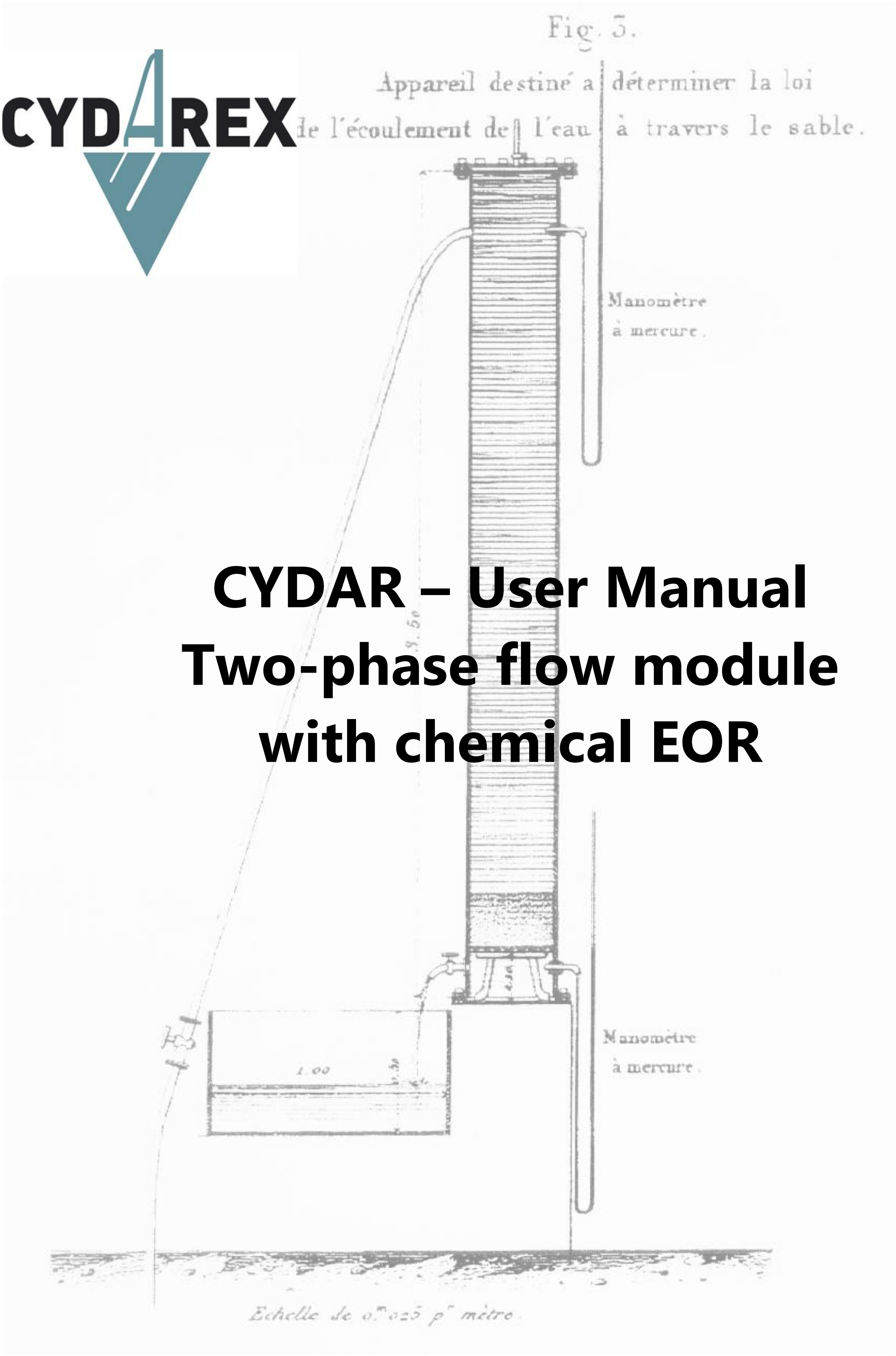


Fig. 5.

Appareil destiné à déterminer la loi de l'écoulement de l'eau à travers le sable.

CYDAR – User Manual
Two-phase flow module with chemical EOR

CYDAR - Two-phase flow module with chemical EOR

This notice describes the functionalities of the module Two-phase flow with EOR of CYDAR. The functionalities of CYDAR common for all modules are described in a separate document ("CYDAR Common Features User Manual"). This user manual only describes the additional functionalities introduced for chemical EOR in the Two-Phase Flow module. For a full description of the Two-Phase Flow module, refer to "CYDAR – SCAL User Manual" available on our website.

All User Manuals are available on our website at www.cydarex.fr.

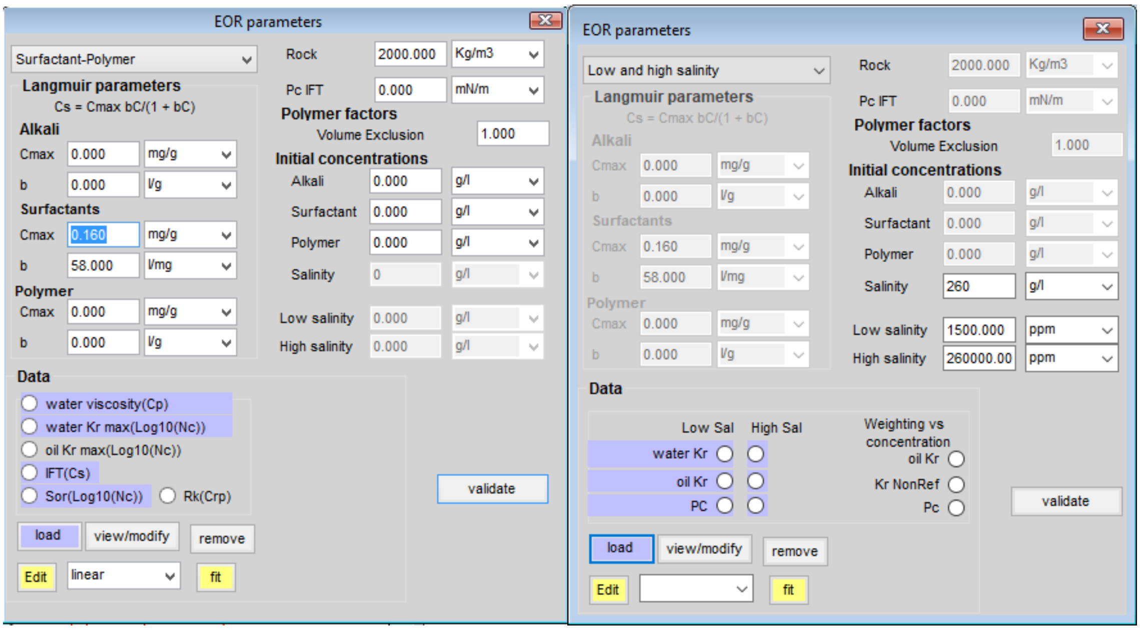
CYDAR – Overview of Two-Phase Flow with EOR

In CYDAR 2018, we are introducing a new Two-Phase Flow module with chemical EOR (Enhanced Oil Recovery). Two type of EOR effects are implemented:

- Alkali-Surfactant-Polymer EOR;
- Low and High salinity EOR.

The EOR module simulates:

- **Effects of polymers:** reduce the aqueous phase mobility and the mobility ratio with the other phase. Polymers lead to water viscosity increase, water permeability reduction, and volume exclusion.
- **Effects of surfactants:** Surfactants reduce the interfacial tension (IFT), capillary pressure Pc, the capillary number Nc and residual oil saturation Sor. Surfactants have also an impact on relative permeability.
- **Effects of low and high salinity:** effects on Pc and relative permeabilities Kr
- **Mixing in the aqueous phase at each simulation step:** calculation of the new concentrations; calculation of the new flow properties (viscosity, capillary pressure Pc, relative permeabilities Kr).
- **Adsorption** for polymers and surfactants, simulated as Langmuir adsorption.
- **Mass balance equation:** mass balance equations for the two fluids, and mass balance equation for each chemical species.



Surfactant-Polymer

Alkali Cmax 0.000 mg/g
Alkali b 0.000 l/g
Surfactants Cmax 0.160 mg/g
Surfactants b 58.000 l/mg
Polymer Cmax 0.000 mg/g
Polymer b 0.000 l/g
Rock 2000.000 Kg/m3
Pc IFT 0.000 mN/m
Volume Exclusion 1.000
Alkali 0.000 g/l
Surfactant 0.000 g/l
Polymer 0.000 g/l
Salinity 0 g/l
Low salinity 0.000 g/l
High salinity 0.000 g/l
linear

Low and high salinity

Alkali Cmax 0.000 mg/g
Alkali b 0.000 l/g
Surfactants Cmax 0.160 mg/g
Surfactants b 58.000 l/mg
Polymer Cmax 0.000 mg/g
Polymer b 0.000 l/g
Rock 2000.000 Kg/m3
Pc IFT 0.000 mN/m
Volume Exclusion 1.000
Alkali 0.000 g/l
Surfactant 0.000 g/l
Polymer 0.000 g/l
Salinity 260 g/l
Low salinity 1500.000 ppm
High salinity 260000.00 ppm

Figure 1: Parameter entries for EOR simulations, Surfactant-Polymer (left) and Low and High Salinity (right).

