F (cp) of muds formulated from local and imported materials

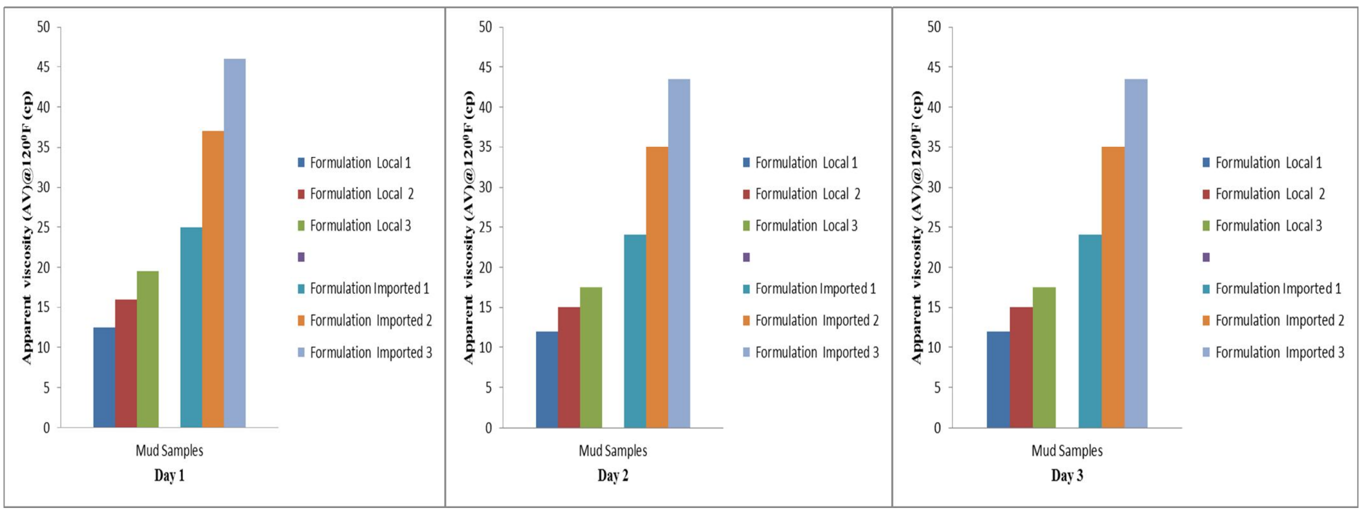

Figure 6: Comparison of the Apparent viscosity (PV)@120 ^{0}F (cp) of muds formulated from local and imported materials

2) *Marsh Funnel Viscosity:* Figure 7 showed that the Muds formulated using local materials compared favourably with the muds formulated using imported materials in terms of their compatibility with API specification.

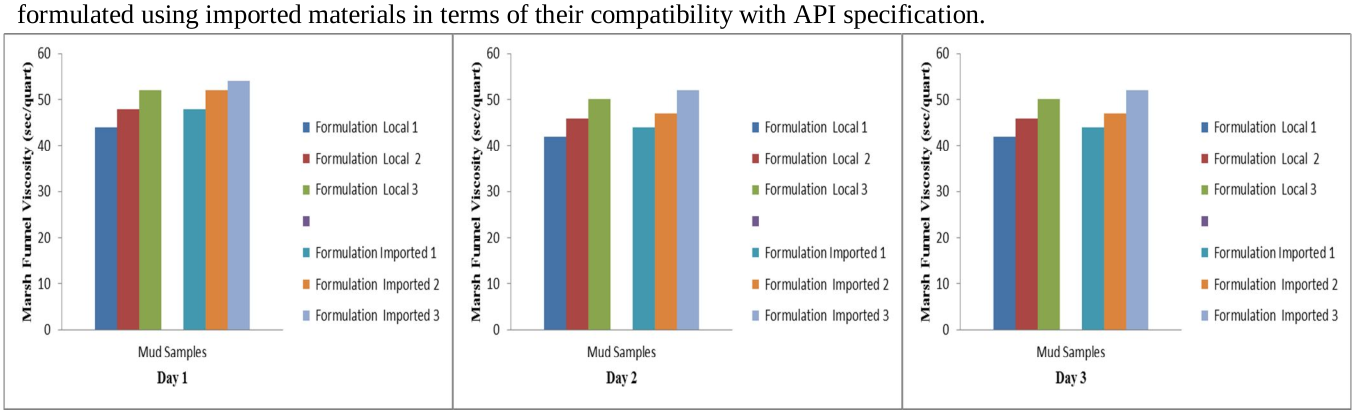

Figure 7: Comparison of the Marsh Funnel Viscosity (sec/quart) of muds formulated from local and imported materials

