Data Article

Comparative dataset on the characterization of natural polymers and nanocomposites for enhanced oil recovery

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A B S T R A C T

Polymer flooding is one of the most effective processes to improve crude oil recovery. However, the capacity of natural polymers to displace crude oil is determined by their rheological behaviour in the face of prevailing reservoir conditions. Poor rheological stability of water-soluble polymers challenges their application in harsh reservoir conditions, making it important to investigate the characteristics of polymers and their corresponding nanocomposites for use in enhanced oil recovery (EOR). The main objective of this work is to conduct characterization tests for three polymers (Gum Arabic, Xanthan Gum and Guar Gum) and three nanoparticles (silica, alumina and cupric), and to investigate the viscosity profile of the polymers under different conditions of temperature, salinity, nanoparticle weight percentage and polymer weight percentage. SEM was used to characterize the nanoparticles while FTIR and TGA were used to characterize the polymers. All viscosity measurements were conducted using an OFITE Viscometer. The SEM, FTIR and TGA results are presented in figures while the viscosity results are presented as raw data in tables. The data should be used to support oil recovery experiments, economic analysis of the use of polymers and nanocomposites in EOR and the study

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of adsorption and permeability impairment in core flooding tests.

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### Specifications Table

| Subject                               | Petroleum Engineering |
|---------------------------------------|-----------------------|
| Specific subject area                 | Characterization and measurement of viscosity |
| Type of data                          | Tables and Figures    |
| How data were acquired                | Brucker Vertex 80v FTIR Instrument, TA Q6000 Instrument for TGA, Quanta SEM 450 Equipment, and Model 800 OFITE Viscometer |
| Data format                           | Raw                   |
| Parameters for data collection        | The following were considered: types of natural polymers, the concentration of natural polymers, types and concentration of nanoparticles, salinity and temperature effect on the viscosity of polymers |
| Description of data collection        | Characterization of the polymers and nanoparticles was done using TGA, FTIR and SEM. Functional groups of the polymers were obtained using FTIR. The thermal stability of the polymers was examined using TGA, and micrographs of the nanoparticles were obtained using SEM. The viscosity of the polymers was measured using a Model 800 OFITE Viscometer and a heating mantle. The effects of polymer concentration, nanoparticle concentration, nanoparticle types, temperature and salinity on the viscosity of three natural polymers were investigated. |
| Data source location                  | Department of Petroleum Engineering, Covenant University, Ota, Nigeria |
| Data accessibility                    | Data is with the article. |

### Value of the Data

- Characterization and rheological study of polymers and nanocomposites make it possible to determine the suitability of these polymers for core flooding experiments and to make a comparison between them based on the conditions typically found in a reservoir formation.
- This data provides significant insight for researchers and industry experts working in the area of chemical enhanced oil recovery processes.
- This data provides a basis for the use of polymers and nanocomposites for core flooding experiments with a view to reducing the possibility of permeability impairment from the viscosity of the polymers and agglomeration of the nanocomposites. The combined use of polymers and nanoparticles make it possible to achieve higher oil recoveries from an increase in volumetric and microscopic efficiencies.

### 1. Data Description

As oil reservoirs around the world decline in crude oil production, several options exist for recovering more crude oil from reservoirs with waning production [1]. Polymers have been reported to enhance oil recovery by improving the volumetric efficiency of the flooding process [2–5]. However, polymers alone are incapable of microscopic interactions, thereby limiting their oil recovery capacity. It is therefore important to investigate the stability of polymers and nanocomposite mixtures under existing reservoir conditions for potential use in EOR. The dataset presented in this article shows the characterization of polymers and nanoparticles using a scanning electron microscope (SEM), Fourier-transform infrared spectroscopy (FTIR) and thermogravimetric analysis (TGA). Also, the effects of polymer weight percentage, nanoparticle weight percentage, nanoparticle type, temperature and salinity on the viscosity of polymers were investigated.
Three nanoparticles were studied: silica, alumina and cupric nanoparticles. The SEM micrographs of these nanoparticles are shown in Figs. 1–3. Three natural polymers were also studied: xanthan gum, guar gum and gum arabic. The thermal stability of the polymers was measured using TGA; the plots of the percentage weight losses against temperature are shown in Fig. 4, and the raw data obtained from the TGA machine are provided in Tables 15–17. The FTIR spectra
for xanthan gum, guar gum and gum arabic are shown in Figs. 5–7; while the list of functional groups is shown in Table 1. The effect of temperature and polymer weight percentage at different shear rates on the viscosities of xanthan gum and guar gum are shown in Tables 2 and 3 respectively. The temperatures used for the viscosity experiments were 30, 50, 75, and 90 °C; while the weight percentages used for the polymers were 0.1, 0.2, 0.3, 0.4, 0.5, and 1% w/w. Table 4 shows the effect of temperature and weight percentage on the viscosity of gum arabic. The same temperatures were used for gum arabic viscosity measurements, but the weight percentages used were 0.4, 0.5, 1, 5, 10 and 15% w/w. Higher weight percentages were used for
Fig. 5. FTIR spectra for xanthan gum polymer.

Fig. 6. FTIR spectra for guar gum polymer.
Table 1
Functional groups contained in polymers.

| Polymers         | Wavelength (cm\(^{-1}\)) | Functional groups                               |
|------------------|---------------------------|-------------------------------------------------|
| Xanthan gum      | 3263                      | O–H stretching                                   |
|                  | 2883                      | C–H stretching                                   |
|                  | 1739                      | C=O stretching                                   |
|                  | 1598, 1404                | COO\(^{-}\) symmetric stretching                |
|                  |                            | COO\(^{-}\) asymmetric stretching               |
|                  | 1250                      | O–H angular deformation                          |
|                  | 1018                      | C=O deformation                                  |
|                  |                            | C–O stretching                                   |
| Guar gum         | 3261                      | O–H stretching vibration                         |
|                  | 2885                      | C–H stretching                                   |
|                  | 1648                      | Ring stretching                                  |
|                  | 1402                      | CH\(_2\) symmetric deformation                  |
|                  | 1143                      | C–OH stretching                                  |
|                  | 1053                      | CH\(_2\)OH stretching                            |
|                  | 1014                      | CH\(_2\) twisting vibration                      |
| Gum arabic       | 3261                      | O–H stretching                                   |
|                  | 2885                      | C–H stretching                                   |
|                  | 1641                      | COO\(^{-}\) symmetric stretching                |
|                  | 1402                      | COO\(^{-}\) asymmetric stretching               |
|                  | 1250-900                  | Carbohydrate fingerprint                        |

