ASSESSMENT OF *MUCUNA SOLANNIE* AS AN ALTERNATIVE FLUID LOSS CONTROL MATERIAL IN SYNTHETIC DRILLING FLUID DESIGN

BY

ONYEKWERE KELECHI. R.
B.ENG (FUTO),
(REG NO: 20174082958)

A THESIS SUBMITTED TO THE POST GRADUATE SCHOOL (PGS) FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF MASTER OF ENGINEERING (M.ENG) IN PETROLEUM ENGINEERING.

NOVEMBER, 2023.

CERTIFICATION

The undersigned certify that the project work entitled **"Assessment of *Mucuna solannie* as an alternative fluid loss control material in synthetic drilling fluid design"** was carried out by **Onyekwere Kelechi Raymond (REG NO: 20174082958)** in partial fulfillment for the award of the degree of Master of Engineering (M. Eng) in Petroleum Engineering of the Federal University of Technology, Owerri, Imo-State, Nigeria.

……………………… 24/11/2023	……………………… Date
Engr. Prof. K.C. Igwilo Principal Supervisor	
………………………	27/11/2023 ……………………… Date
Engr. Dr. N. Uwaezuoke Co-Supervisor	
………………………	27/11/23 ……………………… Date
Engr. Dr. U.I. Duru Head of Department (Petroleum Engineering)	
………………………	27/2/24 ……………………… Date
Engr. Prof. Remy Uche Dean, Faculty of Engineering)	
………………………	……………………… Date
Prof. B.O. Esonu (Dean, Post Graduate School)	
Prof. A.D. Ibrahim Sulaiman ………………………	11/12/23 ……………………… Date
(External Examiner)	

DEDICATION

This project work is dedicated in its entirety to the Almighty God for his blessings, strength, wisdom and favors which have guided me throughout the duration of this program.

ACKNOWLEDGEMENT

The completion of this study would not have been possible without the combined expertise and cooperative efforts of some gifted people who dedicate themselves to excellence and quality in all they do. I wish to firstly acknowledge and express my unequivocal appreciation to my Supervisor, Engr. Prof. K.C Igwilo for his support and unwavering guidance and encouragement from the inception of this program and throughout the period of the research. Sir you are indeed not just a mentor but truly a father and friend. Secondly, I would like to express my immense gratitude to my co-supervisor Engr. Dr. N. Uwaezuoke for all your encouragements, corrections and guidance and also for making me believe in myself again. God bless you sir for your selflessness. Worthy of note is my HOD Engr. Dr. U.I Duru, thanks for your leadership in piloting the departmental affairs. To my amiable reviewer Engr. Dr. N.U Okereke I wish to say a very huge thank you for all your efforts, comments and corrections in ensuring the success of this thesis.

I wish to also use this opportunity to express my sincere gratitude to the Dean School of Engineering and Engineering Technology (SEET) Engr. Prof. Remy Uche, for your input and corrections towards making this thesis a success and the Dean school of Postgraduate studies Prof. B.O Esonu for availing me this wonderful opportunity. To my ever-steadfast and Dedicated Petroleum Engineering lecturers, Engr. Prof. Stanley Onwukwe, Engr. Dr. Nkemakolam Izuwa just to mention a few, I wish to say thank you. My sincere gratitude also goes to my colleagues for being good team players and also for all your efforts throughout the duration of our study. To my lovely and ever supportive wife Mrs. Ijeoma H. Onyekwere, words can't express how grateful I am to have you by my side I love you and to my parents Late Dr. and Dr. Mrs. P.N Onyekwere I am forever indebted to you for your unconditional love and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In recent years, research using biomaterials in drilling fluid design has thrown light on their biodegradability, availability and low cost. Apart from these, they have in some cases shown properties superior to those of synthetic materials. This research assessed Mucuna solannie as a fluid loss control agent, looking at its fluid loss, filter cake quality, rheology and comparing them with those of Sodium Asphalt Sulfonate which is a commonly used drilling mud additive. The Mucuna solannie additive was prepared by removing the shell and the seeds sliced into pieces, soaked in water for 3hrs, then grounded into powder form, dried in an oven for 2hrs at 120^{o}F which is an optimum temperature of retaining the chemical properties and finally sieved and re-grinded until finer powder was recovered. The additives were assessed at varying concentrations of 2ppb, 4ppb, 6ppb and 8ppb, the results obtained were filtrate volumes of 5.5ml against 4.8ml at 2ppb, 5.0ml against 4.5ml at 4ppb, 4.5ml against 4.2ml at 6ppb, and 4.1ml against 3.8ml at 8ppb, all at 30mintues. Field standard value is 5.0ml fluid loss. Filter cake thickness was 1mm for all concentrations of Mucuna solannie. On rheology, plastic viscosity, yield point and yield stress were 27cP against 28cP, 19Ib/100ft^2 against 19Ib/100ft^2, and 5Ib/100ft^2 against 6Ib/100ft^2, showing slight differences in their rheological properties. The chemical structure, molecular binding form of Mucuna solannie shows X-ray diffraction of Mucuna solannie found to be closer to chitosan structure with Calcium salt and organic materials. In terms of Economic Analysis, it could be seen that the Mucuna solannie has a less DCF-ROR of 58.0% against 62.0% of Sodium Asphalt Sulfonate, which indicates that Mucuna solannie is economically and commercially viable, slightly better and gives less economic cost than Sodium Asphalt Sulfonate. This research also established Mucuna solannie as a good fluid loss control agent according to API and field standards.

Key words: Fluid loss, Filtrate, Filter cake, Sodium Asphalt Sulfonate, *Mucuna solannie*;

CHAPTER ONE

INTRODUCTION

I.1 Background of Study.

The world's energy needs increase each year and so does the search for more oil and gas deposits. This translates to drilling oil and gas wells even in difficult terrains like in ultra-deep offshores, over pressured formations, salt zones, troublesome clay formations, thief zones, etc. Finding oil sometimes requires drilling to great depths, or deviating to avoid obstacles. These bring up challenges that are not even considered in shallow wells in addition to safety and environmental concerns. Because drilling costs are high, mud performance must be optimum. (Igwilo, et al 2016).

Mucuna Solannie is a tropical seed-bearing plant commonly found in parts of Africa and Asia. It consists of seed kernel, leaf stem and fruits coat. In Nigeria, the users of this leaf stem extracts confirmed to increase the red blood cell formation "blood booster" and the viscosifying tendencies of the ground seeds are toasted before grinding which serve as thickener in sauce or soup and beverages to women who use it in soup cooking. It contains low lipids, adequate minerals, high fibre, good carbohydrate, fats and crude protein (Nwosu, 2012). It's readily available in all parts of Nigeria, environmentally friendly and economically viable in terms cost and efficiency.

Mud is as vital as ‘blood’ to the drilling process, its functions among other things include; removing cuttings from the well bore, balancing formation pressures, maintaining wellbore stability, transmitting hydraulic horsepower to the bit, cooling and lubricating the bit, protecting the formation with an impermeable filter cake, helping in gathering data through cuttings, cores and logs. Generally, mud is characterized of the base fluid which could be air, water, brine, diesel, synthetic oil, bio-material oils, etc. It is also characterized of mud solids of various particle sizes. These include clays, weighting materials like barite, and also cuttings generated by the process.

Among the huge functions (Suter et al, 2011) studied that drilling has the ability to consolidate the walls of the wellbore being drilled. Apart from consolidating the walls of the wellbore, a thin filter cake has the ability to decline the flow of formation fluids from formation to the drilled well. This is an ideal product of the fluid’s loss control agent. Hence, a thin cake thickness with low permeability should be deposited on the walls of the borehole. However, when a drilling mud is first circulated in a wellbore, there is usually a volume of mud filtrate loss experienced and this is called the spurt loss.

1.2 Problem Statement

Formation damage is a major challenge to effective recovery. It could result from loss in formation permeability mostly due to infiltration of drilling and completion fluids into the formation. Hence, it affects the near wellbore region. Since we cannot eliminate the use of drilling and completion fluids, a good filter cake becomes necessary to protect the formation from further infiltration if the filter cake becomes too thick, it exposes the well to the possibility of stuck pipes. However, there has been limited research on drilling fluids made from biomaterials, specifically utilizing Mucuna Solannie as a cost-effective, environmentally friendly fluid loss additive that is also economically viable in terms of cost and efficiency

1.3 Main Objective of Study.

Comparative Assessment of Mucuna Solannie as an Alternative Fluid Loss Control Material in Synthetic Drilling Fluid Design.

1.3.1 Specific Objectives of Study.

i. Formulate drilling mud using locally derived materials.

ii. Determine the quality of mud cake, filtrate volume and other time interval.

iii. Know the Economic evaluation of proposed mud additives of Mucuna Solannie in comparison to the existing additive.

iv. Analyze the chemical structure and other properties of Mucuna Solannie.

v. Ascertain the degree of suitability and compatibility in terms of economic viability and environmental friendliness.

1.4 Justification of Study.

The major interest of this study is the fact that Mucuna Solannie has viscosifying tendencies and contains high fibre, good carbohydrate, fats, crude protein and adequate minerals which would most likely control fluid loss, minimize cost, readily available, environmentally friendly and economic advantage over imported and synthetic chemical mud additives.

1.5: Scope of Study

Experimental study was conducted and not within the actual industrial drilling condition so as to determine the influence of functional properties of Mucuna Solannie additives as alternative fluid loss control material in synthetic drilling fluid design. Determine the quantity of filtrate, quality of the mud cake, its chemical structure and know, if Mucuna Solannie are economically viable in terms of suitability and compatibility.

CHAPTER TWO

LITERATURE REVIEW

2.1 General Review.

Over the years, lots of researches have been done on drilling fluid formulation using the influence of functional properties and locally available materials as fluid loss control. These studies range from the use of biomaterials which are applicable in the oil and gas operations. Much attention has not been displayed on Mucuna Solannie from biomaterials that is suitable and compatible with oil-based mud. Some of the literature reviews are discussed below.

Olatunde et al., (2012); Omotioma et al., (2015) and Samavati et al. (2014) studied the use of modified fufu for adequate fluid loss control additives to reduce the volume of fluid loss that enters or sips into the wellbore during drilling using hydrochloric acid. They investigated that modified starch is used at depths equivalent to 150^0 C below bottom-hole temperature which indicates the higher the fluid loss into the formation, the tendency for the pipe to get stuck as a result of the mud cakes deposition on the wall of the wellbore. Furthermore, the performance of oil-based mud needs to be improved by using mud additives that are compatible, environmentally friendly and can technically perform and control fluid loss additives.

Demitry et al. (2012) conducted API filtration measurements on aqueous dispersion of (GO), Xanthan Gum and adjustable pH at high temperature and pressure. A filter cake thickness of 20µm with volume filtrate of 6.1ml was recovered at 30mins fluid loss measurement. They evaluated Graphene oxide using simulator and discovered that at low concentration value of 0.2% by low temperature and carbon, used as a primary source of filtration control agent in the drilling fluid. They further studied that if fluid loss is not minimized as a result of invasion of solids during drilling operations that the major consequence is formation damage, especially raising the salt concentration filtrate invasions with fines can caused filtration leak off and reduces the well productivity.

Roy and Sharma (2001) investigated the use of aqueous mud prepared with fresh water can mitigate a negative impact to water reservoir. In their revealed showed that increase in salt concentration and high volume of filtrate loss can minimized the invasion of fines and increase well productivity. They further studied that fluid loss tests and drilling fluid viscosity served as a major indicators for drilling mud stability. The major parameter that influences essential parts of drilling operations is the Rheology. The yield point, gel strength and Low shear rate of the drilling mud which are connection with annular hole cleaning depends on the rheology properties of the mud and a function of high fluid loss can drastically affects rocks fractures and high permeability formations. (Tehrani, 2007)

Olatunde et al. (2012) conducted experimental study on gum Arabic, guar gum, bentonite and polyanionic cellulose (PAC) with oil based drilling fluid. They studied that the filtration loss property of each drilling fluid including the rheological behavior were measured and results obtained was set on API recommended standard procedures. They found that the gum Arabic had less unstable rheological properties with stable gel strength and good filtration loss property while guar gum portrayed highest gel strength and most stable rheological property with poor filtration loss property. However, gum Arabic is located in the northern part of Nigeria and not in Niger Delta region (Southern part) where major drilling operations take place.

