Influence of Clay Content on Surfactant-Polymer Flooding For an Egyptian Oil Field

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Presentation Outline

- Background.
- Surfactant- Polymer Flooding Overview
- Clays Effects on oil recovery by SPF
- Experimental setup.
- Experimental Procedures.
- Experimental observations and results.
- Conclusion
- Future for SPF

What is a Reservoir Engineering?

HC-RESERVOIR COMPONEN

Reservoir Rock:
- Rock Type
- Rock Properties

Rock Properties :
- Porosity (ϕ) → %
- Saturation (S) → %
- Permeability (K) → darcy

Fluid Properties :
- Densitay (ρ)
- Viscosity (μ)
- Formation Volume Factor (Bo)
- Gas Solution (Rs)

Reservoir Condtion
- Pressure
- Temperatur

RESERVOIR TYPE

Resevoir Rock Type
- Clastic
- Non-Clastic
- Metamorphic

Trap
- Stratigraphic
- Structur
- Combination

Fluid Phase :
- Gas
- Condensat
- Oil

Drive Mechanism :
- Solution / depletion Gas Drive Res.
- Gas Cap Drive Res.
- Water Drive Res.
- Segregation Drive Res.
- Combination Drive Res.

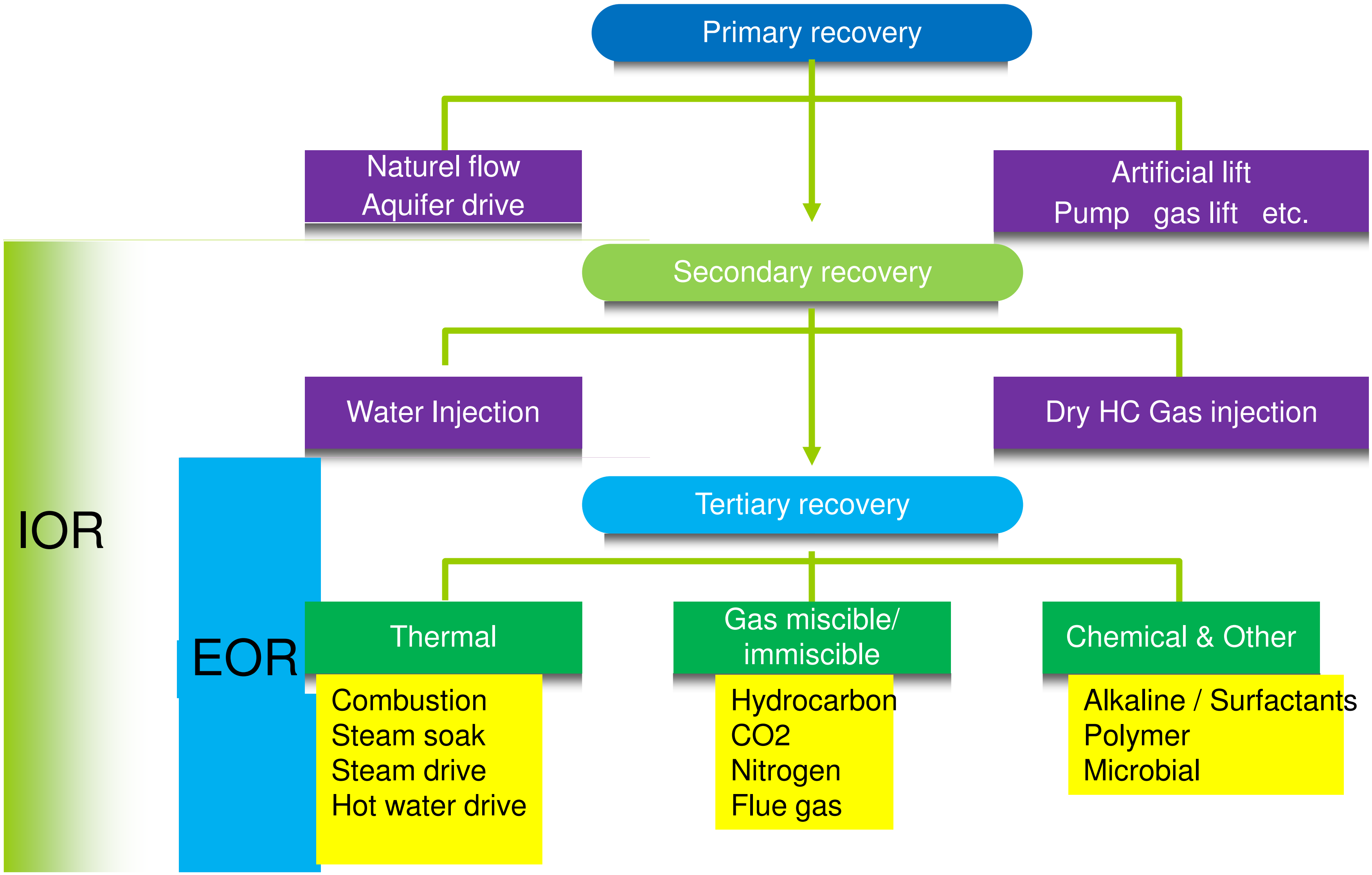
HC-RESERVE

Initial Oil in Place
(IOIP) → Ni
N_R = Ni x RF

- *Volumetric Method*
- *Material Balance Method*
- ***Decline Curve Curve***

Recovery Factor (RF)
(@ drive mechanism

Production Stages



Factors influence Why Oil is Left Behind in Oil Fields

<u>1- Geological Complexity</u>

- **Reservoir dead ends will trap oil.**
- **Structural dead ends.**
- **Stratigraphic dead ends.**
- **Number of reservoir compartment.**
- **Permeability layering.**

