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Effect of Salt on *Grewia Mollis* Gum as Biopolymer Drag Reducing Agent in Slickwater Fracturing

Sulaiman, A. D. I. [1]; **Adamu, M. B.** [1]; **Adamu, Y. Y.** [1]; **and Hezekiah, O. A.** [2]

[1]Department of Petroleum Engineering, Abubakar Tafawa Balewa University, P.M.B 0248 Bauchi, Bauchi State. [2]Department of Petroleum and Gas Engineering, Baze University, Abuja, F.C.T.

Corresponding author: sdibrahim@atbu.edu.ng

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Abstract

The search for lower cost materials that reduce pressure drop in fluid transportation in hydraulic fracturing is of paramount importance. Polymers are known to reduce pressure drop in pipeline flows in a hydraulic fracturing process referred to as friction reducers (drag reducing agents). Drag reducing agents are usually synthetic or natural polymers such as partially hydrolyzed polyacrylamide, polyethylene oxide, Guar gum, xanthan gum. The performance of these polymers as drag reducing agents on pressure gradient (pressure drop; Δp) in pipes are significantly affected by high temperature and salinity. This work focused on the investigation of effects of salinity on a natural polymer - *Grewia Mollis* gum as a drag reducing agent in slickwater fracturing. The sample of Grewia gum was obtained and mucilage was extracted from the inner stem bark by maceration in distilled water at room temperature. XRF and FTIR were conducted to characterize the sample and then the percentage drag reduction of the polymer were determined in the flow loop setup. To establish the baseline for this work, the percentage drag reduction was conducted first by dissolving the polymer in fresh water and then followed by dissolving in 1000 ppm and 5000 ppm of NaCl. Drag reduction results revealed that, the drag reduction performance in fresh water is better with the value of 25% at minimum flow rate of 2.5 m^3 / hr and 42.5 % at maximum flow rate of 4.5 m^3 /hr in brine solution, the drag reduction performance of 21.25% at 200 ppm in brine solution of 1000 ppm was reduced to 20.60% and reduced to 20 % with increase in brine solution to 5000 ppm at flow rate of 4.5 m^3 / hr. It can be concluded that the percentage drag reduction was affected when salts were introduced into flowing fluid.

Keywords: Friction Reduction, Polymers, Grewia Mollis, Slickwater, Hydraulic Fracturing.

Introduction

Natural gas from unconventional sources cannot be recovered using traditional development techniques, but can be exploited economically only through the used modern techniques which improve reservoir permeability of fluid viscosity (Cander 2012; Zou et al 2013; Wang et al 2016). As global energy demand for oil and gas increases, unconventional sources of oil and gas such as shale gas, tight sandstone gas and coal-bed methane have gradually become research hotspot in the oil and gas industry. Unconventional oil and gas reservoirs typically have the following key characteristics: large-scale continuous distribution of oil and gas, indistinct trap boundaries, no natural industrial stable production, insignificant Darcy seepage, porosity lower than 10%, pore throat diameter less than 1 μm, and permeability less than 1 md (Zou *et al.*, 2015: Jia *et al.*, 2019).

Due to the poor physical properties of unconventional oil and gas reservoirs (e.g., low porosity and low permeability), it is usually necessary to use hydraulic fracturing technology to reconstruct the reservoir during commercial development in order to obtain high-yield industrial oil and gas flow. As a widely used oil and gas stimulation technology, hydraulic fracturing has undergone more than 70 years of development since it was first successfully tested in North America in the 1940s (Ren, 2020). Slick water is most commonly hydraulic fracturing fluid used of unconventional hydrocarbon recovery. In the process of hydraulic fracturing, the proppant is usually carried by the fracturing fluid into the formation and used to support the hydraulic fractures after fracturing, thereby forming artificial fractures with a certain conductivity in the formation, providing high conductivity channels for oil and gas seepage (Wang, 1987: Zheng *et al.*, 2022).

Fracturing fluid and proppant are the most critical materials in hydraulic fracturing technology, and their performance directly affects the effect of reservoir fracturing and the success rate of fracturing operations (Pan *et al.,* 2020). Unlike conventional gel fracturing fluids, slick water has much lower chemical loading that translates to lower viscosity. To transport the proppant into the artificial fractures network created by the slick water, high pumping rates of 50 to 100 bbl/m (0.1325 to 0.2650 m^3) is required. Pumping at high rates result to high energy consumption invariably high energy cost (Kuzmyak, 2014). To overcome high pumping requirements, small concentrations of friction reducers 0.5 to 2 gpt (75 to 600 ppm) are added to reduce the energy consumption (Ellis, 2015). The most common polymer used as a friction reducer is the anionic partially hydrolysed polyacrylamide (HPAM) containing copolymers of polyacrylamide and polyacrylate (Ellis, 2015).

Problem Statement

Degradation due to chemical ions occurs in the case of anionic polymers like HPAM where the cations present in produced water (i.e., $Ca^{2+,}$ Na^+, $Mg2^+$, Fe^{3+}) electrostatically interact with negatively charged polymers like HPAM to crosslink, precipitate, coil the polymer and lower its friction reduction performance (Ellis, 2015). Degradation of HPAM can decompose HPAM into its acrylamide monomers which can be toxic towards human health and the environment. HPAM is not as biodegradable as polymers such as xanthan gum (XG), and PEO (Muhammed *et al.,* 2020; Zang *et al.,* 2019). To mitigate the concerns of using HPAM as a friction reducer, salt-tolerant, and shear stable polymers have been used alternative friction reducers to HPAM. These friction reducers include cationic polyacrylamides, and a poly acrylamide-co-2-acrylamido-2methylpropane sulfonic acid) (Abubakar *et al.,* 2014; Le Brun *et al.*, 2016; Edomwonyi-Out *et al* 20219). While these additives are more salt tolerant, and shear stable than the conventional HPAM, their higher costs make them less favourable than the conventional HPAM for industrial applications (Yang *et al.,* 2019). Alternatively, rigid biological polymers (e.g., Guar Gum) are more shear stable, and salt-tolerant than linear and flexible polymers with the cost of a significantly lower friction reducer performance (Habibpour *et al.,* 2017; Zou *et al.,* 2019). In addition, biological polymers are highly biodegradable. Most of these natural polymers explored are not locally available. *Grewia* gum polysaccharide derived from the inner stem bark the edible plant Grewia mollis is locally available, cheap and abundant (Nep *et al.*, 2013). Moreover, Adamu *et al.* (2024) was the first to publish research investigating the performance of *Grewia mollis* as friction reducer in a flow loop. The authors did not examine the effects of the *Grewia mollis* in brine with Na^+, Ca^{2+}, and Mg^{2+} cations, especially divalent cations (Ca^{2+}, and Mg^{2+}) is that divalent are more detrimental towards the friction reduction performance of anionic polymers than monovalent (K^+, Na^+) cations. Furthermore, Na^+ ion, and divalent cations are also commonly found in hydraulic fracturing water solutions (brine). Therefore, the large amounts of water consumed in slick water hydraulic fracturing is problematic in reservoirs where fresh water is unavailable and transporting water to the reservoirs becomes expensive. (Zou *et al.,* 2019). Therefore, it's imperative to investigate the performance of polymer additives with the existence of such salts. The main aim of this work is to investigate the effect of presence of salt in the flowing water on the effectiveness of the *Grewia mollis* as a drag reducer under different concentrations and turbulence using laboratory flow loop system.