Input parameters for EOR simulations:

- **Data for Surfactant-Polymer:** Water viscosity as a function of polymer concentration; IFT tabulated according to surfactant concentration; Water and oil Kr_{MAX} and Sor; reduction factor of the permeability to water Rk tabulated according to the mass fraction of adsorbed concentration.
- **Data for Low and High Salinity:** Kr measured in low and high salinity for the water and the oil phase; Pc measured in low and high salinity. Weighting functions.
- **Langmuir parameters:** CMAX and b for polymer and surfactant.
- **Rock density** to account for the adsorption.
- **IFT** corresponding to the Pc without chemicals.
- **Initial concentration** in the core for surfactant and polymer.

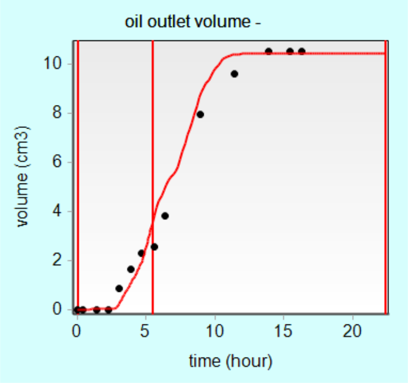
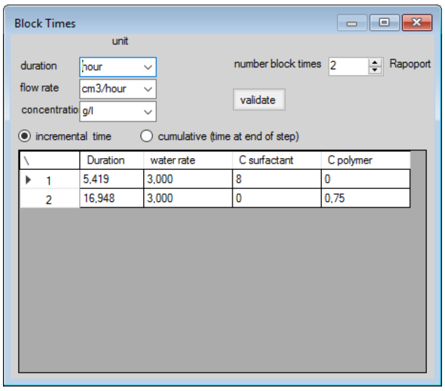


Figure 2: Comparison between measurements (dots) and



duration hour
flow rate cm3/hour
concentratio g/l
number block times 2
● incremental time
○ cumulative (time at end of step)

\	Duration	water rate	C surfactant	C polymer
1	5,419	3,000	8	0
2	16,948	3,000	0	0,75

Figure 3: Block times entries for the injected

simulation, using data from Douarche et al. OGST, 67, 2012.

concentration.

Launching the EOR Module

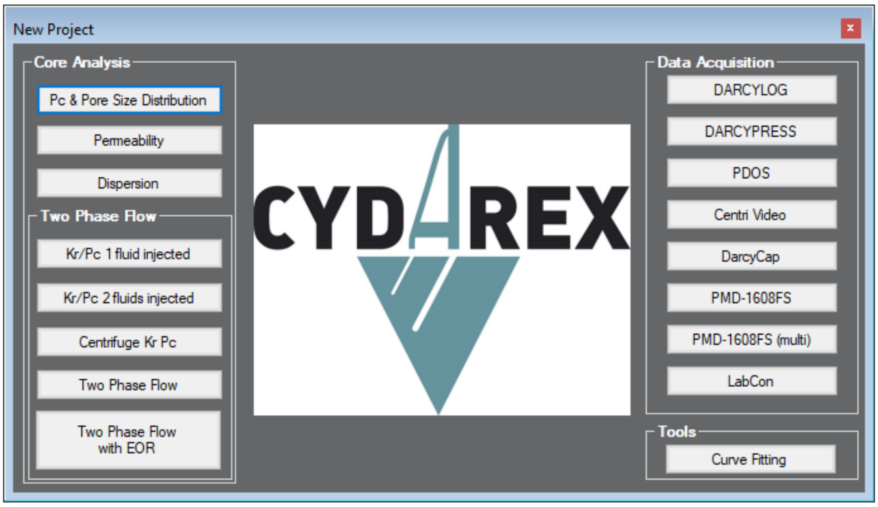


Figure 4: CYDAR new project window.

The Two-Phase Flow with EOR module is launch from the New Project window, by selecting "Two-Phase Flow with EOR." Once open, the TPF with EOR has the same look and functionalities as the TPF module.

The TPF with EOR home window is similar to the TPF's (Figure 5). EOR capabilities can be activated in the Experiment window (Figure 6). If "EOR enabled" is not checked, then the module behaves like the regular TPF module.
The default experimental settings are: imbibitions with one fluid injected at imposed flow rate.

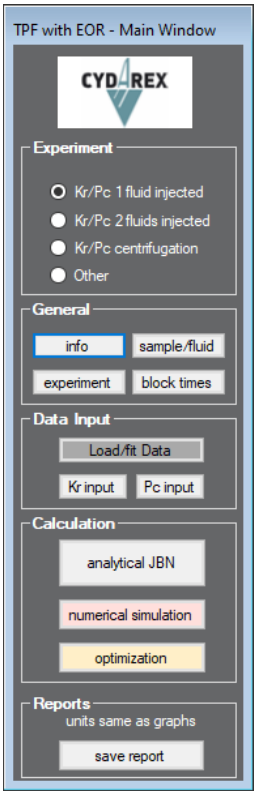
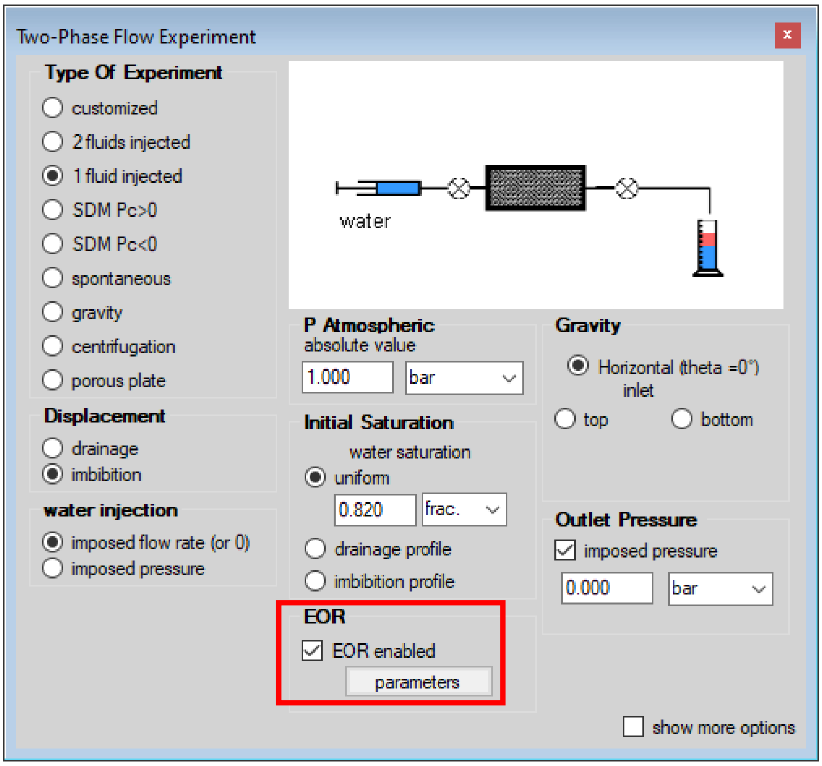


Figure 5: TPF with EOR home window.



Type Of Experiment: ● 1 fluid injected

Displacement: ● imbibition

water injection: ● imposed flow rate (or 0)

P Atmospheric absolute value: 1.000 bar

Gravity: ● Horizontal (theta =0°)

Initial Saturation, water saturation: ● uniform 0.820 frac.

Outlet Pressure: ☑ imposed pressure 0.000 bar

EOR: ☑ EOR enabled

☐ show more options

Figure 6: Example of TPF experiment type window, with the EOR option activated.