<u>2- Fluid physics</u>

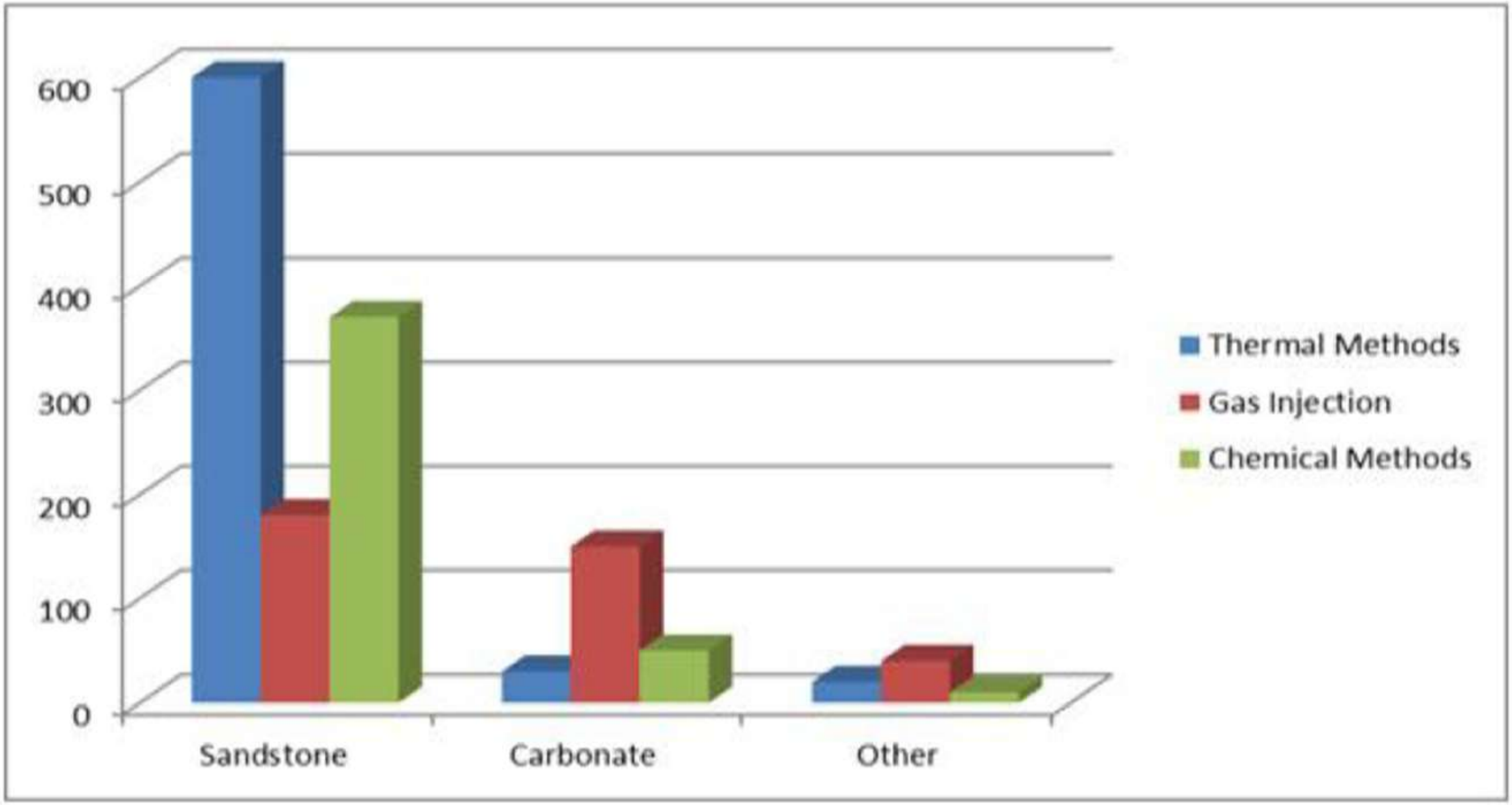
- **Residual oil saturation**
- **Capillary- trapped oil in bedded sandstone**
- **Oil viscosity**
- **Type of reservoir drive mechanism**

<u>3- Economics</u>

1- Oil price . 2- Taxation   3- Onshore or Offshore

4- Operating infrastructure

ENHANCED OIL RECOVERY BY LITHOLOGY



Surfactant-Polymer Flooding Overview

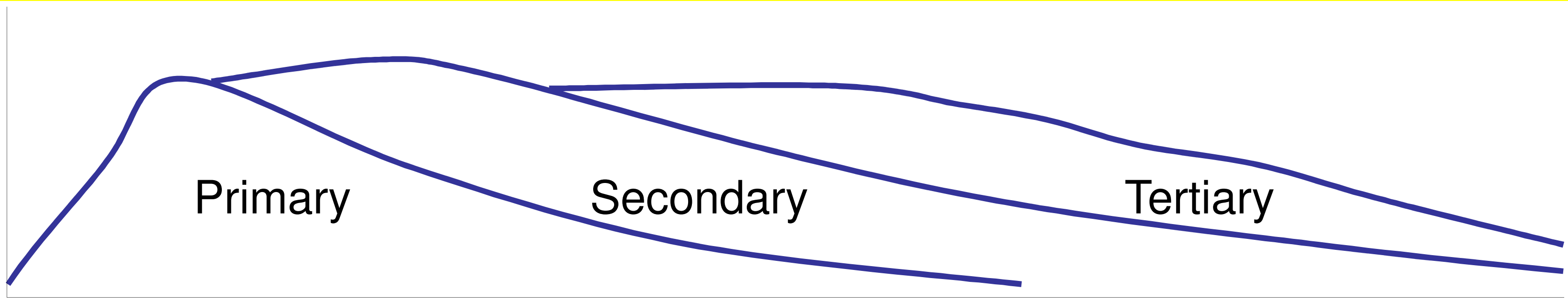
Target of SPF recovery is the residual oil saturation left behind after the secondary recovery process has become uneconomical

WHAT COMES TO MIND WHEN THE PRODUCTION OF YOUR WELLS START TO DECLINE?

Why are we doing Surfactant polymer flooding?

- Primary oil recovery – can only recover 10 percent of a reservoir's original oil in place
- Secondary oil recovery – 20 to 40 percent
- Tertiary oil recovery – 30 to 60 percent
- Undeveloped domestic oil resources still in the ground total more than 430 billion barrels.

Life Cycle Approach – PREPARE for SPF



Primary

Initial fluids

Initial Mobility

Field test for geology

Secondary

Detailed Geological model

Collecting essential data

Laboratory testing

Dedicated field tests on options

Keep track of remaining oil

Tertiary

Sweating the asset

Executing efficiently

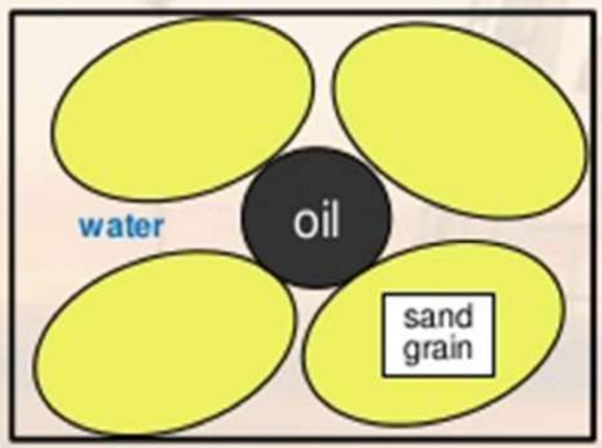
Inventive new solutions & test

Surfactant- Polymer Flooding Why and HOW)

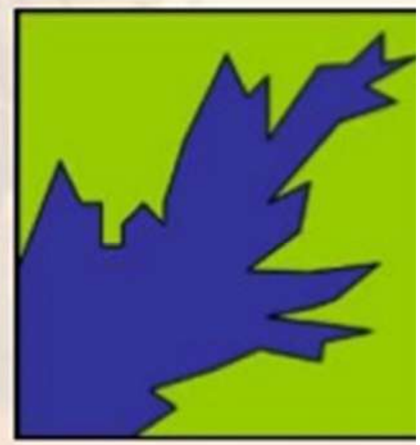
- Improve recovery by changing
  - Fluid properties
  - Fluid-fluid interactions
  - Fluid-rock interactions

Vertical Sweep

- Three contributions to recovery
  - Microscopic sweep
  - Areal sweep
  - Vertical sweep
- Mainly applied to
  - Brown fields
  - Onshore reservoirs



