Formulation of Polymers from Locally Sourced Polysaccharides in Polymer flooding

ABSTRACT

The oil industry is experiencing a paradigm shift where the use of green chemicals is been encourage in order to address environmental issues associated with the use of synthetic chemicals as well as the fact that most of these synthetic polymers like hydrolysed polyacrylamide which is used to reduce the mobility of water in enhanced oil recovery; are imported chemicals. Thus, this brings the need to locally source for polymers that are viable so as to increase indigenous production for the oil industry.

Gum Arabic is a viscosifier mostly found in the northern part of Nigeria. Different concentrations of the Gum Arabic were analysed as to study their rheology as well as the effect of salinity on them which will determine their degree of resistance as this is a criterion for polymer flooding. However, the stability of Gum Arabic was further enhanced by the introduction of Carboxymethyl Cellulose (CMC) at varying concentration to determine its effect on the solution viscosity. From the results, it can be concluded that increased viscosity was as a result of the modification of Gum Arabic by CMC and this could be related to increase bonding with CMC.

Keywords: Gum Arabic; Carboxymethyl Cellulose (CMC); Polymer; Viscosity; Salinity.

INTRODUCTION

Polymer flooding has been carried out for the past 40 years in many marginal oil fields and its effectiveness has proved to be successful in several fields. The general expectation from polymer flooding is to obtain about 50% ultimate recovery with averagely 15 to 20% incremental recovery over secondary water flooding process (Rellegadla, 2017). Both naturally derived polymers like xanthan gum and synthetic polymers such as the partially hydrolysed polyacrylamide (HPAM) have been used basically for the purpose of viscosifying water for polymer flooding. Typical synthetic polymers are partially hydrolysed polyacrylamide (HPAM) and its derivatives have been used for most large-scale field production mostly because it is less costly (Chang, 2011). The commercial bio-polymer used in oilfield application but not frequently used like the HPAM due to its higher cost is xanthan gum (Sun, 2012).

HPAM in produced water (Back produced water) after polymer flooding in oilfield causes serious environmental problems such as difficulty in oil - water separation, the treatment of back produced water from polymer flooding (PWPF) is more difficult to separate than oily wastewater without HPAM (Zhang, 2010, Bao, 2010, Deng, 2002) because the HPAM residual component dissolved in water increases the viscosity of wastewater and also HPAM is equally absorbed onto the oil/water interface, making the separation process much more difficult to attain (Duan, 2014).

Chemical cost of a polymer flooding process is a function of the polymer selected for flooding. For instance, although chemical cost as well as the treatment cost is said to be higher for xanthan gum solutions compared to polyacrylamide solutions, Xanthan's cost is stable when compared to the fluctuating cost of polyacrylamide polymer. The polyacrylamide is actually synthesised from petroleum products and their costs in the market are very sensitive to the crude oil prices. (Rellegadla et al, 2017). Thus, there is need to synthesize less costly environmentally friendly polymers with high degree of stability as this is a sure way of generating more recovery while reducing cost.

Gum Arabic is presently one of the oldest polysaccharides and mostly found in the northern part of Nigeria also known as *Acacia Senegal*. It is produced as tear-drop-shaped globules exudates from bark wound of Acacia trees (Glicksman, 1973). Due to the presence of ionic charges on the backbone of the polymer chain, the viscosity of solution of gum Arabic is based on changes in pH, viscosity is low at low and also at high pH and reaches a maximum at about a pH of 6-8. It occurs majorly as a mixture of calcium magnesium and potassium salts of Arabic-acid and is composed of the following carbohydrates, this include: galactose, arabino pyranose, arabino furanose, rhamnose, glucuronic acid and 4-0 methyl glucuronic (Anderson, 1966). The gum is a highly water soluble polysaccharide, it is principally used in the food and pharmaceutical industries as stabilizer, thickener, suspending and binding agent in the manufacture of confections, dairy products, beverages and tablets (Nahla, 2000).

