

# Analysis of enhanced recovery by treatment of bottom-hole zone of Potochnoye field

E M Almukhametova, A I Zakirov, D I Fattakhov, A A Faizullin

Oktyabrsk branch of Ufa State Petroleum Technological University, 451600, Oktyabrsky, Devonskaya str., 54a

E-mail: elikaza@mail.ru

**Abstract.** The work is aimed at analyzing the efficacy of a recovery enhancement technology by treatment of the bottom-hole zone of Potochnoye field. Such technologies become a must, if there is a possibility of dissolution of rocks or elements that sediment and reduce permeability. When developing a bottom-hole zone, the choice of reagents taking into account all reservoir conditions and the properties of its fluid should be scientifically justified. The results presented in this work are used when planning and implementing technologies for enhanced recovery by treating the field bottom-hole zone. The research analyzes laboratory experiments mimicking the conditions of Potochnoye field. We have studied the core samples of Uryevsk (zones YuV1, AB13 and Ach2) and Severo-Potochnoye (zone BV6) fields and their reaction to chemicals. Compound Eltinoks/1.2 was found to have low corrosion activity in reservoir conditions, correspond to requirements to iron content and stabilization, be compatible with water and completely suitable for operating conditions of Potochnoye field. In addition, the work considers the efficacy of the technologies and compounds for separate zones, which were used to make recommended compounds accounting for the compatibility of reagents with reservoir water, core solubility and compatibility with oil.

## 1. Introduction

Technologies for enhancing recovery by treatment of bottom-hole zone are widely used for increased oil recovery; they allow extending the coverage of development of nonuniform reservoirs having a large number of unwashed zones. Existing experience demonstrates that the treatment of the bottom-hole zone, which affects the reservoir, appreciably improves oil recovery [1]. This effect can be produced when treating the reservoir by hydrodynamic, thermal and physicochemical methods.

The possibility of increased reservoir fluid recovery grows substantially when using new highly effective equipment and technologies. The physicochemical treatment concurrently provides filter cake removal and dissolution of asphaltene sediments in the bottom-hole zone and allows increasing the production rate of low-production payzones consisting of clayish reservoirs due to recovery of reservoir porosity and permeability through cleaning and spread of existing channels and occurrence of new ones, stabilization in remote areas of the bottom-hole zone and along the whole perforated stratum.

## 2. Materials and Methods



Obtained results discussed in the paper are justified by the methods of core sample composition testing under conditions ultimately close to those in the field; also, the data before and after implementation of technologies were compared. The field data were processed on a personal computer using well-known and tested analytical methods. The developed recommendations were tested at oil field and demonstrated positive technological effect.

The results presented in this work are used when planning and implementing technologies for enhanced recovery by treating the field bottom-hole zone.

### 3. Results and Discussion

Let us investigate the results of recovery enhancement technologies using treatment of the bottom-hole zone of Potochnoye field [2].

From the start of development using production wells of Potochnoye field zones, 216 well operations were carried out involving field bottom-hole zone. The well operations involved the following wells: 125 production wells, 1 drilled well, 50 idle wells, 21 suspended wells, 19 piezometric wells.

The success ratio was 87%, total incremental oil production amounted to 288.05 kilotons, average effect duration is 275 days, average incremental oil rate is 5.2 tons per day, specific effectiveness is 1334 tons per well operation or 5.1 tons per day. The effect persisted in 31 wells stimulated from 2009 until 2011.

According to Fig. 1, the majority of activities was performed in 2011, 2010 and 2009 (39, 33 and 32 treatments, correspondingly). There were no treatments in 1984, 1985, 1986, 1989, 1992, 1993, 1995 and 1996. Maximum volume of incremental oil production was in 2010 (56.2 kilotons), while in 1983 and 1990 there was no any.

Treatment of bottom-hole zone on Potochnoye field was performed using the following technologies and compounds (Fig. 2):

- Technologies for bottom-hole zone treatment “Geliy” (119 well operations);
- hydrochloric treatment (HCT) (36 well operations);
- mud-acid treatment (MAT) (32 well operations);
- acid microemulsion (AME) (8 well operations);
- Eltinoks compound (7 well operations);
- Hydrovibration treatment (HVT) (2 well operations);
- Aksis compound (1 well operation);
- vibrowave depression-chemical impact, VDCI (1 well operation).

