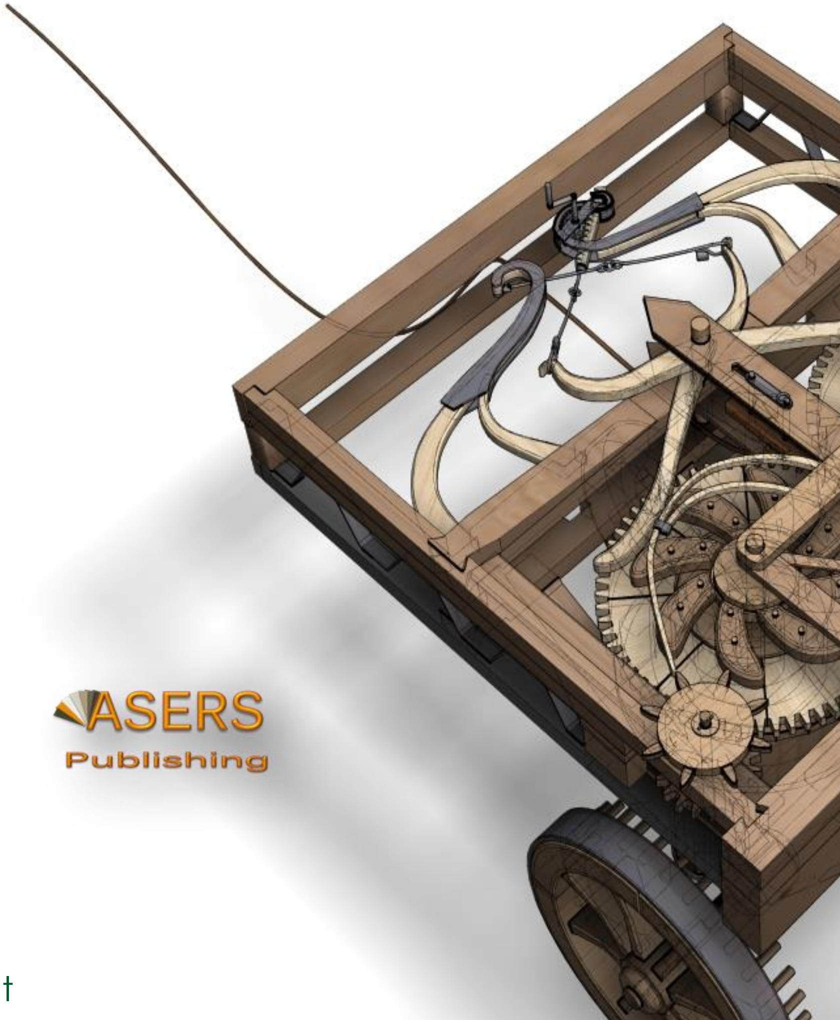
ASERS

Journal of Environmental Management and Tourism



Quarterly
Volume IX
Issue 3(27)
Summer 2018

ISSN 2068 – 7729
Journal DOI
http://dx.doi.org/10.14505/jemt

ASERS
Publishing

SUMMER 2018
Volume IX
Issue 3(27)

Contents:

SUMMER 2018
Volume IX
Issue 3(27)

ASERS Publishing
http://www.asers.eu/asers-publishing
ISSN 2068 – 7729
Journal DOI: http://dx.doi.org/10.14505/jemt

Call for Papers
Fall Issues 2018
Journal of Environmental Management and Tourism

Journal of Environmental Management and Tourism is an interdisciplinary research journal, aimed to publish articles and original research papers that should contribute to the development of both experimental and theoretical nature in the field of Environmental Management and Tourism Sciences.

Journal will publish original research and seeks to cover a wide range of topics regarding environmental management and engineering, environmental management and health, environmental chemistry, environmental protection technologies (water, air, soil), pollution reduction at source and waste minimization, energy and environment, modeling, simulation and optimization for environmental protection; environmental biotechnology, environmental education and sustainable development, environmental strategies and policies, etc. This topic may include the fields indicated above, but are not limited to these.

Authors are encouraged to submit high quality, original works that discuss the latest developments in environmental management research and application with the certain scope to share experiences and research findings and to stimulate more ideas and useful insights regarding current best-practices and future directions in environmental management.

Journal of Environmental Management and Tourism is indexed in SCOPUS, RePEC, CEEOL, ProQuest, EBSCO and Cabell Directory databases.

All the papers will be first considered by the Editors for general relevance, originality and significance. If accepted for review, papers will then be subject to double blind peer review.

Deadline for submission:	15th August 2018
Expected publication date:	September 2018
Website:	https://journals.aserspublishing.eu/jemt
E-mail:	jemt@aserspublishing.eu

To prepare your paper for submission, please see full author guidelines in the following file: JEMT_Full_Paper_Template.docx, then send it via email at jemt@aserspublishing.eu.

DOI: http://dx.doi.org/10.14505/jemt.9.3(27).14

Improvement of Uniform Oil Displacement Technology on the Example of Kazakhstani Fields

Abdeli D. ZHUMADILULI
School of Geology and Oil and Gas Business named after K. Turysov
Satbayev University, Republic of Kazakhstan
d.abdeli@mail.ru

Irina V. PANFILOV
University of Lorraine, High National School of Geology
Vandoeuvre-les-Nancy, France
irina.panfilova@univ-lorraine.fr

Jamilyam A. ISMAILOVA
School of Geology and Oil and Gas Business named after K. Turysov
Satbayev University, Republic of Kazakhstan
djamilya577@gmail.com

Suggested Citation:

Zhumadiluli, A.D., Panfilov, I.V., Ismailova J.A. (2018). Improvement of Uniform Oil Displacement Technology on the Example of Kazakhstani Fields. *Journal of Environmental Management and Tourism,* (Volume IX, Summer), 3(27): 542-552. DOI:10.14505/jemt.v9.3(27).14

Article's History:

Received April 2018; *Revised* May 2018; *Accepted* May 2018.

