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## Nanotechnology in the Oil and Water Preparation Using Nanodemulsifiers

Dashdiyeva T.K.

Doctoral student of the Azerbaijan State University of Oil and Industry, Baku, Azerbaijan

**ABSTRACT.** The article presents scientific novelty and economic efficiency according to the results of the introduction of “IKHLAS” nanodemulsifiers for the purification of oil from formation water and formation water from oil in the conditions of primary oil preparation. Some novelties have elements of scientific discovery. The presented nanotechnology is being introduced at six oil fields of the Republic of Kazakhstan. Actual and expected annual economic efficiency from the use of “IKHLAS” nanodemulsifiers are 359,825 \$ and 2 517 187 \$, respectively.

**KEYWORDS:** “IKHLAS” nanodemulsifiers, oilfield nanotechnology, nanotechnology in the oil productions, oil and water preparation, surfactants, the requirements for demulsifiers.

### I. LITERATURE SURVEY

At each field, the produced fluids from production wells ultimately flow (in most cases with pipeline transportation) to the shop of preparation and pumping of oil (ShPPO), where gas is initially separated, then a demulsifier is dosed into the oil emulsion with a specific consumption. Then, the oil-water emulsion is heated to a certain temperature using process furnaces. At the next stage, oil in technological tanks with a water cushion is washed from salts and mechanical impurities. After this, is provided oil settling for some time for the final phase separation. After the positive results of appropriate analyzes for the content of residual water, chloride salts and mechanical impurities oil is pumped into a commodity tank, and then by transportation to oil refineries Formation water in the form of wastewater (hereinafter referred to as formation water) is transported in a reservoir pressure maintenance system. The oil concentration in the formation water should not exceed a value of 50 mg / dm<sup>3</sup> [1]. Methods for treating formation water from oil can be grouped in three directions: the classical method using sedimentation tanks, in which the level of treatment for durable oil-water emulsions does not meet the requirements of the pressure maintenance systems; method using a complex of expensive modern hydrocyclones. For example, Azerbaijan’s BP installed a special platform on the Central Azeri field equipped with a complex of modern hydrocyclones (costs about 420 million \$) for the preparation and injection of formation water, in which the level of cleaning reaches 29 mg / dm<sup>3</sup> [2]; With the using of reverse demulsifiers. However, these reagents did not find implementation at the oilfield chemistry [3]. In recent years, some new brands of the latest generation demulsifiers have appeared on the world market: “DEMTROL” marks (“Dow” company, USA); marks “DMO” (“Baker Hughes”, USA); marks “Condem” (“Champion Technologies, Inc”, USA); marks “Randem” (company “Rauan Nalko”, USA-Kazakhstan); marks “Kemelix” (“Croda oil and gas” company, England); marks F-929, F-940, R-11, X-2647 (companies “Toho Chemical Industry Co., Ltd”; “Iskra Industry” and others, Japan); “Dissolvan” marks (Hoechst, Basf, Clariant, Almatineftexim, Germany); demulsifiers of the company “Auby” France; demulsifiers of Shanghai Trustin Chemical Co., Ltd, Qingdao Aurora Chemical Co., Ltd, Shanghai Jianying Chemical Co., Ltd. and others. China; marks “SNPX” (“NII Neftepromxim” company, former “Soyuzneftpromxim” company, Russia); “Flek” marks (Flek company, Russia); liquid-crystalline nano-demulsifier TND (Tyumen State University, Russia) [4]; “Khazar” marks (“IPChP” NAS of Azerbaijan); “Alkan” marks (“IPChP” NAS of Azerbaijan); ND marks (Research and Design Institute Oil and Gas, SOCAR). Among the analyzed modern demulsifiers, nano-demulsifiers

