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Utilizing Green Nanoparticles In Drilling Mud: Comprehensive Analysis Between Conventional Nanoparticles And Green Nanoparticles.

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***Abstract**: For successful drilling, drilling fluid is a vital element during drilling operations to improve penetration efficiency, transport cuttings, and preserve wellbore stability. Conventional fluids have a number of disadvantages, including environmental damage and inefficiency in some formations. Water-based mud (WBM), oil-based mud (OBM), and synthetic-based mud (SBM) are examples of these fluids that frequently need chemical additions to increase viscosity and mud weight. OBM has a high efficiency but comes with serious environmental hazards, such as pollution, bioaccumulation, and toxicity. This research investigates the use of environmentally friendly nanoparticles, particularly nanocellulose, into drilling fluids as a viable substitute. Plant and bacterial-derived green nanoparticles have been shown to minimise environmental impact while providing improved rheological characteristics, greater thermal stability, and shale inhibition. This study explores a potential replacement for drilling fluids: the incorporation of environmentally benign nanoparticles, specifically nanocellulose. Green nanoparticles made from plants and microbes have demonstrated the capacity to reduce their negative effects on the environment while offering enhanced rheological properties, increased thermal stability, and shale inhibition.*

Introduction

Drilling fluids are one of the most important materials during any drilling operation. Drilling fluid sometimes known as drilling muds play a vital role in increasing efficiency of penetration, transportation of cuttings and wellbore stability. Drilling fluids are special fluids composed of different chemicals that serve as a lubricant to the drill bit, control well bore pressure and stabilize the well. Basically, there are three common types of drilling fluids namely; Water-based mud (WBM), Oil based mud (OBM) and Synthetic based mud (SBM). These muds are sometimes added with some special additives to improve its efficiency like increasing viscosity or increasing the mud weight.

Over the years, these drilling muds have been noticed to have some several drawbacks when it comes to environmental considerations. Also, some of drilling muds operate at a very low efficiency in some specific formations and they alter the chemical composition of the formation by reacting with the core elements leading to higher permeability deviation. Environmentally, some of the most highly efficient drilling fluids like the oil-based mud (OBM) have a considerable negative effect to the environment when it comes to the disposal issue, bioaccumulation, toxicity and air pollution. Therefore, there is a high need for a sustainable technology that will consider the operating environment and as well as the safety of the workers.

The green and sustainable technology for the future of the drilling fluids is very necessary as much as the environment is concerned. The green nanoparticles are part of the solution in application of sustainable technology for the better drilling resolutions. There are numerous existing nanoparticles grouped into conventional and green nanoparticles that both play a vital part in enhancing the efficiency of the drilling fluid through their unique rheological properties, increased thermal stability and shale inhibition. The green nanoparticles will not only improve the mud rheology and efficiency but also consider the surrounding environment. Additionally, these green nanoparticles provide a sustainable sourcing (from plants and bacteria), shale inhibition, cost effectiveness and Regulatory compliance.

The main objective of this project is to design the green nanoparticles in drilling fluids to suit the environmental aspect and compare the results with other conventional nanoparticles and existing drilling fluids to match the suitability. In this project, Nanocellulose is a preferably nanoparticle to use due its reliability and natural existence while nano-silica (SiO_2) will be a conventional nanoparticle to be used for comparison. This project has proved that green nanoparticles in drilling fluids such as nano cellulose

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characteristics especially in improving the mud pH and viscosity and therefore, it is more encouraged to use rather than the existing drilling muds. This project is also one among the few projects that recommend the use of green and sustainable drilling fluids for the environmental aspect.

Green Nanotechnology

The green nanotechnology emerged in 2000 in account for renewable energy advancements and leveraging principles of green chemistry. The discovery made significant developments and innovations in the synthesis of plant-based nano-particles and waste derived nanoparticles. The green nanoparticles are nanoparticles that are synthesised by utilizing sustainable and environmentally friendly methods. These nanomaterials are characterised by biocompatibility, biodegradability and non-toxicity for both the environment and the safety.

Types of green nanoparticles.

The main types of green nanoparticles can be categorized based on the materials they are made from and their applications. Here are some key types:

a) Metallic Nanoparticles

Metal Oxide Nanoparticles

These include Zinc Oxide Nanoparticles (ZnO NPs), Titanium Dioxide Nanoparticles (TiO2 NPs), Iron Oxide Nanoparticles (Fe3O4 NPs).

Polymeric Nanoparticles

These include Chitosan Nanoparticles obtained from shells of crustaceans, and Starch Nanoparticles.

Carbon-Based Nanoparticles

These include carbon composed nanoparticles such as Carbon Nanotubes (CNTs), Graphene Oxide Nanoparticles.

Nanocellulose

These are made from plant extract and hydrolysis of cellulose such as Cellulose Nanocrystals (CNCs), Cellulose Nanofibrils (CNFs), Bacterial Nanocellulose (BNC)

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These include Zinc Oxide Nanoparticles (ZnO NPs), Titanium Dioxide Nanoparticles (TiO2 NPs), Iron Oxide Nanoparticles (Fe3O4 NPs).

Polymeric Nanoparticles

These include Chitosan Nanoparticles obtained from shells of crustaceans, and Starch Nanoparticles.

Carbon-Based Nanoparticles

These include carbon composed nanoparticles such as Carbon Nanotubes (CNTs), Graphene Oxide Nanoparticles.