Table 2
Xanthan gum viscosity (cP) at different conditions.

| Temperature (°C) | Shear rate (s\(^{-1}\)) | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | wt% |
|------------------|--------------------------|---------|--------|--------|--------|--------|-------|-------|-----|
| 30               | 6.05                     | 9.3     | 12     | 18.6   | 24.5   | 43     | 165   | 0.1   |
| 50               | 4.5                      | 5.7     | 7.8    | 15     | 23     | 38     | 150   |       |
| 75               | 3.85                     | 5.1     | 6.75   | 12     | 19.5   | 31     | 140   |       |
| 90               | 3.5                      | 4.5     | 5.85   | 11.7   | 16     | 29     | 105   |       |
| 1021.38          |                          | 510.69  | 340.46 | 170.23 | 102.14 | 51.07  | 10.21 |
| 30               | 8.65                     | 13.7    | 16.4   | 26.7   | 35.5   | 58     | 245   | 0.2   |
| 50               | 7.05                     | 10.3    | 13.8   | 19.5   | 30     | 51     | 225   |       |
| 75               | 5.15                     | 9.9     | 11.7   | 15.6   | 24     | 45     | 210   |       |
| 90               | 4.5                      | 6.5     | 9      | 14.7   | 22     | 36     | 170   |       |
| 1021.38          |                          | 510.69  | 340.46 | 170.23 | 102.14 | 51.07  | 10.21 |
| 30               | 12.05                    | 20.9    | 24.8   | 47.7   | 58.5   | 105    | 440   | 0.3   |
| 50               | 10.65                    | 18.5    | 21.5   | 38.7   | 49.5   | 87     | 325   |       |
| 75               | 9.85                     | 15.4    | 19.8   | 34.5   | 43.5   | 80     | 260   |       |
| 90               | 7.65                     | 13.2    | 18.6   | 32.1   | 41     | 75     | 200   |       |
| 1021.38          |                          | 510.69  | 340.46 | 170.23 | 102.14 | 51.07  | 10.21 |
| 30               | 13                       | 22      | 31.5   | 45     | 67.5   | 119    | 450   | 0.4   |
| 50               | 10.95                    | 17.8    | 23.3   | 39.9   | 57.5   | 92     | 405   |       |
| 75               | 9.05                     | 16.3    | 19.7   | 34.5   | 55     | 80     | 270   |       |
| 90               | 8.65                     | 14.5    | 18.3   | 32.7   | 50     | 70     | 225   |       |
| 1021.38          |                          | 510.69  | 340.46 | 170.23 | 102.14 | 51.07  | 10.21 |
| 30               | 14.95                    | 23.2    | 33.8   | 53.4   | 82.5   | 156    | 540   | 0.5   |
| 50               | 14.4                     | 21.5    | 31.4   | 48.3   | 76.5   | 145    | 495   |       |
| 75               | 11.65                    | 20.4    | 26.9   | 44.1   | 67.5   | 127    | 405   |       |
| 90               | 10.6                     | 18.3    | 23.9   | 40.2   | 61     | 111    | 375   |       |
| 1021.38          |                          | 510.69  | 340.46 | 170.23 | 102.14 | 51.07  | 10.21 |
| 30               | 31.95                    | 55.3    | 77     | 137.7  | 209.5  | 389    | 1645  | 1.0   |
| 50               | 30.05                    | 53.3    | 74.7   | 134.1  | 201    | 365    | 1515  |       |
| 75               | 28.4                     | 48.9    | 69.5   | 125.1  | 189    | 353    | 1440  |       |
| 90               | 26.95                    | 47.4    | 67.8   | 122.4  | 182.5  | 335    | 1340  |       |
gum arabic due to the practical limitations of using lower weight percentages owing to the low viscosity of gum arabic polymer. The effect of silica, alumina and cupric loading on xanthan gum viscosity at different shear rates are shown in Tables 5–7. The effects of these nanoparticles on guar gum and gum arabic polymers are shown in Tables 8–13 respectively. The effect of salinity on the viscosities of xanthan gum, guar gum and gum arabic is shown in Table 14.

Fig. 7. FTIR spectra for gum arabic polymer.
**Table 3**

Guar Gum viscosity (cP) at different conditions.