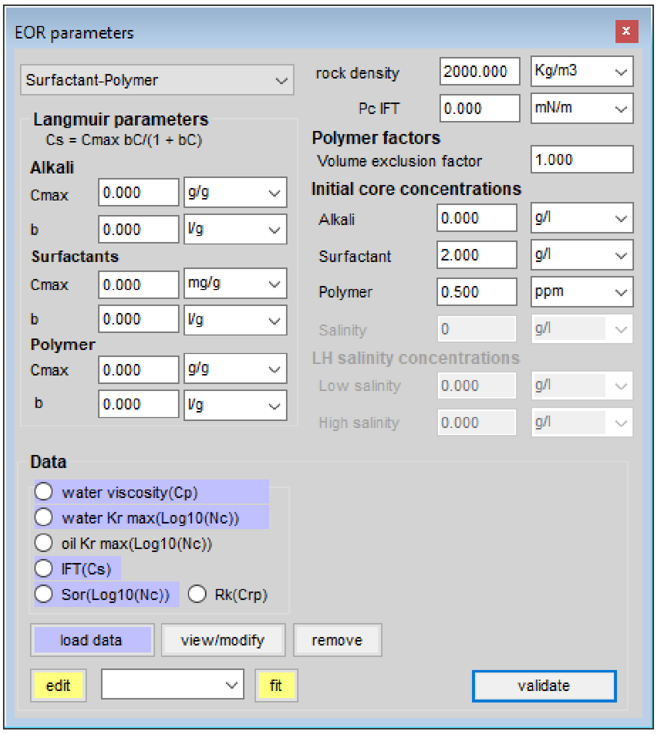
Module Two-Phase Flow with EOR

Input of EOR parameters

Once the EOR is enabled in the window “Two-phase flow experiment” (Figure 6), the following options become available:

- EOR parameters can be entered by pressing the “parameters” button,
- Inlet concentrations can be entered in the “Block times” windows,
- Numerical simulation with EOR can be enabled or disabled in the window “Simulation.”

In the window “Two-phase flow experiment”, the button “parameters” for EOR opens a window with different input parameters for EOR.



EOR parameters

Surfactant-Polymer

Langmuir parameters
Cs = Cmax bC/(1 + bC)

Alkali
Cmax 0.000 g/g
b 0.000 l/g

Surfactants
Cmax 0.000 mg/g
b 0.000 l/g

Polymer
Cmax 0.000 g/g
b 0.000 l/g

rock density 2000.000 Kg/m3
Pc IFT 0.000 mN/m

Polymer factors
Volume exclusion factor 1.000

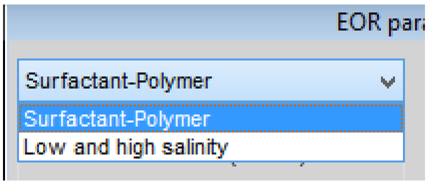
Initial core concentrations
Alkali 0.000 g/l
Surfactant 2.000 g/l
Polymer 0.500 ppm
Salinity 0 g/l

LH salinity concentrations
Low salinity 0.000 g/l
High salinity 0.000 g/l

Data
○ water viscosity(Cp)
○ water Kr max(Log10(Nc))
○ oil Kr max(Log10(Nc))
○ IFT(Cs)
○ Sor(Log10(Nc)) ○ Rk(Crp)

Figure 7: "EOR parameters" windows with entries for Alkali-Surfactant-Polymer parameters.

The combo box at the top left of the “EOR parameters” allows the selection of the EOR type, either “Surfactant-Polymer” or “Low and high salinity”.



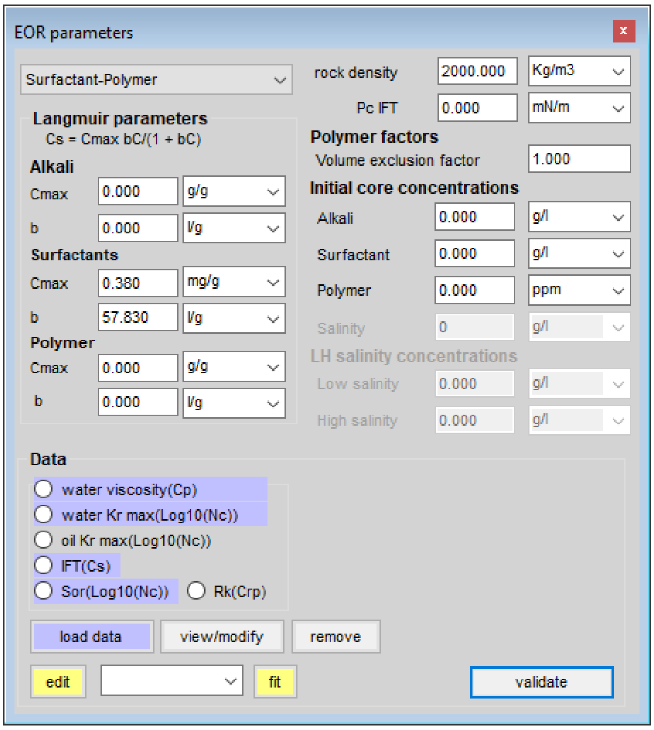
Alkali-Surfactant-Polymer inputs

Figure 7 shows the different inputs for the Alkali-Surfactant-Polymer EOR. The physical meanings of the different inputs are described below.

- “Langmuir parameters”: C^{MAX} and b for polymer and surfactant. Rock density is needed.
- Data, tabulated inputs:
  - Water viscosity tabulated according to polymer concentration.
  - IFT tabulated according to surfactant concentration.
  - Water and oil Kr max and Sor: tabulated according to the log10 of capillary number Nc.

  - The reduction factor of the permeability to water R_k tabulated according to the mass fraction of adsorbed concentration.
- Rock density: This is needed to account for adsorption.
- IFT corresponding to the Pc entered by the user, i.e. without chemicals. This value is used to calculate the local Pc according to the local IFT during simulation. If this value is set to zero but a curve IFT(Cs) has been entered, then a value is calculated from the curve at C_s=0. If there is no curve and no value, then there will be no effects on the PC.
- Initial concentration in the core for surfactant and polymer.
- Reduction and exclusion factor for the water: constants

Low and high salinity inputs



Surfactant-Polymer

Cs = Cmax bC/(1 + bC)

Alkali Cmax 0.000 g/g
Alkali b 0.000 l/g
Surfactants Cmax 0.380 mg/g
Surfactants b 57.830 l/g
Polymer Cmax 0.000 g/g
Polymer b 0.000 l/g

rock density 2000.000 Kg/m3
Pc IFT 0.000 mN/m
Volume exclusion factor 1.000

Initial core concentrations:
Alkali 0.000 g/l
Surfactant 0.000 g/l
Polymer 0.000 ppm
Salinity 0 g/l

LH salinity concentrations:
Low salinity 0.000 g/l
High salinity 0.000 g/l

Data:
○ water viscosity(Cp)
○ water Kr max(Log10(Nc))
○ oil Kr max(Log10(Nc))
○ IFT(Cs)
○ Sor(Log10(Nc)) ○ Rk(Crp)

Figure 8: EOR parameters for low and high salinity experiment.

Figure 8 shows the "EOR parameters" window with the low and high salinity inputs enabled. The reader may notice that ASP inputs are disabled.

- Initial concentrations-Salinity is the initial water salinity at the beginning of the experiment;
- Low salinity is the salinity corresponding to the low salinity data (LS Kr-Pc);
- High salinity is the salinity corresponding to the high salinity data (HS Kr-Pc);

Tabulated data

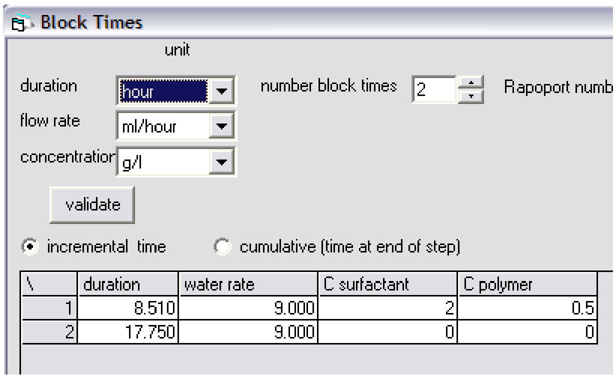
In this module the local Kr-Pc are calculated according to the local salinity value from the Kr-Pc at low and high salinity (see explanation of the calculation below).

The data are loaded and edited as any other data in CYDAR. The user may enter the Kr-Pc versus saturation at the low and high salinity.

The user may also enter a weighting versus concentration for each data.

Inlet concentrations per block times

The “Block Times” window can be opened from the Home window (Figure 5).



unit

duration: hour

flow rate: ml/hour

concentratior: g/l

number block times: 2

● incremental time ○ cumulative (time at end of step)

\	duration	water rate	C surfactant	C polymer
1	8.510	9.000	2	0.5
2	17.750	9.000	0	0

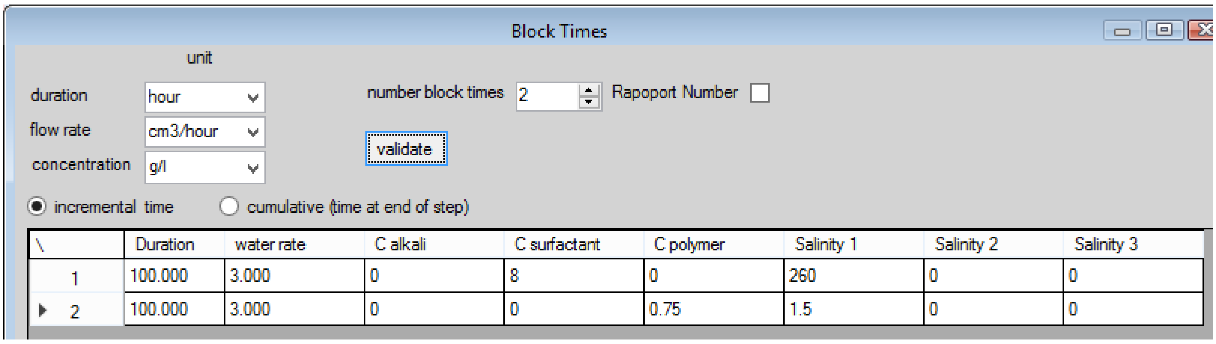
Figure 9: Block times entries for the injected concentration.