Ademiluyi et al. (2011) carried out a study and observed that local polymers have the ability to be used as an alternative to imported samples for fluid loss control. The higher the amount of fluid loss to the formation, the greater is the risk of pipe being differentially stuck due to thick filter cake deposition in the wellbore wall. High solids concentrations due to poor solids removal during drilling also lead to thick filter cake and high filtrate volume. Filtration properties of Pleurotus introduced into the drilling mud as fluid loss control agent to water based mud have been evaluated (Igwilo et al, 2016). They compared the two types of fluid loss control additives and the field Poly-Pac lo-vis. The drilling fluids formulated with Pleurotus and the Poly-Pac lo-vis drilling fluids of the same compositions and subjected to the same temperature of 456^{O}F. However, the two fluid loss additives produced good results but the mud formulated with the existing fluid loss additive is better than the Pleurotus additive.

Kumar (2010); Azar and Samuel (2007) and Awele (2014), carried out experimental study on spurt loss. In their studies, they discovered that when a drilling mud is first circulated in a wellbore, there is, a tendency of loss of filtrate volume experienced in the wellbore and subsequent loss of filtrate after spurt loss is referred as to as continuous fluid loss and is highly undesirable, hence for muds to be proved optimal in their functions, they should be examined and essentially be able to prevent high filter loss volumes while maintaining low and thin permeability cakes.

Kosynkin et al., (2011) studied the use of polymers as a fluid loss control. In their research discovered that the rate at which mud filtrate leaks into the formation being drilled needs to be taken seriously with a way of monitoring and controlling drilling muds. In addition, that reduction in productivity was as a result of formation damage which leads to fluid loss into porous formation.

Mud cakes deposited under the influence of dynamic and static filtration possess various properties in terms of thickness, erodibility and permeability, meaning that high filtrate rates deposit thick filter cakes that has high eroding velocities as such, cake accumulation impacts whether or not the mud is circulated.

Empirical study to the filtration theory investigated the dynamic filtration by a non-linear equation through analytical or empirical approach which was linearized and solved explicitly under certain conditions, this showed that several qualities that affect mechanisms of filtration have no counterpart in static filtration and therefore, dynamic filtration does not depend only on the physical conditions in the properties of the components in the fluid system.

Anietie et al (2014) studied the potentials of hush rice as a fluid loss control agent in oil-based drilling mud and results obtained was compared with the existing filtration loss control additive such as carboxymethyl cellulose and polyanionic cellulose under static fluid loss requirement. An LT-LP filtration test was performed for 30mins. The results deduced that there was a decrease of fluid loss of 59.57% against 62.77% at a concentration of 20g to 350ml mud. Furthermore, the thickness of the filter cake results indicates a decrease of 3.04% and 8.66% when compared to carboxymethyl cellulose and polyanionic. Its economic and commercial viability was also ascertained as environmentally friendly in countries like Nigeria. Thus they concluded that considerable concentration/content of rice husk can be applicable as to control fluid loss agent in oil-based drilling mud can be used as fluid loss control additive in water-based drilling mud as it exhibits good filtration loss control potentials. Limitations of their work still remains the fact that thermal stability of husk rice as fluid loss control agent as filtration under dynamic filtration, high pressure and temperature (HP-HT) test has not been ascertained and therefore was recommended as a further study.

Samavati et al. (2014), studied the rheological properties and fluid loss of oil based mud containing cassava derivative/acid modified fufu starch. In their studied revealed that the rheological properties such as plastic viscosity, gel strength, yield point and apparent viscosity for the acid modified fufu indicates significant improvement when 15% acid was employed. It also shows that the amount of fluid loss reduction was determined within average and light mud formulation weights of 75pcf-100pcf. However, the modified cassava was improved as good fluid loss control additive.

Studies on the application of corn-based starches as a drilling fluid additive and its suitability showed that some currently developed starch products had similar filtration control properties and are easily available in most part of Nigeria. It also revealed that, it is more environmental friendly and economically profitable to used non-food resources such as waste products (periwinkle shells) for filtration control additive or agent.

Chel-Guerrero et al. (2016) conducted an experimental study on starch gotten or extracted from Americana seed "Persea" that can be used as thickening and gelling additives in food systems. In their studies, they still includes an under- utilized resource owing to the fact that the quantity of the Americana seeds utilized in these fields has been far and few. Furthermore, they found that its seed serves as a filtration loss control additive and ways of putting inner boundaries to the menace of environmental pollution in the oil and gas industry. However, polymers are used for filtrate loss control agent in the drilling muds.

2.2 Fluid Loss Theory.

Generally, the major important of base fluid in determining the rheology of drilling mud, is that, it acts as a carrier for mud additives which are the final determinants of the muds properties. Additives are used in drilling fluids during formulation to achieve several purpose such as the viscosity control, weighting control additives, rheology control additives, emulsifiers, and filtration control additives**.**

Fluid loss in drilling hydraulics involves diffusivity and is the measure of the quantity of mud filtrate that goes in directly into the formation. If not monitored or controlled in the reservoir, the formation impairment will occur, leading to high cost in stimulating the well. (Ukachkwu et al, 2010).

The fluid loss theory contains soluble chemical and water that allows fluid to pass through the pore spaces as a result of the permeability from mud to the formation.

As the fluid is lost, a built up filter cake occurs on the face of the wellbore which determines the quantity of fluid in a particular filtration time and the resistance against the fluid flowing through the filter cake. Low-temperature and low-pressure fluid loss test are two types of filtration standard test that measures the quantity of filtrate after a 30minutes period using filter paper often called the American petroleum institute (AP1) test. The low- temperature/ low-pressure or API fluid loss is called basic filtration test which is performed at ambient temperatures and pressure of 100psi. The HTHP filtration test is the more advanced test, this is performed at a temperature closer to the bottom-hole temperature and at a pressure differential of 500psi. For no standard temperature for HTHP test, the temperature of 275^0F-325^0F are often set and used as standard which is dependent on the operator and the area.

A desirable filter cake is achieved by proper maintaining of the concentration of filtration control additives and reducing the drill solids content of the drilling fluid.

A desirable filter cake is achieved by minimizing the drill solids content of the drilling fluid and maintaining the proper concentration of filtration control additives. But these desirable properties cannot be achieved alone from the fluid loss values because many low fluid loss drilling fluids do not have adequate quality of good filter cake.

Filtration of drilling fluid is liquid part of the system that moves through the filter cake and into the formation as a result of the slight difference between hydrostatic pressures (HP) of the mud. The filtration control agent minimizes the volume of fluid loss into the wellbore formation during drilling operations. Its functions includes; organic thinners or deflocculants, Bentonite, various manufactured polymers and starches.

The three conditions necessary or required for filtration to occur are as follows:

i. Presence of permeable medium.
ii. Solids slurry/liquid must be present.
iii. The permeable medium must be lower than the pressure of the Fluid.

There are two types of filtrations: static while the mud is at rest and dynamic while the mud is circulating or in motion. The dynamic filtration occurs at a constant rate when the rate of erosion of the filter cake as a result of the circulating mud matches the rate of deposition of the filter cake. This filtration amounts up to 80% the fluid loss in wall, however, the flow of mud across the borehole wall will result erosion of the depositional force for the cake buildup. It is not only dependent on the physical conditions in the fluid properties of the components in the fluid system but can be achieved with extended circulation, constant cake thickness and quasi-steady state fluid loss. Static filtration is a filtration that take place when the mud is unstable or not being circulated. These causes the filter cake to grow thicker and undisturbed which led to a decrease in loss fluids with time. The filtration test is dependent on Darcy's law which allows the flow of fluids through permeable materials (Mud filter cake, sand and sandstone). It also relates filtrate rate to differentiate pressure, permeability, filter cake thickness and viscosity as shown below.

$$q = {(KA\Delta P)}/{(\mu h)} \quad 1.1$$

Where:

K= Permeability (Darcies).

A= Area (cm^2)

ΔP= Changes in differential pressure (atm).

μ= Viscosity.

h= Filter cake thickness.

q = Filtrate flow rate (cm^3)

2.2.1 Factors Affecting Filtration Loss

2.2.2. Permeability.

This is achieved or determined by the concentration, shape, size of the solids which constitute the filter cake. It is also considered as the major factor that controls filtration loss and filter cake which is constitute of coarse particle, therefore the pores space will be higher and the rate of filtration also greater leading to an increase in filtration rate. (Igwilo, et al 2016)

2.2.3. Differential Pressure

Useful fields for investigating the cake compressibility is to measure the HPHT filtrate in the normal manner and retest with 100psi pressure. The higher the compressibility of the filter cake, the lower the compressibility ratio. However, if the compressibility ratio is greater or 1.5, it could be deduced that colloidal fraction is insufficient and preventive measure are necessary (Igwilo, et al, 2016).

Compressibility ratio = cc at 500psi / cc at 100psi.

The equation below shows the relationship between filtrate loss volume and pressure [Amoco Production Company Drilling Fluids Manual1, 2001]

$$F_1 = f \times \frac{\sqrt{P}}{\sqrt{P_1}} \qquad 2.2$$

F_1= Unknown filtrate at pressure of P_1

F= Known filtrate at pressure "P"

P= Known Pressure

P_1= Unknown Pressure

2.2.4: Temperature

Increase in temperature leads to higher increase in filtration rate due to the adverse effects of temperature on filtration control agents and also decreased the viscosity of the fluid phase. As the temperature increases, solubility of contaminants also increases and thereby decrease the filtration loss control agents. The filtrate changes due to reduction of drilling fluid viscosity as a result of the rise in temperature which can be expressed thus mathematically:

$$F_e = F \text{ x } \frac{\sqrt{u}}{\sqrt{u_0}} \qquad 2.3$$

Where,

F= Volume of filtrate at a known temperature

F_e = Volume of filtrate at an elevated temperature.

μ= Viscosity of oil base at know temperature

μ_o = Viscosity of oil base at an elevated temperature

Amoco production company drilling fluid

2.2.5: Time.

The fluid loss at variable time intervals is important and can be determined by the equation as shown below.

$$F_e = F \text{ x } \frac{\sqrt{T_e}}{\sqrt{T}} \qquad 2.4$$

Where,

F= Know filtrate at a variable time "T"

F_e = Unknown filtrate at a variable time "T_e"

T= Known Time; T_e = Unknown Time.

2.2.6: Viscosity.

The measure of the resistance of a fluid to flow as a result of shear stress or shear rate/ tensile stress which may be thought as a measure of fluid friction is known as Viscosity.

Mathematically can be expressed thus:

Viscosity = Shear stress/ shear rate.

2.2.7: Thickness of filter cake

The ability of the solid components of the mud to rapidly form a thin filter cake of low permeability on a porous formation is a desirable property closely related to hole stability, freedom of movement of the drill string, and the information and production derived from the hole.

When water, carrying suspended solids, comes into contact with a porous, permeable formation such as sandstone, the solids particles immediately enter the openings. As the individual pores become bridged by the larger particles, successively smaller particles are filtered out until only a small amount of the liquid passes through the openings into the formation.

Thus, the mud solids are deposited as a filter cake on the hole wall. The thickness of the cake is related to the type and concentration of solids suspended in the mud. As soon as bridging of the openings has occurred, the sealing property of the mud becomes dependent upon the amount and physical state of the clay and other colloidal materials in the mud, and not on the permeability of the formation.

2.3: Fluid loss Control Mechanism.

The Mechanism of fluid loss control is primarily by promoting and increasing the deposition of filter cake low permeability. However, this can be accomplished or achieved through adequate investigations of the deposition and structure of the drilling mud filter cakes which does yield insights into the process that are taking place while cement slurries and drilling mud do differ; they are both subject to laws of fundamental governing solid-liquid-polymer interaction. Under differential pressure, the suspended solids in a fluid are filtered by permeable strata
(Igwilo et al 2016).

2.4: Classification of Drilling Fluids

Physical and chemical properties of the drilling fluids largely depend on the types of solids in the mud. These solids are categorized as either active or inactive solids. The active solids are those that react with water phase and the dissolved chemicals. On the other hand, the inactive solids are those that do not react with the water and chemical to a significant degree (Azar & Samuel, 2007), some examples of the inactive solids include – Barite and Hematite, these are added to drilling fluids as weighting agents.

Examples of inactive fluids include – clays, polymers and chemicals, which are viscosity enhancers.

Drilling fluids include three main types: Pneumatic, liquid or Pneumatic - liquid mixtures. The broad classification of drilling fluids are as seen below;

Table 2.1: Classification of drilling fluids

Pneumatic fluids	Liquid fluids	Pneumatic – liquid mixtures
Air; Natural gas	Water based mud; oil-based mud	Foam (mostly gas); Aerated water

2.4.1 Pneumatic Drilling Fluids

Pneumatic drilling fluids are recommended for formation where there is potential for circulation loss. Pneumatic drilling are used for under balanced drilling.