| Shear rate (s\(^{-1}\)) | Temperature (°C) | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | wt% |
|--------------------------|-----------------|--------|--------|--------|--------|--------|-------|-------|-----|
|                          | 30              | 4.95   | 6.7    | 8.7    | 14.7   | 19.5   | 35    | 155   | 0.1 |
|                          | 50              | 4.55   | 5.3    | 7.35   | 13.5   | 17.5   | 32    | 145   | 0.1 |
|                          | 75              | 4.25   | 4.8    | 6.3    | 12     | 16.5   | 30    | 135   | 0.1 |
|                          | 90              | 3.95   | 3.7    | 5.55   | 11.1   | 15     | 28    | 100   | 0.1 |
| 1021.38                  | 510.69          | 340.46 | 170.23 | 102.14 | 51.07  | 10.21  |       |       |     |
|                          | 30              | 6.85   | 10.3   | 13.2   | 22.2   | 29.5   | 48    | 205   | 0.2 |
|                          | 50              | 5.75   | 8.8    | 10.95  | 19.2   | 25.5   | 46    | 195   | 0.2 |
|                          | 75              | 4.25   | 6.8    | 7.95   | 13.5   | 24.5   | 37    | 165   | 0.2 |
|                          | 90              | 3.45   | 5.7    | 7.2    | 14.4   | 21.5   | 36    | 160   | 0.2 |
| 1021.38                  | 510.69          | 340.46 | 170.23 | 102.14 | 51.07  | 10.21  |       |       |     |
|                          | 30              | 10.65  | 17.7   | 23.25  | 35.7   | 42.5   | 61    | 270   | 0.3 |
|                          | 50              | 9.95   | 15.2   | 15.75  | 26.7   | 36.5   | 55    | 240   | 0.3 |
|                          | 75              | 7.7    | 10.1   | 12.75  | 21.6   | 30.5   | 49    | 205   | 0.3 |
|                          | 90              | 6      | 8.3    | 7.8    | 14.7   | 24.5   | 44    | 180   | 0.3 |
| 1021.38                  | 510.69          | 340.46 | 170.23 | 102.14 | 51.07  | 10.21  |       |       |     |
|                          | 30              | 16.75  | 24.7   | 30.15  | 43.5   | 61     | 101   | 415   | 0.4 |
|                          | 50              | 13.6   | 20.5   | 27.45  | 34.5   | 47.5   | 83    | 335   | 0.4 |
|                          | 75              | 11.65  | 18.7   | 23.1   | 30.3   | 44     | 77    | 255   | 0.4 |
|                          | 90              | 9.25   | 15.5   | 21.15  | 23.4   | 33.5   | 63    | 195   | 0.4 |
| 1021.38                  | 510.69          | 340.46 | 170.23 | 102.14 | 51.07  | 10.21  |       |       |     |
|                          | 30              | 17.85  | 28.4   | 36.45  | 57.3   | 78     | 117   | 410   | 0.5 |
|                          | 50              | 16.6   | 25.5   | 30.15  | 51.6   | 66.5   | 101   | 390   | 0.5 |
|                          | 75              | 14.75  | 25.2   | 28.35  | 43.2   | 55.5   | 93    | 260   | 0.5 |
|                          | 90              | 13.5   | 23     | 23.55  | 39     | 47     | 80    | 245   | 0.5 |
| 1021.38                  | 510.69          | 340.46 | 170.23 | 102.14 | 51.07  | 10.21  |       |       |     |
|                          | 30              | 53.35  | 93.2   | 126.75 | 207.3  | 300    | 507   | 1510  | 1.0 |
|                          | 50              | 50.45  | 92.9   | 123.3  | 206.4  | 289.5  | 474   | 1370  | 1.0 |
|                          | 75              | 47.6   | 80.7   | 108.45 | 179.7  | 250.5  | 407   | 1085  | 1.0 |
|                          | 90              | 45.85  | 73.4   | 99.45  | 163.5  | 227    | 367   | 915   | 1.0 |
### Table 4
Gum arabic viscosity (cP) at different conditions.

| Temperature (°C) | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | wt% |
|------------------|---------|--------|--------|--------|--------|-------|-------|-----|
| 30               | 2.9     | 5.1    | 7.35   | 9.9    | 15.5   | 30    | 150   | 0.4 |
| 50               | 2.65    | 4.8    | 5.85   | 9.6    | 15     | 30    | 145   |     |
| 75               | 1.75    | 2.8    | 4.95   | 5.1    | 8      | 15    | 70    |     |
| 90               | 1.3     | 2      | 3.75   | 4.8    | 7.5    | 13    | 65    |     |
|                  | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |     |
| 30               | 3.6     | 5.1    | 7.5    | 15     | 24     | 48    | 170   | 0.5 |
| 50               | 2.65    | 5      | 6      | 11.7   | 18.5   | 37    | 155   |     |
| 75               | 2.1     | 3.9    | 5.1    | 7.5    | 12.5   | 24    | 120   |     |
| 90               | 1.9     | 3.7    | 4.5    | 5.1    | 8      | 16    | 100   |     |
|                  | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |     |
| 30               | 6.95    | 12.2   | 16.2   | 19.2   | 33     | 49    | 180   | 1.0 |
| 50               | 6.25    | 11.1   | 13.5   | 18.6   | 27     | 40    | 160   |     |
| 75               | 5.05    | 6.3    | 10.95  | 12.9   | 20     | 35    | 140   |     |
| 90               | 4.6     | 4.6    | 9      | 10.2   | 16.5   | 20    | 135   |     |
|                  | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |     |
| 30               | 8.45    | 13.7   | 19.05  | 20.1   | 35     | 50    | 200   | 5.0 |
| 50               | 6.6     | 12     | 18     | 19.5   | 27.5   | 42    | 180   |     |
| 75               | 6.55    | 9.5    | 15     | 16.2   | 25     | 37    | 170   |     |
| 90               | 4.5     | 6.2    | 12.3   | 12.9   | 18     | 29    | 140   |     |
|                  | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |     |
| 30               | 16      | 19     | 21     | 25.2   | 40     | 55    | 220   | 10.0|
| 50               | 12.5    | 14     | 19.05  | 20.1   | 32.5   | 45    | 200   |     |
| 75               | 9.5     | 9.6    | 18     | 19.5   | 27    | 40    | 180   |     |
| 90               | 6.85    | 8.4    | 13.2   | 14.1   | 20     | 31    | 150   |     |
|                  | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |     |
| 30               | 34.5    | 37     | 37.5   | 40.5   | 47.5   | 63    | 245   | 15.0|
| 50               | 27      | 30     | 28.8   | 30.9   | 45     | 50    | 220   |     |
| 75               | 20.5    | 22     | 25.5   | 27.6   | 30     | 45    | 190   |     |
| 90               | 14.8    | 16.7   | 18.75  | 20.1   | 26     | 35    | 165   |     |