Microscopic Sweep

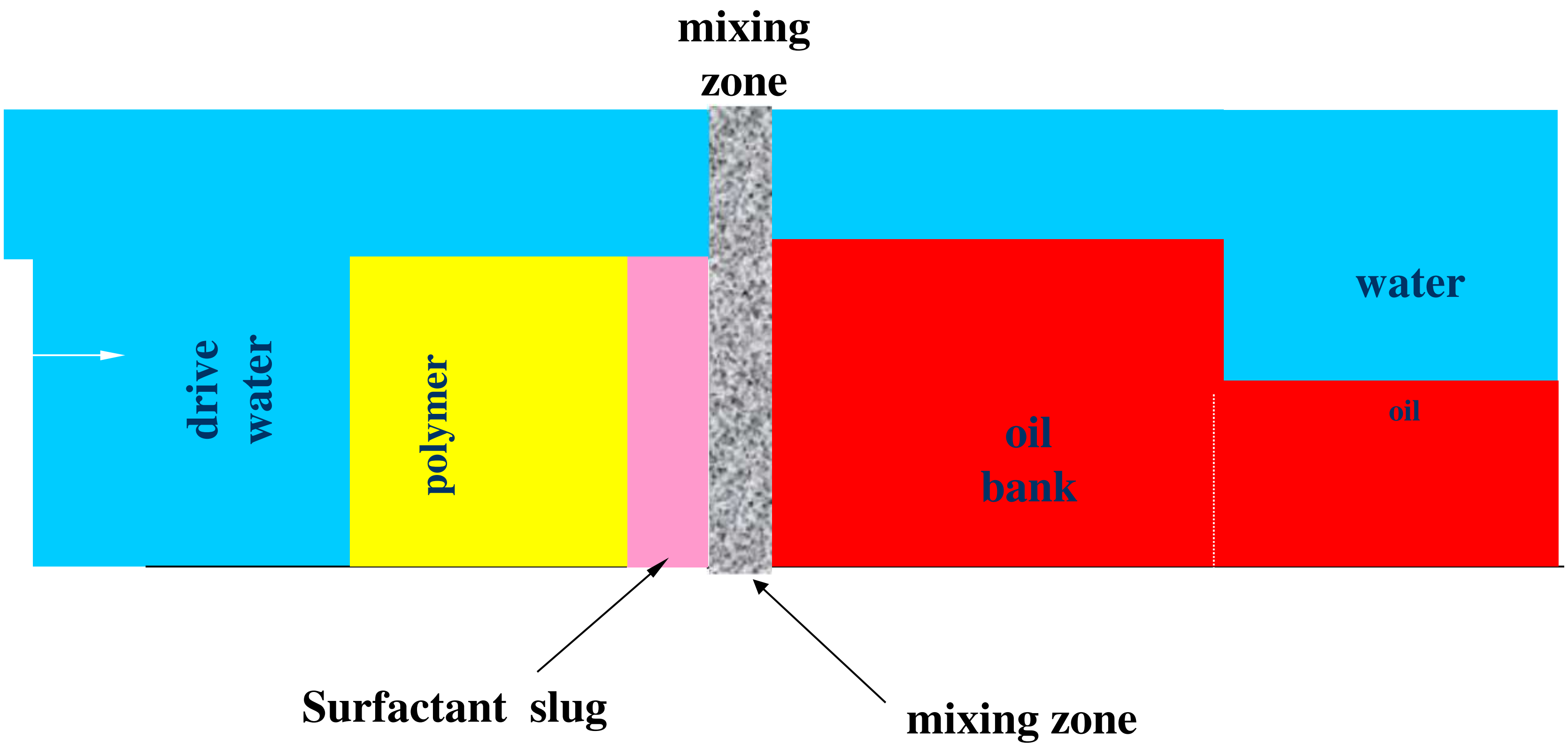


Areal Sweep

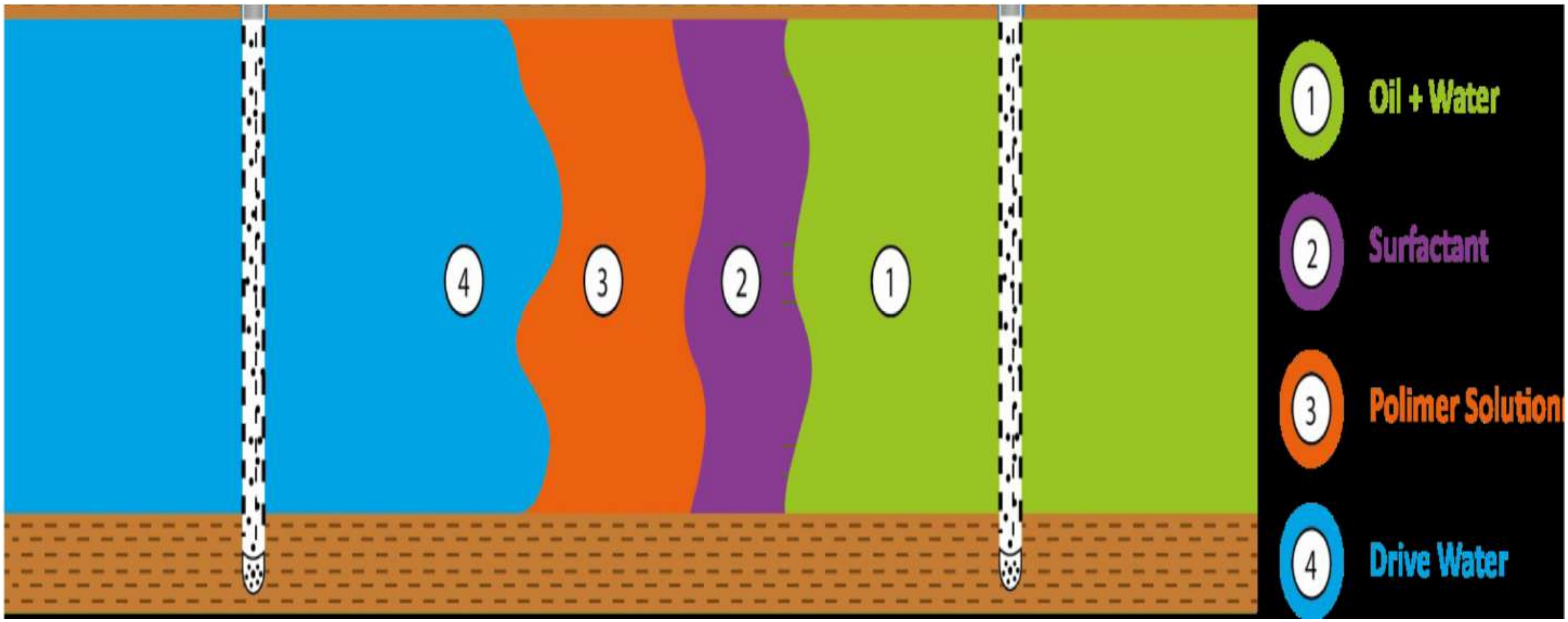
Surfactant-Polymer Flooding

- Surfactant- polymer flooding consists of the injection of a surfactant slug to reduce the interfacial tension (IFT) between oil and water which consequently reduces the capillary force and mobilizes the residual oil trapped after water flooding.
- The addition of polymer to the surfactant slug helps to control mobility and increases the sweep efficiency.