Carboxymethyl cellulose (CMC) is the most popular and cheapest cellulose derivative, it is an anionic and also a water-soluble natural polymer that is well known as a safe and biodegradable polymer which is widely used in the food industries as food additives, oil and gas industries, paper and textile industries e.t.c due to its high viscosity (Ibrahim, 2014). CMC is synthesized by reacting cellulose with sodium hydroxide in the presence of sodium chloroacetate.

In line with Nigerian Oil and Gas Industry Content Development Act, 2010 which seeks to increase indigenous participation in the oil and gas industry by prescribing minimum threshold for the use of local services and materials as well as promoting the transfer of technology and skills to Nigerian staff and labour in the industry, this work investigates the use of Gum Arabic (locally sourced) as a suitable polymer in enhanced oil recovery while CMC was added to determine the effect on its stability at increased water salinity.

MATERIALS AND METHOD

In this analysis, different concentrations of Gum Arabic (Figure 1) from 10,000ppm, 30,000ppm to 50,000ppm were dissolved using 500 ml of water. The solution was stirred gently to achieved homogeneity, this was then allowed to hydrate for a period of 24hrs. Rheological characterisation was carried out using Fann Viscometer to determine the rheology at different Speeds from (600, 300, 200, 100 6) rpm to 3rpm. The stability of the solutions was further analysed using NaCl (1wt%). The concentration of CMC utilized in the formulation was increased from 1wt% to 1.4wt% to study the effect of CMC on the viscosity with respect to salinity after another 24hrs. The rheological study equally captured the investigation of CMC alone as well as when blended with Gum Arabic

FIGURE 1 Gum Arabic

RESULTS AND DISCUSSION

From Figure 2, it is obvious that increasing the Gum Arabic's concentration improved the solution's viscosity at higher concentration of 50,000 ppm just like some other polysaccharides like Xanthan gum, Guar gum e.t.c that show very good rheology at increasing concentrations (Chatterji 1981, Eiroboyi, 2018). Though, Gum Arabic's viscosity did not show much appreciable rheology at low concentration of the gum alone, this could be as a result of the nature of its molecular structure which is in line with the work carried out by Authur, 2014 where he mentioned that Tragacanth gum and Gum ghatti contain the highest amount of rhamnose and arabinose, Gum Arabic contains the least amount of these sugars which makes it less viscous at lower concentrations. Also, the effect of salt affected the viscosity, this is because of the fact that the gum is polyelectrolyte (Glicksman et al, 1983) hence its interaction with NaCl.