Nanocellulose

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Methodology

The main aim is to create high performance water-based mud and adjust its chemical composition by adding nano particles to create a drilling fluid that can substitute oil based mud in well harsh condition. So, a design is applied to 5 specimen of water base mud, base mud without addition of nano particles, water base mud with 0.5gm nano cellulose, water base mud with 1gm nano cellulose, water base mud with 0.5gm nano silicon dioxide, and water base mud with 1gm nano silicon dioxide. Moreover, different tests will be applied to 5 mud samples to compare its rheology and properties in discussion section.

List of material composition used

- water 350 ml
- potassium chloride 10gm
- sodium carbonate anhydrous (soda ash) 0.5gm
- sodium hydroxide flakes AR (caustic soda) 0.4gm
- PAC-SL 0.6gm
- Xanthan gum 1.2gm
- Barite 80gm
- Graphite 2gm
- Silicon dioxide nano powder (0.5gm-1gm)
- Cellulose nanocrystals (0.5gm-1gm)

Preparation of the new drilling fluid composition

1- First prepare 350 ml of water in bottle

2- Put potassium chloride of 10gm for better shale inhibition for sensitive clay formation

3- Put soda ash of 0.5gm to increase drilling fluid PH

4- Put caustic soda of 0.4gm to solubilize acidic compounds, and reduce the corrosivity of drilling fluid

5- Put PAC-SL of 0.6gm for filtration reduction, and make fluid withstand high temperatures (Fig. 5)

6- Put Xanthan gum of 1.2gm to increase viscosity for better cutting lifting (Fig. 8)

7- Put 80 gram of barite as weighting material (Fig. 4)

8- Put 2 gram of graphite for better drilling fluid lubrication and as a sealing agent for various formations

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Results and Discussion

After the preparation of the drilling fluid based on different composition for conventional nanoparticles, green nanoparticles and high-performance drilling fluid, the data obtained from the experiments are compared.

Mud type	Mud weight in ppg
Base mud	10.1

Mud balance.

PH meter

Mud type	PH
Base mud	11.84
Nano Si 0.5g	11.48
Nano Si 1g	11.4
Nano Cel 0.5g	11.61
Nano Cel 1g	10.85

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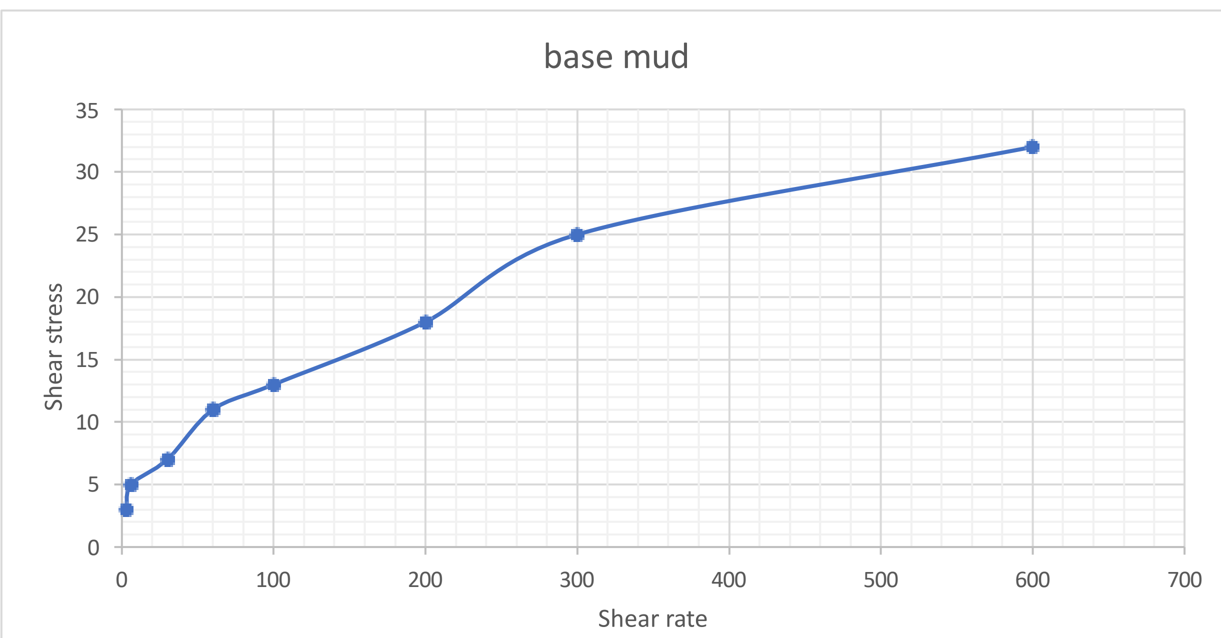
Viscosity (rheology)