### Table 5
Effect of silica nanoparticle loading on xanthan gum viscosity (cP).

| Silica wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|------------|---------|--------|--------|--------|--------|-------|-------|-------------|
| 0.1        | 5.25    | 6.5    | 9.3    | 16.5   | 24.5   | 39    | 170   | 0.1         |
| 0.2        | 5       | 6.3    | 9      | 15     | 22.5   | 36    | 175   |             |
| 0.5        | 5       | 6.2    | 8.85   | 14.7   | 22     | 36    | 175   |             |
| 0.8        | 6       | 7.2    | 9.75   | 18     | 29     | 50    | 190   |             |
| 1          | 5.25    | 6.5    | 9.3    | 17.1   | 25     | 40    | 185   |             |
|            | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |             |
| 0.1        | 16.5    | 26     | 36     | 60     | 92.5   | 148   | 600   | 0.5         |
| 0.2        | 17.75   | 28     | 37.5   | 61.5   | 95     | 165   | 615   |             |
| 0.5        | 18.5    | 29.5   | 39     | 64.5   | 97     | 170   | 625   |             |
| 0.8        | 19.75   | 32.5   | 42     | 68.7   | 100    | 188   | 645   |             |
| 1          | 19.5    | 32     | 41.25  | 67.5   | 98     | 180   | 650   |             |
|            | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |             |
| 0.1        | 36      | 61.5   | 82.5   | 142.5  | 217.5  | 390   | 1675  | 1.0         |
| 0.2        | 35      | 56     | 75.75  | 132    | 205    | 360   | 1680  |             |
| 0.5        | 36.5    | 63     | 87     | 150    | 225    | 390   | 1750  |             |
| 0.8        | 40      | 65     | 88.5   | 156    | 235    | 425   | 1850  |             |
| 1          | 42      | 69     | 96     | 163.5  | 250    | 460   | 1880  |             |
Table 6
Effect of alumina nanoparticle loading on xanthan gum viscosity (cP).

| Shear rate (s⁻¹) | Alumina wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|------------------|-------------|---------|--------|--------|--------|--------|--------|-------|
|                  | 0.1         | 6.25    | 12.4   | 18.3   | 29.1   | 22.5   | 42     | 200   |
|                  | 0.2         | 6.25    | 12.4   | 18.3   | 29.7   | 22.5   | 43     | 200   |
|                  | 0.5         | 5.85    | 11.2   | 15.75  | 28.2   | 22     | 41     | 190   |
|                  | 0.8         | 6.35    | 12.5   | 18.45  | 33.6   | 23.5   | 44     | 205   |
|                  | 1           | 6.75    | 13     | 18.75  | 33.9   | 25     | 45     | 210   |

|                  | 0.1         | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|                  | 15.5        | 23.5    | 30     | 54     | 86     | 145    | 650   | 0.5   |
|                  | 0.2         | 16.75   | 24.5   | 36.75  | 64.5   | 97.5   | 180   | 750   |
|                  | 0.5         | 16.9    | 27     | 37.5   | 69     | 100    | 180   | 800   |
|                  | 0.8         | 16.5    | 24     | 34.5   | 60     | 95     | 170   | 825   |
|                  | 1           | 16.5    | 24     | 33     | 57     | 93     | 155   | 830   |

|                  | 0.1         | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|                  | 32          | 57.5    | 79.5   | 139.5  | 207.5  | 390    | 1650  | 1.0   |
|                  | 0.2         | 32.5    | 58     | 81     | 141    | 225    | 420   | 1675  |
|                  | 0.5         | 37.5    | 62.5   | 88.5   | 156    | 245    | 470   | 1800  |
|                  | 0.8         | 35.5    | 62.5   | 85.5   | 150    | 240    | 440   | 1850  |
|                  | 1           | 33      | 57     | 81     | 144    | 235    | 390   | 1860  |

Table 7
Effect of cupric nanoparticle loading on xanthan gum viscosity (cP).

| Shear rate (s⁻¹) | Cupric wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|------------------|------------|---------|--------|--------|--------|--------|--------|-------|
|                  | 0.1        | 7.5     | 9.5    | 13.5   | 22.5   | 35     | 55     | 205   |
|                  | 0.2        | 6.5     | 9      | 12.75  | 16.5   | 25     | 42     | 200   |
|                  | 0.5        | 6.5     | 9.1    | 13.2   | 21     | 32.5   | 60     | 225   |
|                  | 0.8        | 6       | 11     | 16.5   | 33     | 55     | 80     | 300   |
|                  | 1          | 5.5     | 9      | 13.5   | 27     | 45     | 70     | 325   |

|                  | 0.1        | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|                  | 18.25      | 30      | 42     | 76.5   | 105    | 180    | 705   | 0.5   |
|                  | 0.2        | 16      | 27     | 36     | 69     | 92.5   | 165   | 700   |
|                  | 0.5        | 18.75   | 33.5   | 45     | 84     | 115    | 210   | 850   |
|                  | 0.8        | 17.5    | 27.5   | 40.5   | 72     | 100    | 170   | 850   |
|                  | 1          | 16      | 26     | 34.5   | 66     | 90     | 180   | 900   |

|                  | 0.1        | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
|                  | 37         | 64.5    | 93.75  | 165    | 257.5  | 500    | 1750  | 1.0   |
|                  | 0.2        | 35      | 61     | 82.5   | 150    | 225    | 410   | 1800  |
|                  | 0.5        | 31.5    | 57     | 76.5   | 141    | 215    | 390   | 1850  |
|                  | 0.8        | 39.5    | 65     | 95.25  | 172.5  | 265    | 510   | 1900  |
|                  | 1          | 32.5    | 60     | 81     | 143.4  | 218    | 400   | 1950  |
Table 8
Effect of silica nanoparticle loading on guar gum viscosity (cP).

| Shear rate (s⁻¹) | Silica wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|------------------|------------|---------|--------|--------|--------|--------|--------|--------|-------------|
| 0.1              | 5.15       | 7.5     | 10.05  | 14.7   | 22     | 37     | 160    | 10.1   |
| 0.2              | 5.15       | 7.5     | 10.05  | 14.7   | 21     | 36     | 160    | 10.1   |
| 0.5              | 5.45       | 9       | 11.25  | 15.9   | 25.5   | 41     | 170    | 10.1   |
| 0.8              | 5.45       | 9       | 10.95  | 15.6   | 25     | 39     | 170    | 10.1   |
| 1                | 5.15       | 7.5     | 10.5   | 15     | 23     | 38     | 175    | 10.1   |

| Alumina wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|-------------|---------|--------|--------|--------|--------|--------|--------|-------------|
| 0.1         | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.2         | 11.5    | 32     | 45     | 61.5   | 97.5   | 145    | 550    | 0.5        |
| 0.5         | 23.5    | 38     | 48.75  | 66.9   | 105    | 160    | 595    | 1.0        |
| 0.8         | 22.75   | 38     | 48     | 66     | 100    | 150    | 575    |
| 1           | 24.5    | 40.5   | 50.85  | 69     | 115    | 170    | 700    |