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attract particular attention mainly on issues of oil preparation, but there is no information about the wide introduction of nano-demulsifiers. In addition, the issues of oil purification from formation water, and formation water from oil in the conditions of primary preparation of oil (PPO) are poorly studied. On the other hand, there is a need for the development on the basic requirements for [5] demulsifiers and on the mechanisms of destruction and aging of oil emulsions on the level of the oilfield nanotechnology. In recent times, new theories have been formulated on the structure of crude oil, which are sharply different from classical concepts. In this direction, the most contribution belongs to the Russian scientist I.N. Evdokimov and his staff. With their numerous experimental data, the nanostructure for the dispersion medium of oil-water emulsions as oil colloids was first fixed. In this case, the nanostructure of the dispersed phase (nanoemulsion), the nanoscale molecular adsorption layers (MAS) around the globules of the dispersed phase, and the presence of nanoscale particles of organic and inorganic origin in the MAS make up fourfold nanostructure [6]. Therefore, to weaken counteractions of nanostructured barriers in oil emulsions, demulsifiers must also have a nanostructure. It is from this perspective that the development and implementation of nanodemulsifiers for the purification of oil from formation water and formation water from oil in the conditions of PPO is one of the priority direct of the oilfield nanotechnology.

6. Based on the analysis of data available in the literature, it can be concluded that preventing the formation of strong oil emulsions in wells is one of the priority areas of oilfield chemistry;

## II. LITERATURE REVIEW CONCLUSIONS

1. At the world level, the founder of nanotechnology in oil production is Academician A.Kh. Mirzadzhanzade;
2. For the first time, the ND-1/4 nanodemulsifier developed by scientists at Research and Design Institute of Oil and Gas SOCAR in 2012 successfully passed experimental-industrial tests (EIT) at the “Zhetybai” field of the Republic of Kazakhstan for maximum extraction of commercial oil from hard destructible water-oil emulsions (HDWOE);
3. For the first time, TND liquid crystalline nano-demulsifier was developed, however, there is no supporting information about the widespread use of this reagent;
4. There are no sufficient studies in the field of development and implementation of nanodemulsifiers for the destruction of fractions of nanoemulsions in the composition of oil emulsions such as W / O, O / W and W / O / W in the conditions of PPO;
5. Naphthenic acids and sodium (or potassium) naphthenates, expressing a synergistic effect, form highly persistent water-oil emulsions of the type W / O / W or HDWOE. For the first time, it was established by Mergier and others that on the surface of nanoparticles of mechanical impurities that make up the MAS, strong adsorption layers of humic acids are formed from the inside, and from the outside are formed strong adsorption layers of asphaltene molecules. Naturally, there are also other arguments on the stability of oil emulsions;
6. Based on the analysis of data available in the literature, it can be concluded that preventing the formation of strong oil emulsions in wells is one of the priority areas of oilfield chemistry;
7. Currently, the number of demulsifiers in the world market exceeds thousands of industrial designs such as oxyalkylene block copolymers based on polyhydric alcohols, amines, polyamines, phenol-formaldehydes and epoxies. However, the synergy between the components of the active phase and the solvents in the compositions of demulsifiers is a little studied;;
8. For the components of demulsifiers, questions of the correlation relationships of the type property – structure – optimal effects have also been a little studied;
9. The main achievements in the nanocolloidal states of asphaltenes and resins in the composition of oil emulsions, against the background of conflicting views of other scientists, belong to I.N. Evdokimov and his employees;
10. The presence of conventional nonionic surfactants (nonionic surfactants) in the compositions of new generations of demulsifiers as a wetting component is known. However, the questions of the dependence of the effectiveness of

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demulsifiers on the structure (on the length of the alkyl radical and on the length of the oxyethylene chain) and the establishment of optimal values of the contact angle a little studied;

11. Negatives from oil colloids such as visco-elastic systems (VES) at the PPO and ways to overcome them have not been studied enough;

12. The results of the analysis of the data available in the literature found that nanocolloids in the composition of crude oil, being the reasons for the increase in the strength of all types of oil emulsions, create nano-energy barriers in a dispersion medium that can to lower the possibilities of action of conventional demulsifiers;

13. Given the existence of a variety of nanocolloidal assortments of oil emulsions, the results of artificial model emulsions give rise to well-founded suspicions. Therefore, the objects of research to study the properties of emulsions, as well as to conduct the necessary bottle-tests to determine the effectiveness of demulsifiers, should use only fresh natural emulsions.

The above brief overview and relevant conclusions allow us to formulate the purpose and objectives of the work:

**Purpose of work:** development and implementation of nanodemulsifiers for the purification of oil from formation water, and formation water from oil in the conditions of PPO.