Abstract:

Most of oil companies today are focused on increasing the recovery factor from their oil fields. New drilling and well technologies as well as last advances in reservoir management, monitoring and Enhanced Oil Recovery (EOR) methods are thought to play a major role to meet the future demand of energy. Current decline in discovery of new oilfields intensified by a decline in oil prices make industrial companies to work on development of new efficient and economic techniques that will allow better production at lower cost. One such technology developed at Kazakh National Research University is presented in this paper. The latter propose the use of specific perforated holes on tubing liners in order to control the rate of water injection into variably permeable layers and to prevent non-uniform displacement of oil. The study was initially conducted on experimental facility that proved a positive correlation between the perforation density and water flow rates. Then the simulation test was performed using the data from several Kazakhstani oil fields. The results show an increase of sweep efficiency as well as a decrease in water-cut compared to traditional well case.

Keywords: reservoir heterogeneity; sweep efficiency; water cut; recovery factor; uniform oil displacement

JEL Classification: Q10; Q16.

Introduction

Many reservoir formations represent an irregular permeability profile. Such a heterogeneities lead to the irregular flood fronts of the injected water and its advance in the shape of fingers if the traditional technique is used. The presence of the layers with very high permeability results in water breakthroughs into the producing wells that bypass the oil volumes of reservoir leaving them unswept (Gazizov 2002). Currently, due to reservoir heterogeneity, there are common problems as early water breakthroughs, low oil recovery factors. Water reaches production wells through high permeable layers, low and medium permeable layers still contains oil (Gazizov 2002).

Since the 80s of the last century, numerous methods are being actively introduced to obtain close to uniform sweep in heterogeneous reservoirs. Previous works have been focused on chemical Enhanced oil Recovery (EOR) among which the most widespread was polymer flooding technique, as well as its various modifications. However, according to the analysis of the literature (Gazizov 2002; Choi *et al.* 2004; Sheng 2013; Ekwere 2012; Needham and Doe 1987; Zhang *et al.* 2000; Hirasaki et al. 2011; Wang *et al.* 2012; Li 2014; Panthangkool and Srisuriyachai 2013; Shenglong *et al.* 2015; Muruaga *et al*. 2008; Temizel *et al*. 2016; Dang *et al.* 2014; Hou *et al.* 2006; Ghedan 2009; Al Ayesh *et al.* 2016; Shotton 2016), there are not only a number of limitations in the application of these technologies. Additionally, there is effect of retaining and preserving the agent in the middle and low-permeability zones of the formation, adsorption of the agent that occurs on the pore walls (Choi *et al.* 2004). The use of "smart completion" was suggested by a number of authors (Sheng 2013), but these technologies have a number of drawbacks, which include the complexity of execution and control of injection only in the near-well zone. Recent developments of “smart wells” were made by Schlumberger and Halliburton companies. Besides separate injection of polymers with different concentrations into different permeability zones (Ekwere 2012), was proposed by a number of authors, nevertheless such a method is still difficult to perform. Therefore, despite the interest in this area, there still no unique technology to control the sweep of injected water. A major difficulty lies on geological heterogeneity of reservoirs.

Generally accepted technology of water injection in majority of Kazakhstani oil fields involves injection through tubing bottom into pay zone, and then water goes to high permeable layers and reaches production well, while less permeable layers not flooded and still contain oil. Though, this traditional technology doesn’t take into account reservoir heterogeneity.

Current study aims at reducing the detrimental effect of water entering into the higher permeability zones and proposes a method for improving the oil recovery by control of the water injection rates into different formation horizons. The results demonstrate that the adjustment of the size of perforated holes on the tubing liner allows performing more efficient and uniform displacement of the oil volumes and reducing bug water-cuts on the production well.

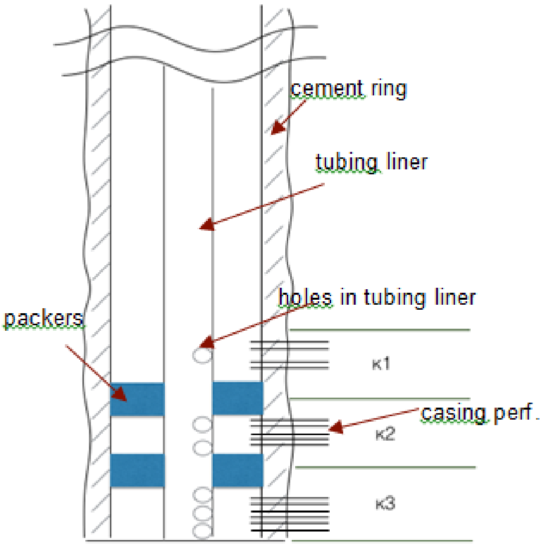
Simultaneous water injection and uniformity of the displacement front is organised through simultaneous water injection by perforated holes of tubing liner.

1. Technology description

Tubing liner of injection well is installed till the bottom of pay zone with the closed at the end and perforated along reservoir pay zone; liner has different perforation densities, as well as cased hole and cement, depending on interlayers’ permeability. The agent is injected into each seam of different permeability by different flow rate that controlled by both number and diameter of perforated holes. Retrievable packers are installed to separate interlayers.

