

# 1 Formulation of Polymers from Locally Sourced Polysaccharides in 2 Polymer **flooding** 3 4

## 5 ABSTRACT

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

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

20  
21 Keywords: Gum Arabic; Carboxyl-Methyl Cellulose (CMC); Polymer; Viscosity; Salinity.  
22

## 23 INTRODUCTION

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

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

42 Chemical cost of a polymer flooding process is a function of the polymer selected for  
43 flooding. For instance, although chemical cost as well as the treatment cost is said to be  
44 higher for xanthan gum solutions compared to polyacrylamide solutions, Xanthan's cost is  
45 stable when compared to the fluctuating cost of polyacrylamide polymer. The polyacrylamide  
46 is actually synthesised from petroleum products and their costs in the market are very  
47 sensitive to the crude oil prices. (Rellegadla, 2017). Thus, there is need to manufacture shear  
48 resistant, also temperature resistant chemicals, as well as environmentally friendly

49 biopolymers that are less costly than xanthan gum as this is a sure way of generating more  
50 recovery while reducing cost.

51 Gum Arabic is presently one of the oldest polysaccharides and mostly found in the northern  
52 part of Nigeria also known as *Acacia Senegal*. It is produced as tear-drop-shaped globules  
53 exudates from bark wounds of Acacia trees (Glicksman, 1973). Due to the presence of ionic  
54 charges on the backbone of the polymer chains, the viscosity of solutions of gum Arabic is  
55 based on changes in pH. Viscosity is low at low and also at high pH and reaches a maximum  
56 at about a pH of 6-8. It occurs majorly as a mixture of calcium magnesium and potassium  
57 salts of Arabic-acid and is composed of the following carbohydrates, this include: galactose,  
58 arabino pyranose, arabino furanose, rhamnose, glucuronic acid and 4-0 methyl glucuronic  
59 (Anderson, 1966). The gum is a highly water-soluble polysaccharide. It is principally used in  
60 the food and pharmaceutical industries as stabilizer, thickener, suspending and binding agent  
61 in the manufacture of confections, dairy products, beverages, cotton-seed oil emulsion and  
62 tablets (Nahla, 2000). The composition of sugars within Gum Arabic is shown in **Equation 1**.

63

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

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

## 76 MATERIALS AND METHOD

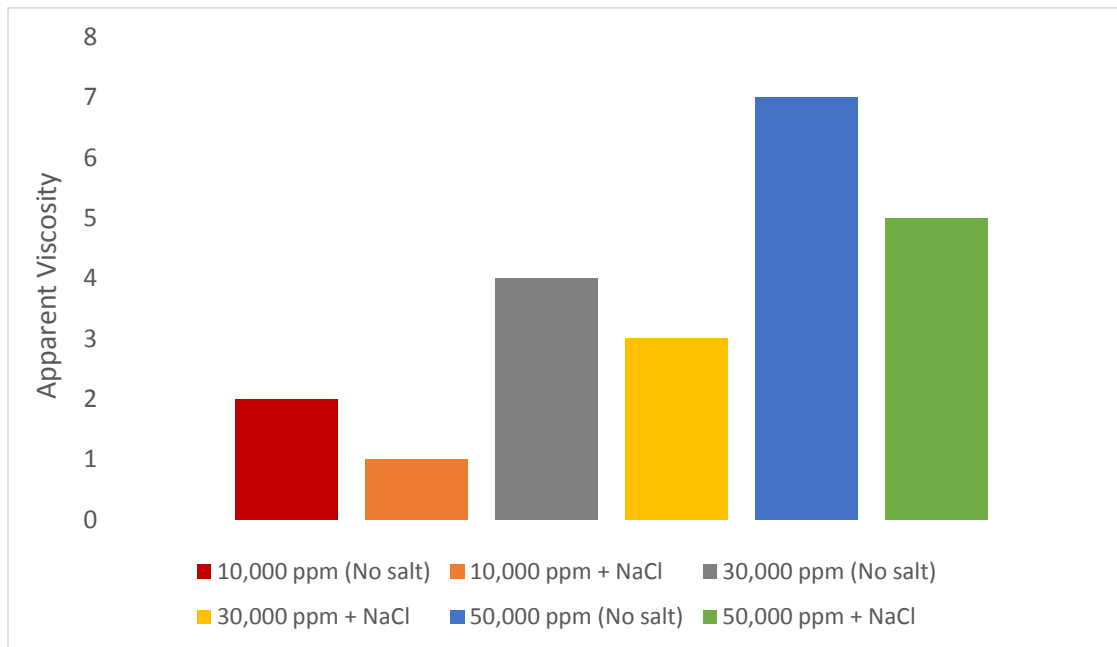
77 In this analysis, different concentrations of Gum Arabic (Figure 1) from 10,000ppm,  
78 30,000ppm to 50,000ppm were dissolved using **500 ml** of water. The solution was stirred  
79 gently to achieved homogeneity in order to avoid the formation of fish eye, this was then  
80 allowed to hydrate for a period of 24hrs. Rheological characterisation was carried out using  
81 Fann Viscometer to determine the rheology at different Speeds from (600, 300, 200, 100 6)  
82 rpm to 3rpm. The stability of the solutions **was** further analysed using NaCl (1wt%). The  
83 concentration of CMC utilized in the formulation was increased from 1wt% to 1.4wt% to  
84 study the effect of CMC on the viscosity with respect to salinity after another 24hrs. The  
85 rheological study equally captured the investigation of CMC alone as well as when blended  
86 with Gum Arabic