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3) *Yield point (YP) and Yield stress (YS)*: The yield point (YP) is usually used to determine the ability of a drilling fluid to lift cuttings out of the annulus. Drilling fluids with high yield points are non-Newtonian fluids; those that carry cuttings better than fluids of similar density but lower YP. Thus results shown in Figure 8, indicated formulated with imported materials are better in terms of yield points. Results also showed that aged drilling fluids tend to have lower yield points. In general, the yield stress of the drilling fluids formulated with imported materials is higher than those formulated with local materials.

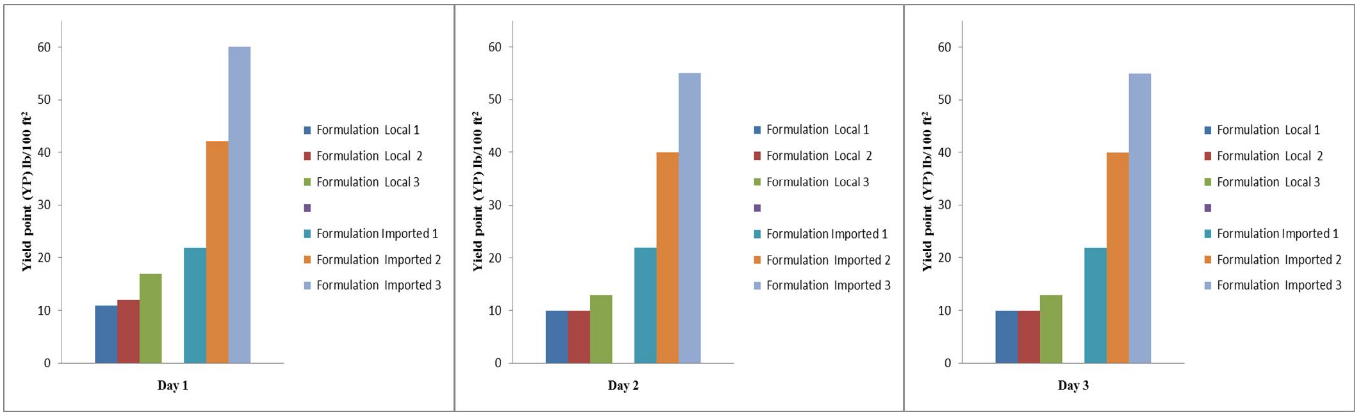

Figure 8: Comparison of the Yield point (YP) Ib/100 ft^2 of muds formulated from local and imported materials

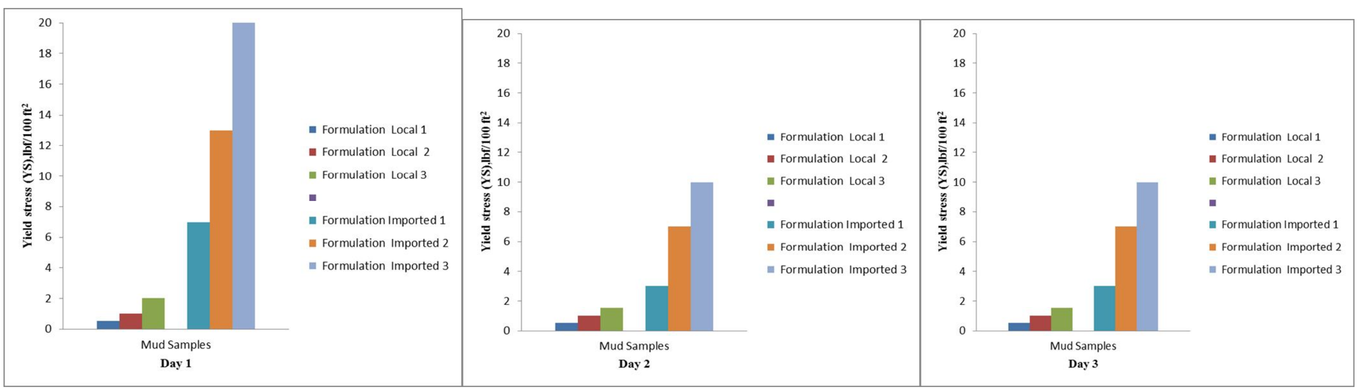

Figure 9: Comparison of the Yield stress (YS), lbf/100 ft^2 of muds formulated from local and imported materials