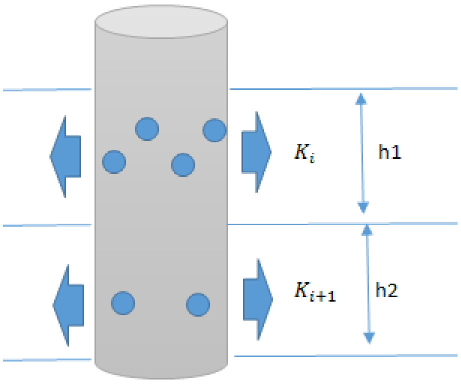
The scheme of tubing liner is shown in Figure 1. This scheme is applicable for multi-layer deposits as Uzen, Kumkol, Karazhanbas, etc in the Republic of Kazakhstan.

Figure 1. Scheme of tubing liner at the injection well



For example let's assume that we have three interlayers with different permeability, so that k1>k2>k3 (figure 2). Thereby, into interlayer k3 water is proposed to be injected within higher perforation density of tubing liner. At the same time injection into the interlayer k1 controlled by lower perforation density of tubing liner.

Figure 2. Scheme of choosing the appropriate rate for each layer



Velocity in each layer is governed by Darcy low. Thus, the different permeability of the layers will lead to the different injection velocities into each interlayer. Let us assume to have two layers with K_i and K_{i+1} permeability of *h1* and *h2* respectively, where h is a layer thickness. Wherein $K_{i+1} > K_i$

According to Darcy law, the total velocity in each *i*-layer is defined as:

$$\frac{\rho}{V_i} = \frac{K_i}{\mu} \frac{(\Delta P + P_c)}{L} \tag{1}$$

where: ΔP, P_c - pressure difference in the layer and capillary pressure respectively, L - layer length, μ - fluid viscosity.

For the sake of simplicity we assume that fluid viscosity, layers length and thicknesses are identical for each presented layer, then:

$$V_i \approx K_i * \Delta P_i \tag{2}$$

Trivial to verify that flow rates through each segment:

$$Q_i = \frac{K_i * A_i * \Delta P_i}{\mu * L} \tag{3}$$

To have uniform water propagation through heterogeneous layers, water velocities in each layer should be equal. Thereby if two layers are present:

$$\frac{K_{i+1}}{K_i} = \frac{A_i}{A_{i+1}} \tag{4}$$

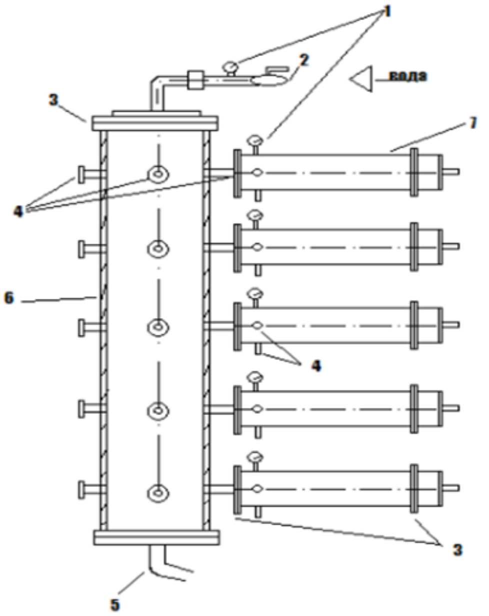
$$A_i = \frac{K_{i+1} * A_{i+1}}{A_{i+1}} \tag{5}$$

This theoretical approach allows to obtain equal velocities of injected water in each layer, perforated area in tubing liner at lower permeability layer (K_i) should be $\frac{K_{i+1}}{K_i}$ times higher than in higher permeability layer (K_{i+1}) and is further tested in reservoir simulations.

2. Experimental setup

Prior to performing numerical modelling the experimental facility has been built in order to test the effect of different layer perforation. The apparatus shown in figure 3 composed of a column 6 with a diameter of 133 mm and a height of 1.8 m with bends in form of pipes of smaller diameter 7 through each 400 mm. There are four connections 4 between main column and each pipes 7. Increasing the number of connections 4 to bend 7 from one to four connections we increase perforation density of tubing liner. Water enters experimental setup through the choke 2 attached to the main pipe 6 by flange connections 3. Through the connections 4, water is further supplied to the pipes 7. Excess water is discharged through outlet 5. The unit is equipped with pressure gauges 1, at the inlet to main pipe 6 and bends 7.

Figure 3. Scheme of choosing the appropriate rate for each layer



Column 6 imitates a perforated tubing liner. The number of connections 4 varies depending on the permeability of the corresponding interlayer. Horizontal pipe bends 7 corresponds to interlayer filled with sand of different fractions.

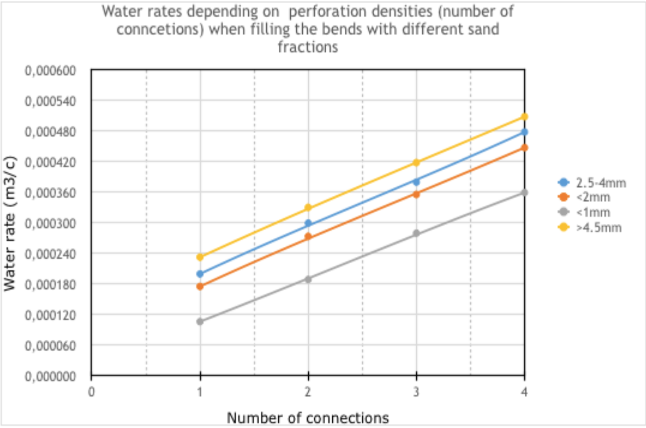
The aim of an experimental work is to establish rational regimes and parameters of simultaneous oil displacement through layers of different permeability.