Literature Review

There are various studies that dealt drag reduction and other variables affecting drag reduction parameters such as flow parameters (pipe diameter, pipe length, flow rate and velocity) and polymer parameters (molecular, charge density, chain flexibility, concentration). Some studies focused on synthetic polymers, others based their studies on biopolymer while some researchers look at different perspectives by studying synergy of mixtures of synthetic and the biopolymer.

Abddallah *et al.,* (2019) investigated the effectiveness of aloe Vera mucilage as a drag reducing agent in a flow loop of uPVC pipe of 20 mm ID and polymer concentration ranging 50 ppm to 500 ppm and Reynolds numbers less 60,000 using U-tube manometer to measure the pressure drop. Their findings revealed that the single-phase water flow, a maximum of drag reduction of 50% at velocity of 1.683 m/s was achieved while 42.86% of drag reduction was observed in multiphase flow in a horizontal pipeline.

Edomwonyi-Out et al (2020) further investigated the synergistic effect of partially hydrolysed polyacrylamide, polyethylene oxide, aloe Vera mucilage and their mixtures as drag reducing polymers with concentrations ranging from 40 – 400 ppm in an unplasticized polyvinylchloride (uPVC) pipe of internal diameter of 0.02 m. their findings showed that the rigidness of the biopolymer was improved by adding synthetic polymers which resulted to increase in drag reduction efficiency. The pressure drop decreased as the Reynolds number increased for the various polymer concentrations. The work observed no appreciable reduction in pressure drop for aloe Vera mucilage at 30 ppm due to lower concentration because polymers are highly rigid or less flexible, which make them less efficient in drag reduction compared to the synthetic ones. The polymers mixture showed high reduction in pressure than the individual polymers at the same concentration due the improvement in the rigidity of the biopolymers and molecules.

Sokhal *et al*., (2019) investigated gum Arabic as a biopolymer to find the effect of injection of gum Arabic directly near the boundary layer to investigate its effect on the maximum possible drag reduction. The biopolymer solution was found to exhibit shearing-thinning behaviour as the shear rate was varied from 0.1 to 1,000 s^{-1} at temperature 25^{o} C and maximum drag reduction of 62.15% was observed with the maximum concentration of gum Arabic, 300 ppm.

Several natural polymers have been explored as potential friction reducers such as guar gum, cellulose, food gum, starch (amylopectin), alginate, carrageenan, chitosan and sap of plant such as okra (Choi *et al.*, 2017). However, past investigations have focused extensively on two food gums, namely guar gum and xanthan gum, on account of their widespread (Barati *et al.*, 2014).

Adamu *et al.*, (2024) investigated the performance of Grewia Mollis gum as a drag reducing agent in slickwater hydraulic fracturing in fresh water. The polymer was found to exhibit shear thinning behaviors with power law index ranging from (n = 0.48 to 0.58) for concentrations of between 500 ppm to 200 ppm. The percentage drag reduction of 37% was achieved at N_{Re} of 74269 by the addition of 200 ppm of the fluid and 56% at the same by addition of 500 ppm.

Materials and Methods

Materials

Friction reduction additives

The polysaccharide gum derived from the inner stem bark of the plant is a water-soluble biopolymer and its widespread species native to tropical Africa, Yemen and Oman. The sample as shown in Figure 1, used for this study was obtained in Buskuri market of Katagum Local Government Area of Bauchi State with Geographical coordinates of latitude and longitude of 10.3203215 and 11.6502121 respectively.

Figure 1: *Inner Stem Bark of Grewia Mollis*

Water composition

Tap water from the department of petroleum engineering (PTDF Building) water supply was used as a baseline for the experiments. The concentration of ions present in tap water were determined using inductively coupled plasma-mass spectrometry device manufactured by Agilent Technologies. For Brine, NaCl, was dissolved in tap water to prepare the brine solution. Brine was adapted from Ibrahim *et al.*, (2018). The pH of the water solutions is equal to 7.0. The solution densities were calculated assuming 60 L of water as the solvent; the densities of tap water and Brine are 1000kg/m^3, 1020kg/m^3, respectively

Experimental flow loop system

The performance of the *Grewia mollis* as a drag reducing additives was evaluated in a laboratory scale closed loop system. The schematic diagram of the flow loop is shown in Figure 2. The system comprises of a pump, storage tank, pipes, valves, flow meter and pressure gauges. The pump was used for circulating the fluid from the reservoir tank to the test section and back to the reservoir tank, the reservoir tank was supported with an exit pipe connected to centrifugal pumps. Ball valve was used for controlling the flow rate, flow meter was installed to measure the flow rate and the two pressure gauges were mounted at distance of 2 m approximately 105 times the pipe diameter (105D) in order to measure a reasonable pressure along the test section and entrance length 2 m approximately 105D for the fluid to develop fully turbulent. Flow starts from the reservoir tank through the pump, ball valve, flow meter and through test section of pipe diameter 19.05 mm, 2 m long. The testing point was located about 105 times of pipe diameter to ensure the turbulent flows were fully developed before the testing process run. Two sets up of pressure gauges were used to detect the pressure drop across the test section.

