Deposits of the hydrocarbon raw materials of the Republic of Kazakhstan, where it is possible to introduce a microbiological method for stimulating the formation

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Abstract. The article is devoted to the analysis and systematization of data on hydrocarbon deposits in the Republic of Kazakhstan, highlighting those aspects that will allow the use of this method. The microbiological method of exposure refers to the chemical methods of the tertiary stage of development of oil reservoirs. It has already proven its effectiveness in highly depleted, waterflooded formations with irregular, diffuse oil saturation. Its main advantages are its relative cheapness, it does not require additional equipment during injecting of the microorganisms into the reservoir, and for their nutrition, as a rule, food industry waste is used, and its implementation cannot cause harmful effects on the environment. Also, a fairly extensive database was compiled, according to which various classifications of the republic's deposits were created.

1 Introduction

The purpose of the study was to identify the parameters needed for the introduction of the method of microbiological influence on oil reservoirs, justification of the need for its use, as well as collection, analysis and systematization of data on all known this type deposits of the republic.

Nowadays, when the reserves-to-production ratio is declining in all countries, which are advanced in oil production, the introduction of methods of improving oil recovery is more urgent than ever before.

Well-known are thermal (steam, hot water, formation combustion are used), gas (carbon dioxide, air, natural gas, nitrogen, flue gases, etc. are injected directly into the formation), chemical (oil is displaced by using surfactants, polymers, alkalis, acids and other reagents), hydrodynamic (water is injected), physical (using wave and electromagnetic radiation, hydraulic fracturing, drilling horizontal wells) and, naturally, combined methods.

Due to extensive application experience, their disadvantages are also known: when pumping steam and hot water, chemical reagents of various types, gases, equipment quickly wears out; and the use of physical methods initially requires the installation of expensive additional equipment.

In addition, when igniting the formation and using chemicals, it is impossible to avoid harmful effects on the environment. In the first case, combustion is difficult to control and as a result, instead of liquefied heavy hydrocarbons, only a dry residue, consisting only of low fractions can be obtained, which will no longer be

removed, plus gases that can be extremely hazardous to health will be released. And chemical solutions can permanently poison underground waters, which will entail the death of all flora on the surface.

2 About the method of the microbiological enhancement oil recovery (MEOR)

This method of exposure is of two types:

1. Method of the biostimulation – injection of nutrients for the development of populations of microorganisms already existed in the oil reservoir.

2. Method of the bioaugmentation – injection of both microorganisms, and nutrients.

These bacteria are aerobic and anaerobic, in the process of their development and life, they liquefy hydrocarbons, absorbing some of them and emitting gases.

Also, their colonies, growing, form biofilms, reducing the possibility of water crossflows, therefore this method is effective when applied in heavily flooded fields.

In comparison with the methods mentioned earlier, it is environmentally friendly, and this is one of the most important advantages today.

To implement it, there is no need to purchase additional equipment, you can simply use the existing one.

Bacterial nutrients can be food waste such as milk serum and molasses.

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3 Data about the characteristics of deposits, where the microbiological method was implemented

In order to derive general characteristics for the use of the above-mentioned method, articles about deposits were studied, where it had already been tested.

These are the projects of San Andres, Queen Sand, Tupunyo Refugio, Huabei, Xinjian [1], Norne [2], Romashkinskoe [3], Pirallahi [4, 5], Lisbon, Novo-Elkhovskoe, Pervomayskoe, Ersubaikinskoe, Berezovskoe, Sterrap [6], White Tiger [7], Bokor [8].

San Andres Project (U.S.A.): it was discovered in 1945, was produced by solution gas drive until the waterflood was started in 1967.

The Microbial EOR started in October 1994 oil in place was 239 bbls/ac-ft with an oil saturation of 41%. Current formation pressure is estimated at 1,000 psi. Rock properties are relatively inhospitable to microbes. The low 1.7 md average horizontal permeability would normally be indicative of pore throat sizes well below what microbes could enter. Reservoir temperature at 115°F is ideal for microbe growth. Average production per well is 14 barrels of oil per day at a 91% water cut.

After 19 months of microbe treating by 10% or 40 barrels per day are received.