Pneumatic drilling is known to have improved rate of penetration better control of loss circulation zones and less damage to formations. However, pneumatic drilling fluids especially dry air/natural gas, have been responsible for causing fire and corrosion to down-hole equipment (Azar & Samuel, 2007)

2.4.2 Liquid Fluids

Water base mud has water as continuous phase and mixture of solids, liquids and chemicals as additives. In general, liquid phase drilling is more prominent as these are water based mud are preferred over the oil based mud due to their economical and a requirement for less strict pollution control measure.

2.4.3 Oil Based Drilling Mud

Oil based drilling mud have liquids phase as oil (diesel, mineral or synthetics). All solids in oil based mud are considered inactive as they do not react with oil. Oil based mud are highly temperature-stable fluids. However, use of oil based mud requires strict safe-guards for environmental protection and safety. Oil based mud are preferred for high temple formations, water sensitive shale's, thick salt sections and low-pressure formation.

2.5: Drilling Fluid Selection

In the Exploration and production industry, for a drilling fluid to be specific selected, the drilling engineers or mud engineers must place their selection upon its rheological properties that are favorable for any drilling operations. The drilling engineer or mud engineer specialist is often or consistent on site to re-evaluate, monitor and maintain the rheological properties as drilling proceeds.

Factors that governs drilling fluid selection.

i. The formation types to be drill.

ii. Temperature range

iii. Formation and strength permeability “ Pore fluids pressure”

Furthermore, Annudeep, (2012) stated that the most favorable that governs drilling fluid selection is the “overall well cost”; hence that drilling fluid selection has other factors that can be informed through some considerable extent such as logistic and safety, environmental impact and production concern.

2.6: Characterization of Mucuna Solannie

Mucuna Solannie is a tropical seed-bearing plant commonly found in parts of Africa and Asia. This plant belongs to family of Fabaceae and sub-family Caesalpinioideae. In Nigeria, the viscosifying tendencies of the ground seeds are well known to women who use it in soup cooking. It contains between 9 to 19% crude protein, 39.8 to 69.49% carbohydrate, 1.84 to 5.9% fats and 11.24 to 17.10 vitamins (Ojayi et al., 2006; Nwosu, 2012).The Species of Mucuna Solannie are M. Veracruz; M. pruries; M. urensi and M. sloani. Mucuna is a genus of around one hundred accepted species of climbing vines and shrubs of the family fabaceae, found worldwide in the woodlands of tropical areas (Obiakor-Okeke, et al, 2014) in several countries of Asia and Africa. The leaves are 3-palmate, alternate or spiraled, and the flowers are pea-like but larger, with distinctive curved petals, and occurring in other legumes, Mucuna plants bear pods. They are generally bat-pollinated and produce seeds that are buoyant These have a characteristic threelayered appearance, appearing like the eyes of a large mammal and like a hamburger in others (most notably solannie) and giving rise to common names like beans, ox-eye beans or hamburger seed.

Mucuna plants bear pods, and the seed pods are protected by velvety hairs. Pods are produced on long, rope that hang from the forest canopy. At maturity, each pod produces several hard, marble like seeds. Mucuna seeds are toasted before grinding serve as thickener in soup or sauce. The Igbo of South Nigeria use it as part of main dish as thickener for soup, beverages and other food items (Afolabi, et al, 2002). Equally, locally, it is known as 'Ukpo' by the Igbos, 'Yerepe' by the Yorubas and 'Karasau' by the Hausas (Onudibia, et al, 2014). Mucuna Solannie attacked by micro-organisms when hydrated (fermentation) unless protected by high pH, high salinity or a biocide. The species of Mucuna Solannie include Mucuna pruries, Mucuna sloanei and Mucuna Veracruz, It grows in clayey-sandy soil with normal rainfall in the South-East, but production of the seeds start with flowering between April and May, and fruits between September and January (Onudibia, et al at least 200-300 seeds per year).

Fig. 2.1: Mucuna Solannie after harvest (Onudibia, M.E., et al 2014)

Table. 2.2: Proximate chemical Analysis of Mucuna Solannie seeds (Obiako-Okeke P.N et al, 2014)

	Raw (dehulled)	Cooked
Carbohydrate (%)	54.4± 0.26	62.3 ± 0.40
Protein (%)	24.0± 0.11	19.6± 0.38
Moisture (%)	10.5± 0.20	12.0± 0.20
Fat (%)	6.5± 0.26	8.3± 0.21
Fibre (%)	3.8± 0.21	5.3± 0.35
Ash (%)	3.3± 0.26	3.0± 0.26

2.6.1: Health Benefit of *Mucuna Solannie*.

Mucuna Solannie have been used for medicinal plants over centuries before orthodox medicine. However, stems, seeds, leaves, roots, fruit, bark and flowers were used for herbal and local medicines. The values and benefits of these medicinal plants are derived from phytochemical, which in turns on the human body produce physiological actions.

The interest of Mucuna Solannie plants (e.g. stem, fruit coat, seed kernel and leaf) have deduce antibacterial activity against proteus vulgaris, Staphylococcus Escherichia coli, and Bacillus cereus (Manjunatha et al., 2006). Several varieties of Mucuna Solannie especially seeds were used as dish by different ethnicity and condiment while leaves are used as vegetables which serve as a dual purpose in pharmaceutical industries. It reduces high concentration of some anti-nutritional constituents, serves as blood booster, increase rate of red blood cell formation which in turns reduced the quality of anti- nutrients in food. (Adebowale and Lawal, 2003).

2.6.2: Chemical Analysis of *Mucuna Solannie*

Previous researches have chemically analyzed *Mucuna Solannie* leaves and seeds, and determined its composition in a bid to identify elements, oxides or compounds responsible for its behaviors at certain conditions such as its rheological properties at low shear rates. Presented in Tables 1 to 3 are tables showing *Mucuna Solannie* compositions.

Table: 2.3: Phytochemical composition of leaves of Mucuna

Phytochemical	% composition
Alkaloids	9.60 ± 0.141
Flavonoids	4.90 ± 0.200
Saponins	24.60 ± 1.979
Cyanogenic glycosides	20.74 ± 0.452
Tannins	32.55 ± 0.778

Table 2.4: Proximate composition of leaves of Mucuna

Nutrients	% composition
Moisture	11.37 ± 0.632
Ash	0.11 ± 0.01
Crude protein	31.91 ± 2.6
Crude fat	2.97 ± 0.009

Table: 2.5 Mineral composition of leaves of Mucuna

Mineral	Composition (mg /100 g)
Calcium (Ca)	108.68 ± 1.05
Phosphorous (P)	11.06 ± 1.51
Magnesium (Mg	4.27 ± 0.17
Manganese (Mn)	0.22 ± 0.01
Iron (Fe)	0.95 ± 0.10
Zinc (Zn)	0.02 ± 0.01
Selenium (Se)	0.09 ± 0.002
Potassium (K)	177.50 ±2.82
Sodium (Na)	16.50 ± 0.42

Table 2.6: Vitamin content of leaves of Mucuna

Vitamin	Values
Vitamin A (mg/100 g)	9.83 ± 0.15
Ascorbate (mg/100 g)	25.36 ± 0.212

2.7: Economic Decision Principles.

Before starting any economic evaluation, the type and nature must be recognized. Therefore economic decision principles are principles that helps in selecting the best alternatives which are either service based or revenue based alternatives. It also required analysis of cash flow estimates over a period of time. In service based alternatives it only required cost cash flows estimate whereas in revenue based alternatives, it alternatives generates both revenue cash flow estimates and cost. The selection of alternatives are based on the use of evaluation tools. Examples, Discount Cash Flow Rate of Return (DCF-ROR) and Net Present Value (NPV). However, in the buying and selling that is, commodity price especially prices of oil or gas over a long period of time are volatile. To deal with such changes, people bring in what is known as "risk evaluation" in which they allow the price to change by a certain percentage, and see what the effect of NPV.

2.7.1: Net Present Value

The net present (NPV) is known as present worth or present value of cash surplus which can be estimated or determined by subtracting the periodic cash outflows from periodic cash inflows of present value. The present value is used to evaluate two or more alternatives with the use of weighted average cost of capital of the investor known as minimum acceptable rate of return or discount rate. For minimum acceptable rate of return in a single cases that is equal to zero or greater than zero, minimum acceptable rate of return is exceeded or met and the alternatives is viable.

The net present worth or net present value of both outgoing and incoming of time series of cash flows, is define as the addition of the present values (PVs) of the individual cash flows of the same entity.

The central tool used in discounted cash flow analysis is net present value which can be also apply in incremental analysis cases and it is a proved standard method for using time value of money to appraise long term investment or projects.

When the net present value at a certain discount rate is positive. It pays the cost of alternative use of fund and value is acceptable which indicates that the rate of return is equal to discount rate on the investment while net present value at a certain discount rate is negative, it suggest or implies that the investment is not worthy in generating earnings equivalent to those expected from the alternative or money being invested, thus causing opportunity loss.

Equations 2.7 and 2.8 show Net Present Value in terms of discounted benefits and discounted costs.

NPV = Discount Benefits - Discounted Costs 2.5

$$\text{NPV} = \frac{s_1}{(1+i_d)^1} + \frac{s_2}{(1+i_d)^2} + \frac{s_3}{(1+i_d)^3} + \frac{s_4}{(1+i_d)^4} + \frac{s_n}{(1+i_d)^n}$$

Where:

i = discount rate, %

t = time of cash flow

n = maximum number of years

s_1= expected net cash flow

2.7.2: Discount Cash Flow Rate of Return.

The discount cash flow rate of return is a method used in the industry for all types of capital investment in a project. However, evaluation tool is used once a Minimum Acceptable Rate of Return has started so as to account for one alternative or select between two or more alternatives. In addition, the discount cash flow rate of return (DCF-ROR) is the bank interest rate that returns the Net Present Value (NPV) to Zero which can be estimated and applied on the cash flow series, this is applicable only when the Net present value should be $0.00. For time value of money to be recognized, the future and past values of money can be converted into their current value equivalent.

Leland Blank, et al, (2020) sated that condition necessary when DCF-ROR exceeds the Minimum Acceptable Rate of Return or equals through the incremental cash flow, the associated alternative should be selected otherwise reject. For greater than two alternatives which can be used as a screening tool to eliminate all alternatives that is less than Minimum Acceptable Rate of Return of DCF-ROR. Another condition is to decide the discount rate factor which the capital needed for the project and return when invested in an alternative venture such as the capital required for Project 1 can earn 10% elsewhere hence the discount rate in the Net Present value calculation should allow a direct comparison made between project 1 and the alternatives. When calculating projects in a constrain environment, it may be important to consider the use of reinvestment rather than firm's weight average cost of capital as the discount factor which indicates, the cost of invest rather than lower cost of capital. For a variable discount rates, NPV is calculated if they are only known for the duration of the investment and better relates the situation than calculating from a constant discount rate for all investment duration,. Therefore, Reinvestment is the rate of return for the firm's investment on weighted average cost. (Baker, 2000).

2.7.3: Net Present Value in Decision Making.

NPVs are additive to the firm which indicates how much values an investment. It account for opportunity cost or time of money, that is, in financial theory For a particular project, if inflow minus outflow shows positive value, the project is in position of discount cash inflow in the time whereas if the outflow shows negative value, the project is in the position of cash outflow in the time. Nevertheless, risked projects that the Net present Values is positive could be accepted but does not give any mandate to be undertaken. In choice of decision, NPV does not compare with other available investment or account for opportunity cost. In two mutually exclusive alternatives, the choice of decision making, is the one yielding the higher Net Present Value (NPV) should selected.

CHAPTER THREE

METHODOLOGY

3.1 Materials and Methods

The apparatus, materials and supplies used in this research include; weighing balance, Fann V-G meter, measuring cylinder, Hamilton beach mixer, HPHT filter press, conical flask, beakers, pH meter, jaw crushers, BS sieve, furnace, thermometer, stopwatch, API filter press, oven, spatula, sieving mesh and filter paper. Also shown is the seed of *Mucuna* (Figure 1).

Fig. 3.1: Mucuna Solannie before grinding

3.2. Experimental Procedure.

The Mucuna Solannie shell was removed, and the seeds were sliced into pieces, soaked in water for 3hrs, then grounded into powder form, dried in an oven for

2hrs at 120°F which is an optimum temperature of retaining the chemical properties and finally sieved and re-grinded until finer powder were recovered.