87  
88 **FIGURE 1** Gum Arabic

89 **RESULTS AND DISCUSSION**

90 From Figure 2, it is obvious that increasing the Gum Arabic's concentration improved the  
 91 solution's viscosity at higher concentration of 50,000 ppm just like some other  
 92 polysaccharides like Xanthan gum, Guar gum e.t.c that show very good rheology at  
 93 increasing concentrations (Chatterji 1981, Eiroboyi, 2018). Though, Gum Arabic's viscosity  
 94 did not show much appreciable rheology at low concentration of the gum alone, this could be  
 95 as a result of the nature of its molecular structure. Also, the effect of salt affected the  
 96 viscosity, this is because of the fact that the gum is polyelectrolyte hence its interaction with  
 97 NaCl.

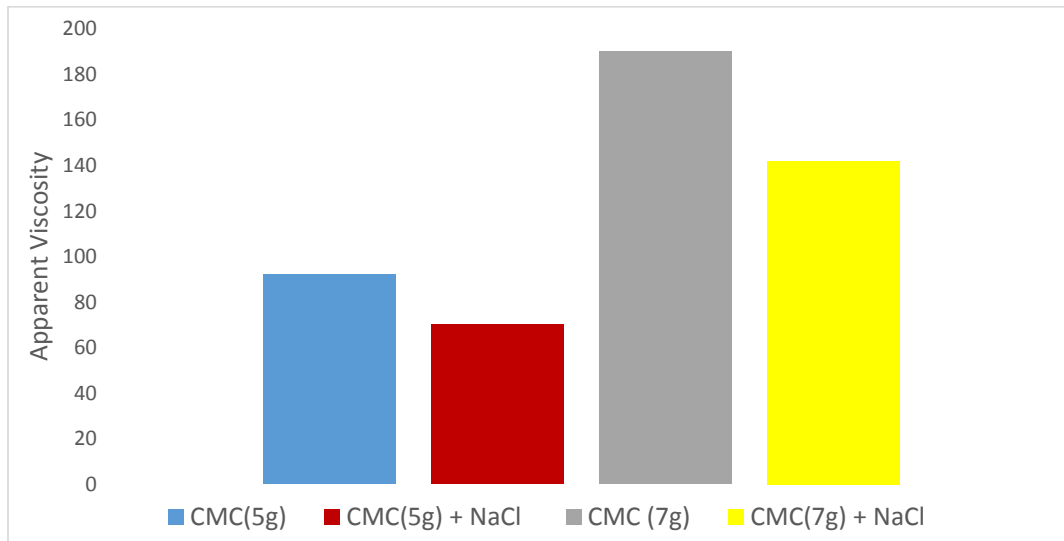


98  
99 **FIGURE 2** The Effect of salinity on Gum Arabic at increasing concentration

100 Figure 3 displays the rheological behaviour of Carboxymethyl Cellulose at increasing  
 101 concentration as well as in the presence of NaCl. However, in this case it was used an  
 102 additive in the formulation. The results show that 1wt % of CMC was very viscous even  
 103 more viscous at increasing concentration of 1.4wt %. This particular analysis was necessary

104 to actually ascertain if there was synergy between the polymers after blending. Both 1wt%  
105 and 1.4wt% reflected reduction in viscosity in the presence of 1wt% NaCl.