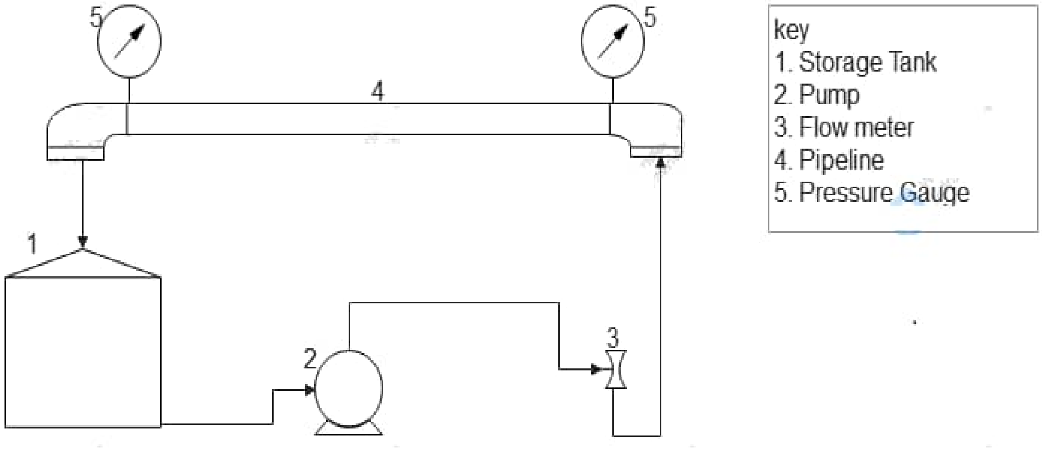

Figure 2: *Flow loop system*

Figure 2 shows the schematic of flow loop used for the experiment. The set-up is made of a 60 litres storage tank connected to a 1HP centrifugal pump (ATLAS 125) with a pumping capacity of 6 to 60 litres/minutes and 2850 rpm, a galvanized steel horizontal pipe test section of length 2.0 m and inner diameter of 19.05 mm. The flow rates were measured using Sea Zhongjiang digital flow sensor with model YF-B6S, thread size of Stainless Steel G3/4 hall effect flow Sensor with working pressure of 0.05- 1 MPa and flow range of 2-30 litre. The pressure drop data along the measuring length of the pipe were gathered using two pressure gauges. At each flow rates, the fanning friction factor (f) is calculated by using equation (1):

$$f = \frac{\tau_w}{\frac{\rho\, u_b^2}{2}} \qquad \ldots (1)$$

Specification of the materials used in the construction of the flow loop is presented in Table 1.

Table 1: Principal Equipment Component Used and their Features

Equipment	Features
Pipe	Material: Galvanised Pipe
Pump	(ATLAS 125) with a pumping capacity of 6-60 L/min
Flow meter	Sea Zhongjiang Digital Flow sensor with model YF-B6S, thread size of Stainless Steel G3/4 Hall Effect Flow Sensor, working pressure of 0.05- 1 MPa and flow range of 230 L
Mixing tank	60 L PVC Tank
Digital weighing balance	
Air oven	
Fourier Transform Infrared	Scanning in the region of 4000 to 650 cm^{-1}, background scans 140 resolution of 4 cm^{-1} Agilent Technologies, model Cary 630
XRF	EDXRF Analyzer UMYU-Katsina

Methods

The study is divided into two parts: characterization of sample and drag reduction measurement in a flow loop experiment. A combination of analytical techniques such as Fourier Transform Infrared (FT-IR) and mineral analysis by XRF were employed to characterize the sample. Polymer solutions were tested in terms of shear- viscosity. The flow rate and the pressure drop over a certain distance were recorded and converted into generalized Reynolds number and friction factor.

Extraction procedure

The sample was first sent to the department of botany, Abubakar Tafawa Balewa University for plant identification. The stems were the separated from the leaves. The inner stem barks of the plant were cut into small pieces and soaked in water for one day. The mucilage collected by filtration through a sieve with mesh diameter of 2000 micro-meter, the mucilage was oven-dried at 60^{0} C for 6 hours, and the dried mucilage was pulverized (Figure 3) and stored in an air tight container for use according to (Adamu *et al.,* 2023).

Figure 3: *Oven-dried Grewia mollis gum*

Characterization

FT-IR spectra was used to determine the functional groups of the *Grewia* gum sample by scanning in the region of 4000 to 650 cm^{-1}, background scans 140 resolution of 4 cm^{-1} using model Cary 630 FT-IR spectrophotometer Agilent Technologies. Data was processed based on the average of 32 scans per spectrum generated by the machine. XRF was used for the mineral analyses of some of heavy metals such as zinc, iron, copper, manganese and magnesium in the stem bark of the *Grewia Mollis* sample according to (Adamu *et al.*, 2023). SEM is employed to analyse the microstructures of the Grewia Mollis drag reducers solutions in fresh water and in salt solutions at different concentrations so as to establish the relationship between the microstructures of the Grewia Mollis gum and drag Reducer performance.

Drag Reducer formulation

The polymer solution was prepared by using mechanical impeller. The speed was initially set on low speed to form vortex so such to avoid scission of the polymer. Water and polymer were added in the vortex. The powder was added in small quantity at different intervals to avoid lumps formation in the solution (Adamu *et al.*, 2023). After addition of the polymer, speed was increased until solution became viscous. The solution was stirred for 2 hours and left overnight for proper hydration. The master solution was prepared with 10000 ppm concentration and during experiment; the solution was diluted as per required concentrations of 200 ppm to 600 ppm.

To prepare Brine, 1000 ppm and 5000 ppm NaCl were used and dissolved in tap water. Figure 4 shows the sample A is the master solution in fresh water, sample B at 1000 ppm salt and sample C at 5000 ppm salt. Since this compound is water-soluble, it is assumed that these compounds fully dissociate into their ions when it is dissolved in water.

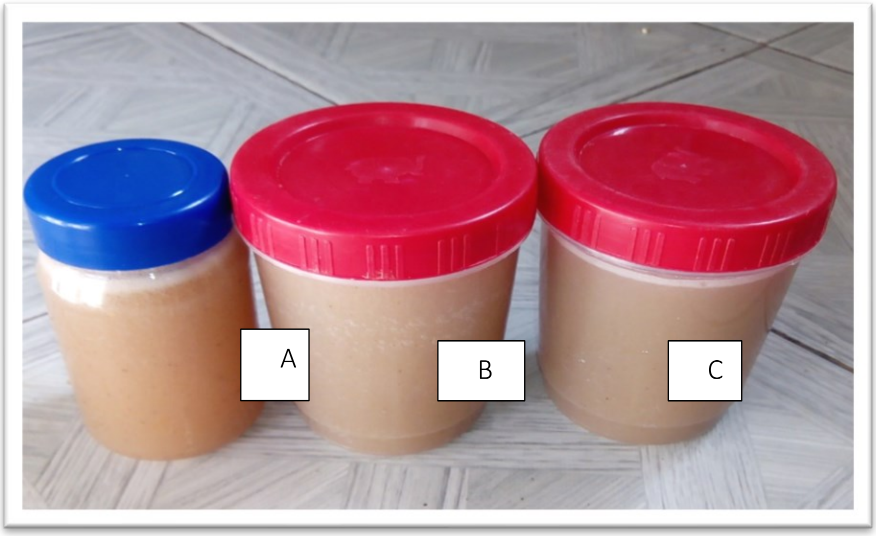

Figure 4: *Solution A @ Fresh water, Solution B @ 1000 ppm Salt and Solution C @ 5000 ppm Salt*