4) *Flow index (n) and Consistency index (K):* Figure 10 showed that drilling fluids formulated using local materials have higher flow index values compared to those formulated using imported materials. Results also showed that aging effects increases the flow index values. Figure 11 showed that drilling fluids formulated using local materials have lower consistency index values compared to those formulated using imported materials. Results also showed that aging effects decreases the consistency index values.

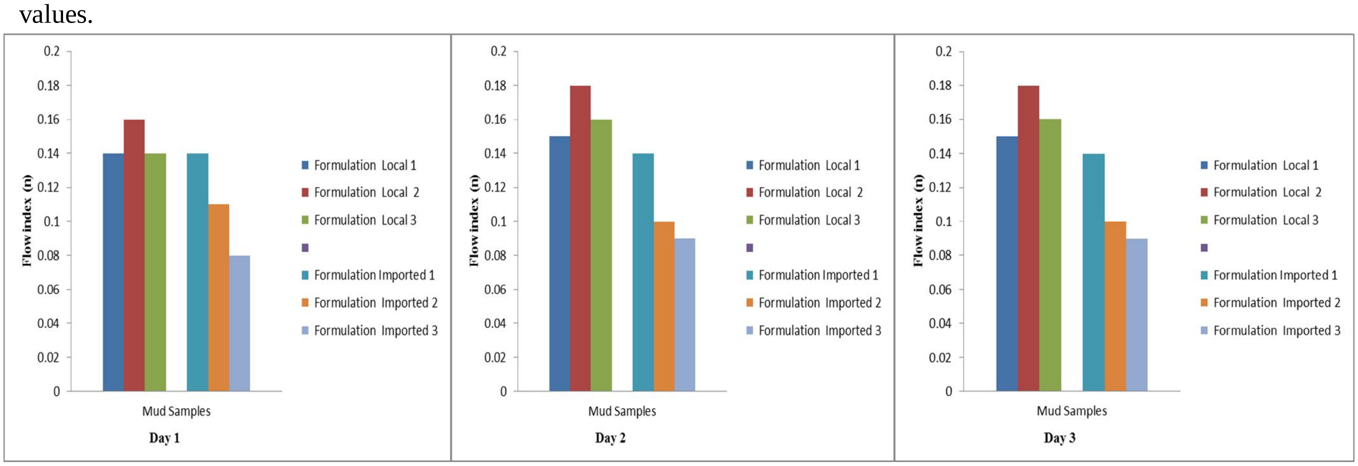

Figure 10: Comparison of the Flow index (n) of muds formulated from local and imported materials