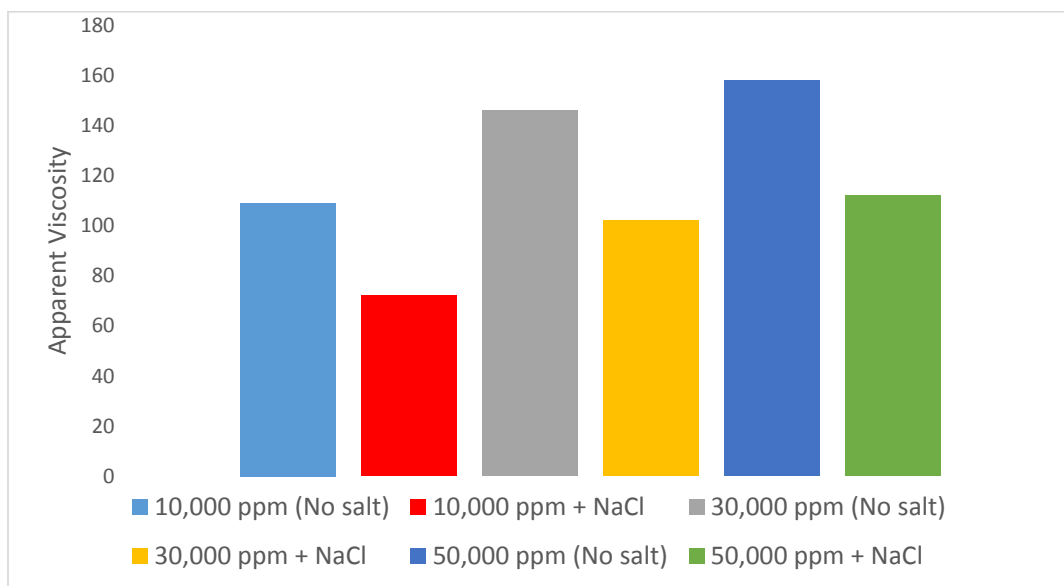
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108 **FIGURE 3** The effect of salinity on CMC at increasing concentration

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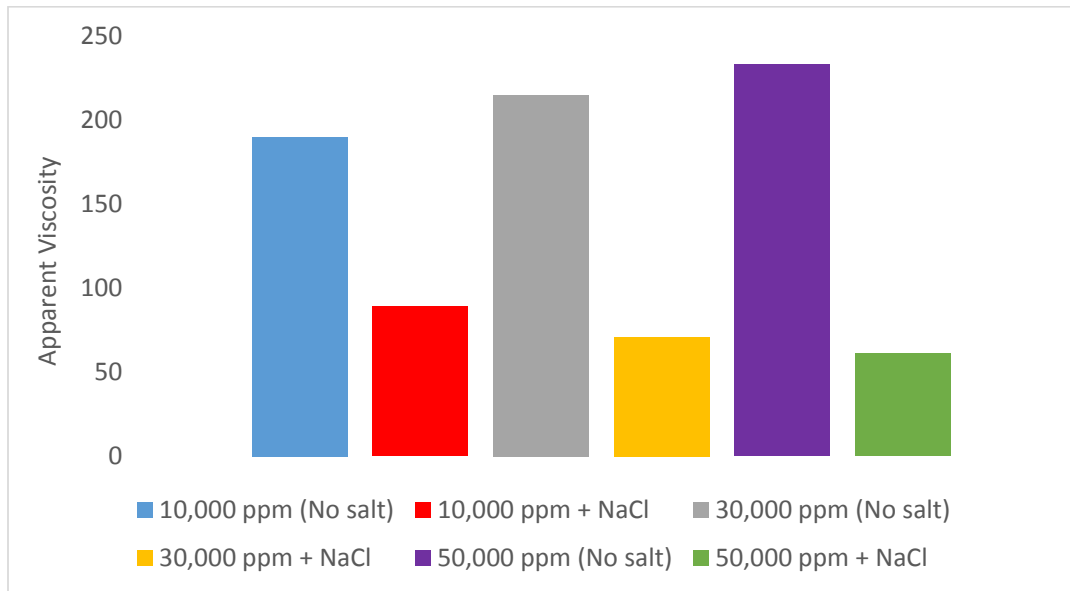
110 **FIGURE 4** The Effect of salinity on a blend of Gum Arabic at increasing concentration

