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Synergistic Study between Gum Arabic and Carboxymethyl Cellulose: Application in Polymer Flooding

I. Eiroboyi[1*], S. S. Ikiensikimama[2], B. A. Oriji[2] and I. P. Okoye[3]

[1]World Bank Centre of Excellence, University of Port Harcourt, Rivers State, Nigeria.
[2]Department of Petroleum Engineering, University of Port Harcourt, Rivers State, Nigeria.
[3]Department of Pure and Industrial Chemistry, University of Port Harcourt, Rivers State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The oil industry is experiencing a paradigm shift where the use of green chemicals is being encouraged in order to address environmental issues associated with the use of synthetic chemicals and also because of the fact that most of these synthetic polymers like hydrolysed polyacrylamide used to improve mobility ratio in Polymer flooding are imported chemicals. Thus, the need to source for other polymers that are viable and equally environmentally friendly.

Gum Arabic used in this analysis was obtained from the northern part of Nigeria. Different concentrations of Gum Arabic were analysed to study their rheology as well as the effect of salinity on them in order to determine their degree of resistance for this is a criterion in polymer flooding. However, the stability of Gum Arabic was further enhanced by the addition of Carboxymethyl Cellulose (CMC) at varying concentration to determine its effect on the solution viscosity. Based on the results, the effect of blending resulted in synergistic viscosity however, the stability of the solution with respect to the effect of salinity was affected.

**Corresponding author: E-mail: ebitoh@yahoo.com;*

Keywords: Gum Arabic; Carboxymethyl Cellulose (CMC); polymer; viscosity; salinity.

NOMENCLATURE

CMC : Carboxymethyl Cellulose
HPAM : Hydrolysed Polyacrylamide
NaCl : Sodium Chloride Salt
PPM : Pounds per million
Cp : Centipoise
PWPF : Produced water from polymer flooding
EOR : Enhanced Oil Recovery

1. 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. 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 [1]. 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. Hydrolysed polyacrylamide (HPAM) and its derivatives have been used for most large-scale field production mostly because it is less costly [2]. The commercial bio-polymer (Xanthan gum) also used in oilfield application that would have suffice as a better alternative because it is environmentally friendly and stable, is not frequently used like the HPAM [3] because of its cost.

Other issues associated with HPAM is that in produced water after polymer flooding (Back produced water) results in serious problems such as difficulty in oil - water separation because of this, the treatment of back produced water from polymer flooding with HPAM (PWPF) is more difficult to separate than oily wastewater from water flooding without HPAM [4,5,6]. Also, the residual HPAM dissolved in water increases the viscosity of wastewater and also HPAM is equally absorbed onto the oil/water interface, making the separation process even much more difficult to attain [7]. Furthermore, the chemical cost of polymer flooding is a function of the polymer selected for flooding, 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 [1]. 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 also known as *Acacia Senegal*. It is produced as tear-drop-shaped globules exudates from bark wound of Acacia trees [8]. The viscosity of the solution of gum Arabic is based on changes in pH, viscosity is low at low pH 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. The gum is a polysaccharide that is highly water soluble, 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 [9].

Carboxymethyl Cellulose (CMC) is one of the most popular cellulose derivative, it is an anionic polymer and also highly water soluble. It 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 very high viscosity [10]. CMC is synthesized by reacting cellulose with sodium hydroxide in the presence of sodium chloroacetate.

In line with the principles of green chemistry aimed at the synthesis of safer chemicals that are environmentally friendly, this work investigates the use of Gum Arabic as a suitable viscosifier while CMC was added to determine its effect on the solution's stability at increasing water salinity.

2. MATERIALS AND METHOD

In this analysis, different concentrations of Gum Arabic (Fig. 1) from 10,000ppm, 30,000ppm to 50,000ppm were dissolved in 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 600, 300, 200, 100, 6 and 3 rpm. The stability of the solutions was further analysed using NaCl (1wt%). The investigation captured the rheology of CMC alone as well as when blended with Gum Arabic, the concentration of CMC utilized was increased from 1wt% to 1.4wt% to study the effect of CMC on the viscosity with respect to salinity after another 24 hrs.