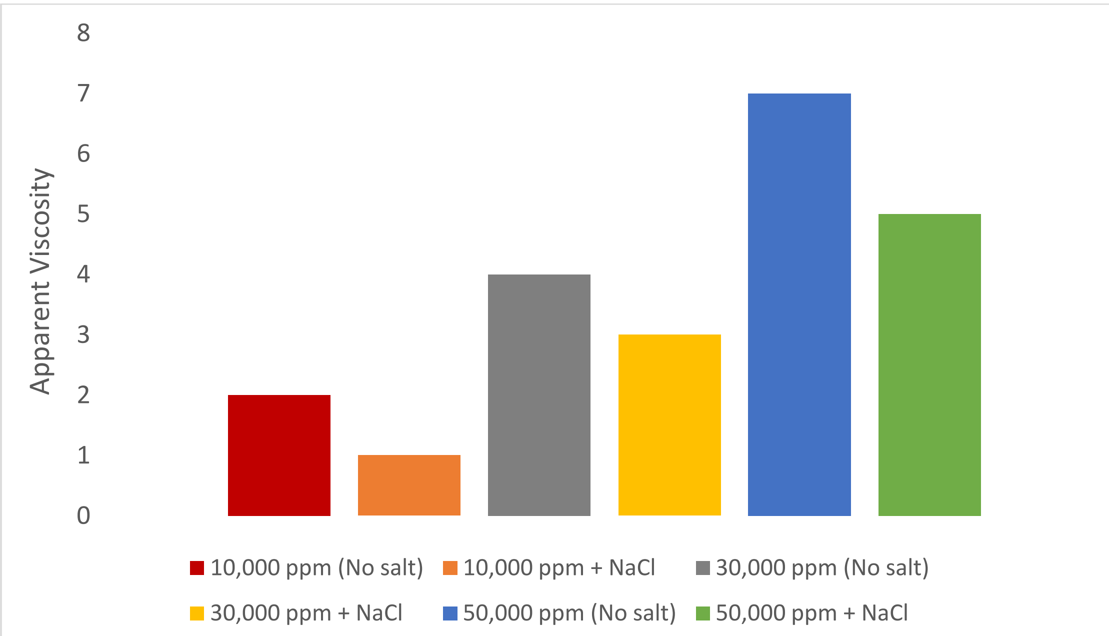

FIGURE 2 The Effect of salinity on Gum Arabic at increasing concentration

Figure 3 displays the rheological behaviour of Carboxymethyl Cellulose alone at increasing concentration as well as in the presence of NaCl. However, in this case it was used an additive in the formulation, the results show that 1wt % of CMC was very viscous even more viscous at increasing concentration of 1.4wt % which agrees with Chatterji et al, 1981 in which they stated that CMC has one of the highest viscosifying ability. This particular analysis was necessary to actually ascertain if there would be synergy between the polymers after blending based on the viscosity values. Both 1wt% and 1.4wt% reflected reduction in viscosity in the presence of 1wt% NaCl, this also confirms the analogy given by Chatterji et al, 1981 in which they mentioned that CMC is anionic making it such that the presence of salt yields negative effect on its viscosity.