Table 9
Effect of alumina nanoparticle loading on guar gum viscosity (cP).

| Shear rate (s⁻¹) | Alumina wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|------------------|-------------|---------|--------|--------|--------|--------|--------|--------|-------------|
| 0.1              | 4.75        | 6.5     | 8.25   | 14.7   | 24     | 41     | 170    | 10.1   |
| 0.2              | 5           | 7.2     | 9.75   | 15.3   | 25     | 43     | 175    | 10.1   |
| 0.5              | 6           | 11      | 15.75  | 16.5   | 26     | 44     | 180    | 10.1   |
| 0.8              | 5.25        | 7.8     | 9.9    | 15.6   | 25.5   | 43     | 175    | 10.1   |
| 1                | 4.25        | 6       | 7.95   | 14.7   | 23.5   | 40     | 170    | 10.1   |

| Alumina wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|-------------|---------|--------|--------|--------|--------|--------|--------|-------------|
| 0.1         | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.2         | 25       | 11.5   | 45     | 61.5   | 97.5   | 145    | 550    | 0.5        |
| 0.5         | 23.5     | 32     | 45     | 61.5   | 97.5   | 145    | 550    | 1.0        |
| 0.8         | 22.75    | 38     | 48     | 66     | 100    | 150    | 575    |
| 1           | 24.5     | 40.5   | 50.85  | 69     | 115    | 170    | 700    | 1.0        |

| Alumina wt% | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 | Polymer wt% |
|-------------|---------|--------|--------|--------|--------|--------|--------|-------------|
| 0.1         | 63       | 108    | 146.25 | 270    | 405    | 750    | 1750   | 1.0        |
| 0.2         | 71.25    | 120    | 162.75 | 280.5  | 412.5  | 770    | 1820   |
| 0.5         | 72.5     | 123.5  | 169.5  | 288    | 427.5  | 776    | 1845   |
| 0.8         | 74       | 126    | 174    | 297    | 440    | 790    | 2065   |
| 1           | 73.5     | 125    | 172.5  | 294    | 435    | 782    | 2160   |
Table 10
Effect of cupric nanoparticle loading on guar gum viscosity (cP).

| Shear rate (s⁻¹) | Cupric wt% | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----------|-----|-----|-----|-----|---|
| 1021.38          | 1021.38   | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1              | 4.5       | 7    | 9.75 | 15.6 | 23.5 | 42  | 160 | 0.1 |
| 0.2              | 5         | 8    | 9.9  | 18.6 | 24   | 44  | 175 | 0.5 |
| 0.5              | 5         | 8    | 11.25 | 19.5 | 25   | 46  | 200 | 0.5 |
| 0.8              | 5         | 8    | 10.5 | 18.9 | 24.5 | 45  | 195 | 1   |
| 1                | 4.75      | 7.5  | 9.75 | 16.5 | 24.5 | 43  | 200 | 1   |

| Polymer wt%      | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----|-----|-----|-----|---|
| 0.1              | 160 | 175 | 200 | 195 | 200|

Table 11
Effect of silica nanoparticle loading on gum arabic viscosity (cP).

| Shear rate (s⁻¹) | Silica wt% | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----------|-----|-----|-----|-----|---|
| 1021.38          | 1021.38   | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1              | 6.5       | 12   | 15   | 19.8 | 32.5 | 50  | 185 | 1.0 |
| 0.2              | 6.5       | 12   | 15.75 | 21.6 | 32.5 | 52  | 195 | 1.0 |
| 0.5              | 6.5       | 10.5 | 15   | 21   | 32.5 | 50  | 195 | 1.0 |
| 0.8              | 6.5       | 12   | 15.9 | 22.5 | 33   | 52  | 195 | 1.0 |
| 1                | 6.5       | 12   | 15   | 21   | 32.5 | 50  | 200 | 1.0 |

| Polymer wt%      | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----|-----|-----|-----|---|
| 0.1              | 185 | 195 | 195 | 195 | 200|

Table 11
Effect of silica nanoparticle loading on gum arabic viscosity (cP).

| Shear rate (s⁻¹) | Silica wt% | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----------|-----|-----|-----|-----|---|
| 1021.38          | 1021.38   | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1              | 8.5       | 13.9 | 19.2 | 24.6 | 35.5 | 51  | 210 | 5.0 |
| 0.2              | 8.5       | 13.8 | 19.05 | 24   | 35   | 50  | 215 | 5.0 |
| 0.5              | 9         | 14.2 | 19.35 | 25.2 | 36.5 | 53  | 220 | 5.0 |
| 0.8              | 9         | 14.5 | 19.5 | 25.5 | 37   | 54  | 225 | 5.0 |
| 1                | 9         | 14.1 | 19.2 | 24.9 | 36   | 52  | 250 | 5.0 |

| Polymer wt%      | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----|-----|-----|-----|---|
| 0.1              | 210 | 215 | 220 | 225 | 250|

Table 11
Effect of silica nanoparticle loading on gum arabic viscosity (cP).

| Shear rate (s⁻¹) | Silica wt% | 0.1 | 0.2 | 0.5 | 0.8 | 1 |
|------------------|-----------|-----|-----|-----|-----|---|
| 1021.38          | 1021.38   | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1              | 34.75     | 38.5 | 39   | 42   | 50   | 70  | 265 | 15.0 |
| 0.2              | 42        | 43.5 | 52.5 | 48   | 60   | 89  | 285 | 15.0 |
| 0.5              | 45.5      | 48   | 57   | 57   | 68   | 92  | 305 | 15.0 |
| 0.8              | 36        | 40   | 48   | 46.5 | 50   | 85  | 315 | 15.0 |
| 1                | 47.25     | 50   | 58.5 | 60   | 70   | 93  | 325 | 15.0 |
### Table 12
Effect of alumina nanoparticle loading on gum arabic viscosity (cP).