Drag reduction test procedure

All the equipment were cleaned in order to avoid contamination of the experiments. After which 60 litres of tap water was prepared for batch test. The friction reducer concentration was then adjusted to fit the 60 litres tank. The friction reducer was weighed out and mixed with water at test concentrations (200 ppm to 600 ppm) until homogeneous solutions were achieved. NaCl was weighed out and dissolved in water to make up of the brine for the desired concentrations of 1000 ppm and 5000 ppm. The mixture of the friction reducer and the brine were stirred thoroughly until homogeneous solutions were achieved. The readings were recorded at 0.5 m^3/s intervals from 2.5 m^3 to 4.5 m^3/s. Tests were repeated until consistency readings were obtained

Friction reduction

A closed loop flow was used for friction reduction measurements (Figure 2). The flow rates were set with different values as shown in Table (2). Pressure drop readings were taken for each flow rate. This procedure was repeated for each polymer concentration. As the flow through the test section becomes turbulent, all the calculations for the outcomes were determined as follows:

Percentage Friction Reduction Calculation

The percentage drag reduction was determined by measuring the corresponding pressure drop, ΔPa of water added polymers compared with pressure drop, ΔP_b solvent (water) at the same condition, as given by equation (2):

$$(\%FR) = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \times 100 \qquad \ldots (2)$$

Where ΔP_b is the pressure drop difference before adding additives, N/m² and ΔP_a is the pressure drop difference after adding additives, N /m²

Velocity and Reynolds Number Calculation

The average velocity (u) and Reynolds number (N_{Re}) were calculated using the solution volumetric flow rate readings (Q), fluid density (ρ), viscosity (μ) and pipe diameter (D), as given by equation (3), (4) and (5) as follows:

$$U = \frac{Q\,(\frac{m^3}{hr})}{A(m^2) * 3600s} = (\frac{m}{s}) \qquad \ldots (3)$$

Q is the flow rate and A is the cross-sectional area of the pipe given as:

$$A = \frac{\pi}{4} D^2 \qquad \ldots (4)$$

$$N_{Re} = \frac{\rho u D}{\mu} \qquad \ldots (5)$$

Table 1: Experimental Flowrate, Velocities and Reynolds Number used

Pipe Diameter, ID (m)	Flowrate, Q (m³/hr)	Velocities (m/sec)	Reynold number
0.0195	2.5	2.33	45435
	3.0	2.79	54405
	3.5	3.26	63570
	4.0	3.72	72540
	4.5	4.19	81705

Table 3: Properties of water used for the experiment

Water at 23°	Value
Viscosity of water	10^{-3} Pa.s
Density of water	1000 kg/m³

Results and Discussion

Physico-chemical Characterization

FTIR Analysis

Figure 5 and Table 4 show the FTIR analysis of the *Grewia Mollis* gum used in this work. The spectrum shows the peaks and bands in Table 4, similar to the Grewia Mollis gum obtained by Adamu *et al.*, 2024. The peaks and bands displayed are in good agreement.

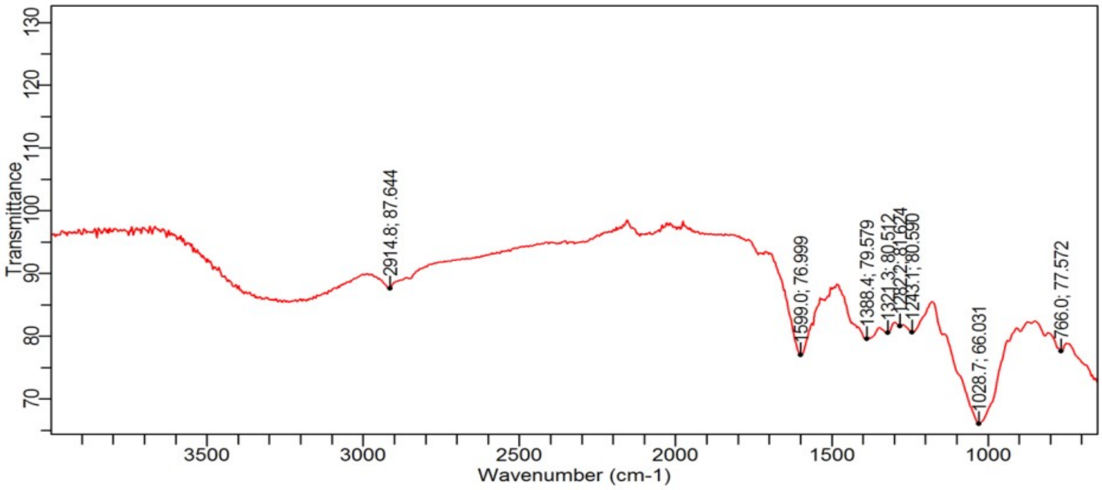

Figure 5: *FTIR Spectrum of Grewia Mollis*

Table 4: FTIR Spectrum of Grewia Mollis, Chracteristic Peak and Functional Groups

Frequency (cm^{-1})	Functional Group	Compound Class
3425	hydroxyl (–OH) groups	
2927	C–H bonds of methyl groups (–CH3)	Rhamnose
1618 and 1420	carboxylate groups	Galacturonic acid
1500 and 1800	carboxylic	
1735 and 1256	acetyl groups	

XRF analysis

Figure 6 shows the XRF analysis of *Grewia Mollis* gum. The analysis shows that it contains elements such as iron (0.11018 %), SiO_2 (0.5668 %), Al_2O_3 (0.112 %) P_2O_5 (0.2355 %), SO_3 (0.4767 %), TiO_2 (0.01249 %), MnO (0.3192 %), CaO (6.497 %), K_2O (2.7221 %), CuO (0.1531 %), ZnO (0.01348 %), PbO (0.1111 %), Cl (0.1531 %), ZrO_2 (0.00179 %), Ta_2O_5 (0.0280 %), SrO (1.055 %), Bi_2O_3 (0.1025 %), BaO (0.01591 %), SnO_2 (0.209 %), CdO (0.407 %), CeO_2 (1.00 %), Y_2O_3 (0.0157 %), 3 (0.0074 %), Nb_2O_5 [-0.6000] %. Similar minerals were reported by Adamu *et al.*, 2024. The traces of some heavy metals in the sample may indicate some level of toxicity if allowed to be accumulated, but at it stands all these values obtained from the analysis fall within level of human intake by World Health Organization. It is imperative to monitor and regulate the levels of heavy metals in environmental media to safeguard public health.