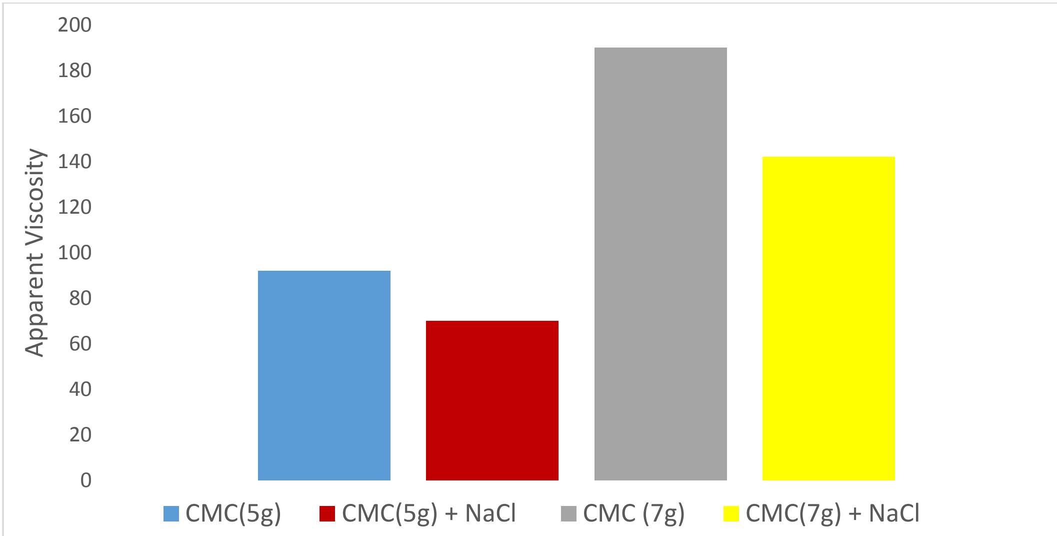

FIGURE 3 The effect of salinity on CMC at increasing concentration

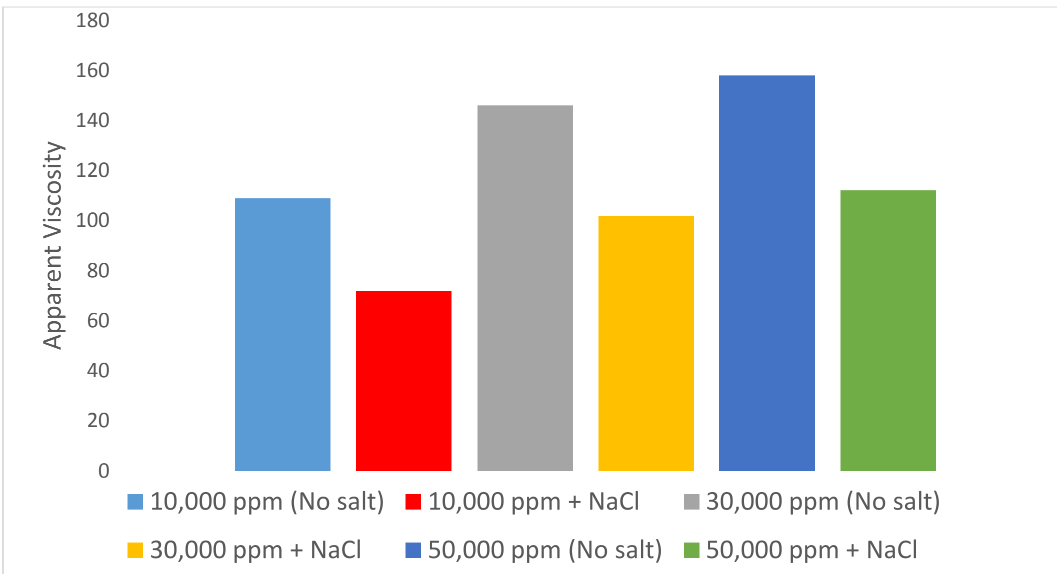

FIGURE 4 The Effect of salinity on a blend of Gum Arabic at increasing concentration and 1wt% of CMC

The presence of CMC in the solution strongly interacts with Gum Arabic solution increasing the viscosity considerably. From Figure 4, 50,000 ppm reflected the highest viscosity than other lower concentrations, this could be as a result of increased intermolecular entanglement from both the molecular chains of Gum Arabic and CMC, this can equally be related to the interaction that occurs when CMC is added to the cassava starch, the result is increased tensile strength, this behaviour was ascribed to the good interaction between cassava starch and CMC (Ibrahim et al. 2014). When compared with the viscosity of the gum alone (Figure 2) and the viscosity of CMC alone (Figure 3), the resultant blend in Figure 4 displayed synergy upon blending. Although, the reduction in viscosity based on the effect of salinity was equally obvious, this is because of the nature of the ionic status of both polymer chains (Ibrahim et al. 2014, Chatterji et al, 1981).

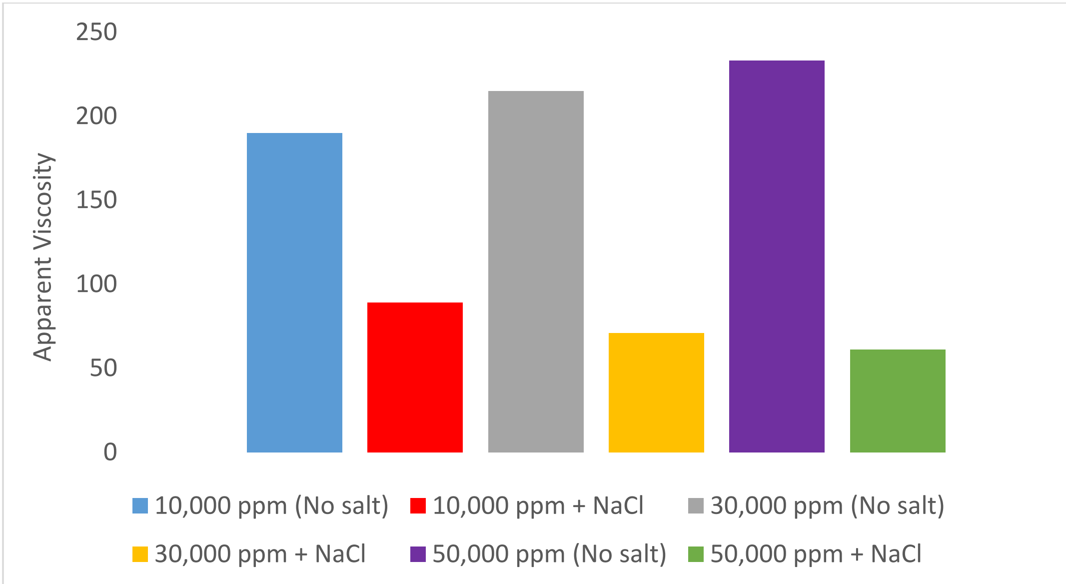

FIGURE 5 The Effect of salinity on a blend of Gum Arabic at increasing concentration and 1.4wt% of CMC