The slugs chemical compositions are entered in the “Block time” window (Figure 9). When EOR is enabled, two new columns are displayed: one for the surfactant concentration in the injected water; the other for the polymer concentration.

When EOR is enabled in the “experiment” window (Figure 6), six new columns are displayed allowing entering the concentrations and salinities in the injected water: C Alkali, C surfactant, C polymer, salinity 1, 2 and 3.

When the EOR type is set to Surfactant-Polymer, the salinities have no effect on the Kr-Pc. They are just tracers. It has to be noted that at this stage, no dispersion effect is implemented.

If the EOR type is “low and high salinity” then the “alkali, surfactant and polymer” concentrations have no effect and behave like tracers. The salinity having an effect on the local Kr-Pc curves is “salinity 1”.



unit
duration: hour
flow rate: cm3/hour
concentration: g/l
number block times: 2
Rapoport Number ☐
● incremental time ○ cumulative (time at end of step)

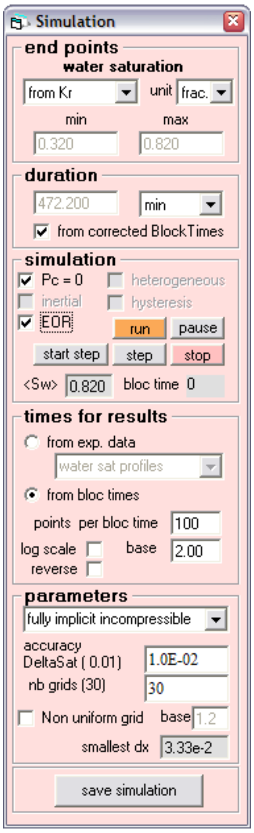
\	Duration	water rate	C alkali	C surfactant	C polymer	Salinity 1	Salinity 2	Salinity 3
1	100.000	3.000	0	8	0	260	0	0
2	100.000	3.000	0	0	0.75	1.5	0	0

Figure 10: Block times entries for the injected concentration.

> **IMPORTANT**: At this stage, the alkali concentration and salinities 2 and 3 have no effect, they are just tracers. The entries are implemented to show the possibility to add other chemicals.

Simulation Window

The simulation Window is very similar to that of the regular TPF module, with the exception of the "EOR" checkbox (Figure 11). If checked, then the numerical solver will take into account all the physics of the EOR, as described in the Model section below.



end points
water saturation: from Kr, unit: frac.
min: 0.320 max: 0.820

duration
472.200 min
☑ from corrected BlockTimes

simulation
☑ Pc = 0 ☐ heterogeneous
☐ inertial ☐ hysteresis
☑ EOR
<Sw> 0.820 bloc time 0

times for results
○ from exp. data: water sat profiles
● from bloc times
points per bloc time: 100
log scale ☐ base: 2.00
reverse ☐

parameters
fully implicit incompressible
accuracy DeltaSat (0.01): 1.0E-02
nb grids (30): 30
☐ Non uniform grid base: 1.2
smallest dx: 3.33e-2

Figure 11: The simulation window of the two-phase flow module.

- "**EOR**": enable/disable the EOR option in simulation. This possibility is accessible only if the EOR is enabled in the "experiment" window. Otherwise, "EOR per BT" is accessible (see SCAL user manual).
- All other options are described in the SCAL User Manual, available on CYDAREX website.

Running a Simulation or an Optimization

Running a simulation or an optimization is similar to the regular TPF module (see CYDAR SCAL user manual). At this point, EOR parameters cannot be optimized.

Alkali-Surfactant-Polymer (ASP) Model

This section described some of the physics included in the ASP EOR calculation. Note that only surfactant and polymer in solution in water are considered.

At each simulation step, the following physical aspect is taken into account:

- Mixing in the aqueous phase at each simulation step: calculation of the new concentrations; calculation of the new flow properties (viscosity, capillary pressure Pc, relative permeabilities Kr).
- Effect of polymers on water viscosity, water permeability, and volume exclusion.
- Effect of surfactants on capillary pressure, Kr_{MAX}, and Sor.
- Adsorption for polymers and surfactants, Langmuir isotherm.

Effects of polymers

Their purpose is to reduce the aqueous phase mobility and to reduce the mobility ratio with the other phase.

Water viscosity increase

This mobility reduction is mainly due to viscosity increase. The user may enter the viscosity dependence with polymer concentration C_p through a tabulated data $\mu(C_p)$.

Water permeability reduction

The adsorption of polymer may also cause a reduction of the permeability to water. This is implemented in a modified Darcy's law with a tabulated reduction factor $R_k(C_{rp})$ according to the adsorbed mass fraction of polymer C_{rp}:

$$Q_w = A\frac{1}{R_k(C_{rp})}\frac{K\,Kr_w}{\mu_w}\Phi_w$$

with Q_w Darcy's velocity of water, A the surface, and Φ the potential. R_k may be superior to 1 if the adsorbed concentration of polymer, C_{rp}, is non zero.

Volume exclusion (depletion layer)

Finally, due to their size, polymers may not flow through small pore space. This is accounting with a volume exclusion factor, α, smaller than one. See Mass Balance Equation below.

Effects of surfactants

Their purpose is to reduce the interfacial tension (IFT) σ. They have an impact on the Pc, the capillary number N_c, i.e. on the Kr and on the residual oil saturation Sor.

The user may load a tabulated data giving the IFT according to the surfactant concentration C_s. In the simulation the IFT between oil and water is then read according to the local surfactant concentration.

Kr_{max} and S_{or}

The capillary number is then calculated and the changes of the maximum value of the relative permeabilities are read from the tabulated data $Kr_{max}\left(Log_{10}(N_c)\right)$ entered by the user. The modification of the residual oil saturation with N_c is read from the capillary desaturation curve, $S_{or}\left(Log_{10}(N_c)\right)$ also loaded by the user. Both data are versus the logarithm with base 10 of the capillary number.

Capillary pressure P_c

Assuming the equality of the Leverett function, the capillary pressure varies as follow:

$$P_c = P_{c_0}\frac{\sigma(C_s)}{\sigma_0}$$

The subscript 0 stands for the values at $C_s = 0$. In CYDAR, the Pc at $C_s = 0$ is the curve used in the two-phase flow, either entered in the “load/fit data” window or as analytical function in the “capillary pressure” window. The IFT is entered in the “EOR parameters” window.

Adsorption

The adsorption is of Langmuir kind. At equilibrium the Langmuir isotherm is:

$$C_{ri} = C_{ri}^{MAX}\frac{b_i\, C_{wi}}{1 + b_i\, C_{wi}}$$

C_{ri} are the adsorbed concentration. C_{ri}^{MAX} is the maximum coverage on the surface, b is a constant dependant of the system solid-liquid. Both are at this stage constant entered in the “EOR parameters” window. The subscript i is p for polymer and s for surfactant.

Mass balance equation for chemical species

In addition to the mass balance equations for the two fluids, there is a mass balance equation for each chemical species, i, in solution in water:

$$\phi\frac{\partial \alpha_i \rho_w S_w C_{wi}}{\partial t} + (1-\phi)\frac{\partial \rho_r C_{ri}}{\partial t} + \frac{1}{A}\frac{\partial \rho_w Q_w C_{wi}}{\partial x} = 0$$

α_i is the exclusion volume. It is equal to unity for the surfactant and may be smaller than one for the polymer, see above. ϕ is the porosity. S_w is the water saturation. C_{wi} is the concentration of species i in water. ρ_w is the water density and ρ_r is the rock density. C_{ri} is the adsorbed concentration of species i. Q_w is the local water flow rate given by the Darcy's law. This equation is coupled to the Langmuir isotherm.

Low and High salinity model

At this stage only the change in the Kr-Pc curves according to the salinity are considered and implemented. It implies the effect on the Sor through these data.

The principle is to calculate the local value according to the local salinity by interpolation between values at low and high salinity.