Base mud	Shear stress	32	25	18	13	11	7	5	3
	Shear rate	600	300	200	100	60	30	6	3
	Gel strength @10 sec	3							
	Gel strength @10 min	5							
	Plastic viscosity	Reading @600 – Reading @300 32-25= 7 cp							
	Yield point	2xreading @300 – reading @600 $=2 \times 25 - 32 = 18 lb/100ft^2$							
Nano Si 0.5	Shear stress	56	46	33	27	20	16	12	8
	Shear rate	600	300	200	100	60	30	6	3
	Gel strength @10 sec	8							
	Gel strength @10 min	10							
	Plastic viscosity	56-46= 10 cp							
	Yield point	$2 \times 46 - 56 = 36 lb/100ft^2$							
Nano Si 1	Shear stress	63	51	38	32	23	20	15	11
	Shear rate	600	300	200	100	60	30	6	3
	Gel strength @10 sec	11							
	Gel strength @10 min	13							
	Plastic viscosity	63-51=12 cp							
	Yield point	$2 \times 51 - 63 = 39 lb/100ft^2$							

Nano cel 0.5	Shear stress	37	26	20	16	13	9	7	4
	Shear rate	600	300	200	100	60	30	6	3
	Gel strength. @10 sec	4							
	Gel strength. @10 min	6							
	Plastic viscosity	37-26 = 9 cp							
	Yield point	$2 \times 26 - 37 = 15 lb/100ft^2$							
Nano cel 1	Shear stress	41	29	23	17.5	13	11	8	5
	Shear rate	600	300	200	100	60	30	6	3
	Gel strength. @10 sec	5							
	Gel strength. @10 min	7							
	Plastic viscosity	41-29=12 cp							
	Yield point	$2 \times 29 - 41 = 17 lb/100ft^2$							

Graphs:

For base mud



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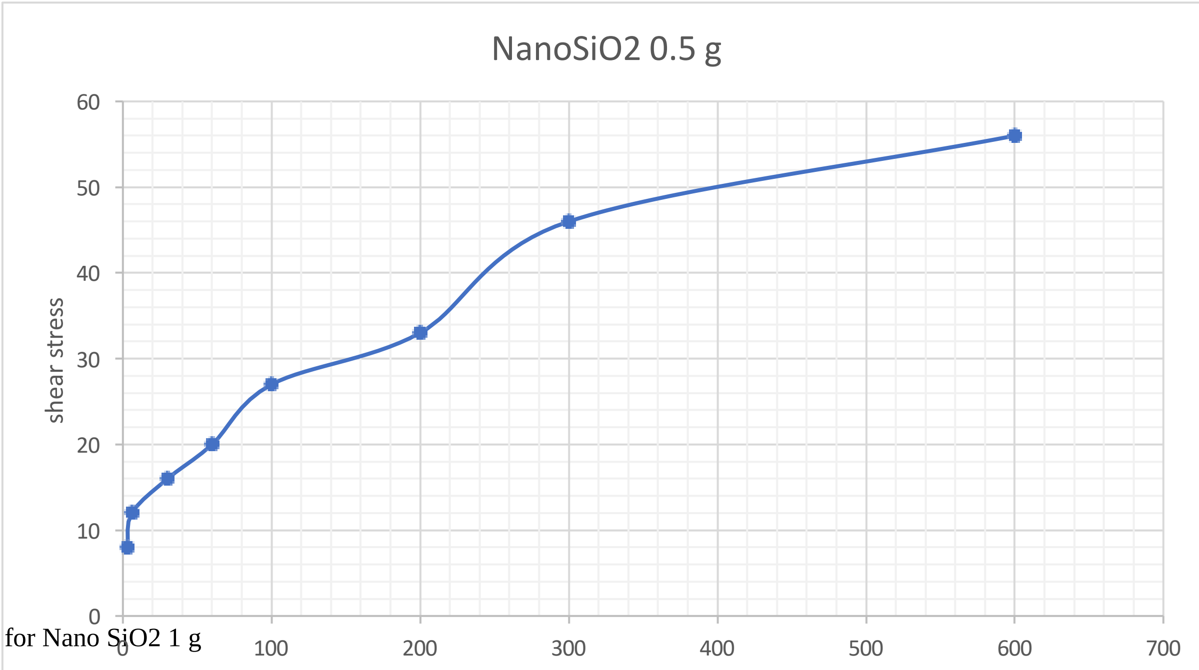
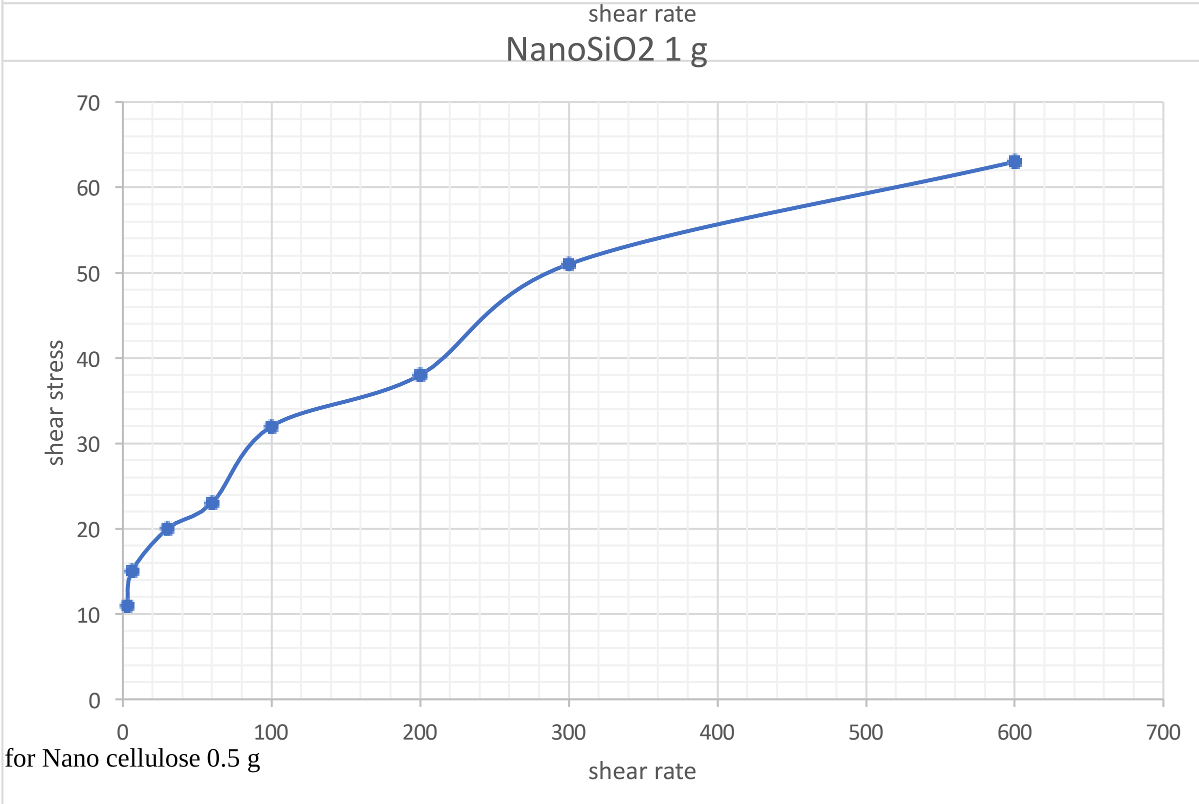
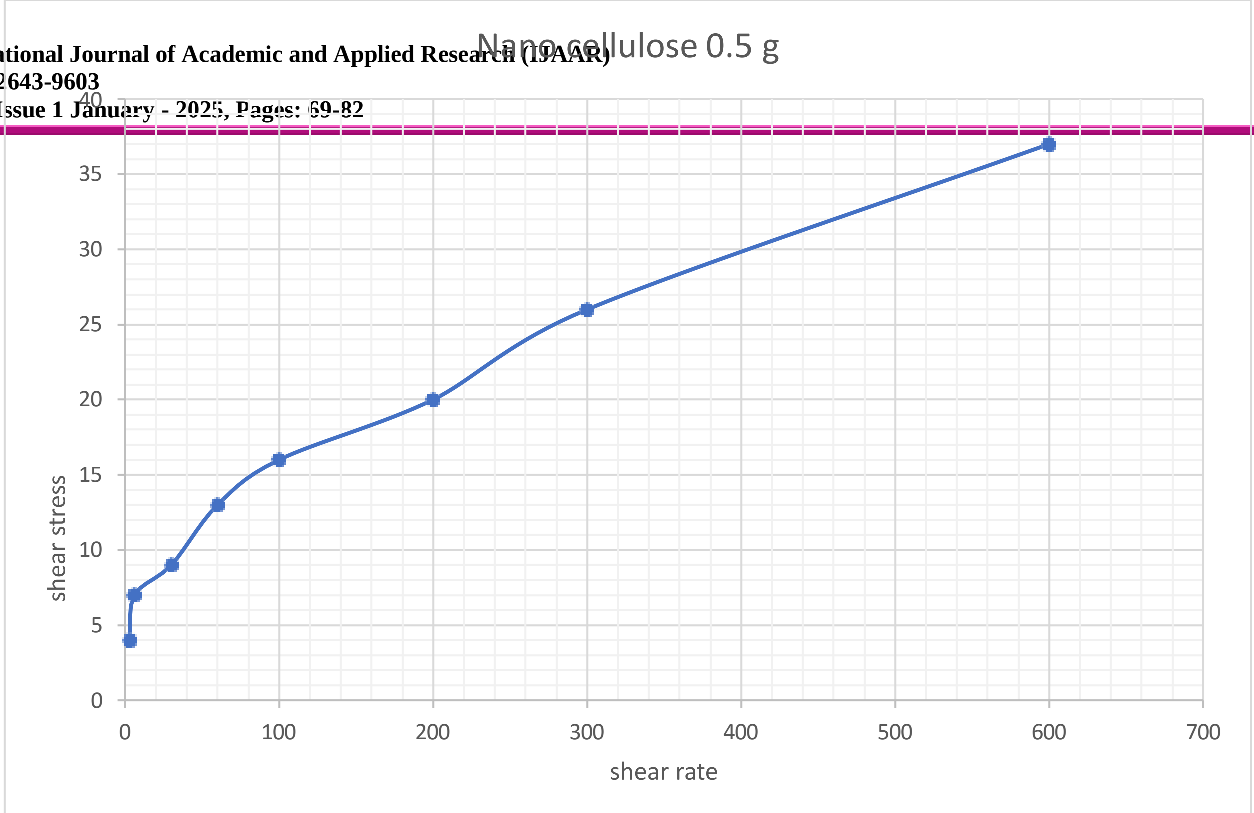
For Nano SiO2 0.5 g