| Alumina wt% | Shear rate (s⁻¹) | Polymer wt% |
|-------------|-----------------|-------------|
|             | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1         | 7.25     | 12.9   | 16.5   | 24.3   | 35.5   | 55    | 195   | 1.0   |
| 0.2         | 6.65     | 12     | 15.75  | 22.5   | 33.5   | 52    | 200   |       |
| 0.5         | 7.25     | 12.5   | 16.35  | 24     | 35     | 54    | 200   |       |
| 0.8         | 7.25     | 12.38  | 16.2   | 22.5   | 34.5   | 52    | 210   |       |
| 1           | 7.25     | 12.38  | 16.2   | 23.1   | 34.5   | 53    | 215   |       |
| 0.1         | 1021.38  | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.2         | 9        | 14.8   | 19.65  | 25.8   | 39     | 58    | 210   | 5.0   |
| 0.5         | 8.5      | 14.3   | 19.2   | 24.9   | 37.5   | 55    | 215   |       |
| 0.8         | 9        | 14.7   | 19.5   | 25.5   | 38.5   | 57    | 225   |       |
| 1           | 9.75     | 14.9   | 19.8   | 26.1   | 39.5   | 59    | 240   |       |

### Table 13
Effect of cupric nanoparticle loading on gum arabic viscosity (cP).

| Cupric wt% | Shear rate (s⁻¹) | Polymer wt% |
|------------|-----------------|-------------|
|            | 1021.38 | 510.69 | 340.46 | 170.23 | 102.14 | 51.07 | 10.21 |
| 0.1         | 7.3     | 13.3   | 16.5   | 24.6   | 37     | 58    | 195   | 1.0   |
| 0.2         | 6.7     | 13     | 16.65  | 24     | 36     | 57    | 205   |       |
| 0.5         | 8.5     | 13.8   | 17.25  | 25.5   | 38     | 59    | 210   |       |
| 0.8         | 8.5     | 13.6   | 17.1   | 25.2   | 38.5   | 60    | 220   |       |
| 1           | 8       | 13.5   | 16.95  | 24.9   | 38     | 59    | 225   |       |
| 0.1         | 10      | 15     | 19.8   | 26.1   | 39.5   | 59    | 225   | 5.0   |
| 0.2         | 10.5    | 15.1   | 19.95  | 26.4   | 40     | 60    | 250   |       |
| 0.5         | 10.75   | 15.2   | 20.25  | 27     | 40.5   | 62    | 260   |       |
| 0.8         | 11      | 15.5   | 20.4   | 27.3   | 41     | 64    | 280   |       |
| 1           | 10.5    | 15.1   | 20.1   | 26.7   | 40     | 61    | 290   |       |
| 0.1         | 36      | 35     | 44.25  | 48     | 55     | 72    | 275   | 15.0  |
| 0.2         | 42.5    | 53     | 54     | 51     | 65     | 90    | 300   |       |
| 0.5         | 52.5    | 79     | 74.25  | 84     | 85     | 115   | 340   |       |
| 0.8         | 50      | 72.5   | 67.5   | 72     | 80     | 110   | 340   |       |
| 1           | 46      | 59     | 60     | 66     | 72.5   | 100   | 345   |       |

### Table 14
Effect of salinity on the viscosity (cP) of polymers at 10.21 s⁻¹.

| Brine weight percentage (wt%) | Xanthan gum | Guar gum | Gum arabic |
|-------------------------------|-------------|----------|------------|
| 0.05                          | 1550        | 1450     | 250        |
| 0.15                          | 1550        | 1400     | 240        |
| 0.25                          | 1450        | 1350     | 220        |
| 0.35                          | 1425        | 1325     | 210        |
| 0.45                          | 1400        | 1300     | 190        |
Table 15
TGA data for xanthan gum polymer showing temperature and weight progression.

| Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) |
|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|
| 22.642    | 7.692       | 46.943    | 7.472       | 64.842    | 7.158       | 75.984    | 6.980       |
| 23.009    | 7.688       | 47.022    | 7.471       | 64.923    | 7.156       | 76.069    | 6.979       |
| 24.014    | 7.678       | 48.805    | 7.442       | 65.008    | 7.155       | 77.917    | 6.952       |
| 24.986    | 7.672       | 49.952    | 7.423       | 65.744    | 7.142       | 78.003    | 6.951       |
| 25.042    | 7.671       | 50.027    | 7.422       | 65.825    | 7.141       | 79.937    | 6.925       |
| 26.055    | 7.665       | 50.939    | 7.406       | 65.903    | 7.140       | 80.022    | 6.924       |
| 27.025    | 7.659       | 51.015    | 7.405       | 65.993    | 7.138       | 81.948    | 6.898       |
| 28.013    | 7.654       | 51.849    | 7.390       | 66.074    | 7.137       | 82.036    | 6.897       |
| 28.993    | 7.648       | 51.925    | 7.389       | 66.156    | 7.135       | 83.967    | 6.873       |
| 29.073    | 7.647       | 52.003    | 7.387       | 66.240    | 7.134       | 84.049    | 6.872       |
| 29.928    | 7.642       | 52.996    | 7.370       | 66.322    | 7.133       | 85.991    | 6.850       |
| 30.015    | 7.642       | 53.066    | 7.368       | 68.798    | 7.091       | 86.080    | 6.849       |
| 30.989    | 7.635       | 53.989    | 7.352       | 68.882    | 7.090       | 87.925    | 6.828       |
| 31.082    | 7.635       | 54.072    | 7.350       | 68.963    | 7.089       | 89.865    | 6.808       |
| 32.814    | 7.623       | 55.065    | 7.332       | 69.045    | 7.087       | 90.036    | 6.806       |
| 32.903    | 7.623       | 56.071    | 7.314       | 69.128    | 7.086       | 93.676    | 6.771       |
| 32.993    | 7.622       | 56.928    | 7.299       | 69.217    | 7.084       | 95.783    | 6.752       |
| 33.091    | 7.621       | 57.004    | 7.297       | 69.298    | 7.083       | 95.869    | 6.751       |
| 33.927    | 7.615       | 57.948    | 7.280       | 69.552    | 7.079       | 95.957    | 6.750       |
| 34.019    | 7.615       | 58.024    | 7.279       | 69.634    | 7.078       | 96.042    | 6.750       |
| 34.945    | 7.608       | 58.967    | 7.262       | 69.717    | 7.076       | 96.122    | 6.749       |
| 35.039    | 7.607       | 59.050    | 7.260       | 69.802    | 7.075       | 96.210    | 6.748       |
| 35.963    | 7.600       | 59.925    | 7.245       | 69.880    | 7.074       | 96.294    | 6.748       |
| 36.057    | 7.599       | 60.001    | 7.243       | 69.967    | 7.072       | 96.377    | 6.747       |
| 36.970    | 7.591       | 60.964    | 7.226       | 70.213    | 7.068       | 100.960   | 6.711       |
| 37.060    | 7.590       | 61.042    | 7.224       | 70.296    | 7.067       | 101.210   | 6.709       |
| 37.980    | 7.582       | 61.925    | 7.209       | 70.377    | 7.066       | 108.162   | 6.665       |
| 38.073    | 7.581       | 62.002    | 7.207       | 72.055    | 7.039       | 110.618   | 6.651       |
| 46.000    | 7.486       | 62.971    | 7.190       | 72.139    | 7.038       | 110.701   | 6.651       |
| 46.531    | 7.478       | 63.049    | 7.189       | 73.809    | 7.012       | 113.762   | 6.636       |
### Table 16