Let's take for example the water relative permeability Kr. The user enter a water Kr versus saturation corresponding to an injection of water at low salinity, and the companion data corresponding to an injection of water at high salinity value (Figure 8).

For recall, the values of the low salinity and the high salinity are entered in the same window than the data (Figure 8).

Figure 12 shows an example of such a set of Kr:

- K LS in red is the Kr which corresponds to a water injection at low salinity value, the Kr maximum is 0.6 and the Sor is 0.3 (end point Sw = 0.7);
- K HS in blue is the Kr which corresponds to a water injection at high salinity value, the Kr maximum is 0.8 and the Sor is 0.1 (end point Sw = 0.9);

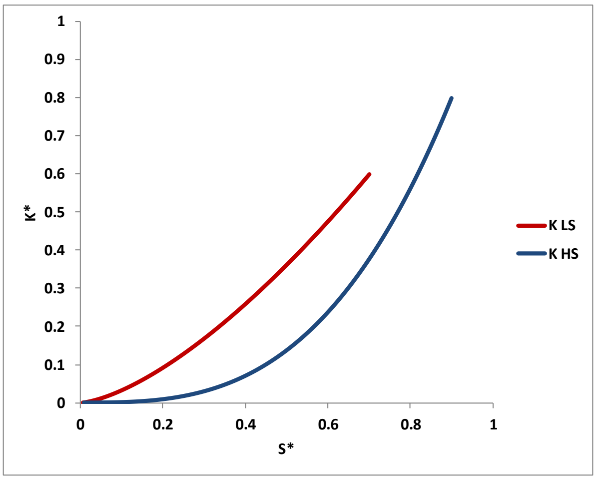


Figure 12: water Kr versus saturation for injections at low (in red) and high (in blue) salinity value.

The minimum saturation end point is the same for both data.

The linear interpolation is first done on normalized data Kr*, both Kr and saturation are normalized. In the following we note:

- C, C_{LS} and C_{HS} respectively the local, the low and high salinity values;
- Kr* and S* the normalized Kr and saturation data.

The normalized LS and HS data are simply calculated as follow:

$$Kr^* = \frac{Kr - Kr_{MIN}}{Kr_{MAX} - Kr_{MIN}} = \frac{Kr}{Kr_{MAX}}$$

$$S^* = \frac{S - S_{MIN}}{S_{MAX} - S_{MIN}}$$

The local maximum saturation is calculated by linear interpolation between the LS and HS ones:

$$S_{MAX}(C) = S_{MAX_{LS}} + \frac{S_{MAX_{HS}} - S_{MAX_{LS}}}{(C_{HS} - C_{LS})}\,(C - C_{LS})$$

From this, the local normalized saturation is calculated:

$$S^*(C) = \frac{S(C) - S_{MIN}}{S_{MAX}(C) - S_{MIN}}$$

Then, the local normalized Kr is calculated by linear interpolation:

$$Kr^*(C) = Kr^*_{LS} + \frac{Kr^*_{HS} - Kr^*_{LS}}{C_{HS} - C_{LS}}(C - C_{LS})$$

Figure 13 shows an example for a concentration which would be the average of the LS and HS salinities $C = 0.5(C_{HS} + C_{LS})$.

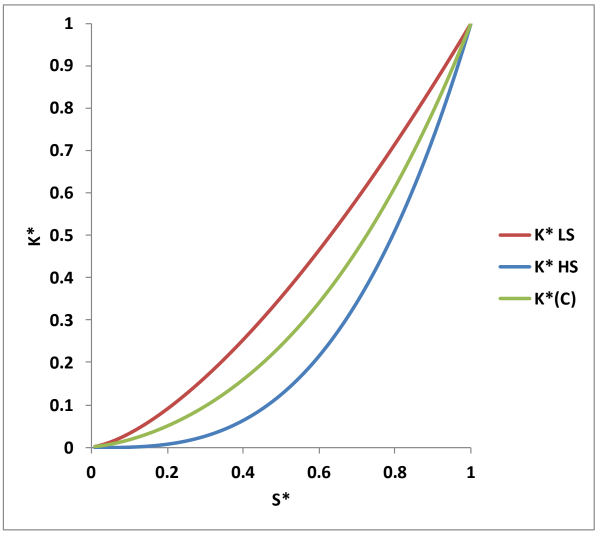


Figure 13: linear interpolation between normalized LS and HS Kr curves, here the concentration is the average of the LS and HS values.

This local normalized value is then resizing according to the local Kr maximum value, which is also calculated by linear interpolation between the LS and HS values:

$$Kr_{MAX}(C) = Kr_{MAX_{LS}} + \frac{Kr_{MAX_{HS}} - Kr_{MAX_{LS}}}{(C_{HS} - C_{LS})}\,(C - C_{LS})$$

Because the Kr minimum value is zero, the local Kr is simply given by:

$$Kr(C) = Kr^*(C)\,Kr_{MAX}(C)$$

Figure 14 shows the Kr resizing. The maximum Kr value and the maximum saturation of the local Kr curve are calculated by linear interpolation between LS and HS values according to the local salinity.

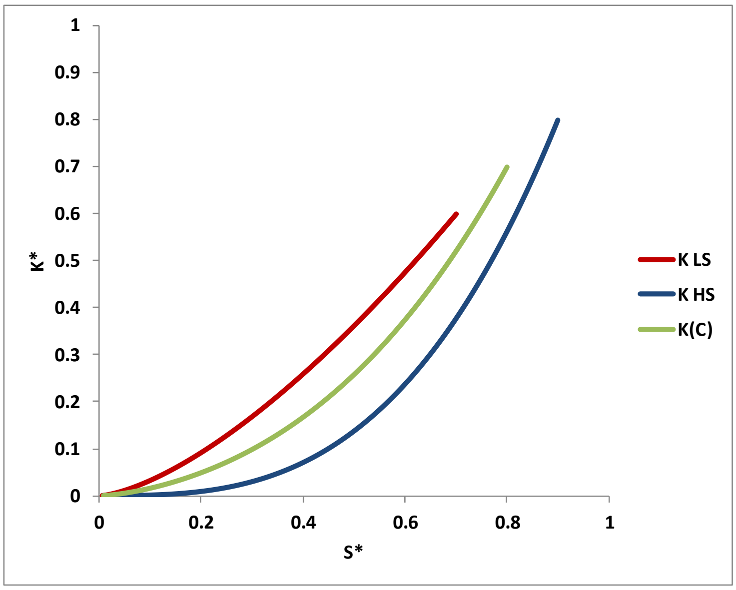


Figure 14: after the linear interpolation between the normalized LS and HS value, the Kr is resized with the maximum Kr and the saturation end point calculated by linear interpolation according to the salinity value.

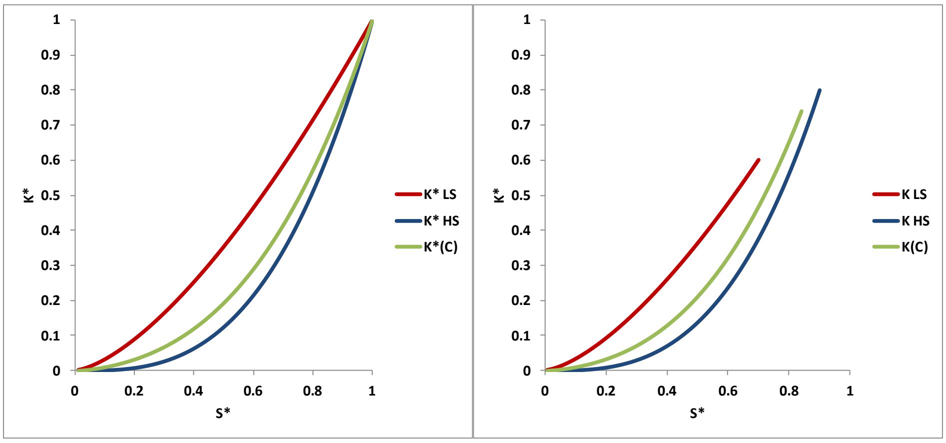
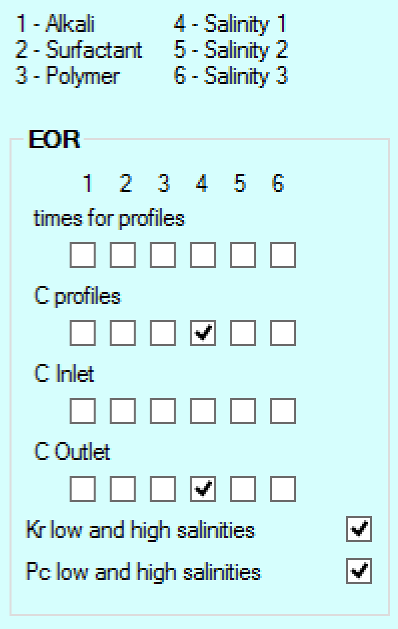


Figure 15: an example with a salinity $C = C_{LS} + 0.7(C_{HS} - C_{LS})$.