Queen Sand Project (U.S.A.): it was discovered in 1984, this reservoir was quickly waterflooded due its very low solution gas content. Injection was begun in 1990 and oil production increased quickly from 200 to 2,500 barrels per day. This rate continued until late 1991 when a rapid decline began.

The Microbial EOR started in August 1992, oil in place was 758 bbls/ac-ft with an oil saturation of 56%. Rock properties are generally favorable for microbe colonization. Average permeability is 13 md with an upper limit of 300 md and provides adequate pore throat size for microbes to colonize. Additional permeability developed by fracture treatments with 60,000 gallons and 135,000 pounds of sand on initial completion provide excellent porous media for microbe colonization. Reservoir temperature at 110°F is ideal for microbe growth. Average production per well is 42 BOPD at 75% water cut.

After 24 months of treating by 43% or 300 barrels per day are received.

Tupungato-Refugio Project (Argentina): it was discovered in 1930. The field was produced by a combination of solution gas drive, water drive and waterflood.

Microbial EOR was started on one well in June 1994 and on the other two wells in March 1995. At the start of the project oil in place was 625 bbls/ac-ft with an oil saturation of 47% and a gas saturation of 10%. The wells are on approximately 42 acre spacing. Rock and fluid properties are all favorable for microbe colonization.

After 14 months of treating by 29% or 60 BOPD are received.

Huabei Project (P. R. China): it contains seven wells located in the Huabei Petroleum Administration Bureau. The wells, in the later stage of being waterflooded, are

scattered and not in the same reservoir. Therefore, while production data can be analyzed, reservoir performance cannot be determined for this grouping.

Microbial EOR started September 1994. The wells are rod pumped, with pumps set an average of 2,500 feet above the perforations. Reservoir and fluid parameters are all favorable for microbe growth.

Twelve months after the first treatment by 552% or 127 BOPD are received.

Xinjiang Project (P. R. China): it contains ten wells located in the Xinjiang Petroleum Administration Bureau. The wells, most in the later stage of being waterflooded, are scattered and not in the same reservoir. Therefore, while production data can be analyzed, reservoir performance cannot be determined for this grouping.

Microbial EOR started January 1995. The wells are rod pumped, with pumps set from 200 to as high as 6,000 feet above the perforations on one well. Reservoir and fluid parameters are all favorable for microbe growth.

Six months after the first treatment by 36% or 80 barrels per day are received.

Norne Project (Norway): was discovered in 1992, developing started in 1997. Oil density is 862 kg/m³, Sulphur content is 0,21%, oil viscosity – 3 mPa·s.

The incremental oil recovery due to biofilm formation can be around 2 % OOIP.

In conclusion, an incremental oil recovery of almost 15 % OOIP can be achieved by the combined effect of surfactant, biofilm formation and the resulting microscopic fluid diversion. Each mechanism contributes to the overall effect, where the main contribution comes from production of surfactant.

Romashkinskoye Project (Russian Federation): production started in 1975, carbonate collector, depth 493–515 m, porosity – 9,8%; pressure – 6–7 MPa, temperature of stratum – 17–23 °C, oil density 903 kg/m³, oil viscosity – 50–80 mPa·s, stratal water mineralization – 40–60 g/l.

The studying of the implementation of the Microbial EOR started in 1997. As the result 27% of residual oil can be recovered against 13% in the beginning.

Pirallahi Project (Republic of Azerbaijan): the production started in 1902. Before Microbial implementation oil production in the 3-d quarter of 2009 comparing with the 1-st decreased on 30%, production rate was 0,39.

Microbial EOR started in August 2009. For the well number 931 production increased from 0,7 tons per day up to 1,8 tons per day.

Lisbon Project (U.S.A.): North Carolina state. It was the first implementation of the Microbial EOR in 1954, which also was successful.

Novo-Yelkhovskoye, Pervomayskoye, Yersubakiyskoye, Berezovskoye Projects (Russian federation): they are operated by OJSC “TatNef”, water cut 90%, sandstone collectors.

After Microbial EOR implementation the production increased on 59,8; 44,5; 9,3; 7,4 thousand tons.

Sterrap Project (U.S.A.): Kansas State, depth of occurrence – 1600 m, water cut – 95%.