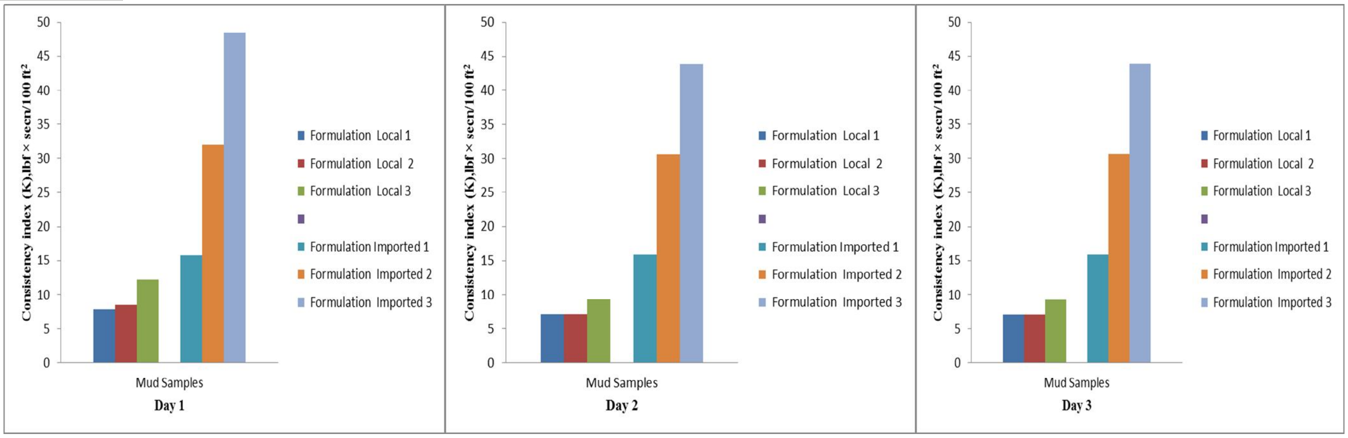

Figure 11: Comparison of the Consistency index (K), Ibf x sec n /100 ft^2 of muds formulated from local and imported materials

C. Gel Strength

The gel strength is a property of drilling fluid that demonstrates the ability of the drilling mud to suspend drill solid (drilled cuttings) and weighting material when mud circulation is stopped. Muds formulated using local materials has lowest gel strength values at both 10 seconds and 10 minutes compared to those formulated using imported materials (Figure 12).

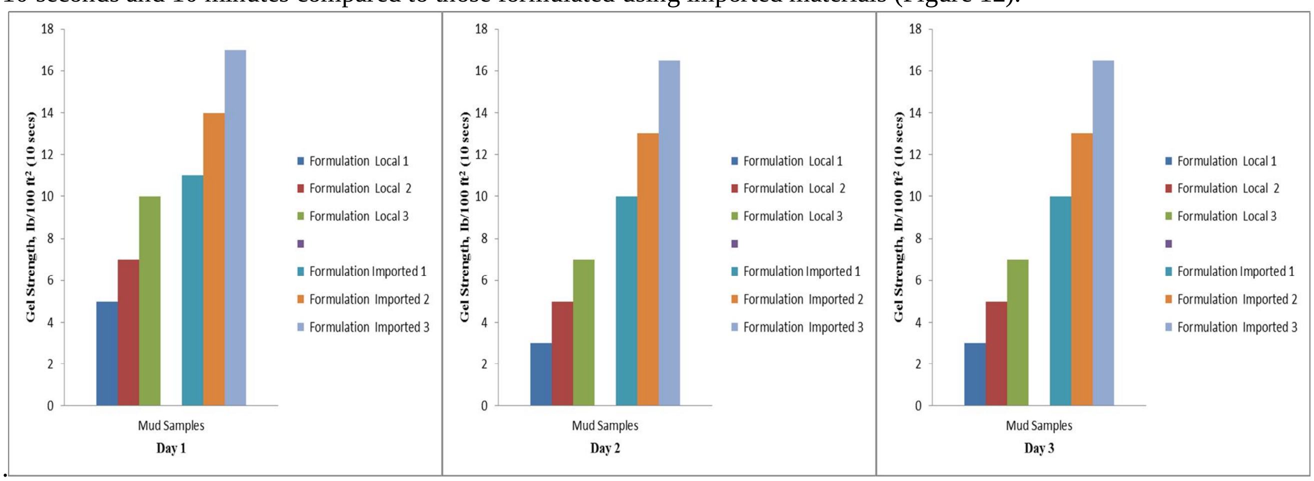

Figure 12: Comparison of the Gel Strength, lb/100 ft^2 (10 sec) of muds formulated from local and imported materials