Surfactant- Polymer flooding injection profile



Mechanism of Surfactant polymer during Flooding



Factors Influence Why Surfactant-Polymer Flooding?

- **Surfactant-polymer flooding technology is dramatically better than 30 years due to:-**
- **More experience.**
- **Better understanding**
- **Better enable technologies**
- **Better modeling**
- **Better chemicals at lower cost**
-

What are Clay Effects on oil recovery by Surfactant- Polymer Flooding?

The success or failure of enhanced oil recovery methods may be controlled to a large extent by the amount and type of clays in the formations to which the methods are being applied.

Mechanisms Involved in Formation Damage by Clay Minerals:-

1- Swelling clay minerals

2- Dispersion of various of clay minerals.

3- Transportation of clay minerals to other minerals phases.

Clay Effects on Surfactant polymer flooding oil recovery

Surface area and cation exchange capacity of clay minerals lead to:

a- Surfactant precipitation.

b- Polymer degradation

C- Formation damage

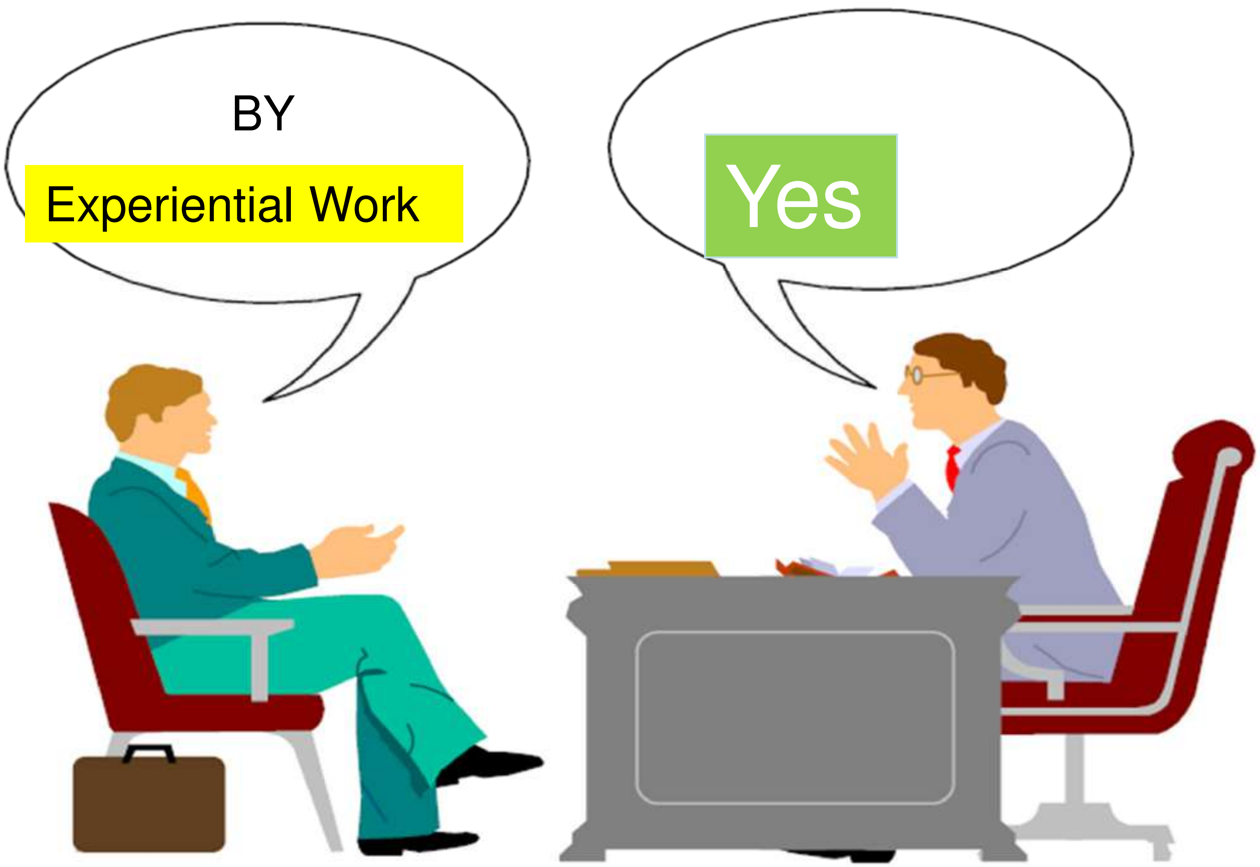
Clay effects on Reservoir Quality

1- Reduce pore –throat size and permeability.

2- Increase irreducible water saturation.

3- Increase the surface area of sand grains.

How Do You Predict Surfactant –Polymer Flooding?



1- Experimental Materials

1- Reservoir Fluids

- Actual crude oil, formation brine and sand pack samples from July oil field are used to conduct this experimental study.

2- Surfactants, Surfactant EZEFLO (F75N)Color White .

3- Polymer for mobility control (Polyacrylamides)
which is used in this work , appears to be the
only polymer used in the field in a large scale as a mobility control.

4- Clay mineral (Bentonite is composed primarily of smectitealong with varying amounts of quartz, feldspar, kaolinite, micas, and carbonates)

- **5- The mixture of reservoir rock sand (40-65 mesh).**

July Field Reservoir Data

• Depth	9000 feet
• Type of pay zone	Sandstone
• Temperature	220 F
• Porosity	18.5 %
• Clay Content (Bentonite)	0 -25 %

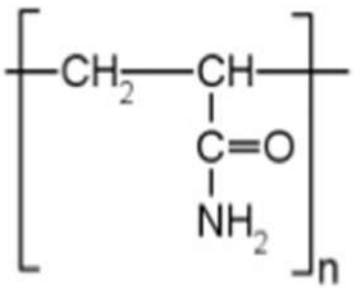
Crude oil of July field sample properties