Fig. 1. Gum Arabic

3. RESULTS AND DISCUSSION

Based on the results from Fig. 2, it is obvious that increasing the Gum Arabic's concentration improved the solution's viscosity especially at higher concentration of 50,000 ppm just like the rheology of some other polysaccharides like Xanthan gum, Guar gum e.t.c that also show good rheology at increasing concentrations [11,12]. 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, in line with the work carried out by [13] where he mentioned that Tragacanth gum and Gum ghatti contain the higher amount of rhamnose and arabinose, however, 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 hence its interaction with NaCl.

Fig. 3 displays the rheological behaviour of Carboxymethyl Cellulose alone at increasing concentration as well as in the presence of NaCl, the results showed that 1wt % of CMC was very viscous even more viscous at increasing concentration of 1.4wt % which agrees with [11] in which they stated that CMC has one of the highest viscosifying ability among other EOR polymers. 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% polymer concentration reflected reduction in viscosity in the presence of 1wt% NaCl, this agrees with the work carried out by [11] in which they mentioned that CMC is anionic as such in the presence of salt (NaCl), the resultant viscosity is reduced. Also [14] stated that the presence of salinity screens the ions on the polymer chains thus reducing the electrostatic repulsion between the polymer chains as well as results in reduction in viscosity.

CMC interacts strongly with Gum Arabic solution increasing the viscosity considerably (Table 1). From Fig. 4, 50,000 ppm reflected the highest viscosity than other lower polymer 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 was added to the cassava starch, the result is increased tensile strength, this behaviour was ascribed to the good interaction between cassava starch and CMC [10]. When compared with the viscosity of the gum alone and the viscosity of CMC alone, the resultant blend displayed synergy upon blending (Table 1). 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 [10,11].

The presence of increasing concentration of 1.4wt% of CMC in the absence of salinity shown in Fig. 5 increased the solution's viscosity more than that of 1wt% CMC. However, after the impact of salinity the resistance provided did not improve when the polymer concentration was increased. This behaviour is in line with [14], in which they described the reduction in viscosity associated with polyelectrolytes, in this case both polymers are polyelectrolytes and thus they are ionic, this ionic status in the presence of NaCl results in the shielding of the ions of the polymer as well as the reduction in the electrostatic repulsion on the polymer chains and eventually a reduction in the viscosity.

Fig. 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.