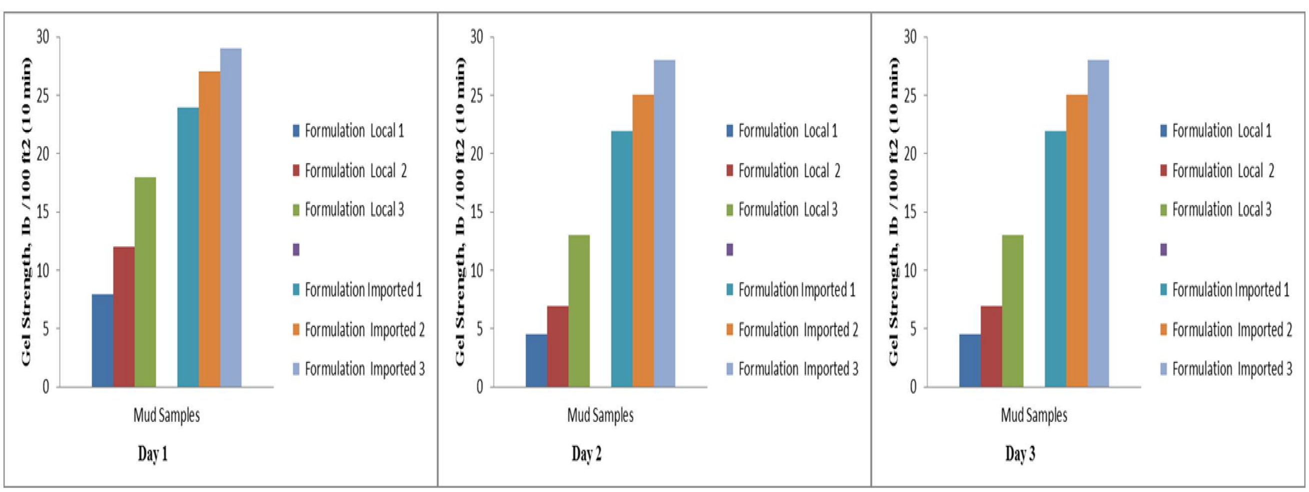

Figure 13: Comparison of the Gel Strength, lb/100 ft^2 (10 min) of muds formulated from local and imported materials

D. Mud pH

pH affects viscosity of drilling fluids. For minimizing problems, a pH of 8.5 to 9.5 is the best for hole stability and control over other mud properties. Experimental Results showed in Figure 14 indicated that pH values of all the freshly mud formulated are within the range. The values are also comparable to API specification [18].

Aging effects: The results showed initial slight increases in pH values (Day 1 to Day 2) due to further absorption of moisture by the some of the deliquescent materials used in the formulation. This is followed by slight decreases in pH values due to aging effects (Day 2 to Day 3) by evaporation and degradation of the mud components. The corrosion of metal is increased if it comes into contact with an acidic fluid. From this point of view, the higher pH would be desirable to protect pipe and casing [24]. The comparative study of the pH values of muds formulated using local materials with muds formulated using imported materials showed that the local materials performs efficiently. Thus the ashes from burnt calyx corolla of palm fruits can be used in placed of imported Potash as pH control materials.

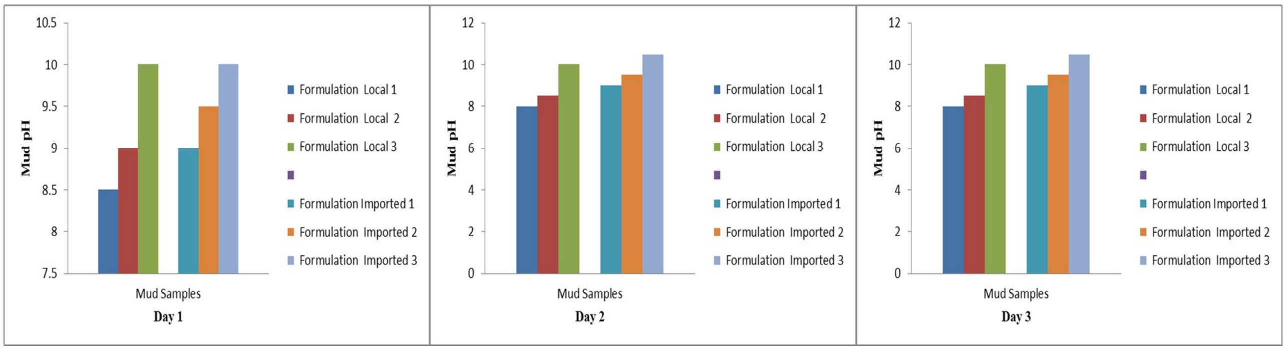

Figure 14: Comparison of the pH of muds formulated from local and imported materials

E. Sand Content

Figure 15 showed that that sand content in the drilling fluid formulated with local materials generally have more sand contents.