Oil API 33.0 of 60 F
Oil Viscosity 10.0 cp

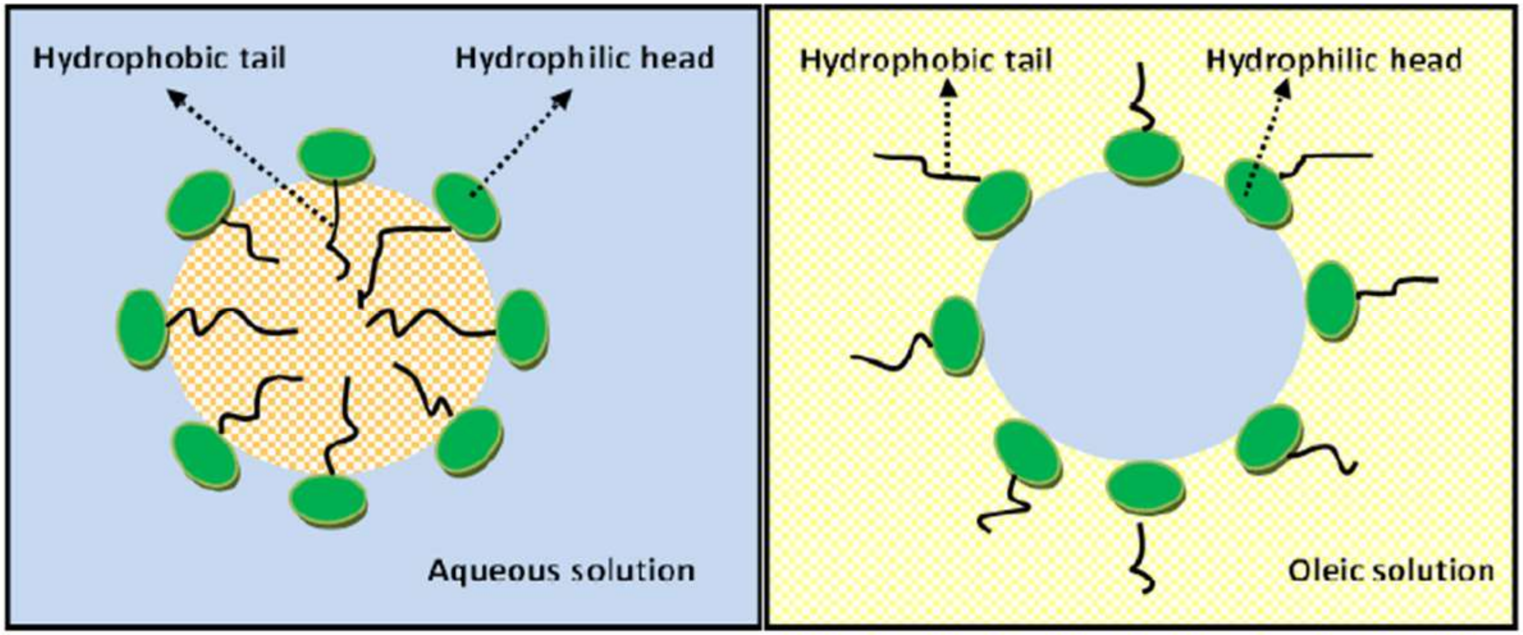
Formation Water Analysis (Rudies)

Na^+	321920 ppm
Ca++	101521 ppm
Mg++	1216 ppm
Cl-	71588 ppm
So4 -	303 ppm
Co3-	0.0 ppm
Hco3-	1525 ppm
OH-	0.0
TDS	139394 PPM
PH	5.7 20C,
S.P GR	1.108 &20C

Polymer (Polyacrylamide)



Polyacrylamide powder or "**PAM**" is a non-toxic powder that is a long-chain molecule first used in **cleaning** wastewater at wastewater treatment plants. In polymer flooding, PAM makes the water "**Gel**" greatly improving the production of oil.



The figure on the left shows when surfactant form in water. And the figure on the right shows when surfactant form in oil

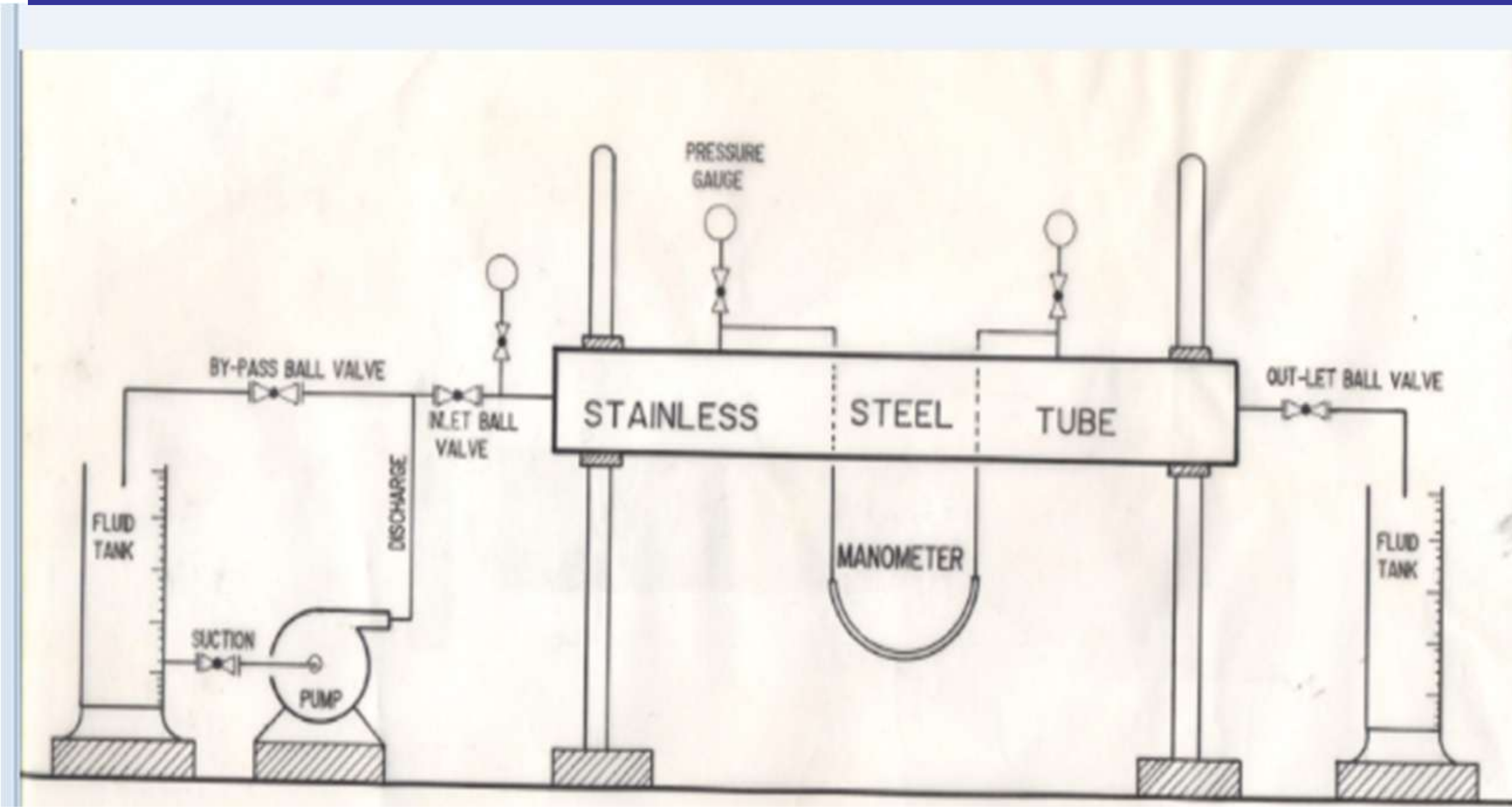
The main functions of surfactants are

1- To reduce interfacial tension

2- Wettability alteration

1. Reduction in interfacial tension

2- Experimental Apparatus



The Model consists of :-

1- A stainless steel tube (L= 60 cm, D= 5 cm

2- Two threaded plug ends

3- Two screens

4- A pressure gauge and a mercury manometer

5- A centrifugal pump and vacuum pump

3- Experimental Procedures

1- The model was washed, dried and then filled with the mixture of reservoir rock sand (40-65 mesh) and clay (Bentonite).

2- Clay content varies between zero to 20 %.