After Microbial EOR implementation, the production increased on 50-55 thousand barrels.

White Tiger Project (Socialist republic of Vietnam): it is located in the shelf, it's flooded by sea water, salinity 35-37 g/l, reservoir temperature 120°C, pressure 4 MPa.

After Microbial EOR implementation, the oil displacement efficiency amounted to 57.4%. Using a combined physico-chemical and microbiological method increased oil displacement efficiency by 14.2%.

Bokor Project (Malaysia): high viscosity crude (4 to 10 cp) and low oil specific gravity of 20°API, low recovery factor in major reservoirs ranges from 19% to 25% of its original oil in place. Water depth of near 220 feet below msl; porosity – 15-32%; permeability – 50-4000 mD; oil gravity – 19-22°API in the shallower reservoirs (1500 – 3000 Ft. ss) to 37°API in the deep reservoirs (6300 Ft. ss).

After Microbial EOR implementation over 5 months period significant increase of the oil production rate and reduction of water cut were observed. The average oil production rate for the period increases by 270 b/d, which is equivalent to 47% oil incremental.

Summarizing the data of these articles, we can draw the following conclusions:

Table 1. Range of characteristics for the application of the microbiological method of impact on oil deposits.

Options	Range
Depth of occurrence, m	180 – 2500
Total thickness, m	3,88 – 18,2
Collector types	terrigenous, carbonate
Open porosity, %	7,9 – 24
Permeability, mcm ²	0,03 – 300
Temperature, °C	17 – 120
Pressure, MPa	0,344 – 7
Density, kg/m ³	830 – 914
Water type	calcium chloride
Mineralization of groundwater, g/l	8 – 235

Taking into account everything, mentioned before, it is obvious, that MEOR is applicable for most of the existing fields.

4 Low-profit deposits in Kazakhstan in accordance with the official data

Naturally, in order to offer this method, first you need to find potential customers, collect information about fields, where it is already required, to implement methods for improving the oil recovery.

Although it is known, that most of the republic's oil reservoirs have been in operation for a long time, and, as written in the many articles, they are at a last stage of operation. The search on state sites gave the following results: relating to the Resolution of the Government of the Republic of Kazakhstan No. 449 dated June 27, 2019, and also the estimates of the independent experts we receive the following table.

Table 2. List of low-profit fields.

Field	Location	Geological reserves, mln tons
1. Containing high viscosity oils		
Temir district, Aktope region	Temir district, Aktope region	Temir district, Aktope region
Tupkaragan district, Mangistau region	Tupkaragan district, Mangistau region	Tupkaragan district, Mangistau region
Temir district, Aktope region	Temir district, Aktope region	Temir district, Aktope region
Isatai district, Atyrau region	Isatai district, Atyrau region	Isatai district, Atyrau region
2. Low-income		
East Akshabulak	Syrdarya district, Kyzylorda region	n/d.
North Akshabulak	Syrdarya district, Kyzylorda region	n/d.
Yeszhan	Syrdarya district, Kyzylorda region	n/d.
Zhylankabak	Zhylyoi district, Atyrau region	n/d.
Zholdybay	Makat district, Atyrau region	1,5 recov. - 297 thousand tons
Kalzhan	Syrdarya district, Kyzylorda region	n/d.
South Kamyskol	Zhylyoi district, Atyrau region	n/d.
Kokzhide post-salt	Temir district, Aktope region	50,9 on the 1 st Jan. 2008 res.rec.res. – 12,5
Krykmyltyk	Zhylyoi district, Atyrau region	n/d.
Tobearal	Kurmangazy district, Atyrau region	n/d.
3. Waterflooded		
Uzen	Karakiya district, Mangistau region	1100
Kumkol	Ulytau district, Karaganda region	90 280 - geol., 130 - recov., 15 bln m ³ gas
East Kumkol	Ulytau district, Karaganda region	n/d.
Arman	Mangistau district, Mangystau region	30
Karaarna	Zhylyoi district, Atyrau region	27,6 25,4 - recov.
East Kokarna	Zhylyoi district, Atyrau region	6,8 4 - recov.
Matin	Makat district, Atyrau region	30
North Pridorozhnoe	Beineu district, Mangystau region	30
4. Irreplaceable (worked out)		
Zhaksymay	Temir district, Aktope region	25
Shubarkuduk	Temir district, Aktope region	n/d.