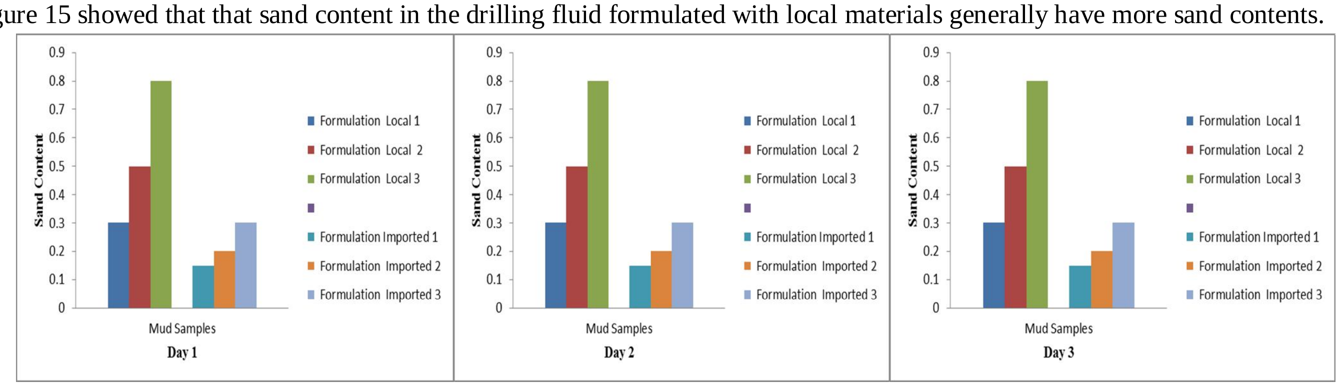

Figure 15: Comparison of the Sand Content of muds formulated from local and imported materials

F. Filtration Properties

Figure 15 showed that mud formulated with local material tend to lose more fluid than those formulated using imported materials. However, fluid loss decreased with increased in the concentrations of drilling fluid components. The study further showed that age drilling tends to lose more fluid than freshly drilling fluids.

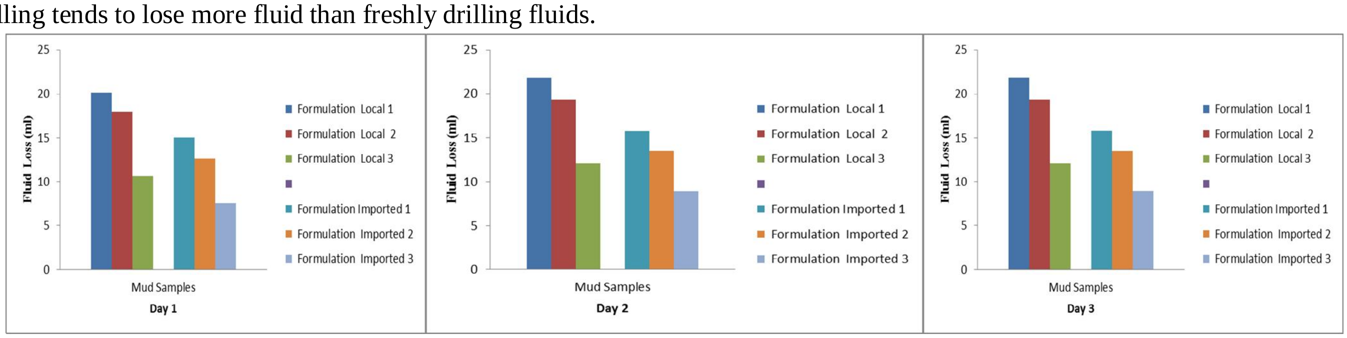

Figure 15: Comparison of the fluid loss from the muds formulated from local and imported materials

IV. CONCLUSIONS

Laboratory investigations were carried out to determine the suitability of formulating drilling fluids using locally sourced materials. Locally sourced materials were used to formulate drilling mud and the properties evaluated and compared with those formulated using imported materials as well as the industry standard.

While some of the drilling met the required industry standard, others need some minor treatments. Although, the drilling fluids formulated with imported materials tend be better, results showed that muds formulated using local materials compared favourably with the muds formulated using imported materials in terms of their compatibility with API mud weight, pH and viscosities specifications. The plots of viscosity against shear rates showed that increase in shear rate as well as decrease in the viscosities. Thus suggesting that the two mud systems have good hole cleaning properties hence they are good drilling fluids. Muds formulated using imported materials have higher viscosities. The Yield Point, Consistency Index, Yield Stress, Gel Strength and Marsh Funnel Viscosity results showed that they followed the same trends as the plastic viscosities. Muds formulated using local materials tends to age faster than muds formulated using imported materials. Therefore, for local muds samples to be used effectively, they should be given some little treatments**.**

V. ACKNOWLEDGMENT

The authors wish to thank all individuals and organizations that contributed to the success of this report. Prominent among them are those that provided the drilling fluid components.