3- The model was then vibrated for 30 minutes using mechanical vibrator to ensure a good packing of the mixture in the model.

4- This model resembles the pay zone of Egyptian July oil field the Rudies formation.

5- The model was then saturated with formation water of July field, until four times pore volume of the injected water have been produced.

6- Then the porous medium was flooded by the crude oil of the July field until the production of water was ceased leaving only the irreducible water.

7- Effective oil permeability, at irreducible water saturation, is calculated at various stabilized flow rates using Darcy's equation for linear horizontal flow. Properties of both formation water and crude oil used are shown in table (1).

8- Finally, - The porous medium was flooded by formation water until a water cut 100% in the produced fluid.

- **The oil remaining for SPF processes was determined and chemical slug of surfactant was injected by the protective slug of polymer solution.**
- **The displacement was continued by driving water until the oil production was nil.**
- **The produced fluids were collected and the recovery factor was determined.**

***The above procedure was repeated with*:-**

- **Surfactant slug concentration of 2%, 3% ,4% and 5%.**
- **And for different values of clay content (0%,3.5%,5%,10%,15% and20%)**

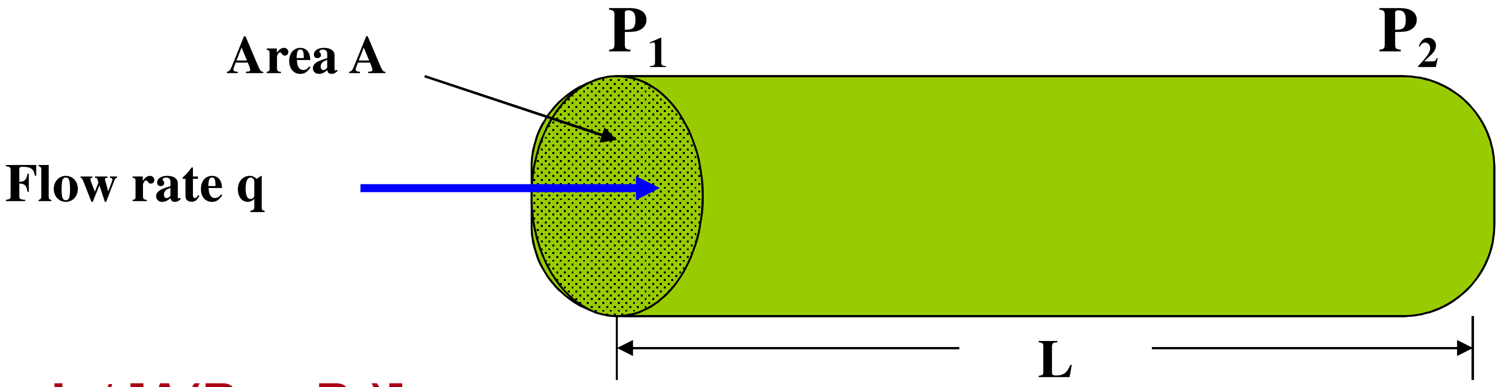
Governing Equations for Surfactant-Polymer Modeling

$$PV\ (ml) = \frac{\text{Weight of sand pack 100 \% saturated (g)} - \text{weight of sand pack dry}}{\text{density of liquid (g/ml)}}$$

$$\text{Porosity (\%)} = \frac{\text{pore volume of sand pack (ml)}}{\text{Bulk volume of sand pack}} \times 100$$

Flow Equation (Darcy's Law)

Lab measurements for Permeability



- $k = q \mu L / [A(P_1 - P_2)]$

Where

k = permeability, Darcys

μ = viscosity of the flowing fluid, cp

dp/dL = pressure drop per unit length, atm/cm

q = flow rate through the porous medium, cm3/sec

A = cross-sectional area across which flow occurs, cm2

Determine Sw , So and Oil in place

Water saturation: $S_w = \frac{V_w}{V_p}$ **Oil saturation**: $S_o = \frac{V_o}{V_p}$

Oil In Place (OIP): $OIP = V\phi\ S_o = V\phi\ (1 - S_{wc})$

$V\phi$ **= The total pore volume (PV)**
S_o = The oil saturation
S_{wc} = ***"connate water"*** **– the original water saturation**

Oil recovery factor

R= Vprod X 100/ OOIP

Objectives of Experimental Work

The objective of this work is to first, investigate the key aspects influencing Surfactant- polymer flooding for the purpose of enhancing oil recovery of Egyptian July reservoir.

1- **Build a model that resembles the actual July main field conditions, based on the available fluid and rock properties.**

2- **Design optimum surfactant slug concentration.**

3- **Design optimum slug injection rate for July oil field.**

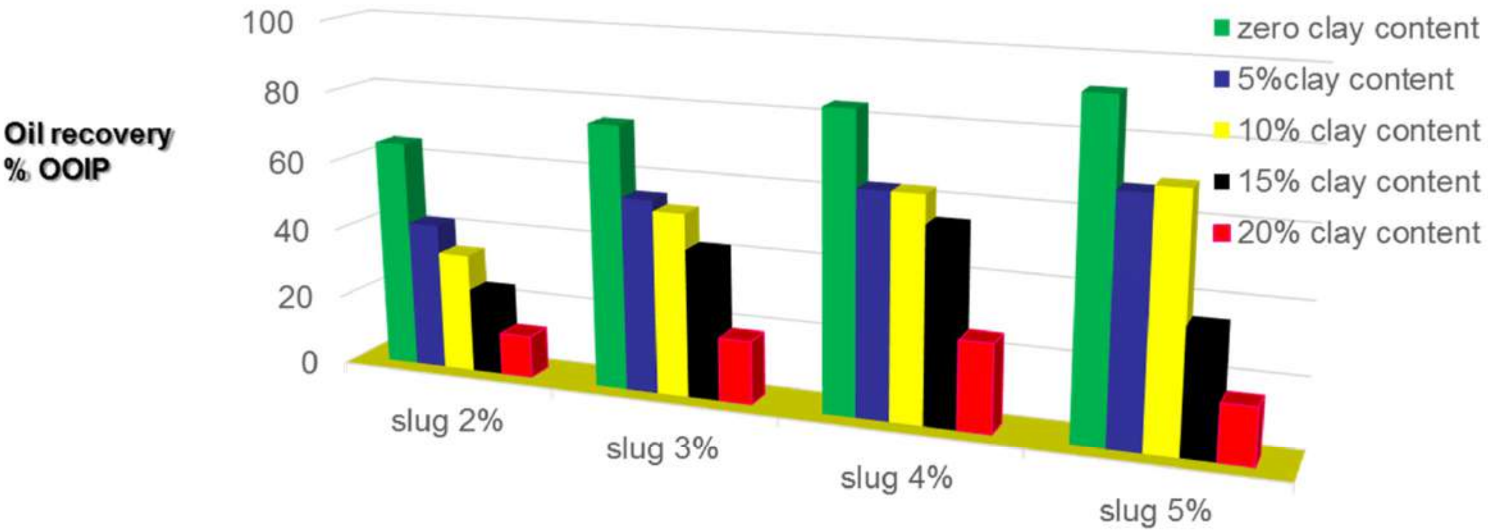
4- **Identify the effects of clay content on oil recovery.**