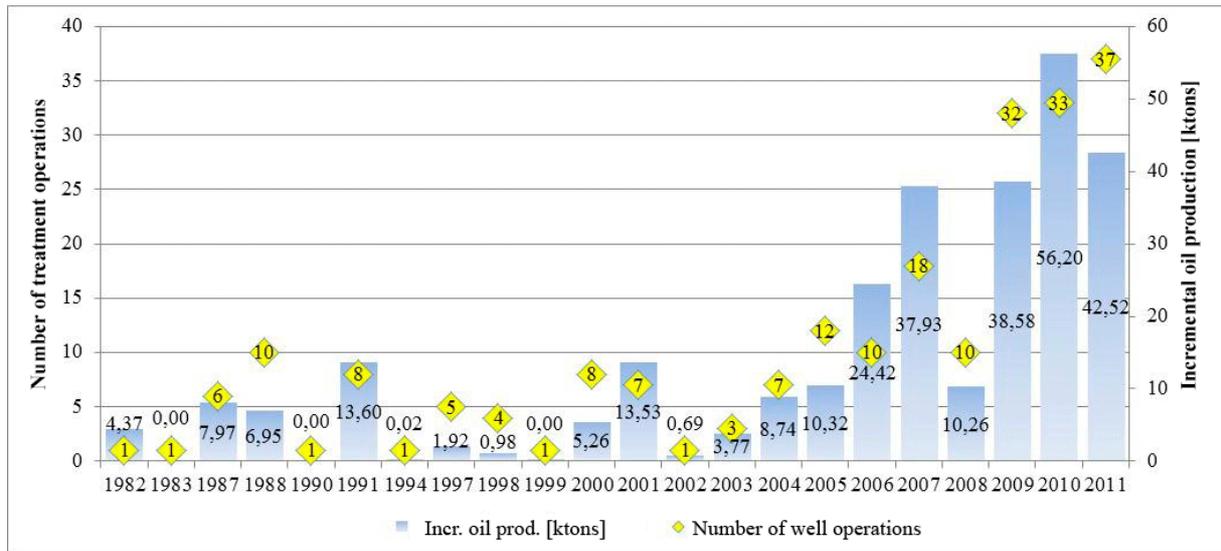
For 10 wells, there is no information on compounds used.

The majority of treatment operations were made for zones AV<sub>1-2</sub> and Ach (112 and 52 well operations, correspondingly). The next group includes zones BV<sub>6</sub>, BV<sub>8</sub> and BV<sub>10</sub> (27, 14 and 9 well operations, respectively) (Fig. 3). For each of zones BV<sub>5</sub> and YuV<sub>1</sub>, 1 well operation was performed.

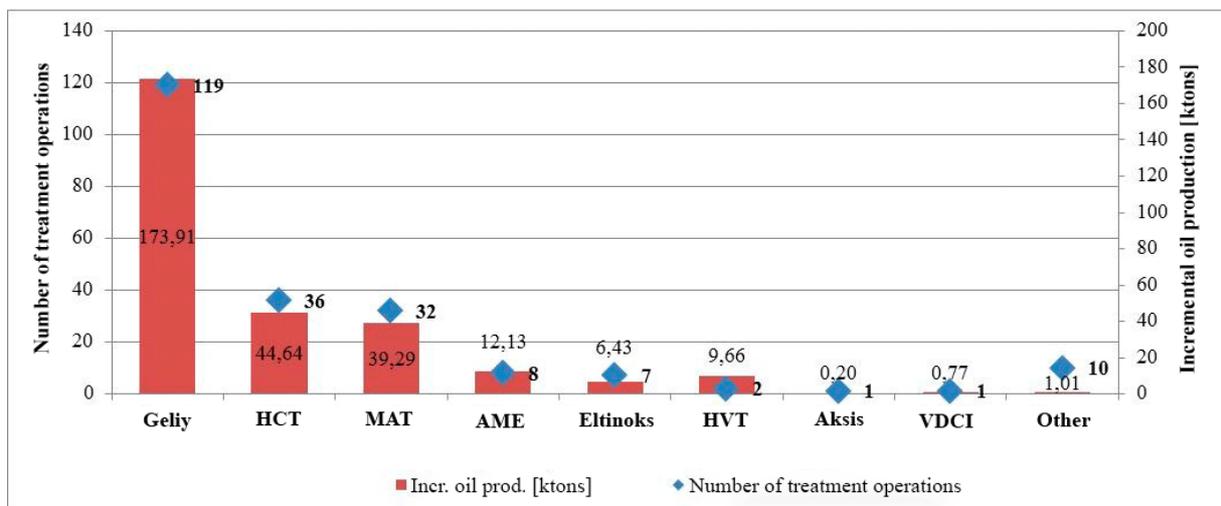
In general, the volume of incremental oil production corresponds to the number of treatment operations; there is nearly linear dependence between them [3].