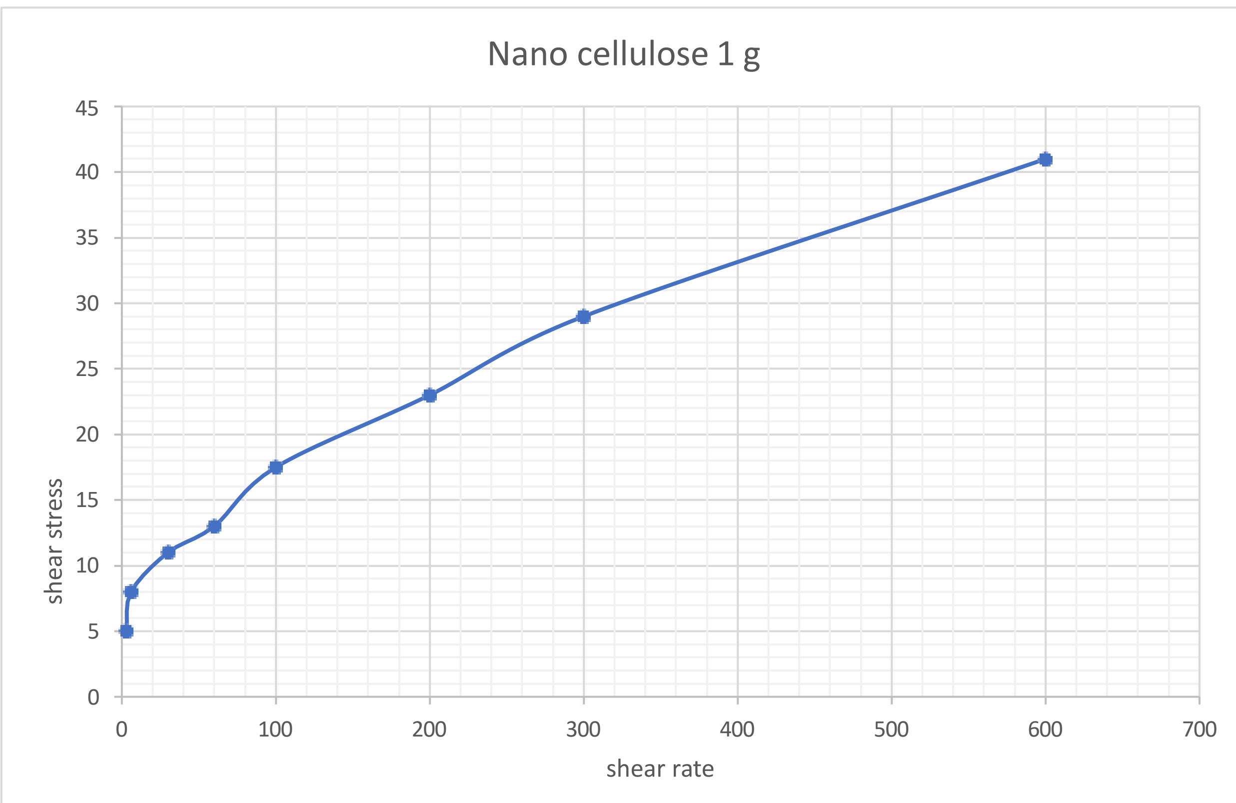
for Nano SiO2 1 g



for Nano cellulose 0.5 g



for Nano cellulose 1 g



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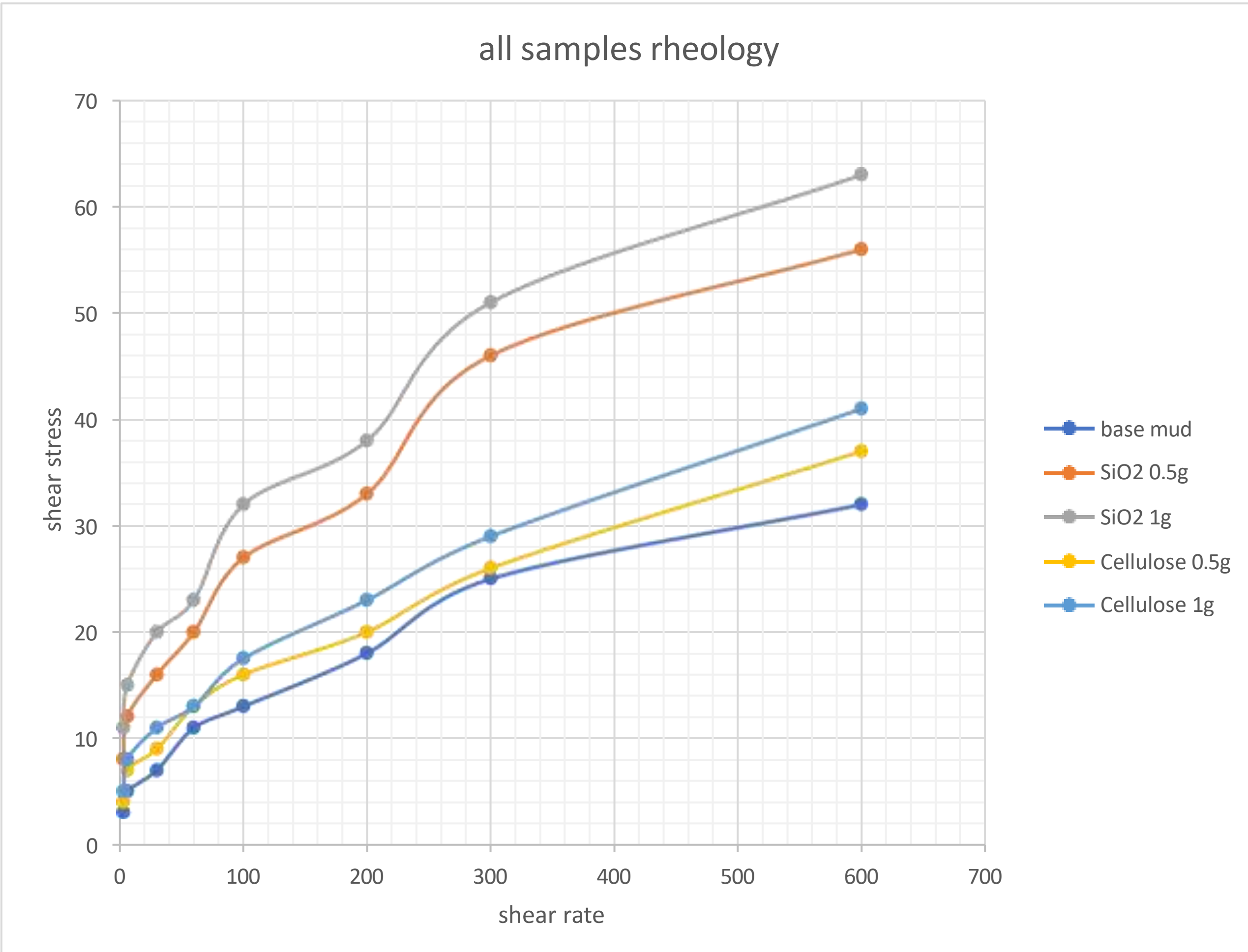
Comparison between 5 samples rheology