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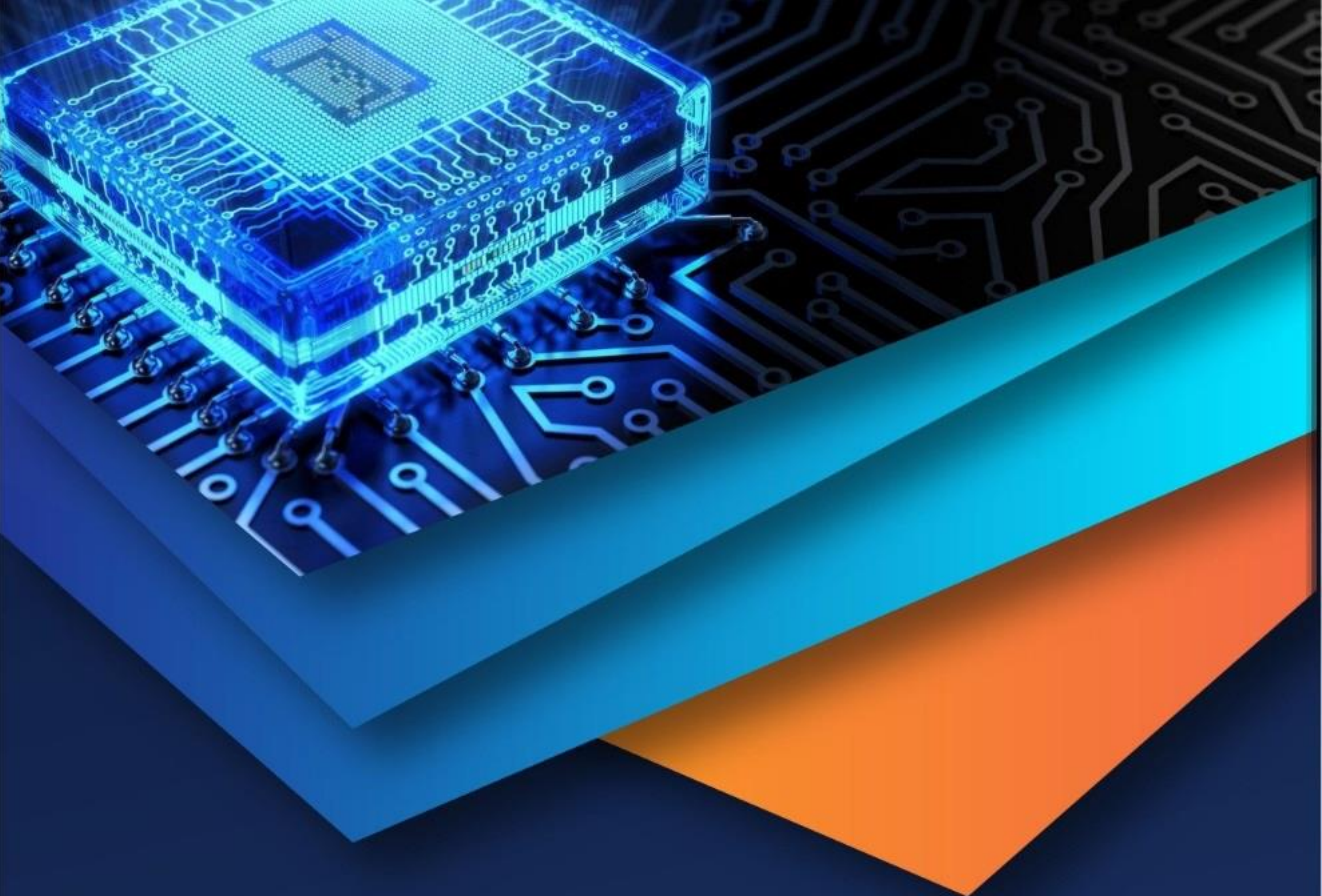

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