It turns out there are only 24 fields, at the same time there is an article by NOC Kazakhoil, which states that out of 45 fields they operate, at least two, Dossor and

Makat, are among the oldest in terms of exploitation time [9].

In this paragraph, the abbreviation “n/d.” appears for the first time, meaning “no data”, i.e., unfortunately, this information is closed for public use. It will often meet further.

5 Classification of the hydrocarbon deposits of the Republic of Kazakhstan

Further searches for the necessary information led to even more interesting discoveries – the number of deposits, published on the Wikipedia site is 216 deposits, and those found by mentions in media publications for five months – 269.

The database in Excel format was compiled, which includes information on 289 fields, of which 269 are Kazakhstani and 20 foreign, where the microbiological method of stimulating the formation has already been introduced. As a result, we've got the following table:

Table 3. Comparison results.

Deposit volume	Known number of deposits (site Wiki2.org)	Number of deposits mentioned on the Internet
Supergiant (more than 5 bln tons)	1	2
Giant (more than 1 bln tons)	3	3
Large (from 100 mln tons)	11	29
Medium (from 10 mln tons)	26	42
Others	more than 1000	40
No data	-	153

The difference is quite tangible. Especially considering that the second supergiant, the Kurmangazy field, discovered in Soviet times with reserves of 6,200 million tons of raw materials and then called Kulalinskaya, for some reason is only mentioned in Russian sources, although its estimated reserves are only slightly inferior to Kashagan, which is the largest in the world offshore field with reserves of 6,400 million tons.

It's needed to pay attention to the fact that there are no data on the geological reserves of 153 fields out of 269, i.e. more than half of the known deposits are in operation without disclosing their characteristics.

Another classification was drawn up in accordance with a slightly different division by geological reserves [10].

Table 4. Second classification.

Options	Q-ty	Deposits' names
Unique deposits (more than 300 mln tons of oil &/ or more than 300	13	Bekturly, Darkhan, Kalamkas, Karachaganak, Kashagan, Khvalynskoye, Kurmangazy, Nursultan, Rakushechnoye-sea, Tengiz, Uzen, Zhanazhol, Zhetybai

Options	Q-ty	Deposits' names
Large deposits (deposits 30 – 300 mln tons of oil &/ or 30 – 300 mln m³ of gas)	42	Akshabulak, Aktoty, Arman, Asar, Atash, Bobek, Bozoba, Chinarevskoe, Dosmukhambetovskoe, Dunga, East and Central Prorva, East Tegen, Imashevskoye, Isatayskoye, Kairan, Kalamkas-sea, Karakuduk, Karaton-Koshkimbet, Karazhanbas, Karpovsky Northern block, Kenbai, Kenkiyak post-salt, Khasar, Kokzhide post-salt, Korolevskoye, Kultuk Mertvyi, Kumkol, Makhambet, Morskoye, Mortuk, North Buzachi, North Pridorozhnoye, North Truva, Prigranichnoye, Rakushechnoye, Shagyrly-Shomyshy, Tub-Karagan, Turkmenoy, West Prorva, West Terenozek, Zhambyl, Zhemchuzhina
Medium deposits (deposits 5 – 30 300 mln tons of oil &/ or 5 – 30 mln m³ of gas)	32	Amangeldy, Ashhisay, Auezov, Bolganmola, Borankol, East Kokarna, East Zhagabulak, Kamenistoye, Kamenskoye, Kansu, Karaarna, Karataikyz, Karatube, Kemerkol, Komsomolskoye, Kozhasay, Kulzhan, Kumsay suprasaline, Maibulak, Masabay, North Akkar, North Karagie, North Karamandybas, Nuraly, Oymasha, Rozhkovskoye, Rozhkovskoye-Fedorovsky block, South Gremyachinskoe, Tyubedzhik, Zhaksymai, Zhambay South Sea, Zhangurshi
Small deposits (deposits 1 – 5 mln tons of oil &/ or 1 – 5 mln m³ of gas)	17	Airakty, Akingen, Aksai, Anabai, Doschan, East Karaturun, Karabulak, Kopa, Kyzylowskoye, North Nuraly, North Usharal, North-West Konys, Rostoshinskoye, West Karabulak, West Tuzkol, Zholdybai, Zhylandy
Very small deposits (less than 1 mln tons of oil &/ or less than 1 blm m³ of gas)	12	Akkuduk, Arysskoe, Asanketen, Ayraantaky, Borkyldakty, East Kyzylzhar, Koschagyl, Kulsary, Sagiz, Tuilis, Uytas, West Sagiz
No data	153	Abay, Abylaikhan, Aiyrtau, Aksu-Kenderly, Aktas, Aktobe, Akzhar, Alatyube (East block), Alatyube, Alibekmola, Alimbay, Altykol, Aryskum, Arystan, Ashchiagar, Atambay-Sartube, Auketayshagyl, Ayrankol, Baishonas, Balgimbaev, Bazayskoye, Bekbike, Bektas, Besbole, Botakhan, Burmasha, Daraimola, Daryinskoe, Dauletaly, Dossor, East Akshabulak, East Akzhar, East Gremyachinskoe, East Kumkol, East Moldabek, East Normaul, East Ongar, East Saztobe, East Uzen, East Zhetybay, Eskene, Espelisay, Eszhan, Gran, Gremyachinskoe, Gryadovoe, Kalzhan, Karagan, Karagay, Karakuduk, Karatal, Karaturun Marine, Kisimbai, Konys, Korsak, Kenlyk, Kumisbek, Kyrykmyltyk, Kyzylkiya, Laktybay, Makat, Makhhat, Maldybai, Matin, Munaily, Munaily-Mola, Narmundanak, Naryn, North Akshabulak, North Baklaniy, North Karazhanbas, North