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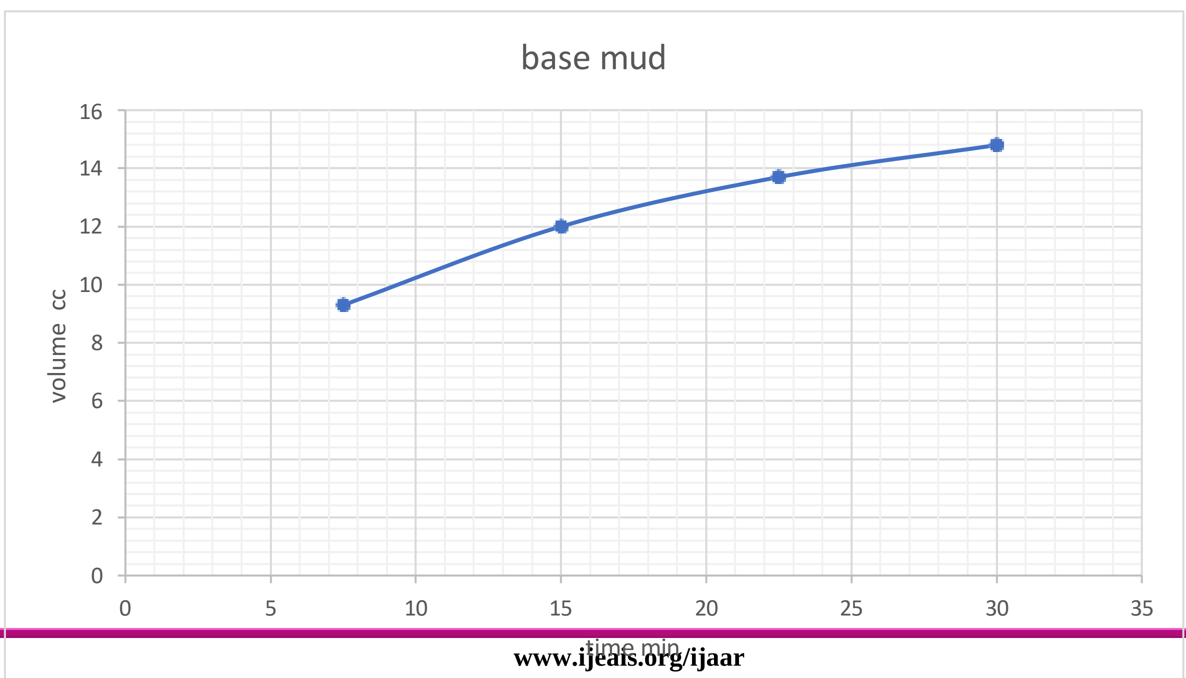
1. API filter press

Base mud	Volume cc	9.3	12	13.7	14.8
	Time min	7.5	15	22.5	30
	Spurt loss	1.3			
Nano Si 0.5	Volume cc	8.5	11.5	13.65	15.2
	Time min	7.5	15	22.5	30
	Spurt loss	0.9			
Nano Si 1	Volume cc	7.7	11	13.6	15.6
	Time min	7.5	15	22.5	30
	Spurt loss	0.6			
Nano Cel 0.5	Volume cc	9	12	13.9	15.4
	Time min	7.5	15	22.5	30
	Spurt loss	2.4			
Nano Cel 1	Volume cc	8.8	12.1	14.1	16
	Time min	7.5	15	22.5	30
	Spurt loss	3.3			

Graphs:

For base mud



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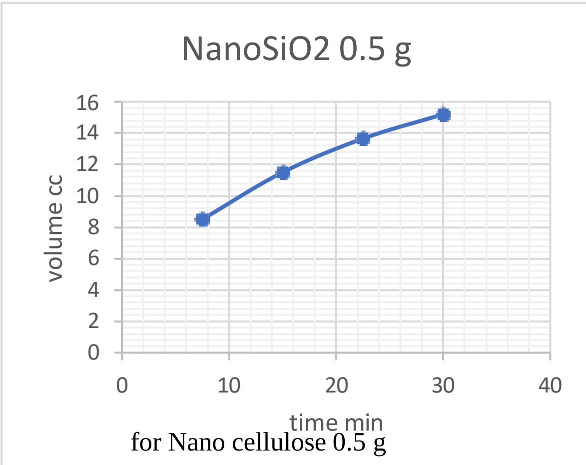
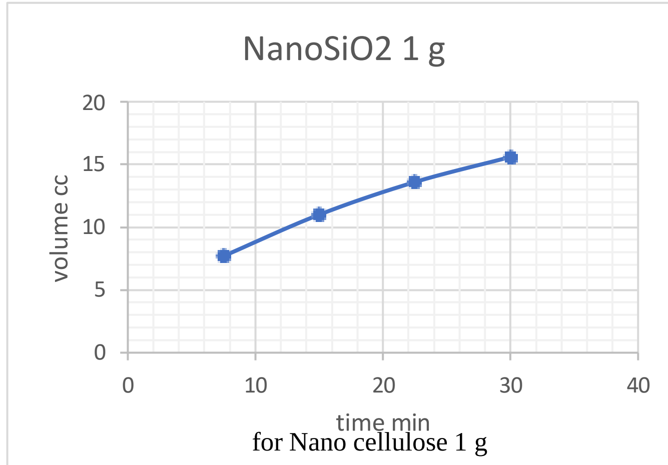
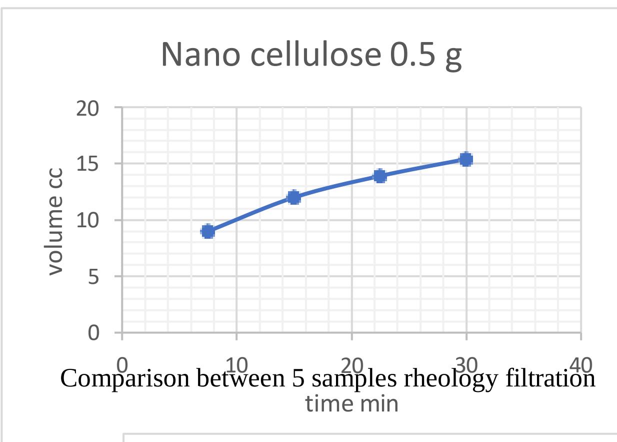
For Nano SiO2 0.5 g



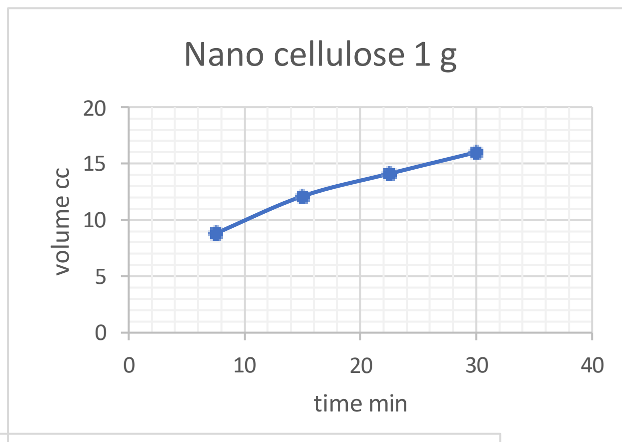
For Nano SiO2 1 g



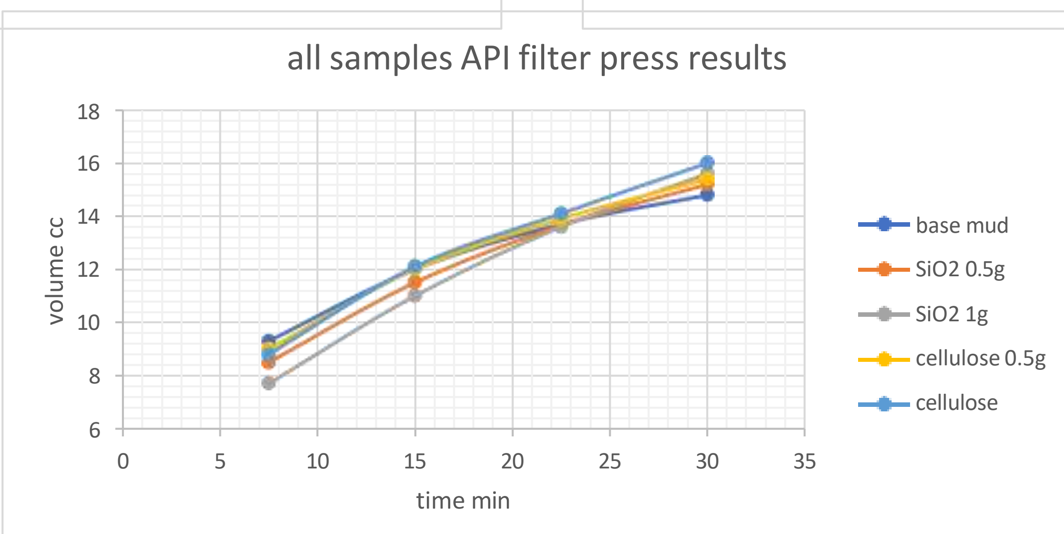
for Nano cellulose 0.5 g



for Nano cellulose 1 g



Comparison between 5 samples rheology filtration



Discussion

Drilling fluids with varying nanoparticle compositions, such as nano-silica (SiO_2) and nanocellulose, have been analysed experimentally. The results shed light on the characteristics and performance of these fluids in comparison to base mud.