110

111 and 1wt% of CMC

111

112 The presence of CMC in the solution strongly interacts with Gum Arabic solution increasing  
113 the viscosity considerably. From Figure 4, 50,000ppm reflected the highest viscosity than  
114 other lower concentrations, this could be as a result of increased intermolecular entanglement  
115 from both the molecular chains of Gum Arabic and CMC. When compared with the viscosity  
116 of the gum alone (Figure 2) and the viscosity of CMC alone (Figure 3), the resultant blend in  
117 Figure 4 displayed synergy upon blending. Although, the reduction in viscosity based on the  
118 effect of salinity was equally obvious, this is because of the nature of the ionic status of both  
119 polymer chains.

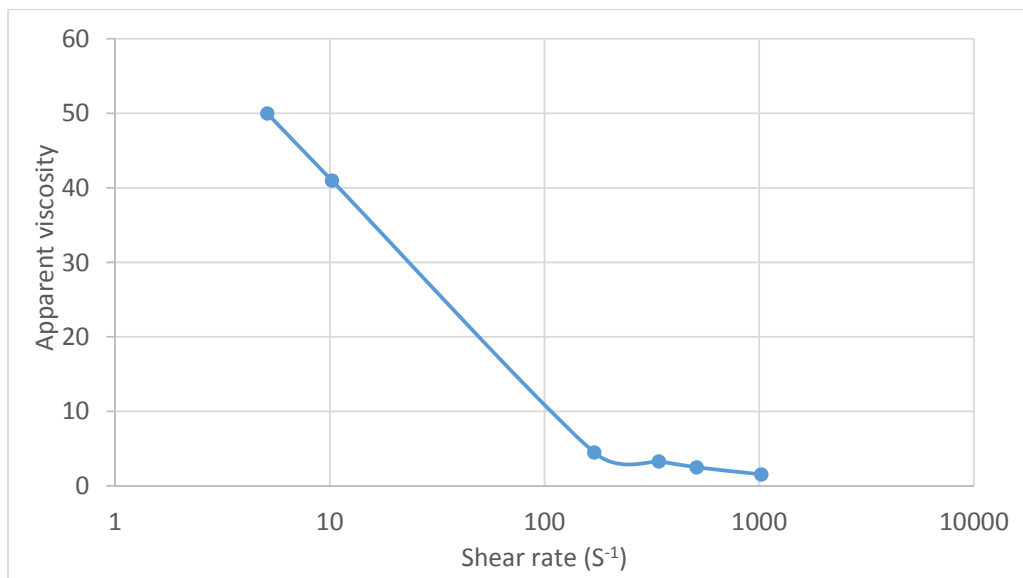


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121 **FIGURE 5** The Effect of salinity on a blend of Gum Arabic at increasing concentration  
 122 and 1.4wt% of CMC

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

130



131

132 **FIGURE 6** Viscosity-shear rate behaviour

133 Figure 6 depicts that the viscosity reduces with increasing shear rate, this reflects Gum  
134 Arabic's shear thinning behaviour.

## 135 **CONCLUSIONS**

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

- 139 • It is obvious that Gum Arabic at increasing concentration with CMC was able to produce  
140 increased viscosity which is a requirement in polymer flooding though Gum Arabic as a  
141 polymer alone is a low viscous polymer.
- 142 • Gum Arabic with CMC especially at increasing concentration of CMC and Gum Arabic  
143 solution did not produce adequately the stability against salinity for the solution.
- 144 • The experiment analysis proved that attraction and repulsion of molecular charges are  
145 responsible for the resultant solution viscosity especially because both polymers are  
146 ionic.
- 147 • This reduction could be related to the increase in anions from the polymers in solution  
148 because both of them are polyelectrolytes and as such would interact strongly with the  
149 cations of NaCl solutions thereby decreasing the electrostatic repulsion of the polymer  
150 chains in solution.
- 151 • In the use of Gum Arabic, additives that are non-ionic would suffice better than ionic  
152 polymers in the face of high salinity.

153

## 154 **NOMENCLATURE**

155 **CMC = CarboxylMethyl Cellulose**

156 **HPAM =Hydrolysed Polyacrylamide**

157 **NaCl= Sodium Chloride Salt**

158 **PPM = Pounds per million**

159 **Cp = Centipoise**

160 **PWPF= Produced water from polymer flooding**

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