Options	Q-ty	Deposits' names
		Kotyrtas, North Zholdybai, North-East Karaturun, North-East Saztobe, North-West Zhetybai, Nsanovskoe, Oktyabrskoe, Okzhetpes, Ortalyk, Oryskazgan, Pionerskoye, Port-Arthur, Pribrezhnoe, Pridorozhnoe 1, Pridorozhnoe 2, Pustynnoe, Ravninnoe, Rovnoe, Sarsenbay, Satbayev site, Sazankurak, Shagala, Shattyk, Shingiz, Shinzhir, Shubarkuduk, Sinelnikovskoye, South Alamurnyn, South Kamyskol, South Karatube, South Karaturun, South Koshkar, South Kozha, South Narmundanak, South Tagan, South Tanatar, South Zhetybai, South-East Bekturly, South-East Kamyshitovoye, South-East Novobogatinskoye, South-East Saztobe, South-West Dossor, South-West Kamyshitovoye, South-West Tazhigali, Tamdy, Tanatar, Tasbulat, Tastobe site, Tasym, Tazhigali, Tenge, Tenteksor, Teplovskoe, Tobearal, Tokarevskoe, Tolegen, Tolkyn, Tortay, Tsentralnoye, Tsyganovskoe, Tulpar, Ulyanovskoe, Urikhtau, Usharal, Ushkultas, West Aktas, West Novobogatinskoye, West Opak, West Tenge, West Teplovskoe, Yuzhnaya Rovnaya, Zaburunye, Zhanatalap, Zhanatan, Zhanazhol, Zhangel'dy, Zharty, Zhenis site, Zhilankabak, Zhilankyr, Zhubantam

Table 5. Classification of the deposits by location.

Names of regions (districts)	Quantity
1. Aktobe region	25
Baigany district	7
Mugalzhar district	6
Temir district	10
Shalkar district	2
2. Atyrau region	88
Zhylyoi district	39
Isatay district	13
Kyzylkogy district	10
Kurmangazy district	3
Makat district	22
Makhambet district	1
3. Zhambyl region	5
Moyinkum district	3
Talas district	2
4. West Kazakhstan region	19
Baiterek district	14
Burlinsky district	1
Zhangalinsky district	1
Kaztalovsky district	1
Taskaly district	2
5. Karaganda region	5
Ulytau district	5
6. Kyzylorda region	18
Zhalagash district	4
Syrdarya district	13
Shiely district	1
7. Mangystau region	65
Beyneu district	12

