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DEVELOPMENT OF NANOSTRUCTURED COMPOSITE COMPOUND FOR IMPACT ON THE BOTTOMHOLE AREA (BA) IN UTILIZATION WELLS FOR THE MANAGEMENT OF PRODUCED WATER (ON THE SIYAZAN FIELD EXAMPLE)

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Abstract. The aim of the article is to improve the regularity of the re-injection process of the layer water produced with oil in old oil fields for various purposes (maintenance of production pressure, utilization, etc.) on an atomic-molecular basis, including nanotechnology. In order to solve the problem, composites of waste liquids with nanostructured polycrystalline powders based on coordination polymers synthesized with a number of nanostructured reagents, have been prepared at the Research Institute of Petroleum Geotechnological Problems and Chemistry under ASOIU and laboratory-scientific researches on the influence of produced water on their physical-chemical properties have been carried out. After analyzing the results of laboratory studies, it has been recommended to use a 1.0% composite of BAF-1 and BAF-2 nanostructured polycrystalline powders in alkaline diesel fraction waste (ADFW) to improve the quality of produced water and the uptake capacity of disposal wells.

Keywords: *environment, produced water, utilization methods, water injection wells, microbiological pollution.*

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1. Introduction

The final stages of oil field development are characterized by irrigation of well products, which, along with a significant decline in oil production, causes a number of technological and environmental problems and leads to a decline in the technical and economic performance of the enterprise.

Flooding of reservoirs and wells is mainly related to geological-physical, technological and technical reasons. In order to prevent flooding, it is very important to identify its regularities and specific causes and to choose effective methods of control. In the regulation of formation water, it is possible to increase the technical and economic performance of hydrocarbon fields only by new methods, effectively using the potential production opportunities of wells (Golubev & Lyagov, 2010; Baykov *et al.*, 1981). However, in many cases, the uncertainty of the influence of various factors on this process complicates the work and leads to a high degree of well flood (Mansurova & Ahmedov, 2018).

In oilfield practice, sedimentation, filtration and flotation methods are used to treat produced water (Scholz, 2016). In industrial practice, coagulation, a physicochemical method, is widely used in the purification of formation water from oil and oil products (Khramtsova & Baklanov, 2010).

For these reasons, the impossibility preparing of formation water in accordance with the required condition, its use in recycling processes leads to various environmental risks for the environment (Gerry, 2007). During the injection of highly mineralized water into the formation in order to restore the formation pressure, the salts precipitate in the capillary channels of the productive strata, deteriorating the collector properties of the rock (Kuznetsov & Gradova, 2006). It also causes corrosion of equipment used in technological processes (Stroganov, 1973). Thus, in water wells, there are cases of short-term contamination of the wellbore area (WA) and a significant decrease in permeability.

In order to manage the produced waters of different genetic types, different physical and chemical properties, extracted from the world's oil fields, the process of their injection is carried out (Khosravi & Alamdari, 2009). However, this process is a high-risk process, the results of which are uncertain, and mostly are followed by geological and environmental risks. Thus, produced water contains dissolved organic and radioactive substances, mineral salts, emulsified oil particles, mechanical mixtures (sand, clay, etc.), chemical compounds.

The results of the chemical analysis of produced water taken from the “Gil-Gilchay” irrigation area at SMOF are given in Table 1 (BDO - biological demand for oxygen, CDO - chemical demand for oxygen, SAS - surfactant), and the amount of radioactive elements determined in produced water at different depths is given in Table 2.

Table 1. The amount of radioactive elements detected in produced waters at different depths

Ions in water	Permissible limit, mg/l	In fact, mg/l	In fact, mg. eq/l	In fact, %-eq
BDO	3,0	318,0	-	-
CDO	4,0-6,0	690,0	-	-
SAS	0,1	0,32	-	-
Oil products	0,05	0,42	-	-
Dependent substances	1,6	420,0	-	-
Minerality	1000,0	23131	-	-
HCO_3^-	30,0	1952,0	32,0	8,47
SO_4^{2-}	500,0	1710,0	35,62	9,43
Cl^-	350,0	11005	310,0	82,09
Ca^{2+}	180,0	300,0	15,0	3,97
Mg^{2+}	40,0	192,0	16,0	4,24
Na+K	170,0	7972,38	346,63	91,79
NO_2^-	0,08	0,36	-	-
NO_3^-	45,0	9,8	-	-
NH_4^-	0,5	4,6	-	-
Fe^{+3}	0,5	0,520	-	-
Cu^{+2}	0,001	0,090	-	-
Al^{+3}	0,5	0,120	-	-
Zn^{+2}	0,01	0,086	-	-

Note: The permissible limit for water hardness was 7.0 mg*eq/l, while the actual was 31 mg*eq/l.