Graphs

When the EOR is enabled the user may display inlet and outlet concentrations and salinities, as well as the profiles and the Kr and Pc data at low and high salinities (Figure 16).



1 - Alkali
2 - Surfactant
3 - Polymer
4 - Salinity 1
5 - Salinity 2
6 - Salinity 3

EOR

	1	2	3	4	5	6
times for profiles	☐	☐	☐	☐	☐	☐
C profiles	☐	☐	☐	☑	☐	☐
C Inlet	☐	☐	☐	☐	☐	☐
C Outlet	☐	☐	☐	☑	☐	☐

Kr low and high salinities ☑
Pc low and high salinities ☑

Figure 16: part of the window "Graphs and Tables" allowing displaying data specific to EOR.

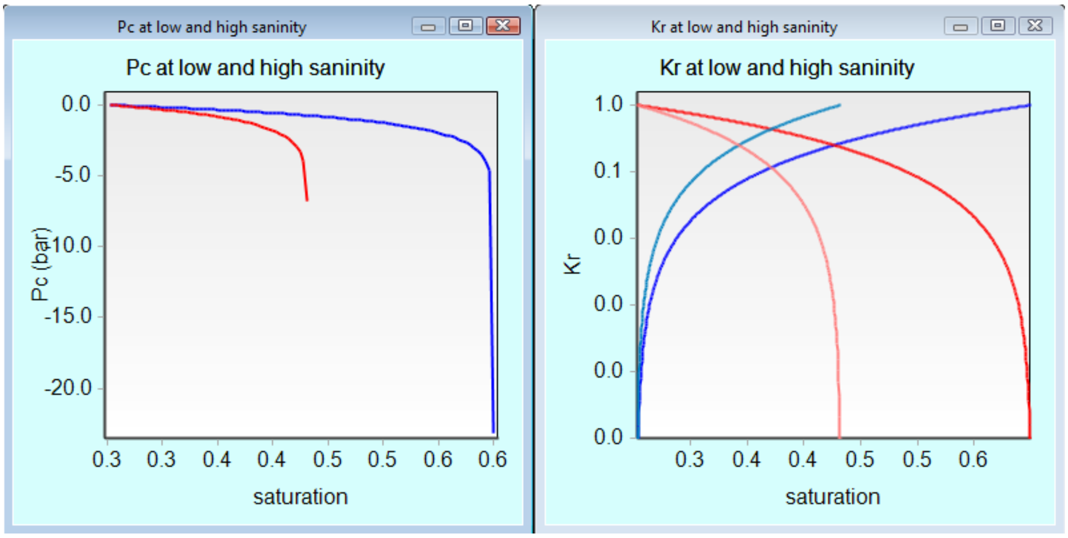
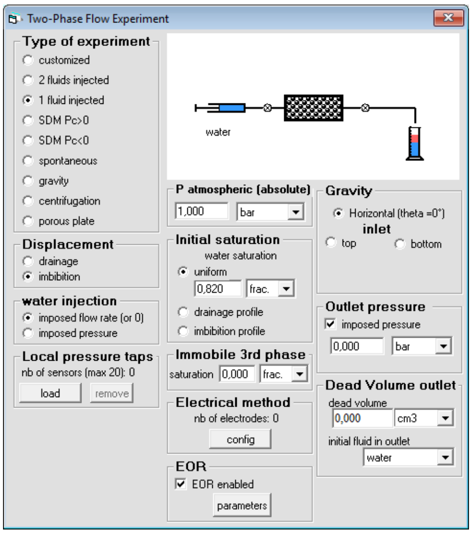


Figure 17: examples of Kr-Pc at low and high salinity.

Tutorial TPF_EOR_Rm.cyd

This tutorial illustrates how the ASP EOR module works, and the effects of surfactants and polymers on oil recovery. It is based on the publication Dourche et al., Oil & Gas Science and Technology, Rev. IFP Energies Nouvelles, Vol. 67 (2012), No. 6, pp. 983-997.

This case corresponds to a one-fluid injected (here water with surfactants and polymers) (Figure 18). The initial water saturation is uniform and equals to 0.82, meaning that the experiment is at the end of an imbibition, and most oil has been recovered.



Type of experiment
○ customized
○ 2 fluids injected
● 1 fluid injected
○ SDM Pc>0
○ SDM Pc<0
○ spontaneous
○ gravity
○ centrifugation
○ porous plate

Displacement
○ drainage
● imbibition

water injection
● imposed flow rate (or 0)
○ imposed pressure

Local pressure taps
nb of sensors (max 20): 0

P atmospheric (absolute)
1,000 bar

Initial saturation
water saturation
● uniform 0,820 frac.
○ drainage profile
○ imbibition profile

Immobile 3rd phase
saturation 0,000 frac.

Electrical method
nb of electrodes: 0

EOR
☑ EOR enabled

Gravity
● Horizontal (theta =0°)
inlet
○ top ○ bottom

Outlet pressure
☑ imposed pressure
0,000 bar

Dead Volume outlet
dead volume 0,000 cm3
initial fluid in outlet water

Figure 18: Experimental details.

If a simulation is run without EOR checked in simulation window, the production of oil is flat (Figure 19).

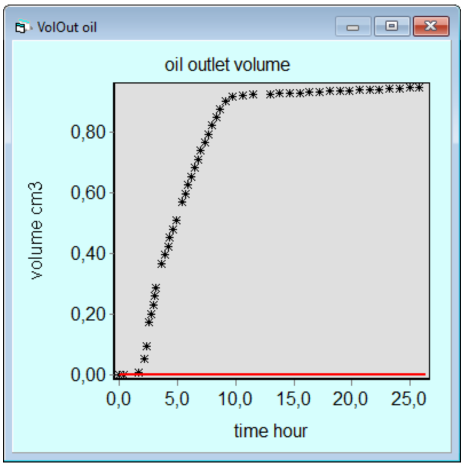
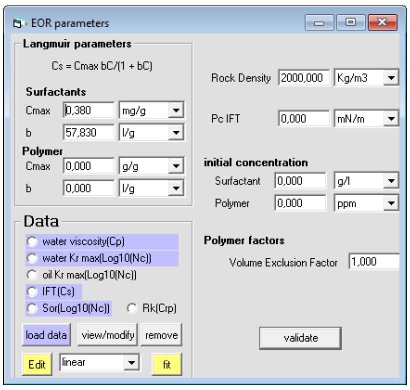


Figure 19: Without EOR, the simulated production of oil (red) is close to zero.

EOR parameters are now entered in the “EOR parameter” and in the “Block Times” windows (Figure 20).



Langmuir parameters
Cs = Cmax bC/(1 + bC)

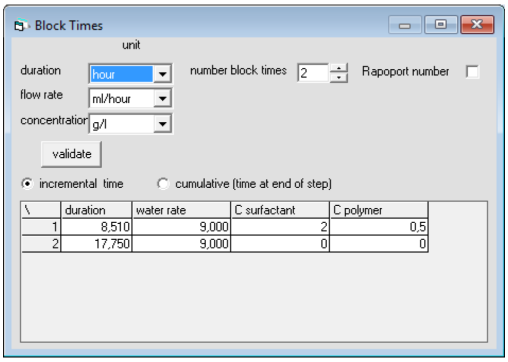
Surfactants
Cmax 0,380 mg/g
b 57,830 l/g

Polymer
Cmax 0,000 g/g
b 0,000 l/g

Rock Density 2000,000 Kg/m3
Pc IFT 0,000 mN/m

initial concentration
Surfactant 0,000 g/l
Polymer 0,000 ppm

Polymer factors
Volume Exclusion Factor 1,000



unit
duration hour
flow rate ml/hour
concentration g/l
number block times 2
Rapoport number ☐
● incremental time ○ cumulative (time at end of step)

\	duration	water rate	C surfactant	C polymer
1	8,510	9,000	2	0,5
2	17,750	9,000	0	0

Figure 20: Parameters for EOR are entered in the Parameter and Block Times windows.

The simulation is run with the EOR capabilities activated (Figure 21). The simulated oil recovery and the oil outlet flow rate match the recorded data.