Flow Chart

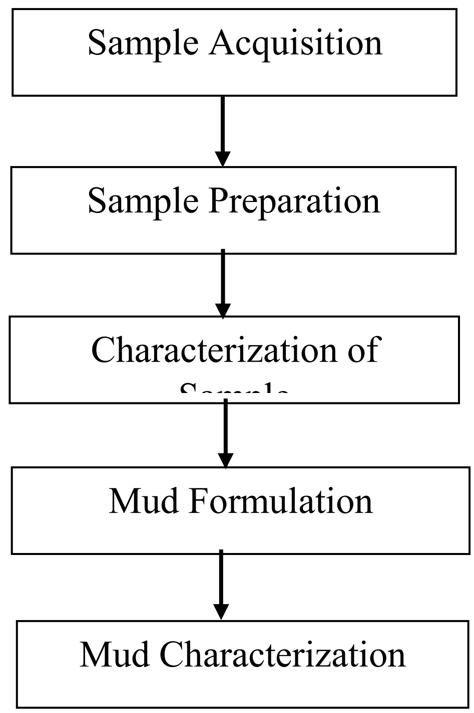


Figure 3.2 : Flow chart showing Processing Procedure

3.3 Method

This section is divided into four parts, namely: (a) mud formulation and weight measurement (b) filtration test at high pressure- high temperature (c) mud rheology testing (d) Chemical structure, molecular binding form and certain functional group of Mucuna Solannie.

3.4. Mud Formulation.

The mud was formulated according to Table 3.1. It was prepared with varying masses of the additives hence obtaining samples with various concentrations. Samples were prepared with two (2) grams of each additive in 350 ml which is one laboratory barrel. This gives a concentration of 2ppb. Samples were also prepared with four, six and eight grams of the additives giving concentrations of 4ppb, 6ppb, and 8ppb. In all, eight samples were prepared; four for each additive. The mud density was measured.

Table 3.1. Formulation of Mucuna Solannie as a fluid loss control additive

	Oil/Water – 75/25, Mud Weight – 10ppg				Product concentration For 1 lab bbl. (350mls)	
PRODUCT	S.G	UNIT SIZE	ORDER OF MIXING	MIXING TIME	gram	mls
Based fluid (EDC-99)	0.805	BBL	1	4	174.9	217.3
Viscosifier	1.7	Lb			2.0	1.2
Lime	2.3	Kg			3.0	1.3
Primary Emulsifier	0.9	gal	2	2	8.5	9.4
Aqueous Phase	1	bbl			76.1	76.1
Brine Phase	3.64	Kg	3	5	25.4	7.0
Barite	3.7	Kg	4	5	139.4	37.7
Total					**429.3**	**350.0**

Table 3.2: Experimental Data of Sodium Asphalt Sulfonate

S/No	**Sodium Asphalt Sulfonate.**	**Quantity of Additive Formulated**	**Units**
1)	Cost unit	500	$
2)	Cost of Mud formulation of Sodium Asphalt Sulfonate	4000	$
3)	Concentration.	7	Ppb.
4)	Quantiy of Additive used.	95	bags.
5)	Required size of Sodium Asphalt Sulfonate.	26	Kg.
6)	Mud volume prepared.	1300	bbls.

3.5: Rheology Test

Rheology tests were carried out with the Fann V-G viscometer. The samples were tested at 120^0 F, simulating down hole temperature condition. The result obtained at the speeds of 3, 6, 100, 200, 300, and 600 rpm's were recorded and carried out according to API standard as shown in Table 3.2 and 3.3.

Table 3.3: Computed Results of Sodium Asphalt Sulfonate of 10.6ppg Mud weight.

Mud Properties	Fluid Loss Control Agent "Sodium Asphalt Sulfonate"				Shear Rate (l/s)
	2ppb	4ppb	6ppb	8ppb	
Mud Weight, ppg	10	10	10	10	
600RPM	73	75	80	81	1022
300RPM	46	47	50	51	511
200RPM	33	35	38	41	341
100RPM	20	23	26	29	170
6RPM	7	8	8	8	10
3RPM	6	7	7	8	5
Plastic viscosity (cp)	27	28	30	30	
Yield Point, ($lb/100ft^2$)	19	19	20	20	
Electrical stability (mV)	320	326	331	336	
Yield stress ($lb/100ft^2$)	5	6	6	8	

Table 3.4: Computed Results of Mucuna Solannie of 10.6ppg Mud weight.

Mud Properties	Fluid Loss Control Agent "Mucuna Solannie"				Shear Rate (l/s)
	2ppb	4ppb	6ppb	8ppb	
Mud Weight, ppg	10	10	10	10	
600RPM	73	75	79	80	1022
300RPM	46	47	49	50	511
200RPM	32	34	37	40	341
100RPM	19	21	23	26	170
6RPM	6	7	7	7	10
3RPM	5	6	6	7	5
Plastic viscosity (cp)	26	27	30	31	
Yield Point, (lb/100ft^2)	19	19	19	20	
Electrical stability (mV)	318	325	329	335	
Yield stress (lb/100ft^2)	4	5	5	7	

3.6: X-ray Diffraction (XRD), Chemical structure, molecular binding form and Physio-chemical properties of Mucuna Solannie

X-ray diffraction was powered and from the panel, the voltage and current were set at 45kV and 40mA. The temperature was set at 21 to 23^0C. The computer system was switched on and the software of XRD was double clicked to run. The settings dialogue was clicked and all the required setting of power and temperature were checked to correspond to that of the XRD. Sample was poured into the sample holder and then placed in the sample chamber column. Then the door was shut and confirmed from the computer. The measurement setting was then set for scan axis as Gonio, start and end position were also set so was the angle and time of scan. The scan began and then stopped at the required time and the result was saved to a file. The result obtained was then matched with different libraries, such as the NIST and PubChem in order to get the chemical structure, name, and other physiochemical properties.

For functional unit determination, the FTIR 8400S was used. Samples were weighted at 0.01Kbr anhydrous by mortar agate. The mixture was pressed by vacuum hydraulic at 1.2psi to obtain transparency pellet. Scanned sample passed through infra-red, where it's continuing wave by detector was connected to computer and given described of tested sample spectrum. Samples were usually scanned in the absorption area of 600 to 4000 cm-1. The results of analysis consisted of chemical structure, molecular binding form and certain functional groups of tested sample as basic of spectrum type. This was gotten by searching through the National Library of Medicine, National Centre for Biotechnology Information data by typing in the molecular formula. Also, the structure was realized from the same library. The molecular weight was calculated based on the result realized from the X-ray Diffraction that was carried out. The XRD brought out the chemical structure which was then used to detect the total compound present and was then used to calculate the molecular weight as shown in table 3.5.

Table 3.5: Chemical Characteristics and Structure of Mucuna Solannie

S/No	Characteristics	MUCUNA SOLANNIE
1	Botanical Name	Mucuna Solannie
2	Chemical Name	Tricosanol
3	IUPAC Name	Tricosan-12-ol
4	Chemical Formula	$C_{23}H_{48}O$
5	Specific Gravity	0.4806
6	Molecular weight	340.627g/mol

7	Calorific Value	72.2186 MJ/kg

3.7: Bond Length Determination.

To determine the bond length, the elements present in the sample was first detected using Scanning electron microscopy with Energy dispersion X-ray spectroscopy. When used the SEM-EDS indicated the element present while the FTIR indicated the bond present. A table of bond length was then used to determine the length of each compound that form the whole substance analyzed. The FTIR helped to discovered some of the functional groups which then confirmed the results and the matching of the XRD. This position of the Carbon - Carbon, Carbon- Hydrogen, Carbon-Oxygen, Hydrogen-Oxygen, etc. indicating the point of single, double or triple bond were confirmed from the FTIR as shown below.

S/No	BONDER	BONDER ORDER	BONDER LENGTH	BOND ENERGY (kJmol
1	H-O	1	0.96	460
2	C-H	1	1.10	410
3	C-O	1	1.43	358
4	C-N	1	1.47	305

5	C-C	1	1.54	347

Table 3.7: Mucuna Solannie (Tricosanol $C_{23}H_{48}O$)

S/No	CHARACTERISTICS	Value
1	Name	Tricosanol
2	Molecular weight (g/mol)	340.627
3	Total bond	71
4	Surface area (Å)	20.2
5	Bond length (pa)	651.2

3.8: HPHT Fluid Loss Experiment.

This is the test of the Wall building properties in the Mud which determines the fluid force directly from the filter paper under the influences of pressure, temperature and time. At high temperatures, and pressures, the filter press helps in simulating the filtration against permeable formation.

The HTHP filter press comprises of cell sample, stem thermometer, carbon dioxide pressure assembly, Heating Jacket with thermometer and back pressure receiver.

Furthermore, the back pressure was used to collect the filtrate volume allowing the test cell to be encased in the heating jacket as to ascertain uniform and complete sample heating while taken measurement on fluid loss in a sample.

HPHT was done using 2ppb, 4ppb, 6ppb and 8ppb as per APIRP 13B-1 standard of the mud formulated with Mucuna Solannie and Carbon-gel. The filter press of High temperature- High pressure comprises cylinder cells of 5- inches and 3-inches internal diameter. The cell bottom was fitted with a sheet of low ash grade filter paper which was hardened and filled with the measured drilling fluid sample. A pressure of 600psi gotten from carbon dioxide cartridge served as a source of input pressure and the bottom gauge was maintained at 100psi after a required connection. HPHT filtration test commenced immediately the mud sample was heated up to 120°F. With a 10ml of graduated cylinder that was placed below the cell, the collection of filtrate volume through the filter paper was 30minutes in milliliters and recorded filtrate volume was doubled because of inner compartment of the filter area as per API standard. The results of the filtrate loss volume obtained for each fluid loss control agent at various concentrations were measured after 30minutes. The time was lowered to 5minutes, 10minutes, 15minutes, 20minutes and 25minutes below the standard time of 30minutes. The filter paper which contained a layer of mud after each HPHT fluid loss test was determined by dismantling mud cell and rinsed with water. Hence, the residual (cake) thickness gotten from the filter paper of the mud measured using Vernier caliper and recorded in millimeters (mm) as shown below.

Figure 3.3: API low-temperature, low-pressure filter press.

Table 3.8: HPHT fluid loss measurement of Mucuna Solannie and Sodium Asphalt Sulfonate.

Physical properties	Concentration of Mucuna Solannie			
	2ppb	4ppb	6ppb	8ppb
Mud density(ppg)	10	10	10	10
Filtrate Volume (ml) of Mucuna Per 30minutes Received	5.5	5.0	4.5	4.1
Filtrate Volume per Field Standard Across the Reservoir (ml)	6.3	6.3	6.3	6.3

Filtrate Volume of Sodium Asphalt Sulfonate	4.8	4.5	4.2	3.8
Electrical instability of the Mud(mV) formulated using Mucuna Solannie	327	331	336	340
Filter Cake Thickness (mm)	1	1	1	1

Table 3:9: Filtration volume at other time intervals using 2ppb optimum Concentration of the additives.

Additive Concentrations (ppb)	Other Time Interval (Mins)	Filtrate Volume (Ml)	
		Mucuna Solannie	Sodium Asphalt Sulfonate
2	5	13.38	10.34
4	10	8.96	7.60
6	15	7.61	6.37
8	20	6.77	5.65

3.10: Electrical Stability of the Mud.

Electrical Stability is only applicable in oil-based mud which determines the degree or level of stability of the drilling mud. It is a function of mud rheology and the fluid loss. However, when there is increase in electrical stability, the concentration of the filtration control agent, the effectiveness and the stability of the drilling mud increases. This is more observed after a mud has been sheared in the hole, at least two up bottoms. To maintain homogeneity, emulsifiers and some fluid loss additives such as Mucuna Solannie and Calcium chloride are added which aid in the stabilization of the mud during maintenance of drilling fluid.

3.10: Economic Analysis.

The steps used for the calculation of Economic Evaluation of the Proposed Mud (Case A as Mucuna Solannie) and the Existing Mud (Case B as Sodium Asphalt Sulfonate) are as follows:

Carbogel) are as follows:

i. Additives market survey price of Mucuna Solannie and Carbogel muds were obtained.

ii. Discount cash flow rate of return were estimated based on the market survey price of Mucuna Solannie and Carbogel.

iii. Assumed 2000bbls of mud.

iv. Discount cash flow rate of return (DCF-ROR) were discount at 10%, 20%, 30%, 40% and 50%.

v. Perform incremental cash flow.

vi. DCF-ROR of yearly incremental were determined by subtracting Carbogel "Case B" from Mucuna Solannie "Case A", that is, Mathematically expressed thus: Case A- Case B.

vii. The Cash flow were distributed equally at the intervals of 10yeras for both muds.