Table 2. The amount of radioactive elements detected in produced waters at different depths

Radioactive elements, 10^7	**Quantity, g/l*10^7**
U	4,0-8,0
Ra	1,75-7,0
Rn	5,13-7,1
Th	1,7-4,1

Most of the mining infrastructure and hydro-technical facilities created for the management of such waters are technically obsolete and unusable. This leads to an increase in environmental problems related to water.

Due to the above-mentioned reasons, it is impossible to prepare produced water in accordance with the condition, the use of this water in secondary technological processes leads to various environmental risks for environmental facilities. Thus, in injection wells, there are cases of short-term contamination of the wellbore area (WA) and a significant decrease in permeability. As a result, with the decrease in the capacity of these wells to receive produced water, the pressure in the irrigation communications increases and the formation of griffins in the wells, the spread of produced water to the surrounding areas, falling into open water basins pollutes the environment (Fig. 1).

Fig. 1. Griffon formation in layer water utilization wells

2. Experimental part

Siyazan monoclinic oil fields (SMOF) – one of the fields of the Republic of Azerbaijan with unique, specific features with anomalous geological-geophysical features, have a monoclinic structure due to tectonics and differ in their complexity and very steep bedding ($45\text{-}90^0$) (Stock materials of Siyazanneft OGPD). In addition, the bed layers are multi-layered, transversely and longitudinally dislocated, overlapping, small in thickness, and characterized by a narrowing of the bed angle in the regional direction. One of the peculiarities of the development of SMOF is that the filters of production wells operated in its oil fields are very long. Typically, ready-made long filters are released during drilling in wells, and then these filters are expanded by perforation as needed. As a result, each well has long-distance filters, which vary in the range of 200-1500 m. This has a negative impact on the overall production of the well and the irrigation rate of the product. In many cases, the opening of additional filters in production wells not only increases oil production, but also increases the percentage of water in production (Murvatov & Karimova, 2014a;b).

It should be noted that in 1976-1987, the process of water injection into the reservoirs was carried out in SMOF in order to maintain the formation pressure. Due to the above reasons, there has been a change in the type and nature of produced water, a further increase in aggressive properties and an increase in the volume of produced water. At the same time, the natural landscape of the surrounding areas was disturbed, the soils became saline and unusable, underground and surface equipment were corroded (Murvatov *et al*., 2014). The samples taken from the produced water reservoir of Siyazanneft OGPD were sent to the Oil and Gas Research Project Institute for testing of sulfate reduction (SRB), hydrocarbon oxidizing (HOB) and iron bacteria (FeB) samples. The obtained results are given in Table 3.

Table 3. Results of the analysis of the formation water sample taken from the reservoir of Siyazanneft OGPD

Measum. unit	**Cations**							**Mineral., mg/l**	**SRB cell/ml**	**FeB cell/ml**	**KOB cell/ml**
	Na^++K^+	**Ca^{2+}**	**Mg^{2+}**	**Cl^-**	**SO_4^{2-}**	**HCO_3^-**	**CO_3^{2-}**				
mg.eq/l	534	8,0	22	525,48	0,56	36,34	2,13	33743	3/10	6/10	7/10
mg.eq, %	47,34	0,70	1,9	46,34	0,04	3,22	0,18	33743			
mg/l	12293,5	160	264	18630	52,84	2216,7	127,8	-			

Note: SRB - sulfate-reducing bacteria; FeB - iron bacteria; HOB - hydrocarbon oxidizing bacteria

The results of the analysis showed that the formation water is exposed to high microbiological pollution, but the amount of oil products and dependent substances is many times higher than the allowable level.

Based on such negative trends, the injection process into the Siyazan field has been stopped since 1987. However, since 2010, the field has been re-irrigated for utilization. Currently, 15 of the 33 disposal wells involved in disposal have been shut down for various reasons.

The main reasons for the short-term closure of disposal wells are due to the deposition and solidification of resinous oil products, mechanical mixtures, disintegrated particles of rocks, mineral salts in the formation water.