Variation in the Mud Density

The density of the various drilling fluids varies slightly, according to the findings of the mud balancing test. 10.1 ppg is the density of the foundation mud. The density is marginally increased to 10.11 ppg and 10.12 ppg, respectively, by the addition of both nano-silica and nanocellulose. This suggests that nanocellulose and nano-silica can both marginally raise the drilling fluid's density, which is advantageous for managing formation pressures. Still, this boost is negligible and has no appreciable effect on the total performance.

pH Measurements

The base mud had a pH of 11.84. The addition of nano-silica and nanocellulose both resulted in a slight reduction in pH but maintained a more stable range. For example, 0.5 g of nanocellulose produced a pH of 11.61 and 1 g produced a pH of 10.85. This stable pH range indicates that nanocellulose provides a more consistent chemical environment, which is crucial for maintaining the stability and reactivity of the drilling fluid with Fm

Retort Analysis (Solid Content)

Both nanoparticles improve the drilling fluid's fluidity by lowering its solid concentration, according to the retort analysis. 1.3% of the base mud was made of solids. The solid concentration somewhat dropped with the addition of nanocellulose, suggesting increased fluidity and a decrease in solids. This characteristic is necessary for effective drilling operations because it provides improved cutting suspension and transportation.

Viscosity (Rheology)

With the addition of nanocellulose, the rheological characteristics—such as shear stress and shear rate—were greatly enhanced. A shear stress of 32 was observed in the base mud at a shear rate of 600 rpm.

Gel Strength

The addition of nanocellulose resulted in significant improvements in the gel strength measurements; the base mud had a gel strength of 3 lb/100ft³ at 10 seconds and 5 lb/100ft³ at 10 minutes; the addition of nanocellulose increased the gel strength to 4 and 6 lb/100ft² at 0.5 g addition and to 5 and 7 lb/100ft² at 1 g addition. These improvements in the gel strength measure better wellbore stability and effectively suspended drill cuttings, which makes nanocellulose an excellent option for improving the properties of drilling fluids.

API Filter Press

Improvements in filtration qualities with nanocellulose were shown by the API filter press results. After adding nanocellulose, the filtrate volume remained approximately 9 cc with a marginal increase in spurt loss, compared to 9.3 cc and 1.3 spurt loss for the base mud after 7.5 minutes. Nanocellulose still provides substantial environmental and performance benefits that exceed the minor difference in filtering control, even if nano-silica demonstrated somewhat better filtration control. In drilling operations, the utilization of nanocellulose sourced from sustainable sources guarantees a decreased environmental effect and fosters sustainability.

Generally, the key performance parameters including density, pH, solid content, viscosity, gel strength, and filtration qualities show considerable improvements when nanocellulose is added to drilling fluids. Although nano-silica has certain advantages, nanocellulose provides a more environmentally friendly and sustainable option. High- performance and environmentally friendly drilling fluids benefit greatly from the added value of nanocellulose due to its exceptional ability to improve rheological properties, maintain a steady pH, and provide sufficient filtration control. It is advised to use nanocellulose rather than more traditional nanoparticles like nano-silica because of these findings, which demonstrate how nanocellulose can advance efficient and sustainable drilling operations.

Conclusions

In conclusion, this study emphasizes the importance of drilling fluids in improving drilling efficiency, particularly through innovative green nanoparticles. The introduction highlighted the environmental challenges and inefficiencies associated with traditional drilling fluids such as water-based mud oil-based mud and synthetic-based mud. The need for sustainable technology to address these issues is clear.

The methodology included developing high-performance water-based mud and enhancing it with nanoparticles such as silica SiO_2 and cellulose nanocrystals. Several tests were run on five mud samples to compare their rheological properties and overall performance.

The findings showed that the addition of green nanoparticles, particularly nanocellulose, significantly improved the mud rheology and properties. The addition of nano cellulose increased the pH and viscosity of the mud, making it a more viable option than conventional drilling fluids. The mud balance, pH readings, retort analysis, viscosity tests, and API filter press results all demonstrated that nanoparticle-enhanced muds performed better.

Overall, this project acknowledges the use of green nanoparticles to create more efficient and environmentally friendly drilling fluids. The findings support the application of sustainable drilling practices, which provide a promising alternative to traditional drilling fluids while simultaneously solving environmental concerns.

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Author links open overlay panelMehran Sadeghalvaad, Highlights•TiO2/PAM nanocomposite synthesis as additive to modify the conventional drilling fluid.•Viscosity of drilling fluid increased with increasing nanocomposite content.•Fluid loss and filter cake thickness decreased with increasing nanocomposite co, AbstractDrilling fluids tend to be used for the drilling of deep wells to clean and transport the rock cuttings,

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