To perform the experimental work, sand of fractions more than 4.5 mm, 4.5-2 mm, less than 2 mm and less than 1 mm were prepared. Four horizontal tubes were filled by sand of prepared fractions respectively and compacted. Water was injected through the choke into experimental setup; pressure at the inlet was 0.4 MPa, pressure at the outlet equals to atmospheric pressure. Water rates were recorded when one hole was connected to each bend; then we increase connections i.e. increase perforation density of a tubing liner, thereby two holes were connected, then three holes and finally all four holes were connected to each bend. Pressure gauges recorded pressures at the inlets of bends. Experiment was repeated 3 times.

3. Results and discussions

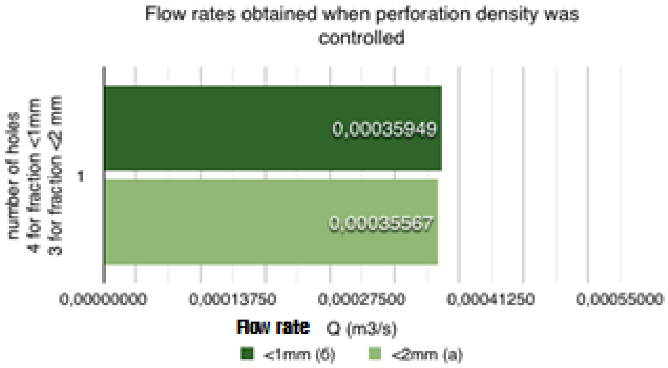
The first set of analyses investigates the dependence of water rates on perforation densities, i.e. number of connections 4 in the experimental setup to the bends 7. Changes in flow rates depending on perforation densities demonstrated in figure 4, where yellow, blue, red and grey lines represents flow rates through bends filled by sand fractions of more than 4.5 mm, 2.5-4 mm, less than 2 mm and less than 1 mm fractions respectively.

Figure 4. Water rates depending on perforation densities



According to results, with the increase of perforation density, the flow rates increases; thereby rate could be controlled using appropriate number of perforation holes.

Figure 5. Uniform flow rates when perforation density was controlled.



Further tests aimed on choosing perforation density for each sand fraction to reach unique fluid propagation. Thus, in the presence of two layers with different permeability, when first bend was filled by sand of fracture less than 2 mm (a), second with sand fraction is less than 1 mm (b), the required number of holes for case (a) - 3 holes, for case (b) - 4 holes, that enables to obtain uniform fluid flow.

Result obtained during experiment is shown in Figure 5. The test showed that use of 4 perforation holes for sand fraction less than 1 mm with the 3 perforation holes for sand fraction less than 2 mm allows obtaining same fluid rates at the outlet of bends. Remarkably that the difference in the final flow rates of the liquid is 0.00000382 m3/s. The analysis confirms the relation between permeability of layers and perforation density $(\frac{K_{i+1}}{K_i} = \frac{A_i}{A_{i+1}})$. Hereby, uniform liquid flow rates at the outlets from horizontal bends represent a uniform displacement front in heterogeneous layers.

4. The Simulation model

Software application ECLIPSE100 was chosen to see the effect from perforated tubing linear on field oil production total and making forecast for 82 years. The data from real Kazakhstani fields were used for the simulation with Eclipse 100. The Black Oil model means the resolution of the mass balance equations for the two phase system. The geometry of model was chosen as a vertical cross-section of the reservoir with the sufficient thickness in y-direction to observe the effect of heterogeneity on the recovery factor. The thermodynamic behavior of reservoir fluid system was taken from the properties of the real field fluids. Local grid refinement of numerical grid was used to simulate tubing linear with different perforations. Datum depth in this model is 4245.41 ft., pressure at datum depth is 2160 psia.

Two cases were modelled within Eclipse 100. First deals with field Y that has layers of different permeability and impermeable layers within them. Second case is about horizon that is totally hydrodymanicaly connected, i.e. it doesn't have impermeable layers.

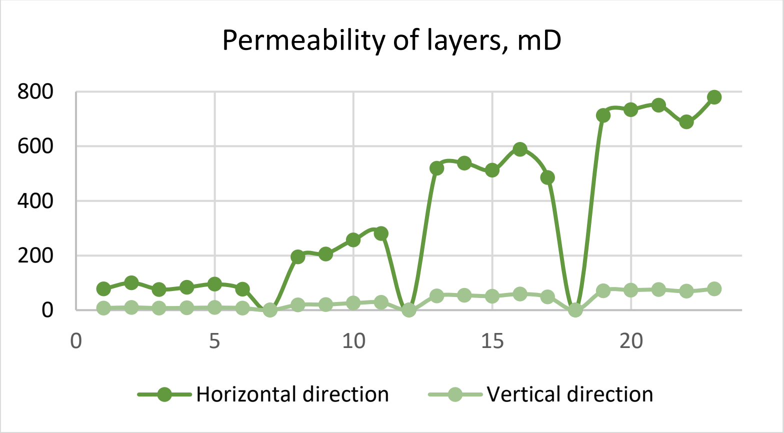
Case1. Y field with impermeable layers within pay zone

The field is heterogeneous and has several thin impermeable layers within pay zone. Porosity is homogeneous and equal to 0.2. Oil saturation equal to 0.8.

Grid section: The number of cell is 8050 with local grid refinement of wellbore zone that is 67420 cells. Model has 23 layers with different permeability.

Permeability variations: Model consists of 23 layers with different permeability (Figure 6).

Figure 6. Layers permeability



Base case

In the base case perforation of injection well in traditional from top of production layer till bottom of production layer. Completion data was inputted using COMPDATL keyword. Well was perforated from top till bottom of a pay zone with coordinates: i= 1, j=8, k=from 1 till 483 cell. Well is open and has diameter of 0.67 ft.