The purpose of the work. The purpose of the work is to restore the operation of utilization wells and ensure their longevity. Thus, a number of geological and technical measures, including hydraulic fracturing, acid treatment of the strata, and, more recently, vibration treatment technology in the wellbore zone, which is considered a multifunctional method, are applied in order to clean the wellbore zone area from sediments (Abdukamalov *et al.*, 2017; Nagiyeva, 2020; Suleimanov *et al.*, 2020). However, in most cases, these methods do not give the expected results, are less effective or inefficient, and create a number of problems. It should be noted that the requirements for the elimination of clogging of the wellbore area, the fluids used to improve permeability and their physical and chemical properties are very different. Complex systems are used to meet these requirements. If the physical and chemical properties of such systems do not comply with the characteristics of the wellbore system, the efficiency of technological operations and processes is not at the required level. In this case, special reagents are usually added to the system to regulate the properties of the fluids used. At present, in order to solve the problem, the development of innovative mechanisms, including the mechanism of impact on the field of the wellbore zone with nanotechnologies at the atomic-molecular level, is a topical issue. For this purpose, laboratory researches with composites based on nanostructured coordination polymers synthesized by the employees of the Research Institute of Geotechnological Problems of Oil and Gas and Chemistry under ASOIU have been conducted. Thus, an alkaline solution of kerosene fraction of BAF-1 and BAF-2 nanostructured polycrystalline powders (Fig. 2) was applied to the formation water sample (250 ml) taken from the formation water intake point of the field “Ata-river water supply and produced water utilization service area”. Physicochemical analysis was carried out with the addition of 7,5 ml of 1.0% composites from the treatment (KFT) and alkaline diesel fraction wastes (ADFW). The results of the analyzes are given in Tables 4 and 5, respectively.

Fig. 2. Mixture of polycrystalline powders with nanostructured BAF-1 and BAF-2

Table 4. Effect of BAF-1 and BAF-2 polycrystalline powders on chemical parameters of 1,0 % composition of formation water obtained from the alkaline treatment of kerosene fraction

Additive volume, ml	**Chemical composition content of formation water, mg/l**						**Type of water**
	CO_3^-	**HCO_3^-**	**Na^++K^+**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	
0	-	0,1584	1,9802	1,2733	0,0111	0,0308	$MgCl_2$
7,5	-	0,1488	1,888	1,1861	0,0190	0,0386	$MgCl_2$

Note: The mineral content of the water was 34.54 g / l before the addition and 32.81 g / l after the addition. Roughness was calculated before the addition of 3.08 mg.eq/ l, after the addition of 4.12 mg.eq/l.

As it can be seen from Table 4, HCO_3^- ions and Na^+ + K^+ ions decreased slightly with the addition of the composite to the formation water, while Ca_2^+ and Mg_2^+ ions increased slightly, reducing the amount of Cl^- ions. Accordingly, the mineral content of the water sample decreased by 1,73 g / l, and the hardness increased by 1,04 mg eq / l.

Table 5. Effect of 1,0 % mixture of BAF-1 and BAF-2 polycrystalline powders in ADFW on chemical parameters of formation water

№	Additive volume, ml	Chemical composition content of formation water, mg/l						Type of water
		CO_3^-	HCO_3^-	Na^++K^+	Cl^-	Ca^{2+}	Mg^{2+}	
1	0	-	0,1584	1,2733	1,9802	0,0111	0,0308	$MgCl_2$
2	7,5	0,036	0,1776	1,1594	1,768	0,0158	0,0337	Alkaline water

Note: The mineral content of the water was 34.54 g / l before the addition and 31.91 g / l after the addition. Roughness: 3.08 mg.eq/l was calculated before the supplement and 3.56 mg.eq/l after the supplement

Table 5 shows, CO_3^- and HCO_3^- ions increased with the addition of the composite to the formation water, while Na^+ + K^+ ions decreased. Ca_2^+ and Mg_2^+ ions increased by 0,005 and 0,003 mg / l, respectively, and Cl ion content decreased by 0,212 mg / l.

A comparison of water samples analyzes (Tables 4 and 5) shows that equal amounts of BAF-1 and BAF-2 reagents in the alkaline treatment waste of the kerosene fraction (KFT) and in the alkaline treatment waste of the diesel fraction (ADFW) Although there was some positive change in the characteristics of the water, its hardness increased significantly (1.04 mg.eq / l), i.e. from soft water to medium hard water. In the second case, the mineral content of the formation water sample decreased significantly (2,63 g/l), and although its hardness increased slightly (0.48 gr. eq/l), its type changed and became alkaline.

