بسم الله الرحمن الرحيم

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كليه العلوم – قسم الكيمياء

Preparation and Characterization of Modified Biopolymers for Improving Crude Oil Production under Egyptian Reservoirs Conditions

Thesis Submitted by

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For the requirement of Ph.D. Degree of Science in Chemistry

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Samah.

LIST OF ABBREVIATIONS

OPEC	Organization of the Petroleum Exporting Countries
OOIP	Original Oil in Place
EOR	Enhanced Oil Recovery
IFT	Interfacial Tension
API	(American Petroleum Institute) defined as stock tank oil API gravity.
N_C	Capillary Number
M	Mobility Ratio
λ_w	Water Phase Mobility
λ_o	Oil Phase Mobility
K_{rw}	Relative Permeability of Water
K_{rw}	Relative Permeability of Oil
μ_w	Water Viscosity
μ_o	Oil Viscosity
S_s	Shear Stress
S_r	Shear Rate
cp	Centipoise (unit of viscosity)
HPAM	Partially Hydrolyzed Polyacrylamide
XG	Xanthan Gum
GG	Guar Gum
AM	Acrylamide

MMA	Methyl Methacrylate	
NVP	N-Vinyl-2-Pyrrolidone	
TEVS	Triethoxyvinylsilane	
$K_2S_2O_8$	Potassium Persulfate	
NaN_3	Sodium Azide	
TDS	Total Dissolved Solids	
NPs	Nanoparticles	
MWD	Molecular Weight Distribution	
Φ	Porosity	
K	Absolute Permeability of Formation	
L	Length of Sandstone Holder	
A	Cross-Sectional Area of Sandstone Holder	
q	Flow Rate of Injected Fluid	
ΔP	Pressure Drop	
ν	Velocity	
S_{or}	Residual Oil Saturation	
S_{oi}	Initial Oil Saturation	
S_{wi}	Initial Water Saturation	
PV	Pore Volume	
V_B	Bulk Volume	
V_{Oi}	Volume of Oil Injected	
V_{Wr}	Volume of Water Remain	

$\mathbf{V_{or}}$	Volume of Oil Remain	
$\mathbf{RF_{Total}}$	Total Recovery Factor	
$\mathbf{RF_{PM+SM}}$	Recovery Factor Obtained by Primary &Secondary Methods	
$\mathbf{RF_{TM}}$	Recovery Factor Obtained by Tertiary Method	
$\mathbf{M_W}$	Molecular Weight	
C	Concentration	
ppm	Part Per Million	
Cc	Cubic Centimeters	
$\mathbf{R_F}$	Resistance Factor	
$\mathbf{R_{RF}}$	Residual Resistance Factor	

ABSTRACT

The world continues to rely heavily on oil for primary energy where, the uses for petroleum have expanded to almost every area of life. To meet the rising energy consumption in the world and depletion of conventional hydrocarbon resources, there is a dire need to produce more crude oil so, the oil and gas industry needs new developed techniques called enhanced oil recovery (EOR) for increasing recovery rate and productive index. Enhanced Oil Recovery occurs after all possible oil is pumped out of the ground using traditional methods (Primary and secondary).

Polymer flooding is one of the most widely used EOR methods to retrieve oil left behind after conventional recovery processes where polymers have benefits in enhancing the viscosity of water solution, which in turn reducing the mobility ratio between water and oil, resulting in improvement of sweep efficiency. It has been used for more than 40 years to effectively recover the remaining oil from the reservoir. Polymers from natural sources have been selected because the raw materials are in abundance, readily available, easy to handle, environmentally friendly, and biodegradable. Their rigid structure and long polysaccharides chains make them suitable to withstand the harsh reservoir conditions. In the last few years, increasing interest has been shown in the synthesis of chemically modified polysaccharides through grafting with synthetic vinyl monomers that combine the advantages of both synthetic and natural polymers.

In this study, two biopolymers (xanthan gum and guar gum), have been modified by introducing vinyl monomers and vinyl silane monomer to xanthan gum, guar gum and a mixture of two biopolymers together by free radical emulsion polymerization reaction using potassium persulfate as an initiator and sodium dodecyl sulfate as emulsifier.

The prepared composites have been characterized through different techniques such as FTIR, 1H-NMR, Atomic Force Microscope (AFM), while particle size and particle size distribution have been characterized by Dynamic Light Scattering (DLS) and thermal properties characterized by Thermal Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). Rheological properties for the prepared composites have been evaluated at different conditions (concentration, temperature, salinity, shear rate and shear stress) simulated to flooding environment.

After that, the prepared composites were be evaluated for EOR applications through flooding experiments using sandstone packed model. Finally, the feasibility study of the product was be studied.

It was indicated from the rheological analysis that all ten modified components are pseudoplastic fluids, which are preferred for chemical flooding tasks. It was also indicated from this analysis that the five modified composites which contain silica particles have more temperature resistance, salt tolerance, and improved viscosity properties than the five modified composites without silica particles and the modified two biopolymers together (XG-g-GG&AM; XG-g-GG, AM&TEVS) are more stable than both separately. The flooding data assumed that the prepared composites are suitable for EOR techniques where they can withstand the severe reservoir condition and achieve a recovery factor up to 33, 36, 52, 55, 23, 25, 43, 47, 62 and 70% from residual oil by using XG-g-AM&MMA; XG-g-AM&NVP; XG-g-AM, MMA&TEVS; XG-g-AM, NVP&TEVS; GG-g-AM&MMA; GG-g-AM&NVP; GG-g-AM, MMA&TEVS; GG-g-AM, NVP&TEVS; XG-g-GG&AM; XG-g-GG, AM&TEVS respectively.

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