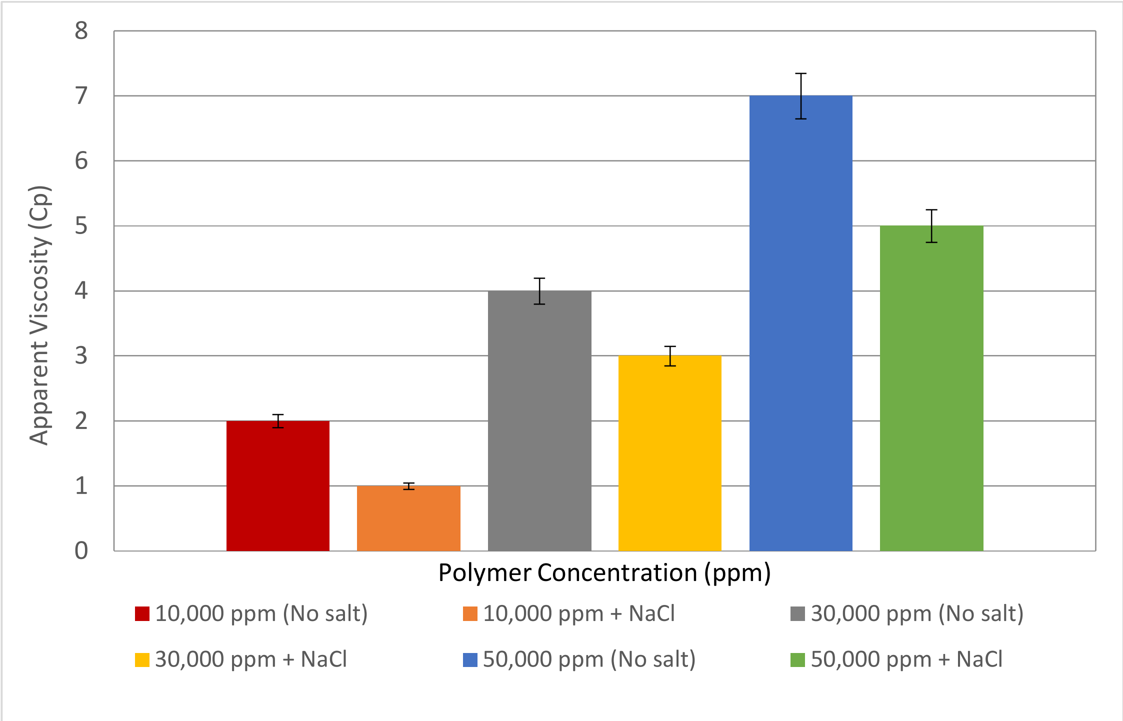

Fig. 2. The effect of salinity on gum Arabic at increasing polymer concentration

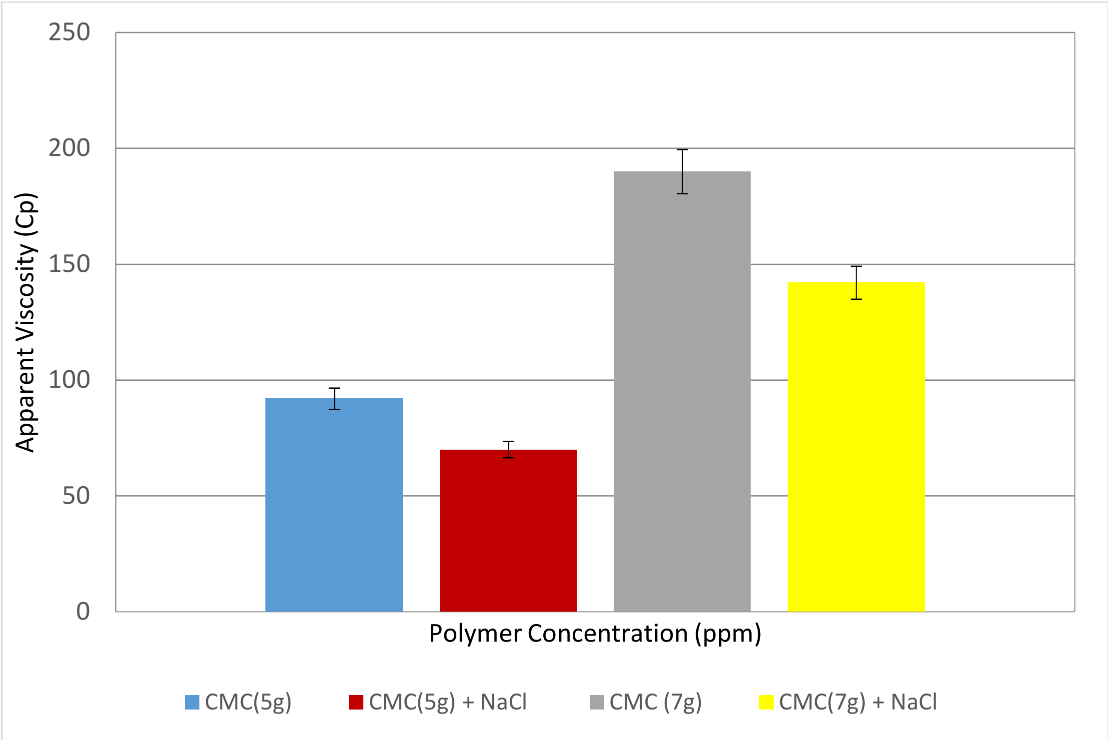

Fig. 3. The effect of salinity