Names of regions (districts)	Quantity
Karakiya district	36
Mangystau district	11
Munaylinsky district	1
Tupkaragan district	5
8. Turkestan region	3
No data about the exact regional location at the district level	3
9. Kazakhstani part of the Caspian Sea shelf	29
10. No data on the exact geographic location	12

Over the period of independence of the Republic of Kazakhstan, i.e. since 1991, only 42 fields have been discovered: Kashagan, Aktoty, Kalamkas-sea, Kairan, Aiyrtau, Asanketen, Auezov, Ashisay, Borkyldakty, Gremyachinskoye Yuzhnoye, Doschan, Vostochny Zhagabulak, Zhambyl, Zhanatan, Zhemchuzhina, Karabulakulak, Zapadny Karaturun North-East, Kemerkol, Kokzhide post-salt, Kyzylzhar East, Laktybay, Narmundanak South, Novobogatinskoye West, Nuraly North, Border, Pridorozhnoe (Mangistau region), Rakushechnoye, Rakushechnoye-sea, Severnaya, Rozhkovskoye, Rostoshinskoye, Western Tuzkol, Tulpar, Uytas, Isataisskoye, Khazar, Khvalynskoye, Centralnoye, Chinarevskoye.

During its time in the USSR – 158 deposits.

Could not find data on the year of discovery of 69 deposits.

In addition, the data on licensed field operators are often hidden, for example, the owners of 85 fields are unknown.

For a more complete picture, the phase states of the collectors have been added to the resulting database, since we are primarily interested in oil deposits.

Table 6. Classification of the deposits by phase state.

Phase state	Quantity
Gas (g)	24
Gas, condensate (gc)	15
Gas, condensate, oil (gco)	2
Gas and oil (go)	16
Oil bituminous (ob)	3
Oil and gas (og)	34
Oil, gas, condensate (ogc)	32
Oil (o)	103
No data	40
TOTAL	269

6 Additional information

Already after writing the chapter of the dissertation, and this article, an additional source of information was found. It is published in Moscow in 2010 the report “Current state and development trends of the oil and gas complex of Turkmenistan and other Central Asian countries of the Near Abroad” [11], which is known only in the circles of oil specialists, but also not in the public domain.

It says, that there are 304 hydrocarbon deposits in Kazakhstan, i.e. even more than was found by me, and

this, of course, also expanded the already existing picture of the data.

In it deposits are listed and described by basins.

Table 7. Classification of the deposits by basins.

Basin name	Fields	Q-ty
Volgo-Uralsky	1 oil field, 1 oilgascondensate field	2
Zaisansky	1 gas field	1
Caspian	11 – gas fields, 6 – gascondensate fields, 98 – oil fields, 49 – oilgas fields, 15 – oilgascondensate fields	179
North Caucasian-Mangyshlak	10 – gas fields, 5 – gascondensate fields, 10 – oil fields, 19 – oilgas fields, 12 – oilgascondensate fields	56
North Ustyurt	12 – gas fields,, 4 – gascondensate fields, 3 – oil fields, 13 – oilgas fields	32
Turgay	2 – gas fields, 2 – gascondensate fields, 7 – oil fields, 11 – oilgas fields, 1 – gascondensate fields	23
Chu-Sarysu	9 – gas fields, 2 – gascondensate fields	11

7 Conclusions

After carrying out of this work, the following conclusions are suggested:

1. Based on the data in the Table 1, it can be concluded that the microbiological impact method is applicable to the most hydrocarbon deposits of the republic, namely, referring to the Table 6, at least 103, if not 172.

2. Table 5 shows that Atyrau and Mangistau regions of Kazakhstan are leaders in terms of the number of deposits and the volume of hydrocarbons contained in them, but at the same time, it can also possible to see that 8 other Kazakhstan regions out of all 14 also have their own hydrocarbon raw materials. For example, we, the residents of the Karaganda region, did not know that we also have deposits of this type. Moreover, one of them, Kumkol, with initial reserves of 280 million tons of oil and 15 billion cubic meters of gas, in accordance with prepared classification belongs to the large one.

3. The oil and gas industry of our republic is one of the most closed to the public. But the disclosure and publication of these data, perhaps, will help to improve this situation.

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