For 36 well after bottom-hole zone treatment, the down hole pumping equipment was optimized. On the ground of calculated effect from equipment change and chemical bottom-hole zone treatment, we have established that:

- for 4 wells (nos. 937, 878N, 104N, 892N), the technological effect was conditioned by optimization of down hole pumping equipment;
- for 11 wells (nos. 1677, 1729, 589, 101, 2701N, 949, 137N, 1688B, 1677, 456, 198), the effect is combined (change of down hole pumping equipment + bottom-hole zone treatment);
- for 21 wells (nos. 780, 972N, 408N, 1962N, 987, 1833N, 730T, 130N, 456, 516, 1927N, 898N, 105B, 1926N, 108T, 2203, 958, 108T, 345N, 105N, 1795), the effect is conditioned only by chemical bottom-hole zone treatment.



**Figure 1.** Yearly distribution of incremental oil production and number of operations

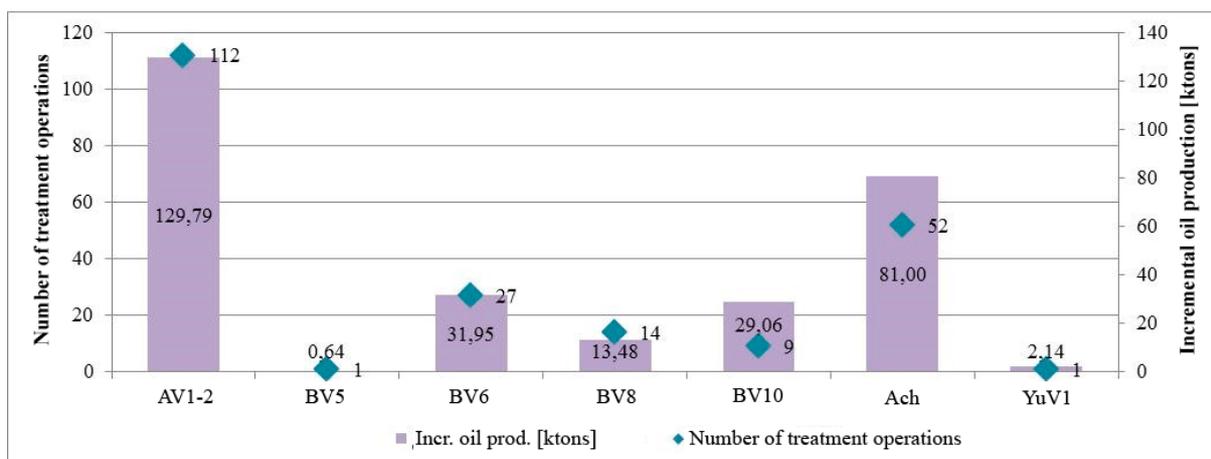


**Figure 2.** Distribution of incremental oil production and number of operations according to technologies/compounds

As a result of comparison of operation regimes of operating wells before and after bottom-hole zone treatment, we have established that:

- for 195 wells there is incremental fluid rate from 2 up to 344.29 tons per day; for 8 wells the fluid rate changed little (up to 2 tons per day); for 13 wells the rate decreased. Thus, from the perspective of incremental fluid rate, the treatment success amounted to 90%.

- for 151 wells the water cut increased up to 99%; for 10 wells it did not change; for 55 wells the water cut decreased down to 52%. We cannot discuss the reasons for water cut decrease due to lacking studies of flow profile before and after the treatment operations. Presumably, the water cut decreased due to changed flow profile [4].



**Figure 3.** Distribution of incremental oil production and number of operations according to zones

From 1982 to 2006, for 27 wells of Potochnoye field, the incremental oil rate was less than 1 ton per day because of water cut along highly permeable interlayer by underlying or injected water, clogging of porous space by reaction products, well lining failure and untimely repair works [5, 6].

Over 2007–2011, bottom-hole zone treatment had no effect on incremental oil rate only for one well. This well was suspended from September 1988 until June 2008; after pumping equipment repairs and field geophysical tests it was put into operation with average monthly production of 1.8 tons per day. The main reason for low success of the treatment was water breakthrough (WBT) from the reservoir border zone along the highly permeable interlayer after installation of large horse-head pump on the well. The WBT is proved by settled well dynamic head before its shutting-in (901 m), which is larger than in the first month after bottom-hole zone treatment (1430 m).

The distribution of technological parameters in regard to the technologies used on Potochnoye field is shown in Table 1.