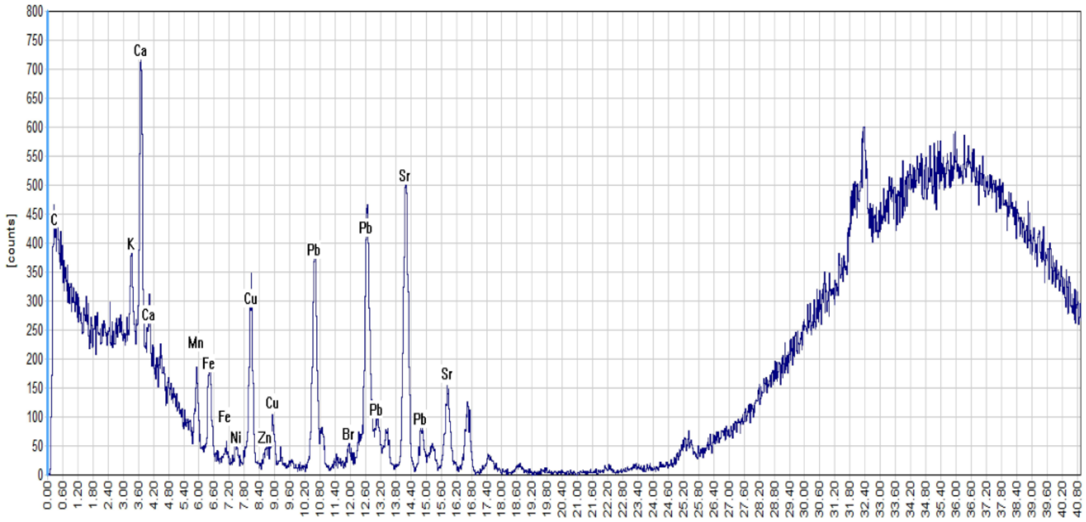

Figure 5: *XRF Analysis of Grewia Mollis Gum*

Drag Reduction Determination

Effect of addition of *Grewia mollis* gum on drag reduction

The effect of flow rate and concentration were observed as shown in Figure 7. It can be seen that there is a significant effect of concentration as well as the flow rate on the percentage drag reduction of *Grewia* gum. At concentration of 200 ppm, the pressure gradient was decreased by 21.25% at maximum flow rate of 4.5 m^3 /hr and 8.33% at minimum flow rate of 2.5 m^3 /hr. It was observed that as the flow rate was increased, the percentage of drag reduction was increased. At concentration of 600 ppm, the value of the pressure drop was reduced by 42.5 % at maximum flow rate of 4.5 m^3 /hr and 25% at minimum flow rate of 2.5 m^3 / hr. As the drag reducing agent concentration is increased, the polymer molecule associates with each other, this results to the change in molecular chain structure. For linear polymer, the degree of chains entanglement increases with increase in concentrations (Ruckenstein, E & Park, J.S. 1988). When the shear rate increases gradually, the percentage drag reduction first increases sharply and then keeps stable or decreases slightly. When external shear stress is applied to molecular chains, their structure will change and apparently increasing the percentage drag reduction (Lee, D.H. 2010). When the external force applied is not enough to the change the polymer structure, or the degree of change is limited, the drag reduction rate increases more slowly. When the flow rate reaches 4.5 m^3 /hr, the structure of *Grewia mollis* gum has been fully extended, and it can no longer fully absorbed the turbulent energy, therefore, percentage drag reduction is significantly increased, as revealed in Figure 7.

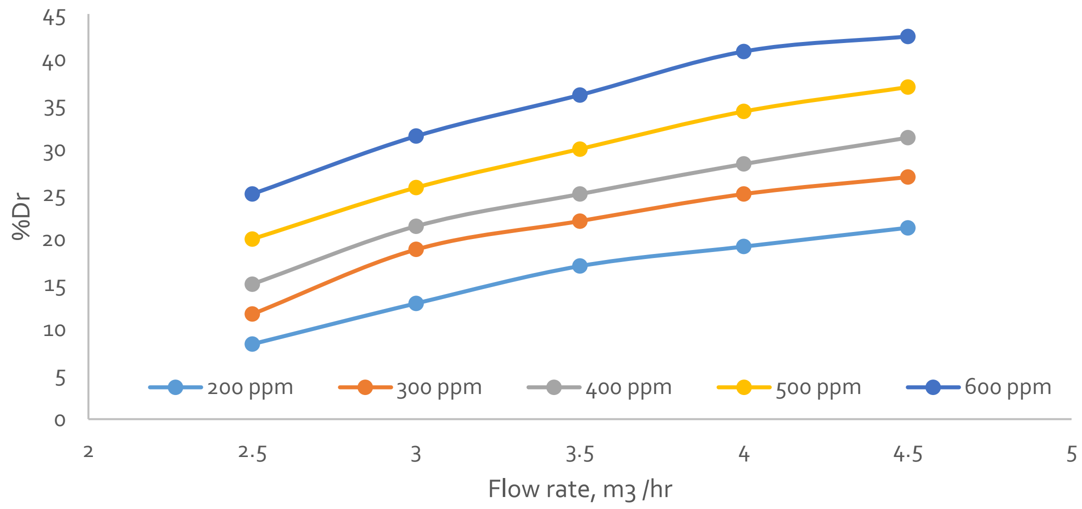

Figure 6: *Percentage Drag Reduction in Fresh Water*

Effect of salt on percentage drag reduction

The experiments were performed to study the effect of adding salt in different concentrations on drag reduction effectiveness of *Grewia mollis* gum in turbulent circulation of tap water and compared with performance of pure polymeric additives (without salt addition). The results in Figures 8 to 13 revealed that the percentage of drag reduction reduces with increase in brine concentrations. At concentration of 200 ppm, the percentage drag reduction was 21.25% but reduced to 20.61% in presence of 1000 ppm salts and 20% with 5000 ppm at flow rate of 4.5 m^3/ hr. this revealed that, the salt acts as inhibitor to the performance of this polymer as friction reducers. Therefore, the effectiveness of *Grewia mollis* is reduced than in water without salt. This result is in accordance with what was observed by Muhammad *et al.*, 2024. As the salt concentration increased, the Grewia Mollis molecule chains became more coiled, because of intermolecular association literally the percentage drag reduction decreased. When the salt concentration is increased, the intermolecular association will appear on large scale which return made an increase in particle size distribution (Podhajecka, K *et al.*, 2007).