Perforated liner case

In the perforated liner case perforation connections were chosen according to permeability within production layer. Thus perforated tubing has four sections, with different perforation density of a tubing liner. First section perforated from 1 till 126 cells, second section from 148 to 193 cells, third from 253 till 271 and the last one from 379 till 384 cell.

Case 2. Pay zone without impermeable layers.

The field is heterogeneous and doesn't have impermeable interlayers within pay zone. Porosity is homogeneous and equal to 0.2. Oil saturation equal to 0.8.

Base case

In the base case perforation of injection well in traditional from top of production layer till bottom of production layer. Well was perforated from top till bottom of a pay zone with coordinates: i= 1, j=8, k=from 1 till 483 cells. Well is open and has diameter of 0.67 ft.

Perforated liner case

Perforated tubing has two sections, with different perforation density of a tubing liner. First section perforated from 1 till 40 cells, second section from 71 to 78 cell.

5. Simulation results and discussions

Case 1. Y field with impermeable layers within pay zone

Figure 7. Injected water propagation (perforated linear case); a-at the middle time of injection, b-at the end of injection

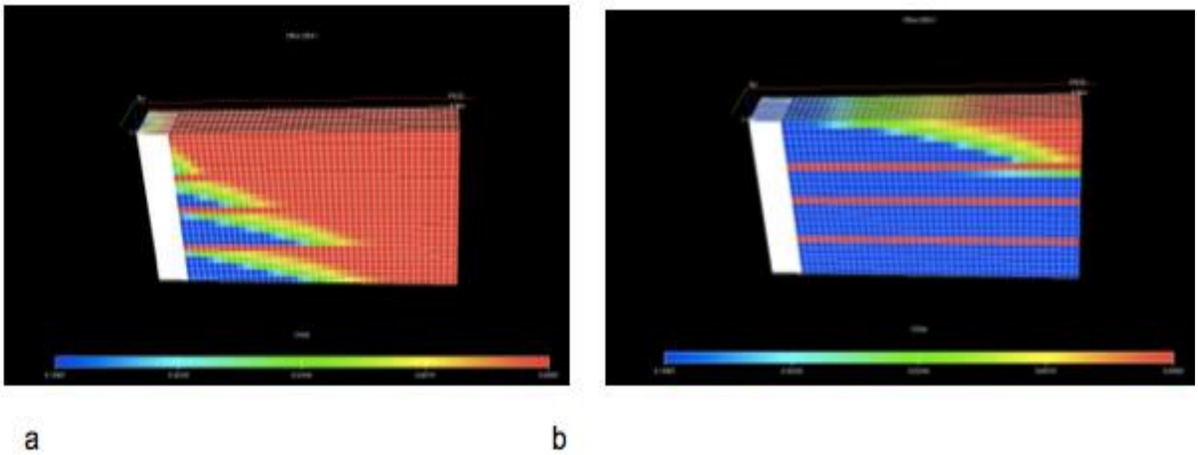


Figure 8. Injected water propagation (traditional well case); a-at the middle time of injection, b-at the end of injection

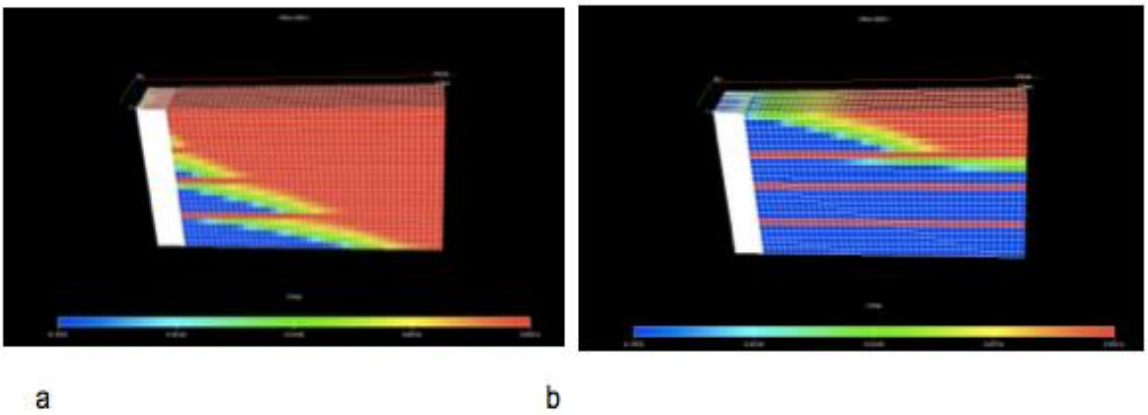
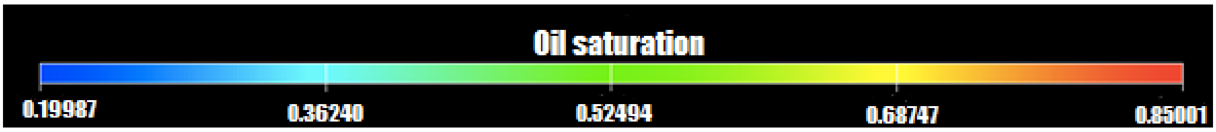


Figure 8c. Oil saturation scale



Simulation results are in line with experimental results. As indicated previously to have close to uniform sweep perforated area in tubing liner at lower permeability layer (K_i) should be $\frac{K_{i+1}}{K_i}$ times higher than in higher permeability layer (K_{i+1}).