Table: 3.10: Operating Expenses of Mucuna Solannie and Sodium Asphalt Sulfonate

Description	Operating Cost "Case A"	Operating Cost "Case B"
Transportation.	$6,000.00	$3,000.00
Seed Dryer	$400.00	$200.00
Equipment's Used	$13,000.00	$9,000.00
Labor (assumed 4 workers)	$4000.00	$2000.00
Seeds (assumed 20000)	$10,000.00	$9,000.00
Safety Materials	$10,000.00	$7,000.00
Dry powder storage	$1,200.00	$1,000.00

Water Supply (Tank)	$5,000.00	$4,000.00
Miscellaneous expenses	$1,000.00	$1000.00
Total	$50,600	$36,200

3.10.1: Economic Evaluation of Mucuna Solannie and Sodium Asphalt Sulfonate Mud using Incremental Cash Flow.

The method used for the evaluation was incremental DCF-ROR, the study assumed cash flow duration of 10years.

Let Carbogel be case A "Existing Mud" and Mucuna Solannie be case B "Proposed Mud". However, this case is a cost reducing project, that is, either choosing the proposed mud, Case A or the existing mud, Case B.

Table 3.11: Data of the proposed mud the Existing mud using Incremental Cash flow.

Year	Cash flow ($) "Case A"	Cash flow ($) "Case B"	Incremental ($), A – B.

1	5,000.00	4,000.00	1,000.00
2	5,000.00	4,000.00	1,000.00
3	5,000.00	4,000.00	1,000.00
4	5,000.00	4,000.00	1,000.00
5	5,000.00	4,000.00	1,000.00
6	5,000.00	4,000.00	1,000.00
7	5,000.00	4,000.00	1,000.00
8	5,000.00	4,000.00	1,000.00
9	5,000.00	4,000.00	1,000.00
10	5,000.00	4,000.00	1,000.00
Total	50,000.00	40,000.00	1,0000.00

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Presentation of Result

The results of the filtration test with 2ppb concentration of the additives and other time interval were plotted and shown in Figure 4.1, 4.2, 4.3. The results of the rheological tests obtained are tabulated in Table 3.2 and 3.3 for Carbogel and Sodium asphalt Sulfonate which gave Comparison plots of Plastic viscosity, Yield Point, Yield stress of Mucuna against Sodium Asphalt at various concentration. The Mud was also shown including the degree of stability in figure 4.4 and 4.5. The chemical structure and other properties of Mucuna Solannie were analyzed. Furthermore, the Economic evaluation plots of both muds were shown in figure 4.8 and 4.9.

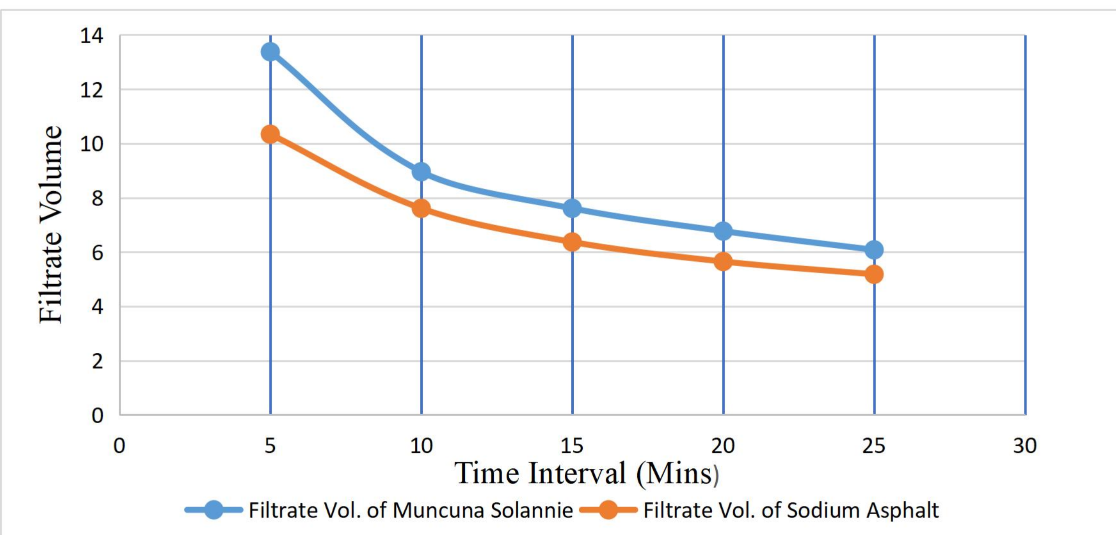


Figure 4.1: Plot of filtrate volumes per time for 2ppb concentration of both additives.

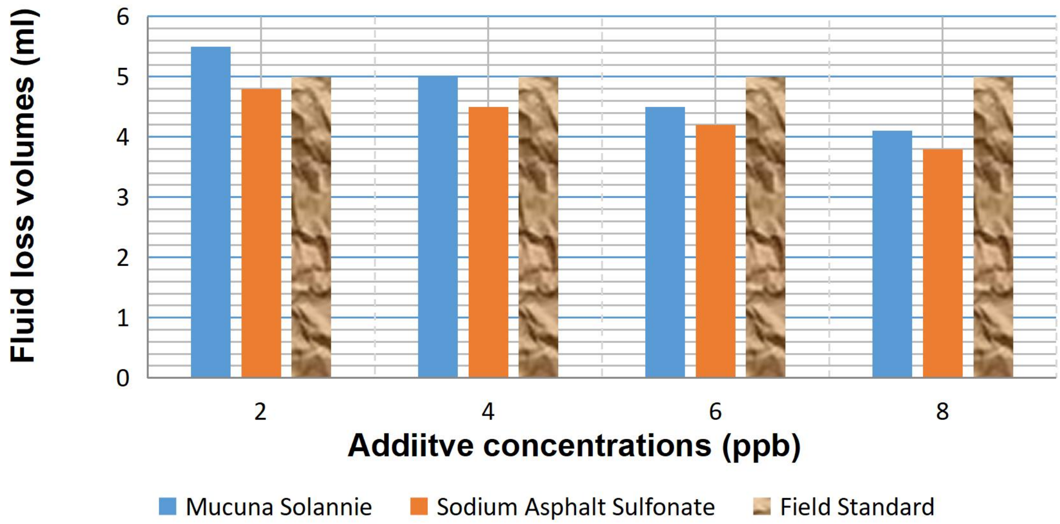


Figure 4:2 Plot of Filtrate volume at various concentrations of both additives against field standard.

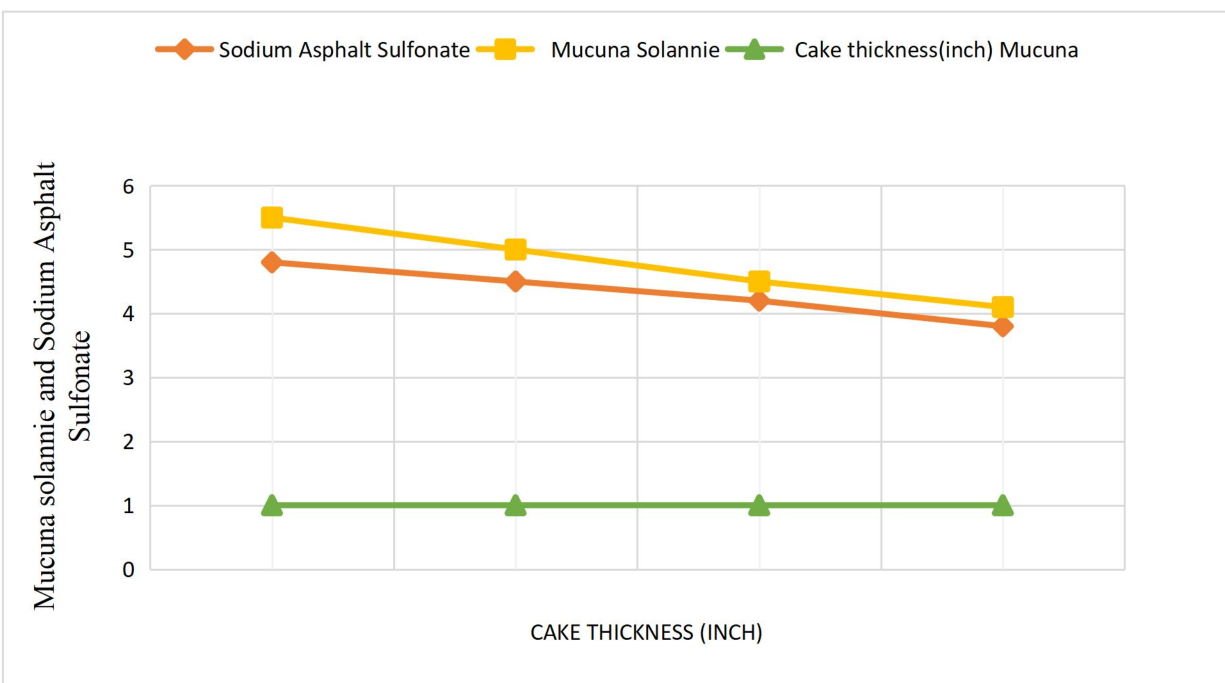


Figure 4.3: Plot of filtrate volume and cake thickness against additive concentration

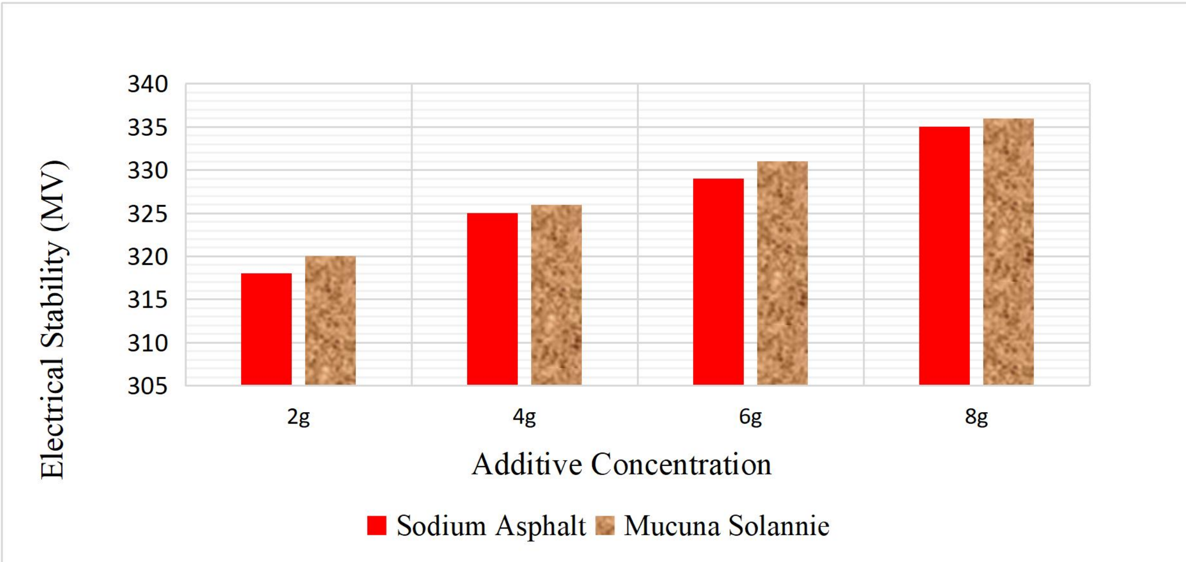


Figure 4.4: Electrical stability of the Mud at different Additive Concentrations.

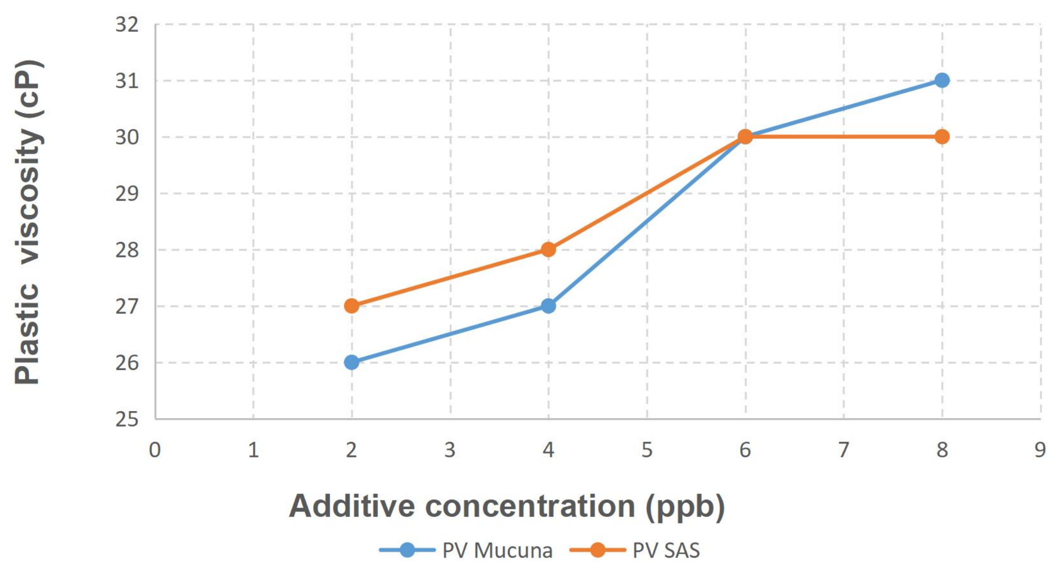


Figure 4.5: Comparison of Plastic viscosity of *Mucuna* against Sodium Asphalt at various concentrations.