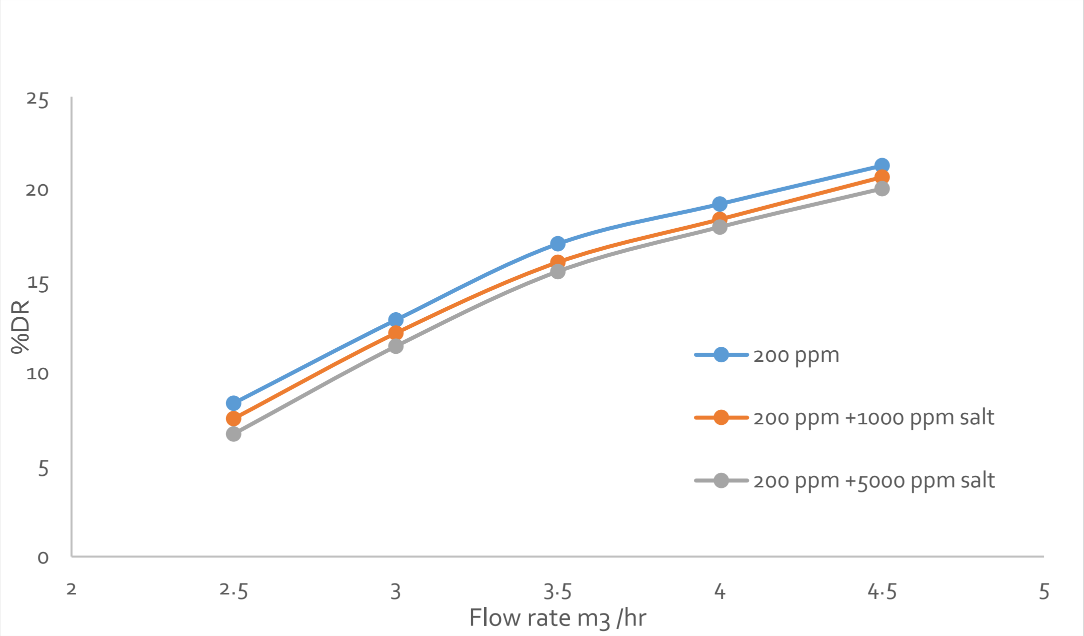

Figure 7: *Mollis Solution at 200 ppm at Various Brine Concentrations*

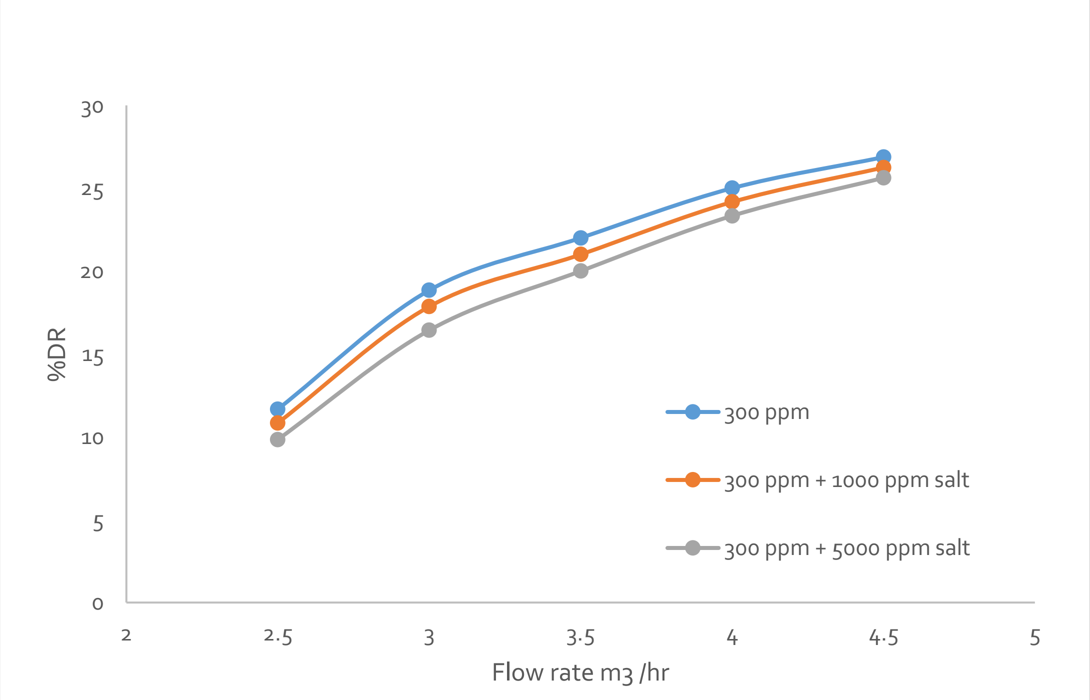

Figure 8: *Grewia Mollis Solution at 300 ppm at Various Brine Concentration*

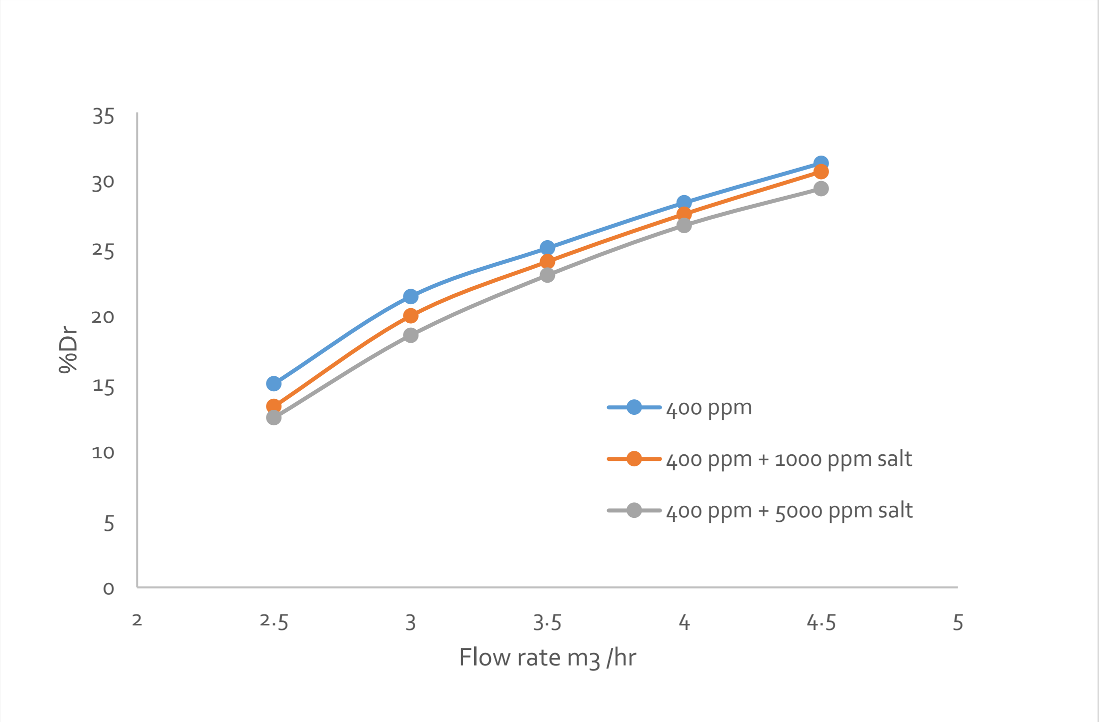

Figure 9: *Grewia Mollis Solution at 400 ppm at Various Brine Concentrations*

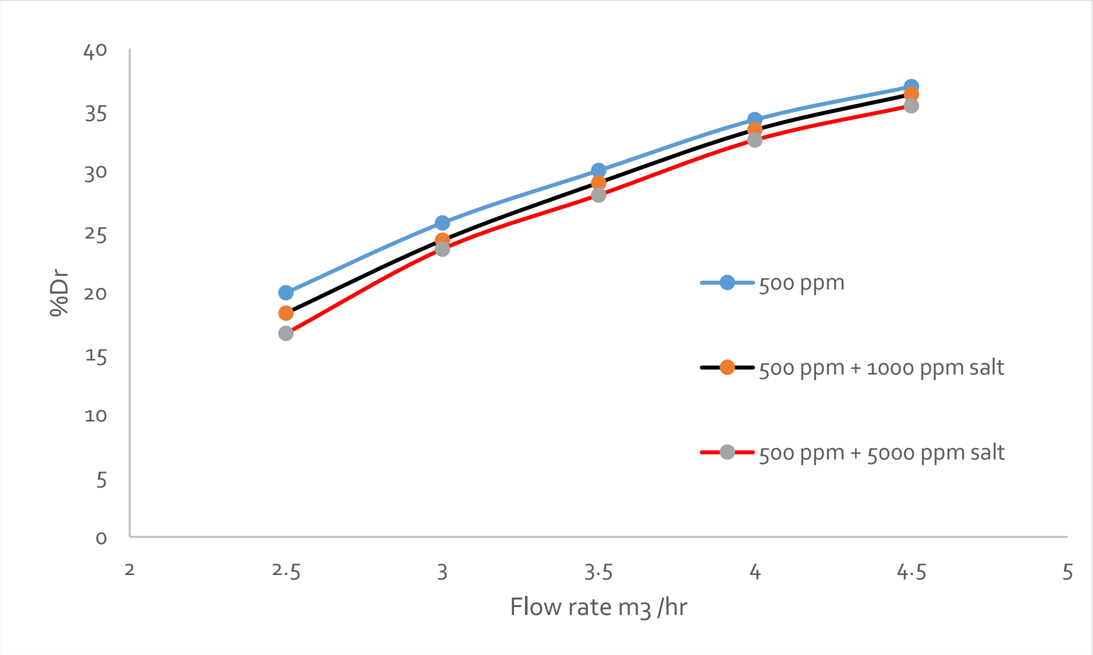

Figure 10: *Mollis Solution at 500 ppm at Various Brine Concentrations*

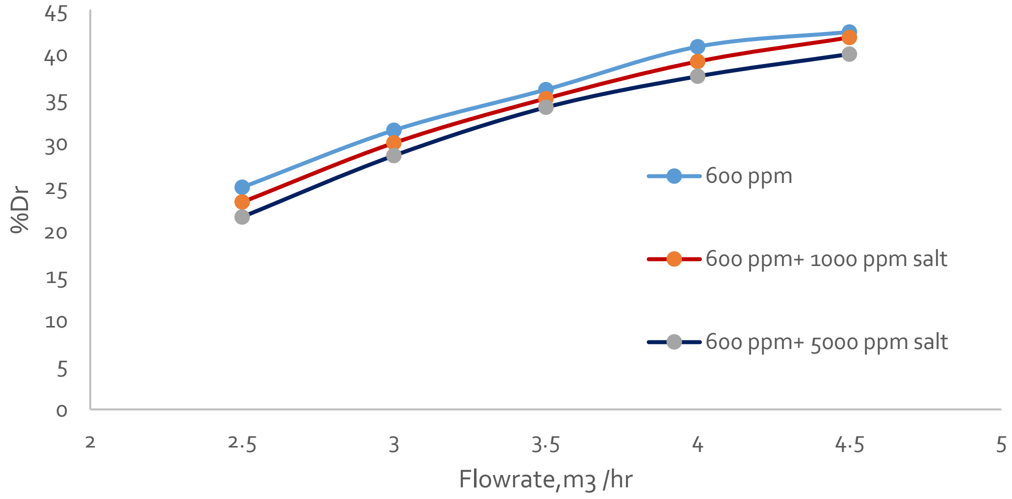

Figure 11: *Grewia Mollis Solution at 600 ppm at Various Brine Concentrations*

Conclusion

The effect of salt on Grewia Mollis gum as drag reducing agent was investigated. It performance was tested in fresh water and then tested in brine solution at 1000 ppm and 5000 ppm NaCl in closed flow loop system. Based on the experimental work, the following conclusions were made.

- Grewia Mollis solution attains a high percentage drag reduction of 25 % in fresh water under low flow rate of 2.5 m^3/ hr and 42.5 % at maximum flow rate of 4.5 m^3 /hr at concentration of 600 ppm.
- In brine, the percentage drag reduction reduced as compared to that obtained in fresh water, at concentration of 200 ppm, the percentage drag reduction was 21.25% but reduced to 20.61 in presence of 1000 ppm salts and 20% with 5000 ppm at flow rate of 4.5 m^3/ hr.
- In conclusion, presence of salt reduced the performance of *Grewia Mollis* gum as drag reducing agent.