Figures 7 and 8 shows injected water propagation through layers. Color legend represents oil saturation, where red color- maximum of oil saturation, blue color is minimum of oil saturation and maximum of water saturation (figure 8c). Within 23 interlayers impermeable thin layers of clay are present. Better sweep efficiency of water propagation is demonstrated in figure 7a, where perforated tubing linear was used in comparison with figure 8a, where tubing ends at the top of pay zone and perforation is traditional.

We found much higher values of field oil production total (FOPT) for the field Y for proposed technology – perforated tubing liner case (blue curve) than FOPT for traditional well case that is green curve. There was a significant positive effect from simultaneous injection with different rates. The difference between FOPT of proposed technology with traditional one is 274896.3STB.

The figure 9 provides additional support for the effectiveness of proposed technology. As you see well water cut for proposed technology that is light blue curve is lower for first 54 years in comparison with well water cut for traditional well case that is dark blue curve. After 20 000 days (54 years) water cut of proposed technology and water cut of traditional well become equal for approximately 6000 days;

Figure 9. Field oil production total

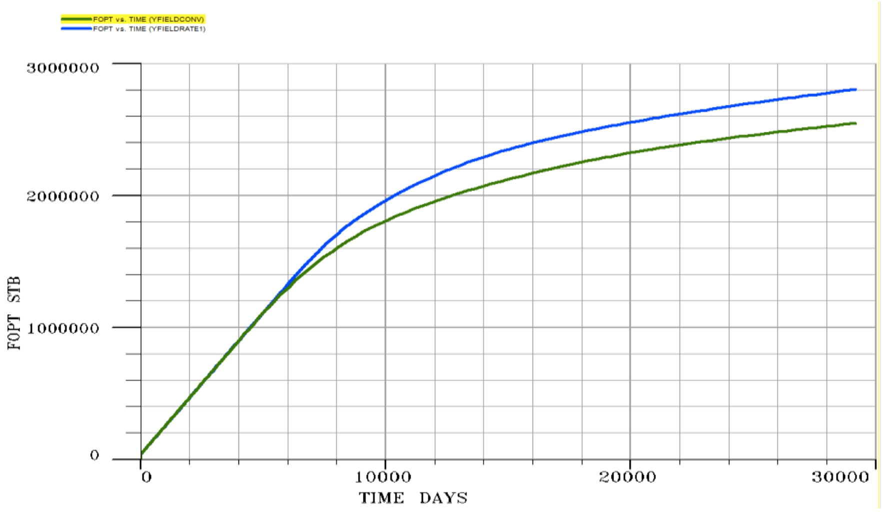
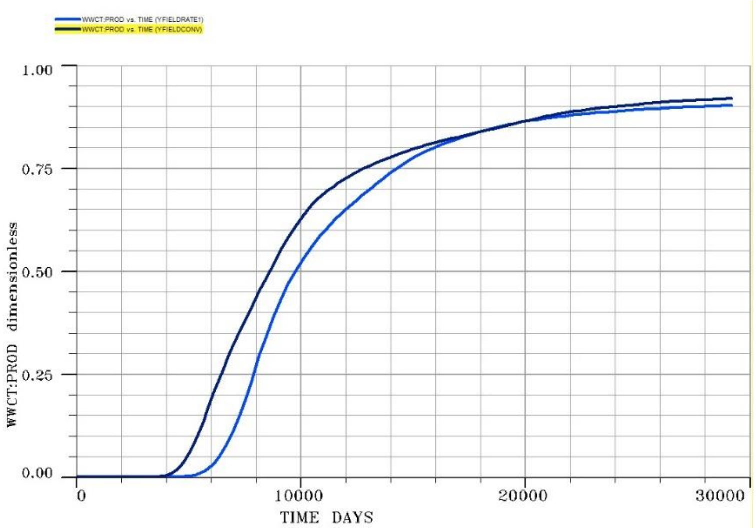
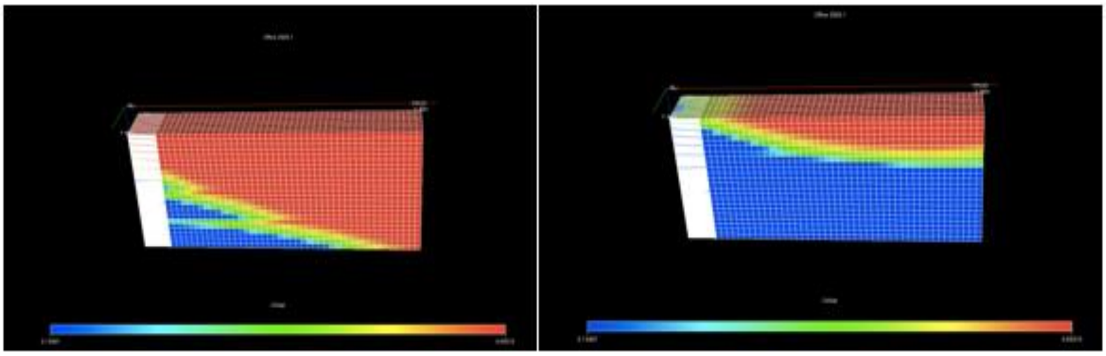