Results

All expermintal runs indicated thant:-

- **Most Surfactant are adsorbed by clay than polymers.**
- **When clay content increases surfactant adsorption increases. This supported by observed low oil recovery for higher clay content greater than 20% .**
- **Adsorption of the surfactants on clay minerals is the major cause of surfactant retention during SP flooding at higher concentration.**
- **Also increasing clay contents causes a significant increase of the interstitial water causing loss of polyacrylamide solutions effectiveness as a mobility control.**
- **By ion-exchange, divalent ions transferred to the surfactant solution from the clays resulting in precipitation of the surfactant and loss of its**

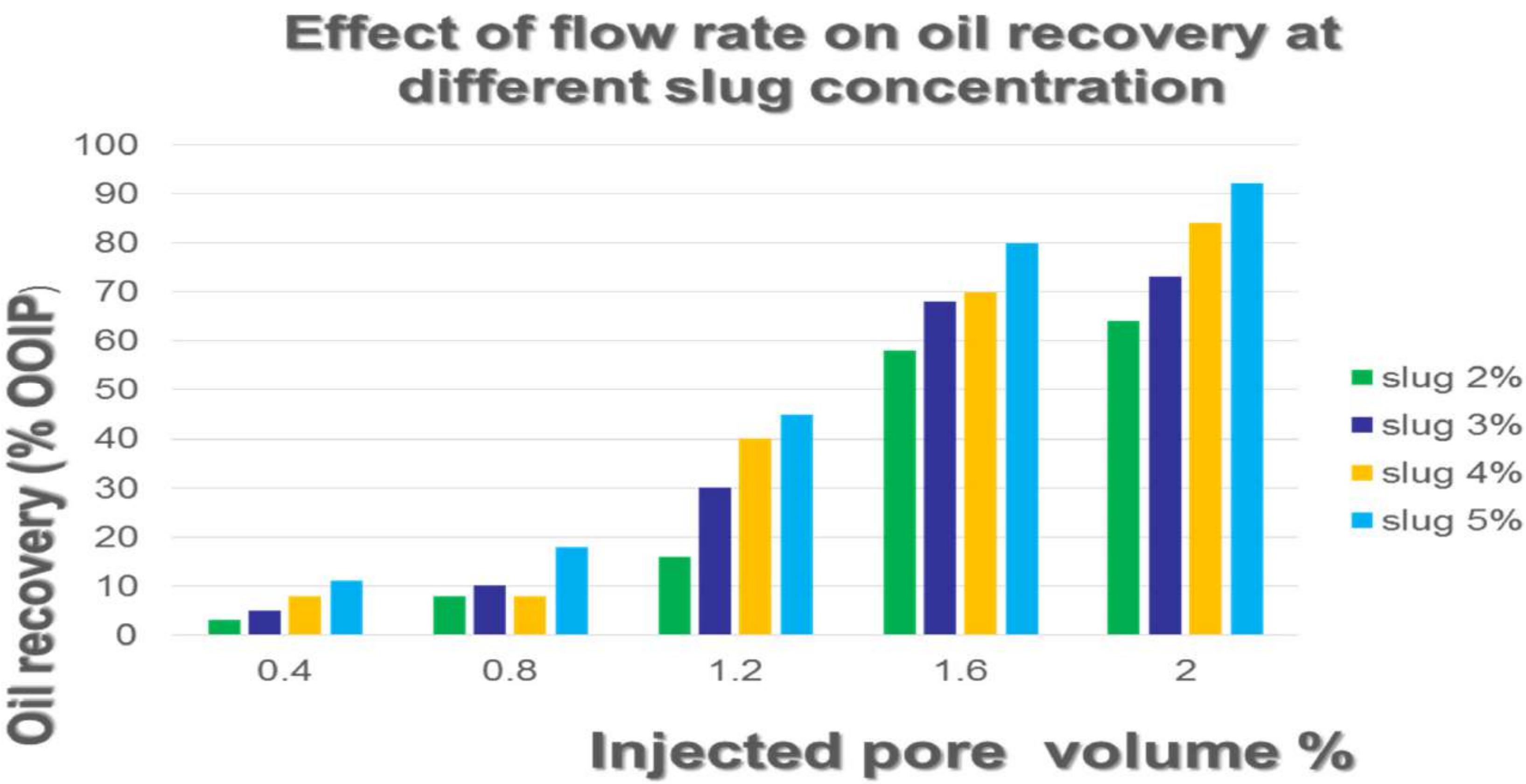
Effect of Slug concentration at various clay content on oil recovery



	slug 2%	slug 3%	slug 4%	slug 5%
zero clay content	65	75	84	92
5%clay content	42	55	63	68
10% clay content	34	52	63	70
15% clay content	24	42	55	35
20% clay content	12	18	25	16