In laboratory testing for conditions similar to Potochnoye field we studied core samples from Uryevskoye (zones YuV<sub>1</sub>, AV<sub>1</sub><sup>3</sup> and Ach<sub>2</sub>) and Severno-Potochnoye (zone BV<sub>6</sub>) deposits and the effect of reagents on them (Table 2).

The most conclusive and closest to field conditions were tests of compounds on core samples [7].

To assess the acid composition, we determined their compatibility with reservoir water, corrosion activity, core sample solubility, stabilization of iron ions, prevention of formation of acid-oil emulsion fluids, dispersion of asphaltene-resin-paraffin deposits, high permeability and increase of core sample phase behavior.

**Table 1.** Distribution of technological parameters in terms of technologies used in zones of Potochnoye field

Zone	Technologies and compounds									Other bottom-hole zone treatment
	Gelijy	HCT	MAT	AME	Eltinok <sub>s</sub>	HVT	Aksis	VDCI		
AV <sub>1-2</sub>	Q <sub>incr</sub>	75.69	23.50	21.60	8.12	0.06	are	0.20	-	0.62
	N	64	18	16	5	1	-	1	-	7
	τ	285	277	257	507	15	-	72	-	87
	Δq <sub>HK</sub>	5.71	3.49	2.84	4.14	4.20	-	2.35	-	-5.03
	K <sub>av</sub>	1.18	1.31	1.35	1.62	0.06	-	0.2	-	0.09

BV <sub>5</sub>	$Q_{incr}$	-	-	0.64	-	-	-	-	-
	N	-	-	1	-	-	-	-	-
	$\tau$	-	-	174	-	-	-	-	-
	$\Delta q_{HK}$	-	-	7.38	-	-	-	-	-
	$K_{av}$	-	-	-	-	-	-	-	-
BV <sub>6</sub>	$Q_{incr}$	12.84	7.74	9.21	2.15	-	-	-	0.00
	N	10	7	7	2	-	-	-	1
	$\tau$	407	336	209	324	-	-	-	-
	$\Delta q_{HK}$	4.74	1.97	8.12	7.21	-	-	-	-0.97
	$K_{av}$	1.28	1.11	1.32	1.08	-	-	-	-
BV <sub>8</sub>	$Q_{incr}$	3.74	0.45	7.04	1.86	-	-	-	0.39
	N	2	2	7	1	-	-	-	2
	$\tau$	473	164	185	754	-	-	-	57
	$\Delta q_{HK}$	3.61	-18.03	7.50	2.00	-	-	-	1.68
	$K_{av}$	1.87	0.22	1.01	1.86	-	-	-	0.19
BV <sub>10</sub>	$Q_{incr}$	20.79	3.92	0.81	-	3.54	-	-	-
	N	5	1	1	-	2	-	-	-
	$\tau$	609	182	104	-	170	-	-	-
	$\Delta q_{HK}$	10.73	42.21	4.70	-	7.84	-	-	-
	$K_{av}$	4.16	3.92	0.81	-	1.77	-	-	-
Ach	$Q_{incr}$	60.85	6.89	-	-	2.83	9.66	-	0.77
	N	38	7	-	-	4	2	-	1
	$\tau$	223	250	-	-	134	440	-	130
	$\Delta q_{HK}$	7.66	3.84	-	-	7.04	12.43	-	6.75
	$K_{av}$	1.60	0.98	-	-	0.71	4.83	-	0.77
YuV <sub>1</sub>	$Q_{incr}$	-	2.14	-	-	-	-	-	-
	N	-	1	-	-	-	-	-	-
	$\tau$	-	375	-	-	-	-	-	-
	$\Delta q_{HK}$	-	6	-	-	-	-	-	-
	$K_{av}$	-	-	-	-	-	-	-	-

where  $Q_{incr}$  is incremental oil production, kilotons; N is the number of bottom-hole zone treatment operations;  $\tau$  is effect duration, days;  $\Delta q_{HK}$  incremental oil rate, tons per day;  $K_{av}$  specific effect, kilotons per well operation.

The basis for all acid compounds are water solutions of hydrochloric acid. According to the composition, the analyzed compositions can be divided into three groups:

- hydrochloric-acid Aldinol 20P, Eltinoks/1.1 and Eltinoks/1.2;
- mud-acid  $HCl_{ing}$ , Eltinoks/1.2 +1%HF;
- hydrochloric-acid with acetic acid, Flaksokor 210.