At the same time, physical and chemical analysis of the oil sample collected on 15.09.2021 was carried out due to the produced water in the reservoir of the Gil-Gilchay water intake. The results of the analysis are given in Table 6.

Table 6. Results of physical and chemical analysis of the oil sample accumulated on the formation water in the Gil-Gilchay reservoir water intake

№	Indices	Results
1	Specific gravity of oil, kg/cm^3	910,0
2	Pure oil sample, %	49,83
3	Water separated from oil, %	0,17
4	Mechanical impurities, %	50,0
5	Resin, %	96,0
6	Kinematic viscosity, sst (50^0 C)	130,0
7	Dynamic viscosity, sPz	128,66

According to the results of the analysis, the mass of oil collected on the produced water used in the injection process consists of 96% resin and up to 50% mechanical impurities. The oil sample collected from the produced water was analyzed by leaching the alkalized diesel fraction of BAF-1 and BAF-2 nanostructured polycrystalline powders from kerosene and reacting them with prepared 1.0% waste composites. The results of the analysis are given in Tables 7 and 8, respectively.

Table 7. Changes in the physical and chemical properties of the oil after the addition of 1,0% composite in the waste from the kerosene treatment of equal amounts of BAF-1 and BAF-2 to the oil sample accumulated from the formation water in the Gil-Gilchay reservoir water intake

№	Indices	Before addition	After addition
1	Specific gravity of oil, kg/cm^3	910,0	910,0 kg/m^3
2	Pure oil sample, %	49,83	49,83
3	Water separated from oil, %	0,17	0,17
4	Mechanical impurities, %	50,0	50,0
5	Resin, %	96,0	76,0
6	Kinematic viscosity, sst (50^0 C)	130,0	42,9
7	Dynamic viscosity, sPz	128,66	41,91

As it can be seen from Table 7, after the addition of the composite, the amount of resin in the oil decreased by 20%, the kinematic viscosity of the oil decreased by 87,1 sSt, and the dynamic viscosity decreased by 86,75 sSt. Other oil indicators have not changed.

Table 8. Results of the effect of BAF-1 and BAF-2 (1: 1) 1.0% composite in DFAW on the oil sample accumulated from the formation water

№	Indices	Before addition	After addition
1	Specific gravity of oil, kg/cm^3	910,0	910,0 kg/m^3
2	Pure oil sample, %	49,83	65,5
3	Water separated from oil, %	0,17	0,5
4	Mechanical impurities, %	50,0	34,0
5	Resin, %	96,0	60,0
6	Kinematic viscosity, sst (50^0 C)	130,0	29,4
7	Dynamic viscosity, sPz	128,66	28,59

Table 8 presents, the effect of the reagent composite prepared in ADFW on the oil sample collected from the formation water was high. Thus, under the influence of this composite, the amount of mechanical impurities in the oil decreased by 16,0%, the amount of resin decreased by 36,0%, the kinematic viscosity of the oil decreased by 100,6 sSt, and the dynamic viscosity decreased by 100,07 Spz.

In addition, samples of produced water taken from the reservoir of the Ata-Chay water supply and disposal service area in the usual way (without any additives) and equal amounts of BAF-1 and BAF-2 nanostructured polycrystalline powders (1:1) ADFW Microbiological analyzes were carried out in the Analytical Research Laboratory of the Oil and Gas Research Project Institute on 29.01.2020-04.02.2020 with the addition of 1.0% composite (3,0%) and the results of the analyzes are given in Table 9.

Table 9. Results of analysis of produced water under normal conditions and with the addition of a mixture of equal amounts 1.0% composition of BAF-1 and BAF-2 in DFAW

Type of bacteria	Measurement unit	Before addition	After composite addition	Normative document
Sulfate reducing bacteria	cell/1 ml	10^2	Not found	Act 39-151-13

In the table, although sulphate-reducing bacteria were normally present in the studied formation water, they were not detected by the addition.

3. Conclusion

The results of laboratory research show that BAF-1 and BAF-2 nanostructured polycrystalline powders in ADFW 1.0% composite in the form of emulsion oil in the form of oil in the form of emulsions, the removal of mechanical impurities from heavy hydrocarbons, and the dissolution of most resinous petroleum products. provides. Also, reducing the amount of sulfate-reducing bacteria that cause corrosion of mining equipment is even more effective in terms of complete destruction. In view of the above, it is recommended to use this composite to clean the bottomhole area in the disposal wells in order to affect the WA, as well as to prepare the produced water in accordance with the condition.

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