on CMC at increasing polymer concentration

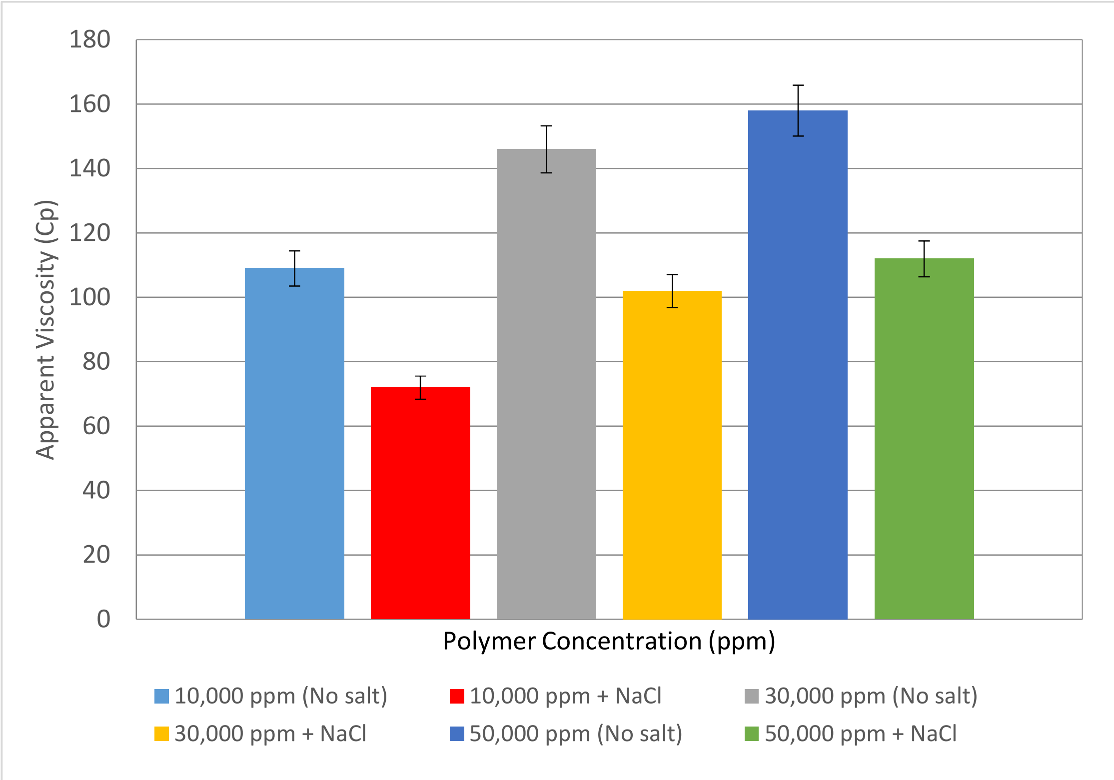

Fig. 4. The effect of salinity on a blend of gum Arabic and 1wt% of CMC at increasing polymer concentration