Figure 10. Well water cut*



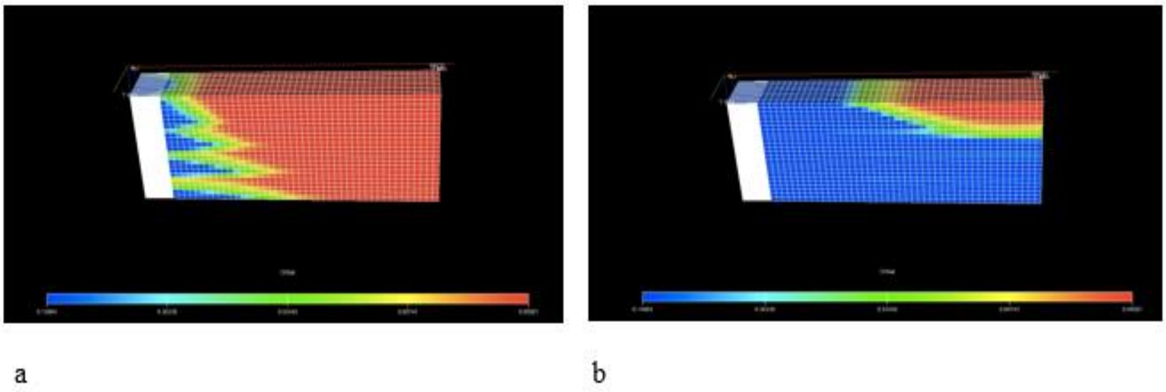
Case 2. Pay zone without impermeable layers.

Figure 11. Injected water propagation (traditional well case); a-at the middle time of injection, b-at the end of injection



a b

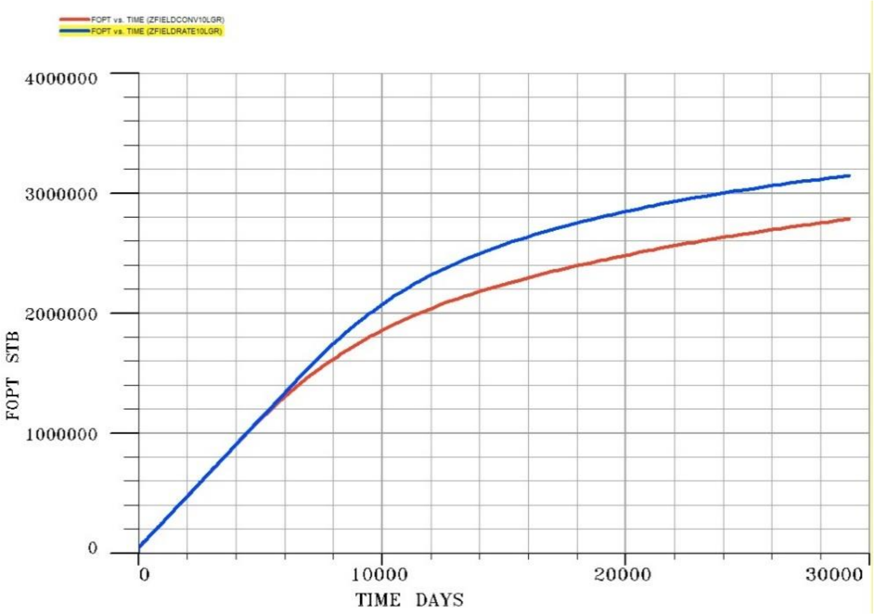
Figure 12. Injected water propagation (perforated linear case); a-at the middle time of injection, b-at the end of injection



Case 2 results are consistent with case 1 results. Although in this case all interlayers are hydrodynamically connected since this model doesn't have impermeable interlayers, the water propagation in proposed technology that (figure 12) is more unique in comparison with traditional well model (figure 11). This confirms that proposed technology clearly has an advantage over traditional one. Importantly, at the end of injection oil saturation in proposed technology model (figure 12 b) is lower than in traditional one (figure 11 b). Thus, results offer vital evidence of efficiency of proposed technology.

Figure 13 demonstrates the difference between field oil production total values in proposed technology that represented by blue curve and traditional well case that is red curve. This graph validates the positive effect when using perforated liner technique in contradiction with traditional well case. The difference between FOPT of proposed technology with traditional one is 219869.5 STB.

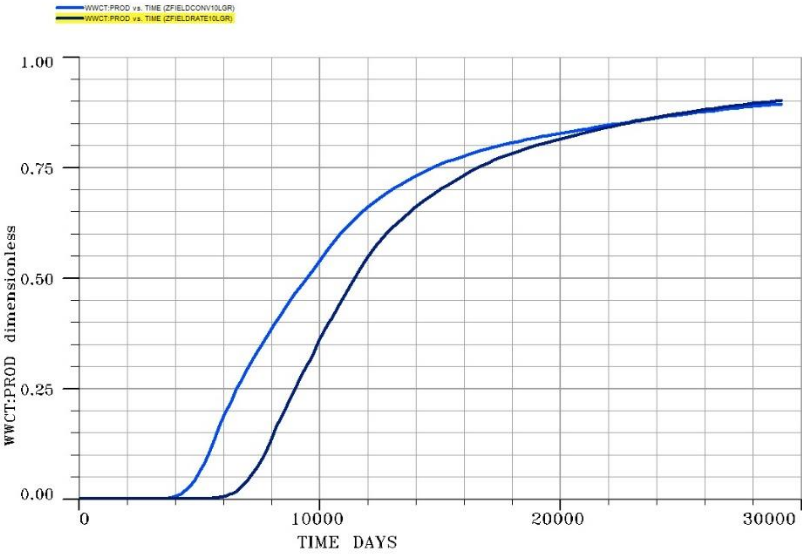
Figure 13. Filed oil production total



Well water cut for traditional well case increases starting from 4000 days of production (light blue curve). Significantly that when using proposed technology (dark blue curve) water cut appears only after 6000 days of production and during production life of a well this value is lower for proposed technique case. This supports previous results that highlights the positive effect of proposed technology.

From figure 9 and 13 one could say that traditional well has shorter period of constant rate in comparison with perforated tubing liner. It is explained by water cut that occurs later in perforated tubing liner case (figure 10 and 14).