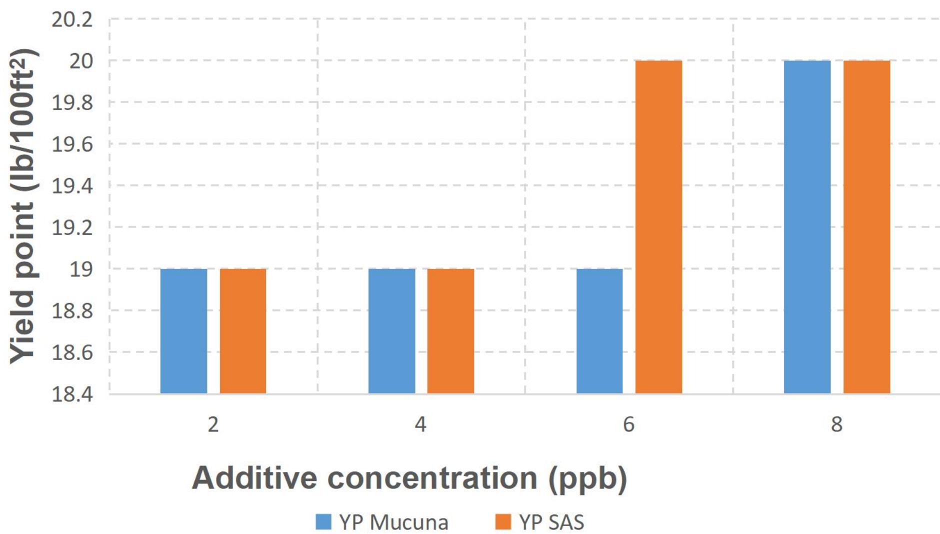


Figure 4.6: Comparison of Fluid Yield point of *Mucuna* against Sodium Asphalt at various concentrations.

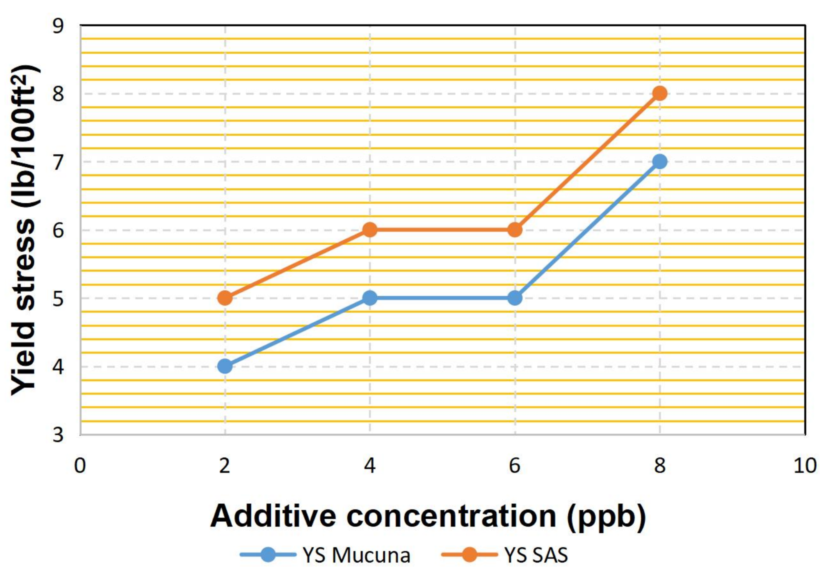


Fig. 4.7: Comparison of Yield stress of *Mucuna* against Sodium Asphalt at various concentrations

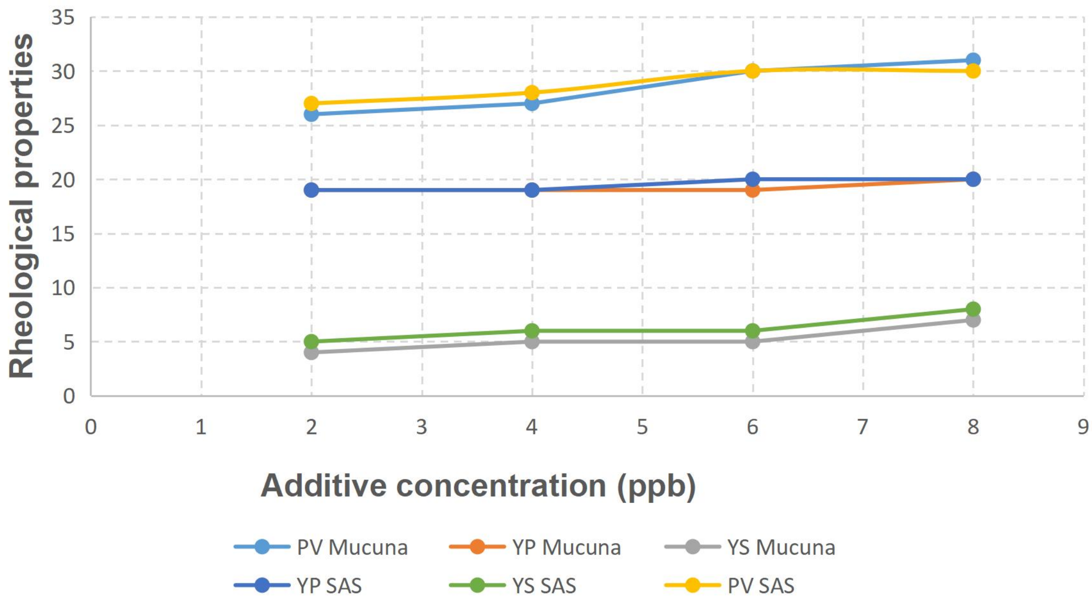


Figure 4.8: Comparison of Rheological properties of *Mucuna* against Sodium Asphalt at various concentrations.

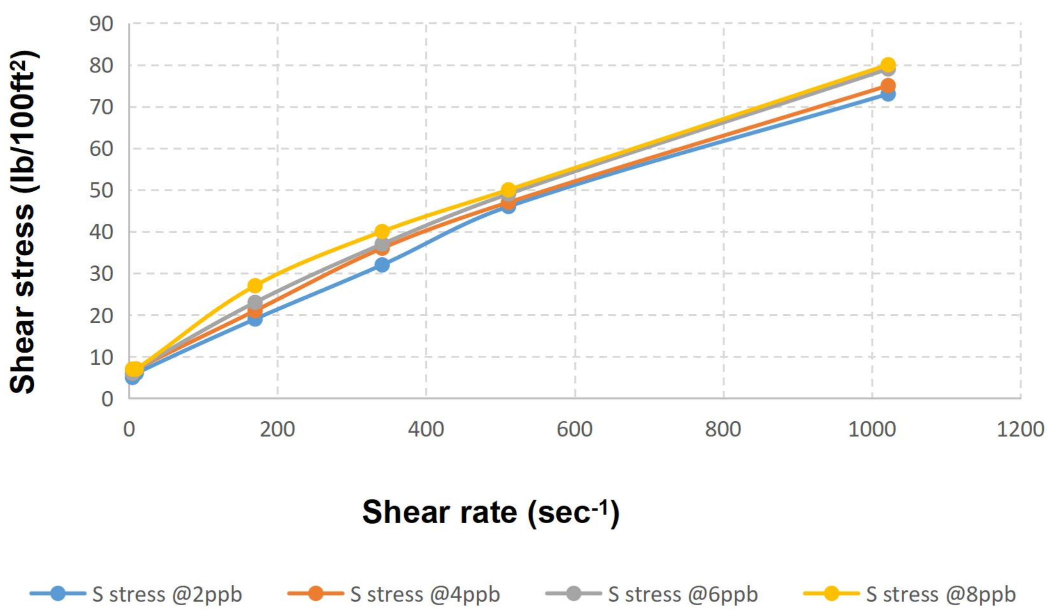


Figure 4.9: Shear stress – shear rate plot of *Mucuna Solannie* at various concentrations.

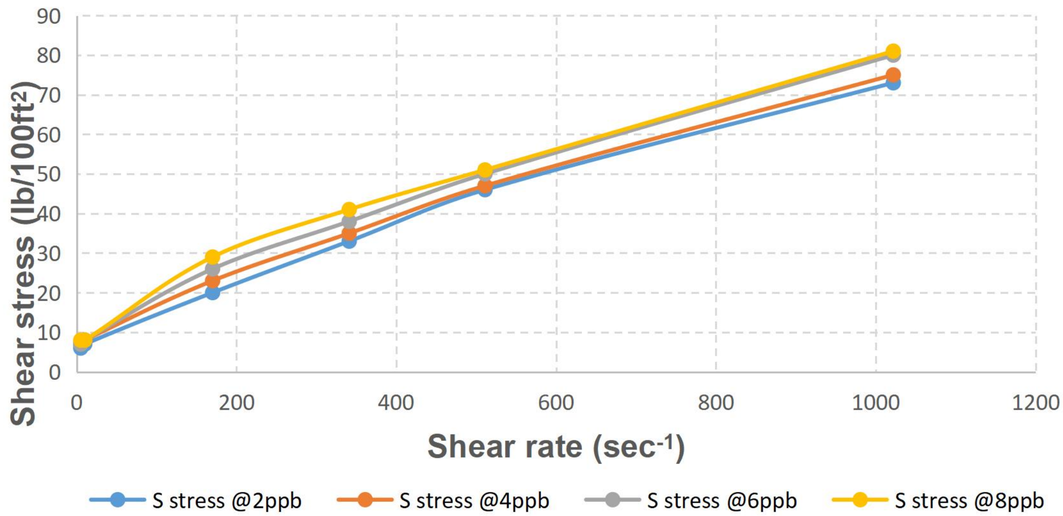


Figure 4.10: Rheogram of Sodium Asphalt Sulfonate at various concentrations.

Chemical Structure.