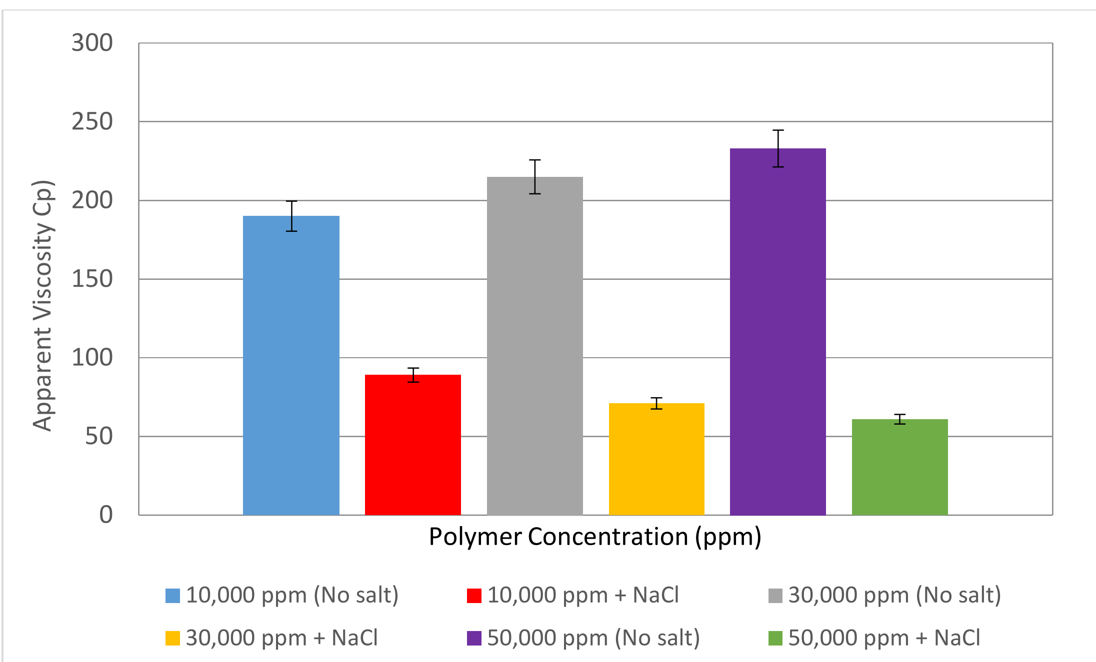

Fig. 5. The effect of salinity on a blend of gum Arabic and 1.4wt% of CMC at increasing polymer concentration

Table 1. Synergistic Viscosity before and after the Impact of salinity

Polymer concentration (PPM)	Apparent viscosity before the effect of salinity in the presence of 1wt% of CMC (Cp)			Apparent viscosity after the effect of salinity in the presence of 1wt% of CMC (Cp)		
	Gum Arabic	Carboxymethyl cellulose	Resultant solution	Gum Arabic	Carboxymethyl cellulose	Resultant solution
10,000	2	92	109	1	70	72
30,000	4	92	146	3	70	102
50,000	7	92	158	5	70	112

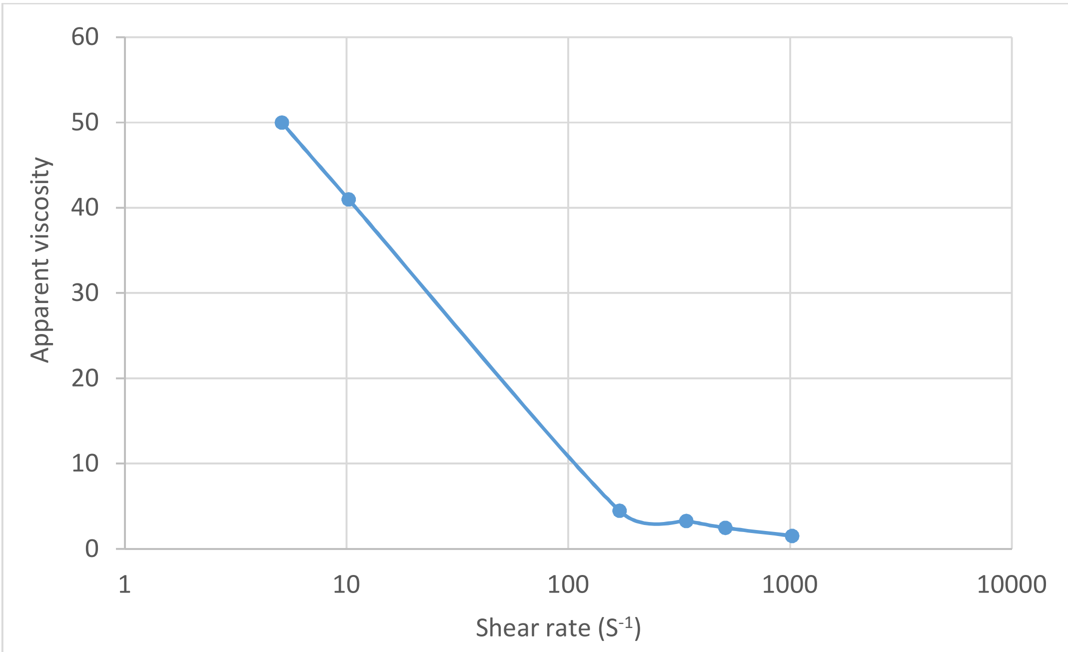

Fig. 6 Viscosity-shear rate behaviour

4. 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. Based on 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.
- Blends of Gum Arabic with CMC especially at increasing concentration did produce adequately stability against the effect of salinity.
- The reduction in viscosity after the effect of salinity is related to the fact that both polymers are polyelectrolytes as such would interact strongly with the cations of NaCl solution thereby decreasing the electrostatic repulsion of the polymer chains in 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.
- 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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