To achieve this purpose, the following tasks were solved:

1. Development of innovative nano-demulsifiers;
2. Conducting studies to substantiate the synergistic compositions of nanodemulsifiers for the purification of oil from formation water and formation water from oil in the conditions of PPO;
3. Isolation and identification of individual oxyethylene ethers of n-aliphatic acids using critical nanoemulsions;
4. Studies of the relationship of the property - structure according to some characteristics for n-aliphatic alcohols, as well as adsorption properties;
5. The study of the most necessary colloidal chemical properties of some liquid crystal demulsifiers such as oxyalkylene block copolymers based on glycerol;
6. Development of a new mechanism for the destruction of oil emulsions;
7. Conducting research in the direction of oil purification from formation water, and formation water from oil in the conditions of PPO using liquid crystal nanodemulsifiers, as representatives of a new hybrid aggregation state of the substance;
8. Study of the wetting ability of individual polyoxyethylene ethers of n-aliphatic acids;
9. Development of requirements for demulsifiers at the level of oilfield nanotechnology;
10. Conducting laboratory and industrial tests for oil purification from formation water, and formation water from oil using nanoemulsifiers, in the conditions of PPO at various oil fields;
11. Calculation of economic efficiency based on the results of the EIT and the introduction of "IKHLAS" nanodemulsifiers at some oil fields in the Republic of Kazakhstan.

### III. EXPERIMENTAL PART

The experimental part of the work includes the following research methods:

- Determination of concentrations of water, chloride salts and mechanical impurities in the oil. The concentration of water in oil is determined in accordance with GOST 2477-2014 at the Dean-Stark installation. The concentration of chloride salts in oil is determined by the titration method in accordance with GOST 21534-76 The concentration of solids in oil is determined by the gravimetric method in accordance with GOST 10577-78;
- Determination of the concentration of oil and oil products (hereinafter referred to as oil) in the composition of water, including formation water, is carried out by spectrophotometric method in accordance with OST 39-225-88 [1];
- Measurements of surface tension and interfacial tension were carried out by the stalagmometric method;

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- Viscosity measurements were carried out on a modern model of a viscometer brand NDZ-8S (China, Shanghai, Ping Xuan Scientific Instrument Co., Ltd) in the range of  $1 \div 10^6$  mPa·s;
  - The effectiveness of demulsifiers was determined by the method of bottle-tests.
- The results of the above tasks No. 1-9 are described in more detail in publications [7-11];

### IV. SCIENTIFIC NOVELTY ACCORDING TO THE RESULTS OF THE WORK

- The present work deals with the solution of an urgent scientific problem of environmental, technological, economic importance, using innovative nanotechnologies for cleaning oil from formation water and formation water from oil, as well as preventing the formation of oil colloids (potential sources of environmental pollution) in the conditions of PPO;
- For the first time, multifunctional nanodemulsifiers with a double nanostructure have been developed and patented, which maximally meet the requirements for demulsifiers, and have been given positive results in laboratory and industrial tests for the purification of oil from formation water and formation water from oil in the conditions of PPO, as well as were confirmed by successful implementations at some oil fields Republic of Kazakhstan;
- The requirements for demulsifiers were revised, with numerous additions, at the level of oilfield nanotechnology;
- In connection with the observed sharp increase in the viscosity of alcohols with the transition from octanol to nonanol, the concept of the critical value of the number of carbon atoms in the alkyl radicals of n-aliphatic alcohols was first introduced, it includes elements of a scientific discovery;
- At first glance, an abnormal pattern was found in the dependence of the melting temperature on the number of carbon atoms (m) in the molecules of n-aliphatic alcohols, because for  $m = 1-3$ , the dependence is inversely proportional, and for  $m > 3$  the function goes to a directly proportional dependence (fig. 1);
- For the first time, surface pressure ( $\pi$ ) and its optimal value  $\pi \geq 40 \text{ mC} / \text{m}^2$  were proposed as a colloid-chemical criterion for a full assessment of the effectiveness of demulsifiers;
- Proposed a new mechanism for the destruction of oil emulsions;
- Similarly to the terminology, emulsion - emulsifier - demulsifier and suspension - suspensifier, the term desuspensifier was first introduced, as a new property of the surfactants, in particular demulsifiers, includes elements of scientific discovery;
- For the first time, a mechanism has been proposed to increase the resistance and aging of oil emulsions, especially with high paraffin contents;
- For organic substances, in the example of "IKHLAS" nanodemulsifiers, the liquid crystal position them was first noted as a new hybrid aggregat state of substance, there are elements of a scientific discovery;
- For visco-elastic systems formed under the conditions of PPO, the ability to absorb water, oil, and other oil colloids was discovered, so they got a new name - colloidal barns;
- For demulsifiers, in the example of "IKHLAS" nanodemulsifiers, the HDWOE inhibitor property was first discovered, and for HDWOE and trapped oil sludge, a new property was established - the emulsifier property in relation to the formation of reverse and direct emulsions;
- The scientific novelty of the work as a whole is also confirmed by patent No. 30960 of the Republic of Kazakhstan dated 2016, Nugmanov AK, Dashdieva TK and others. "Demulsifier for the destruction of water-oil and oil-water emulsions"