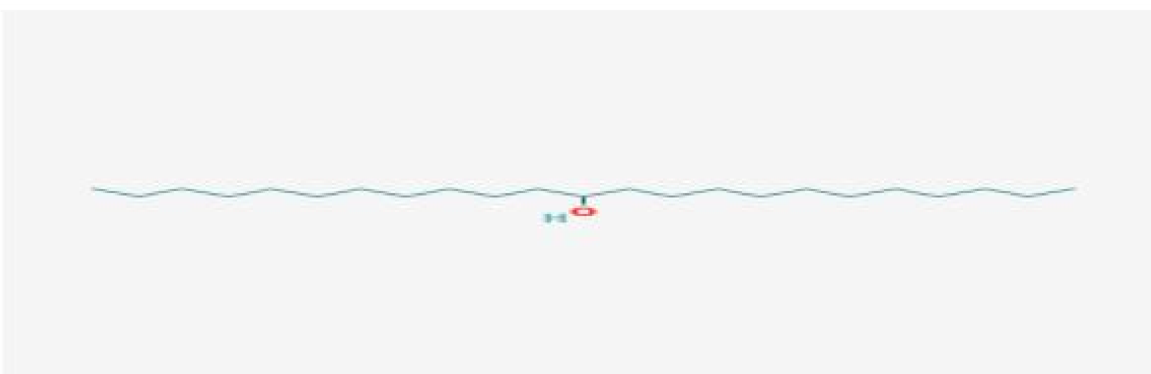


Figure 4.11. Chemical Structure of Tricosan-12-ol

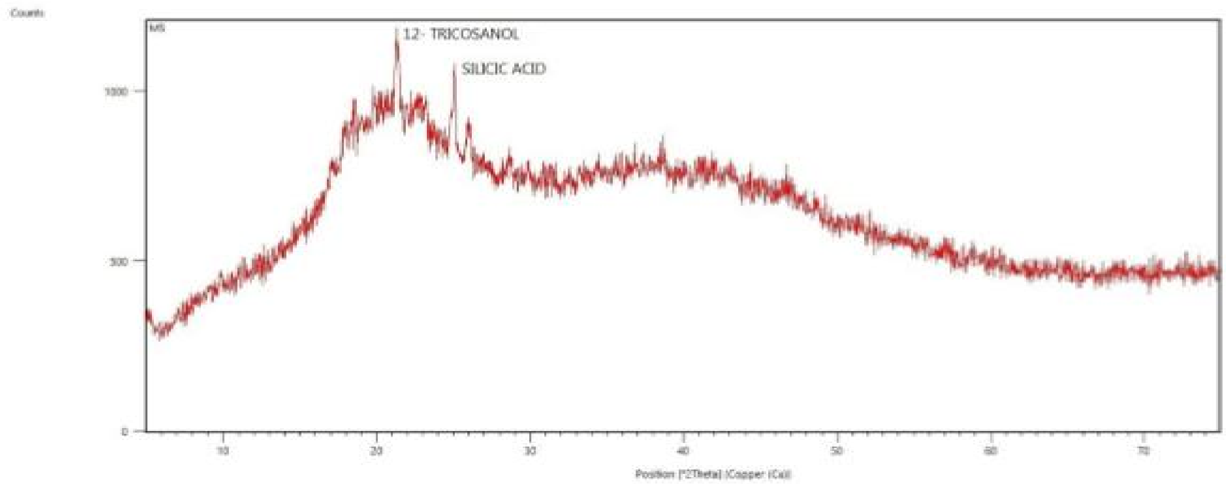


Figure 4.12. Chemical Structure of Tricosanol

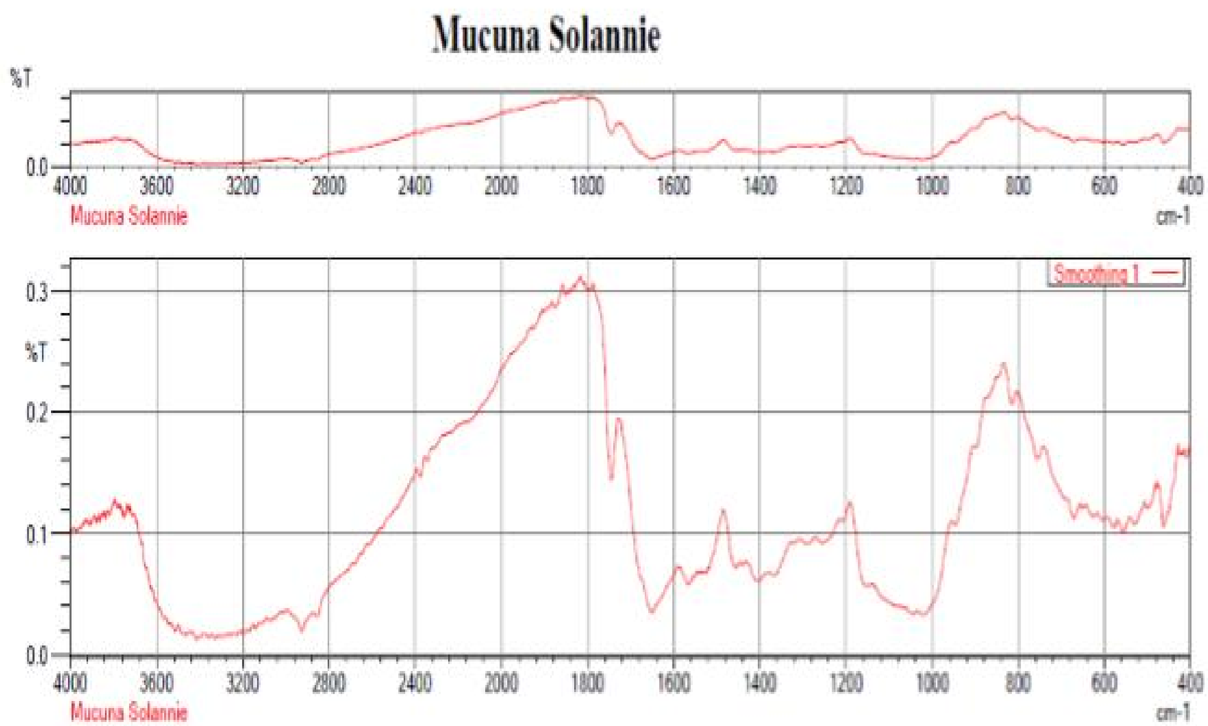


Figure 4.13. Chemical Structure of *Mucuna Solannie*

Table 4.1: Computed Result of Economic Analysis of Net Cash Flow of additive "Project A"

Year	Incremental cash flow ($),	Discount Rates Cash flow ($)					Net Present Value. Project A " Sodium Asphalt Sulfonate"				
		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
1	1,000	909	833	769	714	667	4,545	4,167	3.846	3,571	3,333
2	1,000	826	694	591	510	444	4,132	3,472	2,959	2,551	2222
3	1,000	751	578	455	364	296	3,757	2,894	2,276	1,822	1,481
4	1,000	683	482	350	260	197	3,415	2,411	1,751	1,302	988
5	1,000	620	402	269	186	132	3105	2,009	1,347	930	658
6	1,000	564	335	207	133	88	2,822	1.674	1,036	664	439
7	1,000	513	279	159	95	59	2,566	1,395	797	474	293
8	1,000	466	232	123	67	39	2,333	1,163	613	338	195
9	1,000	424	193	94	48	26	2,120	969	471	242	130
10	1,000	386	162	73	35	17	1,928	808	363	173	87
Total	10,000	6,142	4,190	3,090	2,412	1,965	30,723	20,962	15,459	12,067	9,826

Table 4.2: Computed Result of Economic Analysis of Net Cash Flow of additive "Project B"

Year	Incremental cash flow ($),	Discount Rates Cash flow ($)					Net Present Value. Project B " Mucuna Solannie"				
		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
1	1,000	909	833	769	714	667	3,636	3,333	3,076	2,857	2,667
2	1,000	826	694	591	510	444	3,306	2,778	2,366	2,041	1,778
3	1,000	751	578	455	364	296	3,005	2,315	1,821	1457	1,185
4	1,000	683	482	350	260	197	2,732	1,929	1,401	1041	790
5	1,000	620	402	269	186	132	2,484	1,607	1,077	744	527
6	1,000	564	335	207	133	88	2,258	1,339	829	531	351
7	1,000	513	279	159	95	59	2,053	1,116	637	379	234
8	1,000	466	232	123	67	39	1,866	930	490	271	156
9	1,000	424	193	94	48	26	1,696	775	377	194	104
10	1,000	386	162	73	35	17	1542	646	290	138	69
Total	10,000	6,142	4,190	3,090	2,412	1,965	24,577	16,768	12,364	9,653	7,861

Figure 4.14: Determination of Incremental DCF-ROR of Sodium Asphalt Sulfonate.

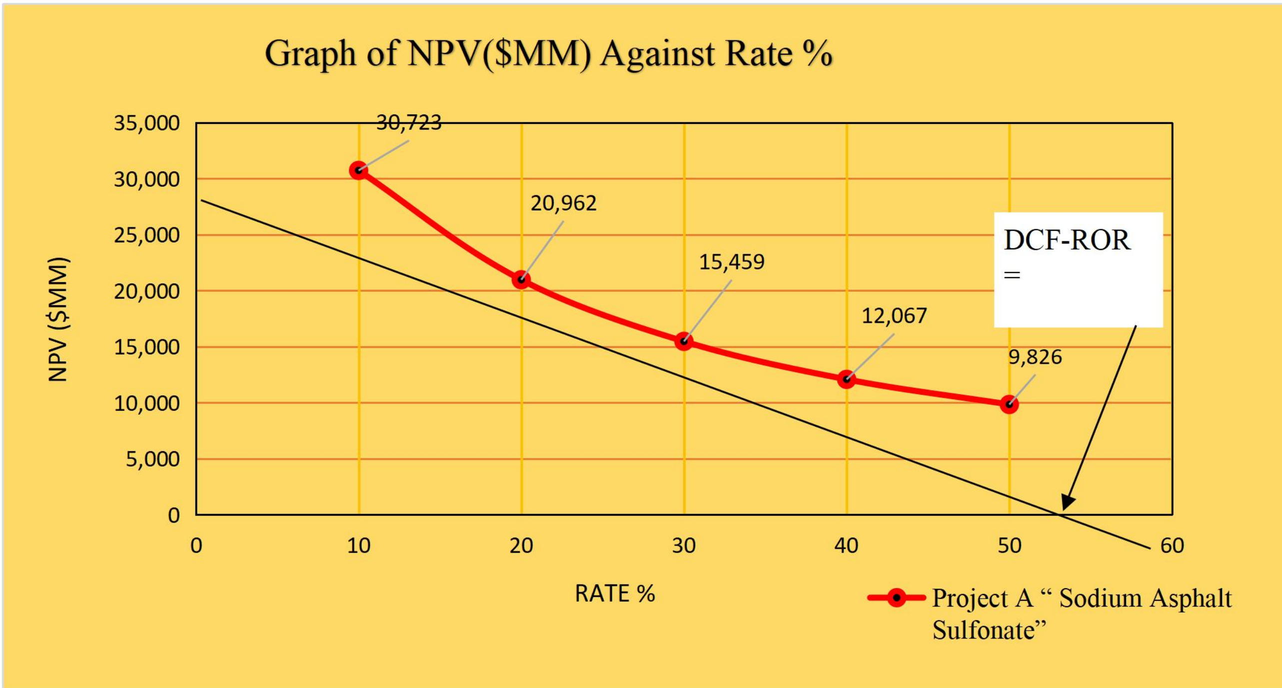
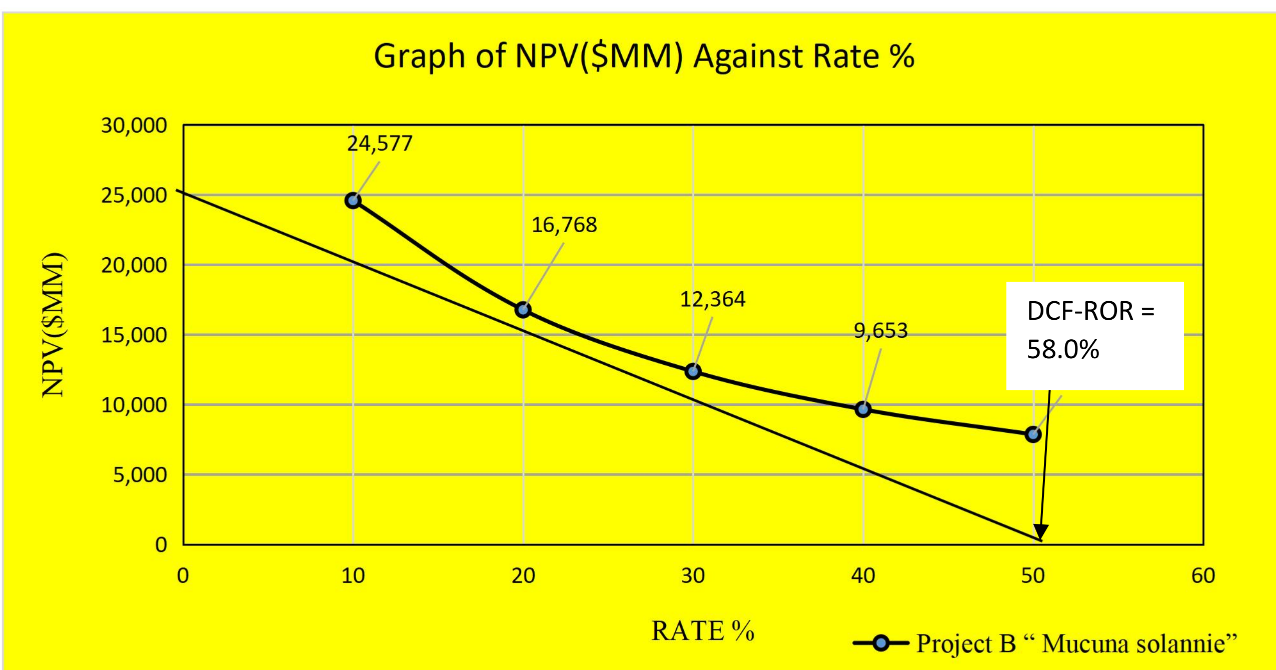


Figure 4.15: Determination of Incremental DCF-ROR of Mucuna Solannie.