Recommendations

The future work needs focus on the following:

- Effect of divalents ions on the performance of Grewia Mollis gum as drag reducing agent.
- Effect of temperature gradients on the performance of Grewia Mollis gum as biopolymer drag reducing agent.
- Investigating the effect of pipe diameter on Grewia Mollis gum as biopolymer drag reducing agent.

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References

Abdallah, M. N. Edomwonyi-Otu, L. C., Yusuf, N. & Baba, A. (2019). Abdallah, M. N. Edomwonyi-Otu, L. C. Investigating the Effectiveness of Aloe Vera Mucilage in Drag Reduction. *International Journal of Mechanical and Materials Engineering, 13*(2), 11-16.

Abubakar, A; Al Wahaibi, T.; Al Wahaibi M, Y.; Al Hashimi, R, A. (2014). Roles of Drag Reducing Polymers in Single and Multi-phase flows. *Journal of Chemical Engineering Research and Design, 92*(11), 2153-2181. DOI: 10.1016/j.cherd.2014.02.031.

Adamu, Y, Y.; Adamu, M, B.; Abdulsalam, S.; Miton, R, Z.; Muhammad, M, A. (2024). Application of Grewia mollis Gum as a Biopolymer Drag Deducing Agent. *ABUAD Journal of Engineering and Applied Sciences, 2*(1), 1-9.

Barati, R.; Liang, T. J. (2014). A Review of Fracturing Fluid Systems Used For Hydraulic Fracturing of Oil and Gas Wells. *journal of Appl. Polym. Sc*, 2-8.

Cander, H. (2012). What Are Unconventional Resources? A Simple Definition Using Viscosity and Permeability. *AAPG Annual Convention and Exhibition.* American Association of Petroleum Geologists and Society for Sedimentary Geology

Choi, H.J., C.A. Kim, I.J. Cohn & Jhon M.S. (2000). An exponential degradation decay function for polymer degradation in turbulent drag reduction. *Pol. Degradation Stability* (60), 341-346.

Edomwonyi-Otu, L. C., & Adelakun, D. O. (2018). Effect of heavy molecular weight polymer on quality of drinking water. *Materials Today Communications* (15), 337-343.

Edomwonyi-Otu, L. C., & Panagiota, A. (2019). Separated Oil-Water Flows with Drag Reducing Polymers *Experimental Thermal and Fluid Science.* (102), 467-478. https://doi.org/10.1016/j.expthermflusci.2018.12.011

Ellis, V. B. (2015). Characterization of Friction Reducing Properties in Oil-Field Operations.

Jia, C. Z.; Zheng, M.; Zhang, Y. F. . (2012). Unconventional hydrocarbon resources in China and the prospect of exploration and development. *Petroleum Exploration and Development, 39* (2), 139−146.

Jiao, F. Z. (2019). Re-recognition of "unconventional" in unconventional oil and gas. *Petroleum Exploration and Development, 46* (5), 847−855.

Kuzmyak, N. J. (2014). Evaluation of Friction Reducers for Use in Recycled Fracturing Flowback and Producesd water.

Le Brun, N; Zadrazil, I; Norman, L; Bismarck, A; Markides, C, N. (2016). On the Drag Reduction Effect and Shear Stability of Improved Acrylamide Copolymers for Enhanced Hydraulic Fracturing, *Journal of Chemical Engineering Science.* 1*46*, 135–143.

Lee, D. (2010). Skin-Friction Drag Reduction by Dilute Polymer Solutions in Turbulent Channel Flow. *486*, 213–238.

Muhammad, A, M.; Hassan, U.; Adamu, M, B.; Ayuba, I.; Adamu, Y, Y. (2024). Performance Evaluation of Rankiya (Grewia venusta) as a Polymer for Enhanced Oil Recovery-Polymer Flooding. *ABUAD Journal of Engineering and Applied Sciences, 2*(1), 20-27.

Pan, L. H.; Wang, H. B.; He, J. Y.; Li, F. X.; Zhou, T.; Li, X. L. . (2020). Progress of simulation study on the migration and distribution of proppants in hydraulic fractures. *Natural Gas Industry 2020, 40*(10), 54−65.

Podhajecka, K.; Prochazka, K.; Hourdet, D. (2007). Synthesis and viscoelastic behavior of water-soluble polymers modified with strong hydrophobic side chains. *Journal of Polymer SC.*, 1586-1595.

Ren, Z. X. (2020). Progress in hydraulic fracturing stimulation technology. *Chemical Engineering & Equipment, 10*(1), 52−45.

Ruckenstein, E. & Park, J.S. (1988). Hydrophilic-hydrophobic polymer composites. *J. Polym. Sci. Pol., 26*(1), 529-536.

Sokhal, K. S. Dasoraju, G. & Bulasara V. K. (2019). Effect of Reynolds Number and Concentration of Biopolymer (Gum Arabic) on Drag Reduction of Turbulent Flow in Circular Pipe. *International Journal of Mechanical and Materials Engineering*, 8-20.

Thiel, G. P.; Lienhard V, J. H. (2014). Treating Produced Water from Hydraulic Fracturing: Composition Effects on Scale Formation and Desalination System Selection. *desalination, 34*(6), 54–69. Retrieved from https://doi.org/10.1016/j.desal.2014.05.001

Wang, H. J.; MA, F.; Tong, X. G.; Liu, Z. D.; Zhang, X. S.; Wu, Z. Z.; Li, D. H.; Wang, B.; Xie, Y. F.; Yang, L. Y. . (2016). Assessment of global unconventional oil and gas resources. *Petroleum Exploration and Development, 43*(1), 925−940.

Wang, H. X. (1987). Principle of Hydraulic Fracturing. *Petroleum industriay press:* Beijin

Zheng, M.; Liang, C.; Dehua, L; Ting, L; Jie, Z and Qi,Y. (2022). Nanomaterials and Technology application for hydraulic Fracturing of Unconventional Oil and Gas Reservoir. *American Chemical Society 7*(34), 29543− 29570. https://doi.org/10.1021/acsomega.2.c02897

Zou, C. N.; Yang, Z.; Zhu, R. K. . (2015). Progress in China's unconventional oil & gas exploration and development and theoretical technologies. *Acta Geologica Sinica-English Edition, 89*(3), 938− 971.

Zou, C. N.; Zhang, G. S.; Hou, L. H.; Tao, S. Z.; Zhu, R. K.; Yuan, X. J.; Yang, Z. (2013). New progress in global unconventional oil and gas exploration and theoretical research. *Proceedings of the 14th annual meeting of the Chinese society of mineral and rock geochemistry*, *31*, pp. 312-322.