Figure 14. Well water cut



Conclusion

This paper has investigated the effect from proposed technology of simultaneous water injection through tubing liner that has variable perforation density. The evidence from this study suggests choosing perforation area of tubing liner taking into account layer permeability ratio. Taken together experimental and simulation results one could highlight the effectiveness of proposed technology which ensures more uniform water flooding in comparison with traditional one used in Kazakhstani fields.

We aware that our research may have several limitations. Since the technology uses retrievable packers, there is limitation in quantity of packers that may be used. As the focus of study was on permeability variation within layers, the very high permeability difference causes difficulties in perforation density that controlled during water injection. The perforated area in tubing liner should be calculated for each case individually.

References

[1] Al Ayesh, A.H. *et al.* 2016. Foam Diversion in Heterogeneous Reservoirs: Effect of Permeability and Injection Method. *SPE Improved Oil Recovery Conference*, Tulsa, Oklahoma, USA.

[2] Choi, B., Yu, K. and Lee, K.S. 2014. Permeability-dependent retention of polymer in heterogeneous reservoirs. *Offshore Technology Conference-Asia,* Kuala Lumpur, Malaysia.

[3] Dang, T. Q. C., Chen, Z., Nguyen, T. B. N., and Bae, W. 2014. The Potential of Enhanced Oil Recovery by Micellar/Polymer Flooding in Heterogeneous Reservoirs. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects,* 36(14): 1540-1554.

[4] Ekwere, J.P. 2012. *Advanced Petrophysics: Volume 1: Geology, Porosity, Absolute Permeability, Heterogeneity, and Geostatistics.* Palo Alto: Live Oak Book Company.

[5] Gazizov, A.A. 2002. *Increase in oil recovery of heterogeneous strata at a late stage of development*. Moscow: Nedra-Business Center.

[6] Ghedan, S., Boloushi, Y., Khan K., and Saleh, M. 2009. Development of Early Water Breakthrough and Effectiveness of Water Shut off Treatments in Layered and Heterogeneous Reservoirs. *EAGE Reservoir Characterization and Simulation Conference*, Abu Dhabi, UAE.

[7] Hirasaki, G., Miller, C.A., and Puerto, M. 2011. Recent Advances in Surfactant EOR. *SPE Journal,* 16(4): 889-907.

[8] Hou, J.R., Dong, M.Z., Yang, J.Z., Liu, Z.C, and Yue, X.A. 2006. Effect of Viscosity of Alkaline/Surfactant/ Polymer (ASP) Solution on Enhanced Oil Recovery in Heterogeneous Reservoirs. *Journal of Canadian Petroleum Technology,* 45(11): 27–33

[9] Li, J.-J., Jiang, H.-Q., Hou, J.-R., and Wang, S.-L. 2014. The Effects of Oil Displacement Efficiency and Conformance Efficiency on Viscosity of ASP Flooding in a Heterogeneous Reservoir. *Petroleum Science and Technology* 32: 830-839.

[10] Muruaga, E., Flores, M.V., Norman, Ch., and Romero, J.L. 2008. Combining Bulk Gels and Colloidal Dispersion Gels for Improved Volumetric Sweep Efficiency in a Mature Waterflood*. SPE Symposium on Improved Oil Recovery*, Tulsa, Oklahoma, USA.

[11] Needham, R.B., and Doe, P.H. 1987. Polymer Flooding Review (SPE-17140). *Journal of Petroleum, Technology* 39(12): 1503-1507.

[12] Panthangkool, A., and Srisuriyachai, F. 2013. Evaluation of Polymer Flooding in Multi-Layered Heterogeneous Reservoir: The Study of Viscosity and Injection Rate of Polymer Solution. *ASEAN Forum on Clean Coal Technology*, Chiang Mai, Thailand.

[13] Sheng, J. 2013. Polymer practice in Daqing. *Enhance oil recovery field studies.* Houston, Texas: Gulf Publishing Company.

[14] Shenglong, S., Yefei, W., Zhongpeng, L., Mingchen, D., and Wuhua, C. 2015. Experimental Study on Stability and Improving Sweep Efficiency with Microfoam in Heterogeneous Porous Media. *Journal of Dispersion Science and Technology,* 37(8): 1152-1159.

[15] Shotton, M., Stephen, K., and Giddins, M.A. 2016. High-Resolution Studies of Polymer Flooding in Heterogeneous Layered Reservoirs. *SPE EOR Conference at Oil and Gas West Asia*, Muscat, Oman.

[16] Temizel, C., *et al.* 2016. Production Optimization under Injection of Biopolymer, Synthetic Polymer and Gels in a Heterogeneous Reservoir. *SPE Eastern Regional Meeting*, Canton, Ohio, USA.

[17] Wang, H., Xiaoqing, L., and Xue, S. 2012. Perforation Optimization for Regulating Production Profile of Horizontal Wells in Heterogeneous Reservoirs. *SPE Heavy Oil Conference Canada,* Calgary, Alberta, Canada.

[18] Zhang, Y., Xiangan, Y., Jianxia, D., and Liu, Y. 2000. New and Effective Foam Flooding To Recover Oil in Heterogeneous Reservoir. *Conference: SPE/DOE Improved Oil Recovery Symposium,* Tulsa, Oklahoma.

ASERS

ASERS
Publishing

Web: www.aserspublishing.eu
URL: http://www.journals.aserspublishing.eu/jemt
E-mail: jemt@aserspublishing.eu
ISSN 2068 – 7729
Journal DOI: http://dx.doi.org/10.14505/jemt
Journal's Issue DOI: http://dx.doi.org/10.14505/jemt.v9.3(27).00