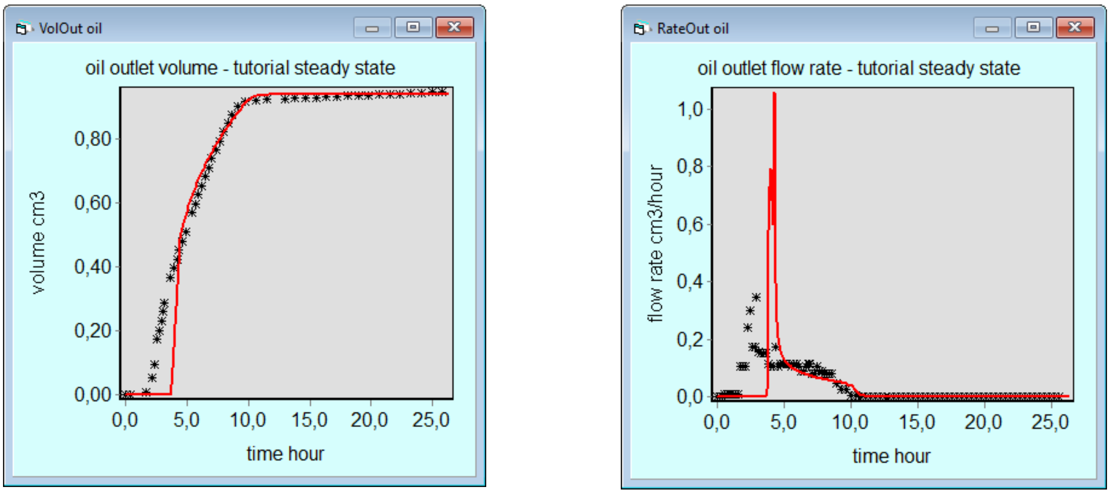
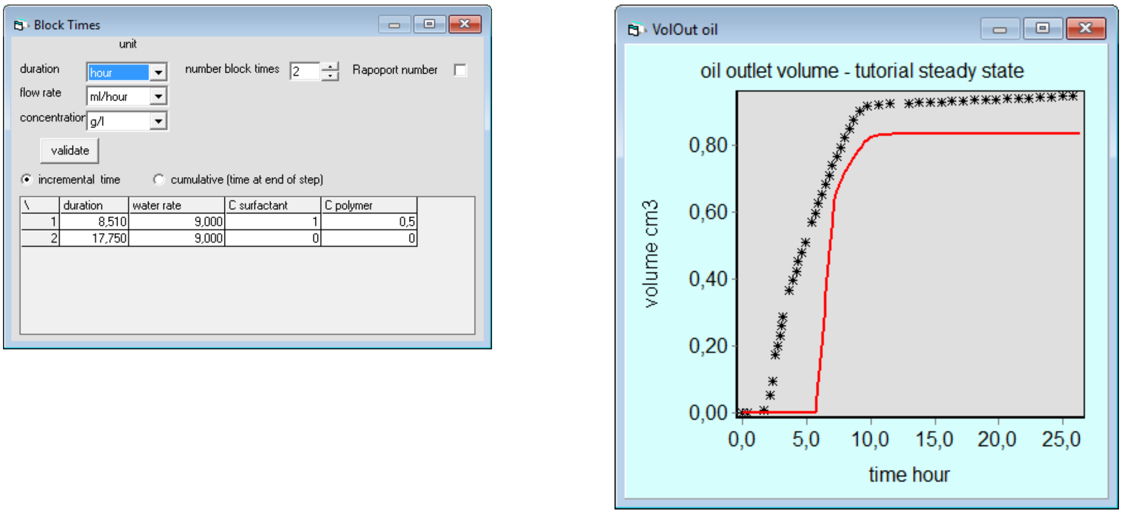


Figure 21: Once the EOR is turned on, the simulated (red) and recorded (black) data match.

If the initial concentration of surfactant is reduced from 2 g/l to 1 g/l, the oil recovery is reduced drastically (Figure 22).



duration: hour

flow rate: ml/hour

concentration: g/l

number block times: 2

Rapoport number ☐

● incremental time ○ cumulative (time at end of step)

\	duration	water rate	C surfactant	C polymer
1	8,510	9,000	1	0,5
2	17,750	9,000	0	0

Figure 22: If the initial concentration of surfactant is reduced, the oil recovered is reduced as well.

Tutorial Salinity

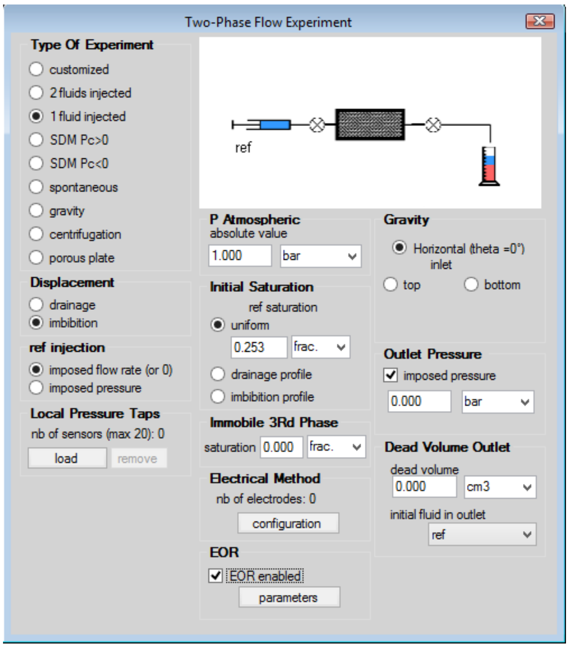
The tutorial contains several files:

- **tutorial_Low_High_salinity.xlsx:** Microsoft Excel file with the experimental data, sample, fluids, Pc and Kr at low and high salinity
- **tutorial_Low_High_salinity.cydx:** Cydar files.

Starting a project

First, start a new project and choose "**Two Phase Flow with EOR**". Then, enter the following data:

- Sample, and fluids properties "**sample/fluids**" (1st sheet of the Excel file);
- Experimental conditions (here most of them are already set) "**experiment**": type set to "1 fluids injected", displacement set to "imbibition", water injection type are "imposed flow rate", initial saturation is 0.253, and enable the EOR module by checking the box "EOR enabled" at the window bottom:



Two-Phase Flow Experiment

Type Of Experiment
○ customized
○ 2 fluids injected
● 1 fluid injected
○ SDM Pc>0
○ SDM Pc<0
○ spontaneous
○ gravity
○ centrifugation
○ porous plate

Displacement
○ drainage
● imbibition

ref injection
● imposed flow rate (or 0)
○ imposed pressure

Local Pressure Taps
nb of sensors (max 20): 0

P Atmospheric
absolute value 1.000 bar

Initial Saturation
ref saturation
● uniform 0.253 frac.
○ drainage profile
○ imbibition profile

Immobile 3Rd Phase
saturation 0.000 frac.

Electrical Method
nb of electrodes: 0

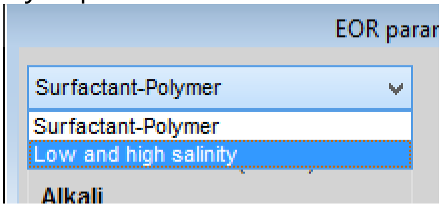
EOR
☑ EOR enabled

Gravity
● Horizontal (theta =0°)
inlet
○ top ○ bottom

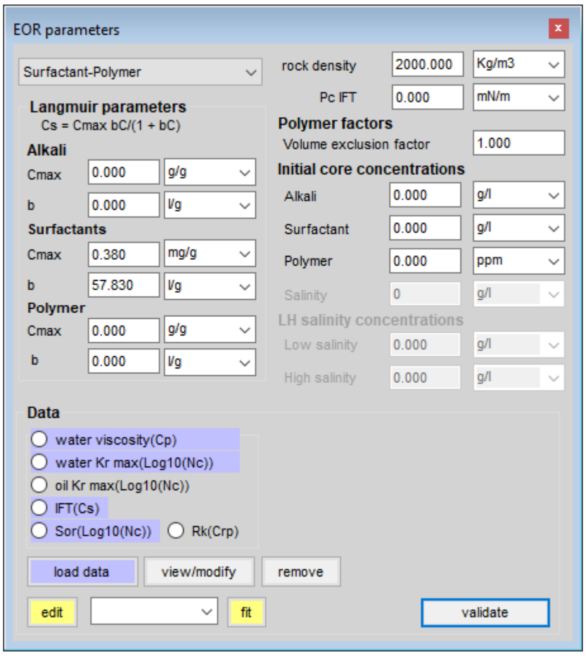
Outlet Pressure
☑ imposed pressure
0.000 bar

Dead Volume Outlet
dead volume 0.000 cm3
initial fluid in outlet ref

- Open the EOR parameters window by clicking on the "parameters" button;
- Select "Low and high salinity" option:



- Then enter the initial salinity, and the low and high salinity values (1st sheet of the Excel file);
- Load the Pc and Kr data at low and high salinity (2nd sheet of the Excel file), the way to proceed is the same than any other data in Cydar: "**Load/fit Data**" then, after selecting the proper raw data type, "**load data points**";



EOR parameters

Surfactant-Polymer

Langmuir parameters
Cs = Cmax bC/(1 + bC)