4.2: Discussion of Results

Results of filtration test at various time intervals from 5 to 25 minutes of 2ppb concentration of Mucuna Solannie and Sodium Asphalt Sulfonate plotted in Figure 4.1 shows that Mucuna Solannie cake is more permeable, hence it allows more filtrate volumes. However, the volume difference between the two additives decreases with time and at 25 minutes has just a 0.9ml difference. The trend of filtrate volume decreasing with time also shows that mud prepared with both additives will build a filter cake that will protect the formation from mud filtrate invasion.

Figure 4.2. Shows at a glance how both additives fare against industry standard of 5.0ml fluid loss. Both additives showed excellent fluid loss control at higher concentrations of 4, 6 and 8ppb.

Figure 4.3 indicates the filter cake thickness with filtrate volumes at the different concentrations. Both additives showed consistency in cake thickness. This shows that they build stable cakes that can withstand drilling activities that would otherwise lead to cake erosion and deterioration. Also, the thin cake thickness means that wells drilled with Mucuna Solannie additive will not be exposed to hole problems like pipe sticking that result from poor cake quality.

Figure 4.4 shows that for both additives, the mud's electrical stability increases with additive concentration, just as filtrate volume decrease with additive concentration, Hence, muds prepared with Mucuna Solannie will exhibit good fluid loss control as well as good hole sweep.

Figures 4.5 to 4.10 shows the rheological properties of both additives showing similar trends. They have high viscosity values at all concentrations showing good viscosifying and hole cleaning tendencies. API rheology standards are a yield point/plastic viscosity of not more than three. Both additives fall within this standard according to Tables 3.3 and 3.4. The yield point of Mucuna Solannie was constant with concentration until at 8ppb. The yield stress however increased with concentration indicating higher cuttings carrying capacity and hence better hole cleaning at higher concentrations. The rheograms (Figures 4.9 and 4.10) clearly show the non-Newtonian nature of mud prepared with these additives.

From Figure 4.11 to 4.13 results consisted the analysis of X-ray Diffraction and chemical structure of Mucuna Solannie, Tricosanol and Tricosan-12-ol that was powered and set at a current of 40mA, voltage of 45kV and temperature of 21^0 to 23^0C. The result deduced that the X-ray diffraction of Mucuna Solannie when compared to other literature was found to be closer to chitosan structure having along with Calcium salt and organic material. Furthermore, as the percentage of temperature increases, the X-ray diffraction of Mucuna Solannie also increase and the position of Carbon-Carbon, Carbon –Hydrogen, Carbon-Oxygen, Hydrogen-Oxygen indicates the point of single, double triple bond.

From Figure 4.14, Figure 4.15 shows Determination of Incremental DCF-ROR of Mucuna Solannie and Sodium Asphalt Sulfonate. It could be seen that the Mucuna Solannie has a less DCF-ROR of 58.0% against 62.0% of Sodium Asphalt Sulfonate, which indicates that Mucuna Solannie is economically and commercially viable, slightly better and gives less economic cost than Sodium Asphalt Sulfonate.

CHAPTER FIVE

CONCLUSION AND RECOMMEDATION

5.1 Conclusion.

The research work was concluded as follows:

1. Mud prepared with Mucuna Solannie gave filtrate volumes of 5.0ml at 4ppb, 4.5ml at 6ppb, and 4.1ml at 8ppb, all within acceptable range for good fluid loss control agent when compared against the field standard of 5.0ml. Also, mud prepared with Mucuna Solannie gave filter cake of 1mm which is thin and of low permeability. This indicates that a well drilled with Mucuna Solannie prepared will most likely not be exposed to drilling challenges like pipe sticking.
2. Muds prepared with both Mucuna Solannie and Sodium Asphalt Sulfonate had yield stress values increasing with concentration pointing to better hole cleaning potentials of the muds at higher concentrations. This research established Mucuna Solannie as a good fluid loss control agent according to API and field standards. It also indicated the adequate dosage of the additive to be used for mud preparation.
3. The result deduced that the X-ray diffraction of Mucuna Solannie when compared to other literature was found to be closer to chitosan structure having along with Calcium salt and organic material

4. It could be seen that the Mucuna Solannie has a less DCF-ROR of 58.0% against 62.0% of Sodium Asphalt Sulfonate, which indicates that Mucuna Solannie is economically and commercially viable, slightly better and gives less economic cost than Sodium Asphalt Sulfonate.

5.2 RECOMMENDATION.

The following recommendation were made:

1) To evaluate and study other fluid loss property of Mucuna solannie and its compatibility in oil and gas operation.
2) To know the Economic Evaluation of investment in Mucuna Solannie production using spider diagram as to determine DCF-ROR.
3) To what extent should fluid loss control additive of Mucuna Solannie and Sodium Asphalt Sulfonate be applicable in Ultra deep HT and HP well.

5.3 CONTRBUTION TO KNOWLEDGE

1. The degree of suitability and compatibility of Mucuna Solannie as a filtration control additive in synthetic based mud as per concentration was established as good fluid loss control agent and can be used to a reasonable extent as a good hole cleaning additive.

2. Mucuna solannie is more commercially and economically valiable and also very accessible for use as alternative fluid loss control additive.

REFERENCES.

Adebowale KO, Lawal OS (2003). Functional properties and retrogradation behavior of native and chemically modified starch of Mucuna bean (Mucuna pruriens). J. Sci. Food Agric., 83: 1541-1546.

Ademiluyi et al (2011): Investigation of Local Polymer (Cassava Starches) as a substitute for imported sample in Viscosity and Fluid Loss Control of Water Based drilling mud. ARPN J Engg Appl Sci. 2011; 6(12): 43– 8p. 3

Afolabi O.A et al (2000) Preliminary nutritional and chemical evaluation of raw seeds from Mucuna sloanei. An underutilized food source. Journal of Agricultural Food Chemistry 38:122 – 124.

Amanullah, M., & Yu, L. (2005). Environment Friendly Fluid Loss Additives to Protect the Marine Environment from the Detrimental Effect of Mud Additives. Journal of Petroleum Science and Engineering, 48, 199–208

Annudeep S. D. (2012) Rheological Properties and Corrosion Characteristics of Drilling Mud Additives.

Anietie, N.O., Francid, D.O., Perpetua, G.B. (2014). *Evaluation of rice husk as fluid loss control additive in water-based drilling mud*. NAICE, SPE Nigeria, Lagos.

AOAC (2000) Official methods of analysis, 17th edn. AOAC International, Gaithersburg

Awele, N. (2014). Investigation of additives on drilling mud performance with 'TØNDER GEOTHERMAL DRILLING'

Azar, J.J. and Samuel, G.R (2007). *Drilling Engineering*. PennWell Books pp5-10 volume 2.

Baker,S.L.(2000):"Perils of Internal Rate of Return",

http:/hspm.sph.sc.edu/COURSES/ECON/invest.html

Caenn-Guerrero, L., Barbosa-Martín, E., Martínez-Antonio, A., González-Mondragón, E., and Betancur-Ancona, D. (2011). *Some physicochemical and rheological properties of starch isolated from Persea americana seeds*. International Journal of BiolMacromol, 86, 302-8. doi: 10.1016/j.ijbiomac.2016.01.052.

Demitry, V., Gabriel, C., Kurt, C., Jay, R., Jason, T., Arvind, D., and James, M. (2012). *Graphene Oxide as a high-performance fluid-loss-control additive in aqueous muds*. ACS Materials and Interfaces, 4(1), 222 – 27.

Hamida, T.; Kuru, E.; PIckard, M. (2010) Filtration loss characteristics of aqueous waxy hull-less barley (WHB) solutions. Journal of Petroleum Science and Engineering, v. 72, p. 33-41.

Igwilo, K., Ohia, P., and Onwugbuchulem, V. (2016). *Evaluation of the fluid loss properties of pleurotus and its commercial availability*. International Journal of Application in Engineering and Management .5(5): 259 – 64.

Kosynkin, D.V., Ceriotti, G., Wilson, K.C., Lomeda, J.R. Scorsone, J.T., and Tour, J.M. (2011). Graphene *Oxide as a high performance fluid loss control additive in water based drilling fluids*. ACS Applied Material and Interfaces. dx.doi.org/10.1021/am2012799.

Kumar, A. (2010). *Fluid Loss as a function of position around the wellbore*. American Association of Drilling Engineers Fluids Conference and Exhibition held at the Hilton Houston North, Houston, Texas, AADE-10-DF-HO-18.

Manjunatha BK, Patil HSR, Vidya SM, Kekuda TRP, Mukunda S, Divakar R (2006). Studies on the antibacterial activity of Mucuna monosperma DC. Indian Drugs, 43: 150-152.

Meng et al. (2012) .Effects of carbon ash on rheological properties of waterbased drilling fluids. Journal of Petroleum Science and Engineering, v. 100, p. 1-8, 2012. http://dx.doi.org/10.1016/j.petrol.2012.11.011

Nwosu JN. The Rheological and Proximate Properties of some Food thickeners (“Ukpo”, “Achi” and “Ofo”) as affected by processing. Int J Basic Appl Sci. (2012); 1(4): 304–12p. 8

Olatunde, A. O., Usman, M. A., Olafadehan, O. A., Adeosun, T. A., & Ufot, O. E. a (2012). Improvement of rheological properties of drilling fluid using locally based materials. Petroleum & Coal, 54(1), 65–75.

Onudibia ME, Dim LA, Ogunleye PO. (2014) Elemental Analysis of Common food Thickeners: Ukpo (Mucuna Solannie), Achi (Brachystegia Eurycoma) and Ofo (Detarium Microcarpum). Nigerian Journal of Physics; 25(2): 144–9p

P.N. Obiakor-Okeke, J.N. Chikwendu, T. Anozie, (2014) "Effect of Different Processing Methods on the Chemical, Functional and Microbial Properties of Mucuna solannie Seeds (Ukpo)," International Journal of Nutrition and Food sciences, Vol. 3, No. 6, pp. 551-559.

Samavati, R., Abdullah, N., Tahmasbi, N. K., Hussain, S. A., & Awang, B. D. R. (2014). Rheological and fluid loss properties of water based drilling mud containing HCl-modified fufu as a fluid loss control agent. International

Suter et al, (2011). Rule based design of clay-swelling inhibitors. Energy Environmental Science, v.4, p. 4572-4586, 2011. http://dx.doi org/10.1039/ c1ee01280k

Ukachukwu, C., Ogbogbe, O., and Umorem, S. (2010). Preparation and characterization of biodegradable polymer mud based on millet starch. Chemical Engineering Communications, 197(Pt8), 1126 – 39.

NOMENCLATURE

API- American Petroleum Institute.

YP- Yield Point

AV- Apparent Viscosity

PV- Plastic Viscosity

γ = Shear rate in sec^{-1}

μ = viscosity, centipoises

RPM – revolutions per minute

PPb= pounds per barrel

Ppg= pounds per gallon

HT-HP=High Temperature High Pressure

DCF-ROR – Discounted Cash Flow Rate of Return

NPV= Net Present Value

ES= Electrical Stability

XRD= X-Ray Diffraction

Appendix

Anchor Scan Parameters

Dataset Name:	Mucuna Solannie
File name:	C:\Users\USER\Desktop\DOCS\2020\07\9_07_20\MS.xrdml
Comment:	Configuration=Flat Sample Stage, Owner=User-1, Creation date=7/22/2010 4:15:08 PM Goniometer=Theta/Theta; Minimum step size 2Theta:0.0001; Minimum step size Omega:0.0001 Sample stage=Stage for flat samples/holders Diffractometer system=EMPYREAN Measurement program=SLS Flat Programme, Owner=User-1, Creation date=3/15/2017 3:38:00 PM
Measurement Date / Time:	09/07/2020 12:04:19
Operator:	U
Raw Data Origin:	XRD measurement (*.XRDML)
Scan Axis:	Gonio
Start Position [°2Th.]:	5.0024
End Position [°2Th.]:	74.9684
Step Size [°2Th.]:	0.0260
Scan Step Time [s]:	29.0700
Scan Type:	Continuous
PSD Mode:	Scanning
PSD Length [°2Th.]:	3.35
Offset [°2Th.]:	0.0000
Divergence Slit Type:	Automatic
Irradiated Length [mm]:	4.00
Specimen Length [mm]:	10.00
Measurement Temperature [°C]:	25.00
Anode Material:	Cu
K-Alpha1 [Å]:	1.54060
K-Alpha2 [Å]:	1.54443
K-Beta [Å]:	1.39225
K-A2 / K-A1 Ratio:	0.50000
Generator Settings:	40 mA, 45 kV
Diffractometer Type:	0000000011078671
Diffractometer Number:	0
Goniometer Radius [mm]:	240.00
Dist. Focus-Diverg. Slit [mm]:	100.00
Incident Beam Monochromator:	No
Spinning:	No