TGA data for guar gum polymer showing temperature and weight progression.

| Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) |
|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|
| 22.666    | 12.370      | 55.009    | 11.871      | 89.080    | 11.045      | 110.922   | 10.813      |
| 23.961    | 12.350      | 56.993    | 11.815      | 92.920    | 10.989      | 111.008   | 10.813      |
| 24.995    | 12.341      | 57.069    | 11.813      | 93.006    | 10.988      | 111.097   | 10.812      |
| 25.043    | 12.340      | 58.929    | 11.760      | 94.973    | 10.962      | 111.186   | 10.812      |
| 26.942    | 12.325      | 59.008    | 11.758      | 97.982    | 10.926      | 111.274   | 10.811      |
| 27.009    | 12.324      | 60.968    | 11.701      | 98.067    | 10.925      | 111.359   | 10.810      |
| 33.019    | 12.275      | 61.046    | 11.699      | 99.957    | 10.905      | 111.439   | 10.810      |
| 34.958    | 12.257      | 62.951    | 11.644      | 100.042   | 10.904      | 111.608   | 10.809      |
| 35.049    | 12.256      | 63.033    | 11.642      | 104.587   | 10.861      | 111.692   | 10.808      |
| 36.973    | 12.235      | 64.968    | 11.587      | 107.585   | 10.837      | 111.780   | 10.808      |
| 37.059    | 12.234      | 65.048    | 11.585      | 107.670   | 10.836      | 111.864   | 10.807      |
| 38.942    | 12.211      | 66.922    | 11.533      | 108.959   | 10.827      | 111.952   | 10.807      |
| 39.025    | 12.209      | 67.001    | 11.530      | 109.041   | 10.826      | 112.038   | 10.806      |
| 40.944    | 12.182      | 68.979    | 11.477      | 109.128   | 10.825      | 112.123   | 10.806      |
| 41.031    | 12.181      | 69.063    | 11.474      | 109.216   | 10.825      | 112.207   | 10.805      |
| 42.946    | 12.150      | 70.968    | 11.424      | 109.298   | 10.824      | 112.291   | 10.805      |
| 43.034    | 12.149      | 71.050    | 11.422      | 109.385   | 10.824      | 112.373   | 10.804      |
| 44.964    | 12.113      | 72.970    | 11.373      | 109.469   | 10.823      | 112.466   | 10.803      |
| 45.039    | 12.112      | 73.061    | 11.370      | 109.554   | 10.822      | 112.548   | 10.803      |
| 46.930    | 12.073      | 76.835    | 11.280      | 109.644   | 10.822      | 112.635   | 10.802      |
| 47.004    | 12.072      | 76.919    | 11.278      | 109.730   | 10.821      | 112.720   | 10.802      |
| 48.989    | 12.027      | 77.000    | 11.276      | 109.818   | 10.820      | 112.805   | 10.801      |
| 49.066    | 12.025      | 79.885    | 11.213      | 109.902   | 10.820      | 112.886   | 10.801      |
| 50.946    | 11.979      | 79.967    | 11.211      | 109.984   | 10.819      | 112.977   | 10.800      |
| 51.013    | 11.977      | 80.052    | 11.209      | 110.071   | 10.819      | 113.061   | 10.800      |
| 52.974    | 11.926      | 84.981    | 11.113      | 110.159   | 10.818      | 113.147   | 10.799      |
| 53.047    | 11.924      | 85.066    | 11.112      | 110.242   | 10.818      | 113.232   | 10.799      |
| 54.853    | 11.875      | 86.938    | 11.079      | 110.328   | 10.817      | 113.324   | 10.798      |
| 54.933    | 11.873      | 87.027    | 11.078      | 110.752   | 10.814      | 113.406   | 10.798      |
| 54.991    | 11.871      | 88.989    | 11.046      | 110.839   | 10.814      | 113.491   | 10.797      |
Table 17
TGA data for gum arabic polymer showing temperature and weight progression.

| Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) | Temp (°C) | Weight (mg) |
|-----------|-------------|-----------|-------------|-----------|-------------|-----------|-------------|
| 21.853    | 11.528      | 56.402    | 11.015      | 92.778    | 10.441      | 110.661   | 10.254      |
| 22.940    | 11.507      | 56.483    | 11.013      | 92.868    | 10.440      | 110.739   | 10.253      |
| 24.089    | 11.497      | 58.415    | 10.973      | 94.812    | 10.417      | 110.826   | 10.252      |
| 24.154    | 11.497      | 58.494    | 10.972      | 97.777    | 10.384      | 110.913   | 10.252      |
| 26.238    | 11.481      | 60.538    | 10.931      | 97.862    | 10.383      | 110.994   | 10.251      |
| 26.322    | 11.481      | 60.625    | 10.930      | 99.724    | 10.363      | 111.080   | 10.250      |
| 32.541    | 11.429      | 62.603    | 10.891      | 99.810    | 10.362      | 112.011   | 10.241      |
| 34.452    | 11.409      | 62.687    | 10.890      | 104.310   | 10.315      | 112.096   | 10.241      |
| 34.538    | 11.408      | 64.686    | 10.852      | 107.275   | 10.286      | 112.179   | 10.240      |
| 36.409    | 11.387      | 64.770    | 10.851      | 107.354   | 10.285      | 112.267   | 10.239      |
| 36.497    | 11.386      | 66.701    | 10.816      | 108.624   | 10.273      | 112.351   | 10.238      |
| 38.311    | 11.362      | 66.781    | 10.815      | 108.709   | 10.272      | 112.442   | 10.238      |
| 38.393    | 11.361      | 68.810    | 10.780      | 108.796   | 10.272      | 112.523   | 10.237      |
| 40.233    | 11.334      | 68.889    | 10.778      | 108.884   | 10.271      | 112.611   | 10.236      |
| 40.315    | 11.332      | 70.828    | 10.745      | 108.964   | 10.270      | 112.689   | 10.236      |
| 42.166    | 11.302      | 70.913    | 10.744      | 109.052   | 10.269      | 112.776   | 10.235      |
| 42.252    | 11.301      | 72.857    | 10.713      | 109.134   | 10.268      | 112.860   | 10.234      |
| 44.137    | 11.267      | 72.945    | 10.711      | 109.222   | 10.267      | 112.945   | 10.233      |
| 44.217    | 11.265      | 76.765    | 10.653      | 109.303   | 10.267      | 113.026   | 10.232      |
| 46.070    | 11.230      | 76.845    | 10.651      | 109.387   | 10.266      | 113.112   | 10.232      |
| 46.144    | 11.229      | 76.934    | 10.650      | 109.472   | 10.265      | 113.197   | 10.231      |
| 48.140    | 11.188      | 79.818    | 10.608      | 109.559   | 10.264      | 113.285   | 10.230      |
| 48.212    | 11.187      | 79.898    | 10.607      | 109.643   | 10.263      | 113.365   | 10.229      |
| 50.132    | 11.147      | 79.988    | 10.606      | 109.731   | 10.263      | 113.448   | 10.229      |
| 50.212    | 11.145      | 84.908    | 10.539      | 109.813   | 10.262      | 113.534   | 10.228      |
| 52.221    | 11.103      | 84.987    | 10.538      | 109.898   | 10.261      | 113.626   | 10.227      |
| 52.298    | 11.101      | 86.852    | 10.514      | 109.980   | 10.260      | 113.703   | 10.226      |
| 54.174    | 11.061      | 86.936    | 10.512      | 110.404   | 10.256      | 113.788   | 10.226      |
| 54.251    | 11.060      | 88.885    | 10.488      | 110.489   | 10.255      | 113.823   | 10.226      |
| 54.334    | 11.058      | 88.971    | 10.487      | 110.570   | 10.255      | 113.959   | 10.224      |
2. Experimental Design, Materials and Methods

2.1. Materials

Xanthan Gum and Guar Gum were purchased from Ojota Chemical Market in Lagos while Gum Arabic was purchased from Pantek Market in Kaduna State. Silica and alumina nanoparticles were purchased from Sigma Aldrich while cupric nanoparticle was purchased from BDH AnalAr. Sodium chloride was used to prepare the brine solution.

2.2. Characterization of polymers and nanoparticle

High-resolution micrographs were obtained for the nanoparticles using Quanta SEM 450 Equipment. Scanning was done at a spot size of 3–5 and a voltage range of 3–5 kV. FTIR analysis was done for the three polymers using Brucker Vertex 80v Instrument with an Attenuated Total Reflectance (Type A225/Q) in transmittance mode, and the analysis was done with the OPUS 7.0 software. The sample time scan and background time scans were both 64 scans. The spectra were taken between 400 and 4000 cm\(^{-1}\). TGA was done using TA Instrument Q6000 (SDT V20.9 Build 20) to examine the thermal stability of the polymers. Thermal stability was measured based on weight change using a horizontal dual beam with automatic beam growth compensation. The gas flux and heating range used for the measurements were 100 mL/min and 10 °C/min respectively, and between a temperature range of 20–120 °C.

2.3. Preparation of polymer and nanocomposite fluids

Polymer fluids were prepared by adding measured quantities of the required polymer directly to deionized water according to standard method API 63 – “Practices for evaluation of polymers used in EOR.” Gum Arabic fluid was prepared to the following weight percentages: 0.4, 0.5, 1, 5, 10 and 15% w/w. Xanthan Gum and guar gum were prepared to the following weight percentages: 0.1, 0.2, 0.3, 0.4, 0.5 and 1% w/w. The viscosity of Gum Arabic varies widely from the other two polymers; hence, lower weight percentages could not be prepared for gum arabic. The preparation of polymer nanocomposites was also prepared using the direct addition method. Xanthan Gum and Guar Gum were allowed for 24 h before measurements were taken while Gum Arabic was allowed for 48 h. This was to ensure complete dissolution.

2.4. Measurement of rheological properties of polymers at different temperatures

A Model 800 OFITE viscometer was used to obtain dial readings at different shear rates which were then converted to viscosity values. Desired temperatures (30, 50, 75 and 90 °C) of polymer solutions were achieved using the heating mantle of the viscometer. The viscosity values were calculated from the dial readings using the formula in Eq. (1).

\[ \eta = KF \frac{\theta}{\text{RPM}} \]  

(1)

where \( \eta \) is the viscosity in centipoise, \( \theta \) is the dial reading obtained from the viscometer, \( K \) is the machine constant of the Rotor – Bob combination (R1B1) and \( F \) is the spring factor. \( K \) value for the R1B1 is 300 while its \( F \) value is 1.

Declaration of Competing Interest

None.
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