Alkali
Cmax 0.000 g/g
b 0.000 l/g

Surfactants
Cmax 0.380 mg/g
b 57.830 l/g

Polymer
Cmax 0.000 g/g
b 0.000 l/g

rock density 2000.000 Kg/m3
Pc IFT 0.000 mN/m

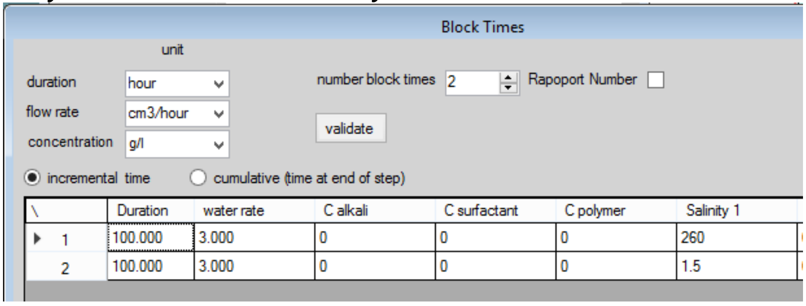
Polymer factors
Volume exclusion factor 1.000

Initial core concentrations
Alkali 0.000 g/l
Surfactant 0.000 g/l
Polymer 0.000 ppm
Salinity 0 g/l

LH salinity concentrations
Low salinity 0.000 g/l
High salinity 0.000 g/l

Data
○ water viscosity(Cp)
○ water Kr max(Log10(Nc))
○ oil Kr max(Log10(Nc))
○ IFT(Cs)
○ Sor(Log10(Nc)) ○ Rk(Crp)

- Open the “Block Times” window and enter the relevant data: duration, water rate and input salinity in the column “Salinity 1” (1^{st} sheet of the Excel file):



Block Times

unit
duration hour
flow rate cm3/hour
concentration g/l

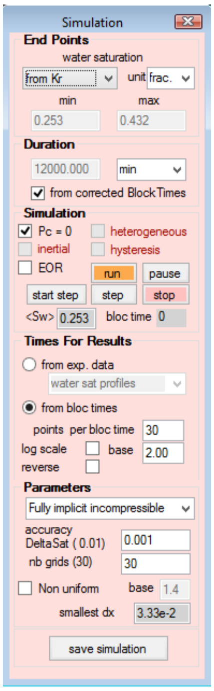
number block times 2
Rapoport Number ☐

● incremental time ○ cumulative (time at end of step)

\	Duration	water rate	C alkali	C surfactant	C polymer	Salinity 1
▸ 1	100.000	3.000	0	0	0	260
2	100.000	3.000	0	0	0	1.5

- You can enter Kr and Pc for simulation without EOR enabled (1^{st} sheet of the Excel file).

Simulation



Simulation

End Points
water saturation
from Kr unit frac.
min 0.253 max 0.432

Duration
12000.000 min
☑ from corrected Block Times

Simulation
☑ Pc = 0 ☐ heterogeneous
☐ inertial ☐ hysteresis
☐ EOR
<Sw> 0.253 bloc time 0

Times For Results
○ from exp. data
water sat profiles
● from bloc times
points per bloc time 30
log scale ☐ base 2.00
reverse ☐

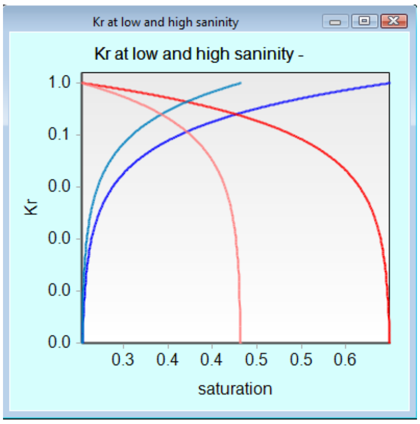
Parameters
Fully implicit incompressible
accuracy DeltaSat (0.01) 0.001
nb grids (30) 30
☐ Non uniform base 1.4
smallest dx 3.33e-2

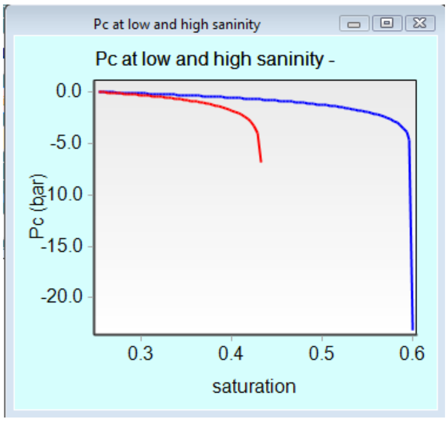
Direct simulation may be run by opening the simulation window.

To enable the EOR check the “EOR” box.

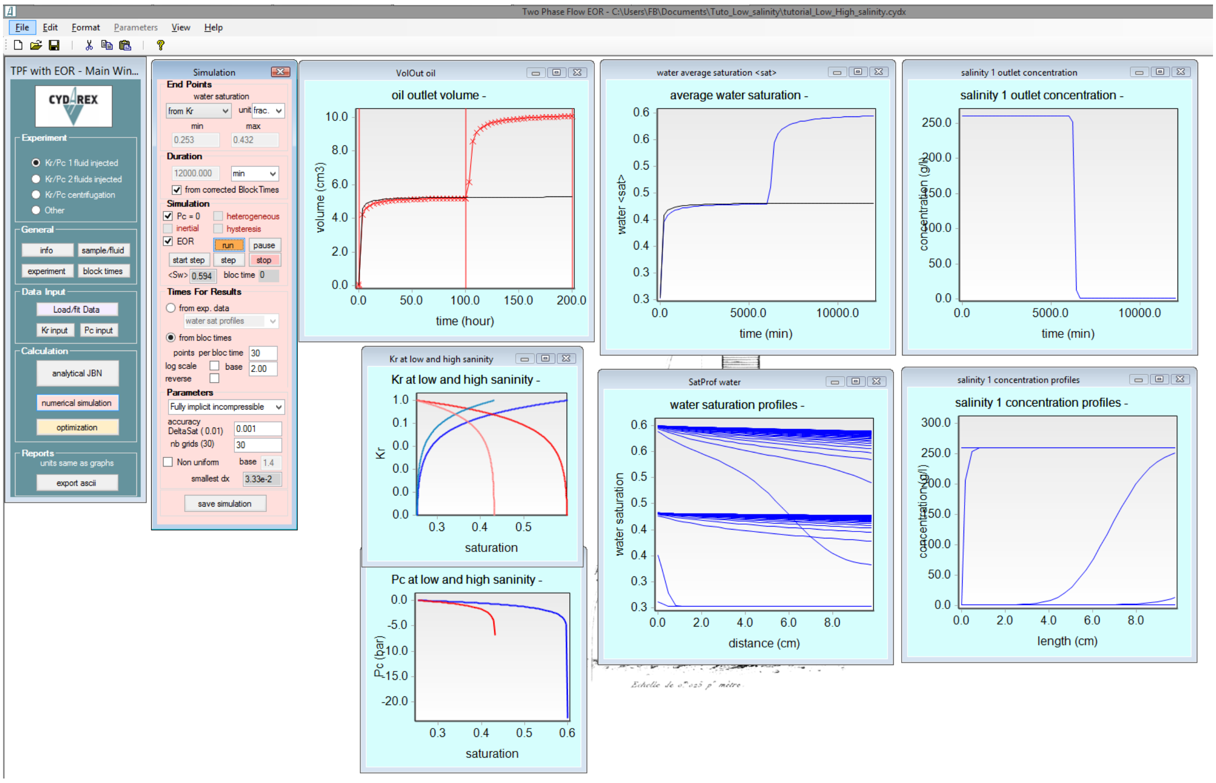
We recommend an accuracy DeltaSat at 0.001 at least.

When the EOR is enabled the local Kr and Pc will be taken according to the local salinity value by a kind of interpolation between low and high data.





The figure below shows the result of the direct simulation without capillary pressure. The black curve stands for the simulation without the EOR option enabled. We can see the effect of the decrease of Sor.


Two Phase Flow EOR - C:\Users\FB\Documents\Tuto_Low_salinity\tutorial_Low_High_salinity.cydx

Experiment: ● Kr/Pc 1 fluid injected

End Points
water saturation: from Kr, unit frac.
min 0.253 max 0.432

Duration
12000.000 min
☑ from corrected Block Times

Simulation
☑ Pc = 0 ☐ heterogeneous
☐ inertial ☐ hysteresis
☑ EOR
<Sw> 0.594 bloc time 0

Times For Results
○ from exp. data water sat profiles
● from bloc times
points per bloc time 30
log scale ☐ base 2.00
reverse ☐

Parameters
Fully implicit incompressible
accuracy DeltaSat (0.01) 0.001
nb grids (30) 30
☐ Non uniform base 1.4
smallest dx 3.33e-2