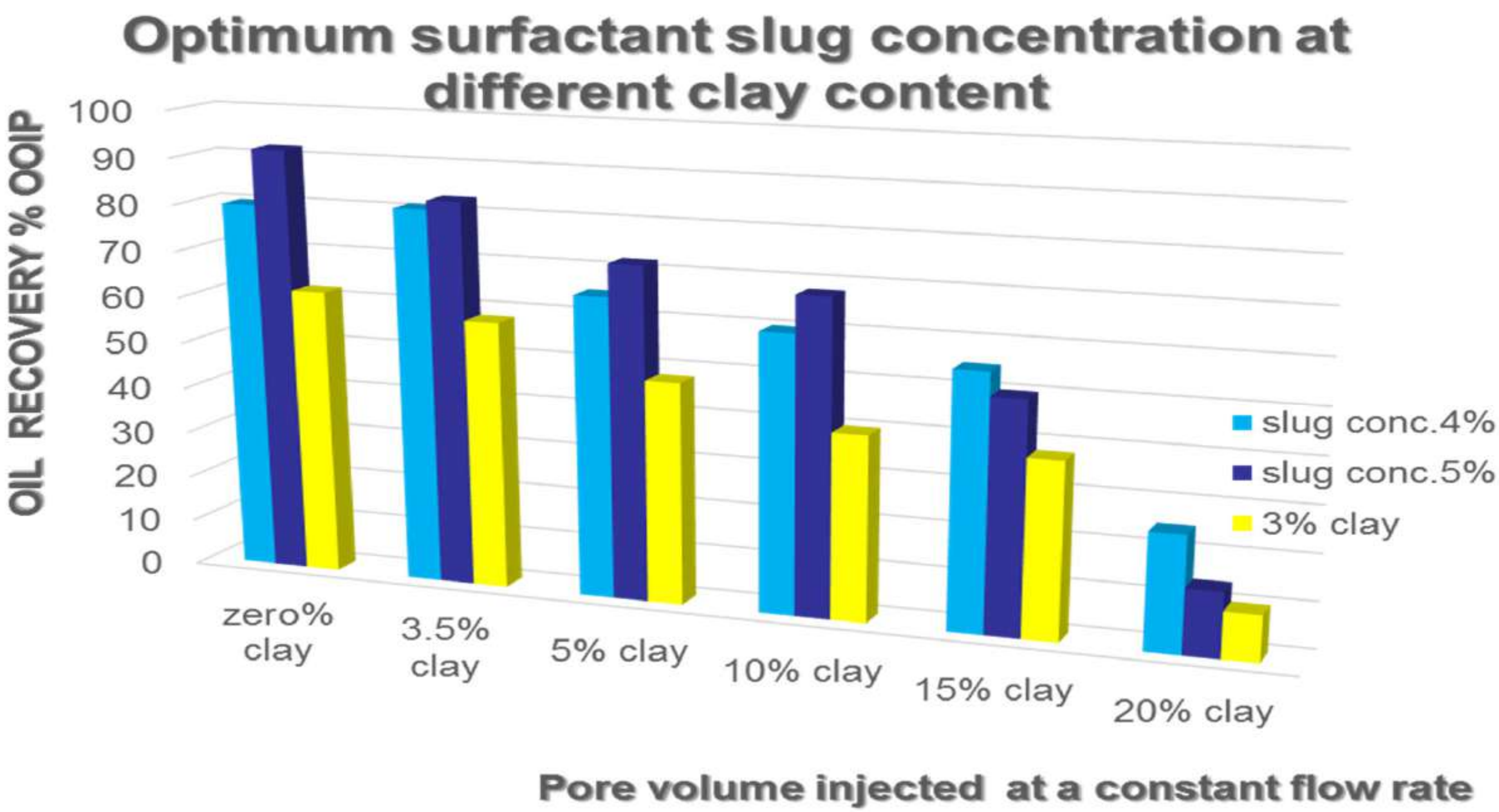
It is can be observed that:-

The additional oil recovery increases as the concentration of surfactant increases.
The additional oil recovery attained maximum at 5% of S and began to get stable.
Concentration for surfactant is one of the important parameter for surfactants flooding.

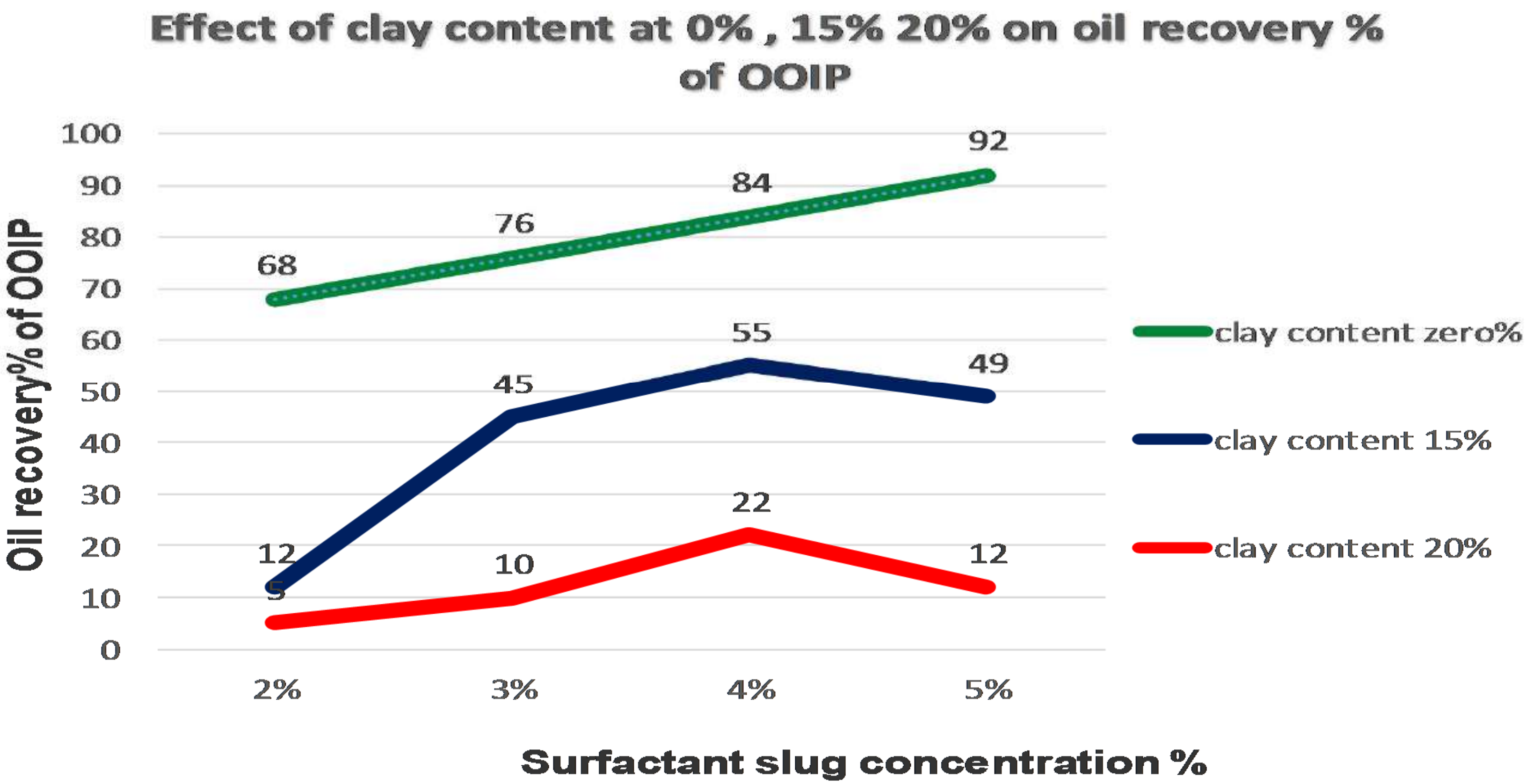


It was observed that:-

Low oil recovery at flow rate injected from 0.4 to 0.8 PV %.
High oil recovery at 1.6-2.0 pore volume.
Optimum flow rate at 2 PV injected for all slug concentrations.



Optimum flow rate at 2 PV injected for all slug concentrations(3%,4%,and5%) and also for clay contents from zero% to 20%.



@ zero % of clay content oil recovery reached up to 90% of OOIP
@ 15% of clay content at 4% slug concentration oil recovery started to decrease at 5% slug concentration mainly due to surfactant adsorbed on clay
@ clay content exceeds 20 % ,it is not recommended to use the surfactant-polymer flooding method.

CONCLUSION

Experimental observations and results indicated that:-

1- Oil recovery is directly proportional to the surfactant slug concentration and oil recovery is inversely to the clay content.

2- An optimum value of surfactant slug concentration at each clay content was also determined.

3- The results of the model also helpful for better understanding the role of Surfactant- Polymer flooding injection processes in large scale in the field.

CONCLUSION

5- Oil recovery increases from 68% to 92% is observed as surfactant concentration slug increased from 2 % to 5 % .

6 - In case of clay content less than 10%, it is more efficient to use a large pore volume of surfactant slug with slug concentration (4%-5%).

7- For clay content grater than 15% , it is recommended to use small pore volume of surfactant slug, with high concentration greater than 5% in order to compensate surfactant loss and consumption.

8- As clay content exceeds 20% , it is not recommended to use the surfactant- polymer flooding.

The Future of Surfactant –polymer flooding

The future is bright – Reasons?

- ***Energy demand***
- ***Diminishing reserves***
- ***Past experience***
- ***New technologies***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Thank You