The presence of increasing concentration of 1.4wt% of CMC shown in Figure 5 without the influence of salinity increased the solution's viscosity more than that of 1wt% CMC. However, the resistance provided by Gum Arabic concentration did not improve when the concentration increased. This behaviour could be related to the fact that the presence of increased CMC concentration increased the anions present within the solution such that in the presence of NaCl, there was increased reaction with NaCl, thereby reducing the electrostatic repulsion increasingly on the polymer chains which eventually decreased the viscosity.

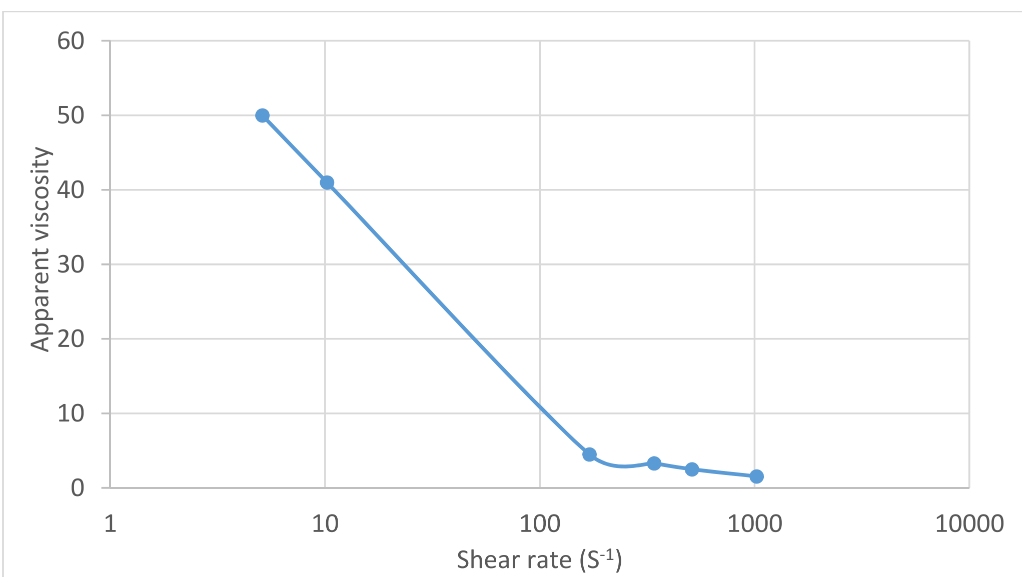

FIGURE 6 Viscosity-shear rate behaviour

Figure 6 depicts that the viscosity reduces with increasing shear rate, this reflects Gum Arabic's shear thinning behaviour just like other biopolymers used in enhanced oil recovery which also show shear thinning behaviour when subjected to the effect of shear.

CONCLUSIONS

During polymer flooding, one of the characteristics of a polymer is its ability to remain stable in the presence of high salinity as such the injected solution must have the ability to maintain its viscosity for a particular duration. From the experimental analysis,

- It is obvious that Gum Arabic at increasing concentration with CMC was able to produce increased viscosity which is a requirement in polymer flooding
- Blend of Gum Arabic with CMC especially at increasing concentration did not produce adequately the stability against the effect of salinity for the solution.
- The experimental analysis proved that attraction and repulsion of molecular charges are responsible for the resultant solution viscosity especially because both polymers are ionic.
- The further reduction in viscosity is related to the increase in anions from the polymers in solution because both of them are polyelectrolytes and as such would interact strongly with the cations of NaCl solution thereby decreasing the electrostatic repulsion of the polymer chains in solution.
- With respect to the use of Gum Arabic, additives that are non-ionic would suffice better than ionic additives especially in the face of high salinity.

NOMENCLATURE

CMC = Carboxymethyl Cellulose

HPAM =Hydrolysed Polyacrylamide

NaCl= Sodium Chloride Salt

PPM = Pounds per million

Cp = Centipoise

PWPF= Produced water from polymer flooding

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