**Table 2.** Characteristics of acid compounds

o.	Reagent	Compound
	Inhibited HCl	Hydrochloric acid, hydrofluoric acid, corrosion inhibitor VNPP-2V
	Aldinol 20P	Hydrochloric acid, polyatomic alcohol, surfactant, corrosion inhibitor
	Eltinoks/1.1	Hydrochloric acid, corrosion inhibitor, sludge inhibitor,

Eltinoks/1.2	demulsifier, VR25 solvent
Eltinoks/1.2, HF	Hydrochloric acid, sludge inhibitor, corrosion inhibitor, demulsifier, VR25 solvent, 1% HF
Flaksokor 210	Hydrochloric acid, acetic acid, surfactant, corrosion inhibitor
Flaksokor 210, HBF <sub>4</sub>	

Relatively good results were obtained for Eltinoks/1.2. It has low corrosion activity in reservoir conditions, correspond to requirements to iron content and stabilization, be compatible with water and completely suitable for operating conditions of Potochnoye field [8].

#### 4. Conclusions

For zone YuV1 we recommend using complex compounds Eltinoks/1.2 with addition of hydrofluoric acid (no more than 1%) with time for reaction to finish. In wells with high carbonate content or carbonate sediments and in cases of well killing by calcium chloride, we recommend using this compound without hydrofluoric acid [9, 10].

For zone Ach<sub>2</sub> we recommend using pure Eltinoks/1.2 without hydrofluoric acid. This zone is recommended to be treated by acid without waiting for reaction to finish.

According to the results, the most favorable for zone AV<sub>1</sub><sup>3</sup> is compound Eltinoks/1.2 with addition of 1% hydrofluoric acid. This reagent is compatible with reservoir water; the core sample solubility is higher than average [11]. The initial solution and treated solution are compatible with oil.

For zone BV6, compounds Eltinoks/1.2 and Flaksokor 210 can be used. These compounds are recommended as basic ones. Wells with increased clayiness can be treated with addition of 1% hydrofluoric acid or 3% butyl phosphoric acid into mentioned compounds.

#### References

- [1] William Carey J, Zhou Lei, Esteban Rougier, Hiroko Mori, Hari Viswanathan 2015 Fracture-permeability behavior of shale. *Journal of Unconventional Oil and Gas Resources* **11** 27-43
- [2] Sharipov R R, Coyedjo A A, Quagu J M, Gazizova F I, Mingazov R R, Bashkirtseva N Yu 2017 Development of Reagents for Enhanced Oil Recovery of High-Temperature Formations. *Socar Proceedings* **2** DOI: 10.5510/OGP20170200316
- [3] David Dogon, Michael Golombok 2016 Wellbore to fracture proppant-placement-fluid rheology. *Journal of Unconventional Oil and Gas Resources* **14** 12-21
- [4] Bing Bai, Ken Carlson, Adam Prior, Caleb Douglas 2015 Sources of variability in flowback and produced water volumes from shale oil and gas wells. *Journal of Unconventional Oil and Gas Resources* **12** 1-5
- [5] Zeygman Yu V, Mukhametshin V Sh, Khafizov A R, Kharina S B, Abutalipova E M, Avrenyuk A N 2017 Peculiarities of selecting well-killing fluids composition for difficult conditions. *Neftyanoe Khozyaystvo - Oil Industry* **1** 66-69
- [6] Davletbaeva A Y, Kovalevaa L A, Nasyrova N M, Babadagli T 2015 Multi-stage hydraulic fracturing and radio-frequency electromagnetic radiation for heavy-oil production. *Journal of Unconventional Oil and Gas Resources* **12** 15-22
- [7] Mukhametshin V V 2017 The need for creation of a unified comprehensive method of geological and field analysis and integration of data on effective influence on the bottom-hole formation zone. *Neftyanoe Khozyaystvo - Oil Industry* **4** 80-84
- [8] Petrova L V, Sadvakasov A A, Zakirov A I, Valiev A M 2017 The main problems and prospects of development Romashkinskoye field. *The scientific heritage* **2-9** 53-56
- [9] Almukhametova E M, Akimov A V, Kalinina S V, Fatkullin I F, Gizetdinov I A 2017 Efficiency of preliminary discharge of stratum water in Tuymazinskoe oil field. IOP Conference Series: Earth and Environmental Science, 2017, Vol. 87, number 062001

- [10] Almukhametova E M, Gizetdinov I A, Kilmamatova E T, Akimov A V, Kalinina S V, Fatkullin I F 2017 Use of precipitate formation technology to increase oil recovery under Tarasovskoye field conditions . *IOP Conference Series: Earth and Environmental Science* **87** 052001
- [11] Kondrat O R, Hedzyk N M 2017 Increasing natural gas production from tight terrigenous reservoirs. *Socar Proceedings* **4** DOI: 10.5510/OGP20170400329