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### V.CALCULATION OF THE ECONOMIC EFFICIENCY IMPLEMENTATION OF “IKHLAS” NANODEMULSIFIERS AT SOME OIL FIELDS RK

**V.I. Calculation of the actual and expected economics effect for the “IKHLAS-1” nanodemulsifier at the “Zhetybai” field of “MMG” JSC**

**V.I.I. Calculation of the actual economic effect**

**Initial data:**

In the period from 03.11.14-03.12.14, the “IKHLAS-1” nanodemulsifier EIT was performed at the “Zhetybai” field of “MMG” JSC. The results were very successful.

Base demulsifier: “Randem-2219” (Rauan Nalco);

The cost of one ton of “Randem-2219” is 1,450,000 tenge;

The cost of one ton of “IKHLAS-1” is 1 200 000 tenge;

The volume of annual oil production: 2 157300 t;

Average monthly oil production:  $2\ 157300:12 = 179\ 775\ t$ .

The average specific consumption of the base demulsifier “Randem-2219” 204 g / t;

The average specific consumption of the “IKHLAS-1” nanodemulsifier is 178 g / t;

Recommended average specific consumption of “IKHLAS-1” nanodemulsifier 160 g / t;

The daily volume of HDWOE formed is  $\sim 100\ m^3$ , and the annual volume is  $\sim 36\ 500\ m^3$

The cost of processing  $1\ m^3$  HDWOE on a tricanter, for the basic technology is 18 000 tenge;

The average specific consumption of the “IKHLAS-1” nanodemulsifier for PPO together with HDWOE is 178 g / t, i. no additional dosages required;

**Calculation of the actual economic effect for EIT “IKHLAS-1”:**

Actual economic effect at the “IKHLAS-1” EIT:

$107,215,000 - 38,400,000 = 68,815,000$  tenge (177,514 \$, dollar to tenge exchange rate on September 22, 2019: 1 \$ = 387.66 tenge).

**Conclusions:**

1. The actual economic effect of the “IKHLAS-1” EIT at “Zhetybai” field “MMG” JSC is 68,815,000 tenge (177,514 \$).
2. The level of reduction in the concentration of oil and oil products in the composition of formation water from 600-1400 mg / dm<sup>3</sup> to 20-28 mg / dm<sup>3</sup> (a decrease of 20-28 times) meets of the requirements of system the maintenance reservoir pressure (oil in the composition of formation water is not more than 50 mg / dm<sup>3</sup>).

**V.I.II. Calculation of the expected economic effect**

The expected annual economic effect of the use of the “IKHLAS-1” nanodeemulsifier:

$1,295,000,000 - 414,000,000 = 881,000,000$  tenge (2,272,610\$)

**Conclusions:**

1. The annual expected economic effect for the “IKHLAS-1” nanodeemulsifier at the “Zhetybai” field “MMG” JSC is 881,000,000 tenge ( 2,272,610 \$);
2. The level of reduction in the concentration of oil in the composition of formation water from 600-1400 mg / dm<sup>3</sup> to 46 mg / dm<sup>3</sup> (a decrease of 20-28 times) meets of the requirements of system reservoir pressure maintenance.

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### V.II. Calculation of the actual economics effect for the “IKHLAS-1” nanodemulsifier at the “Tenge Oil & Gas” field

#### Initial data:

In the period 05.10.17-05.06.17 at the “Tenge Oil & Gas” field, the “IKHLAS-1” nanodemulsifier EIT was carried out. Since the beginning of 2018, the “IKHLAS-1” nanodemulsifier is successfully implemented at the “Tenge Oil & Gas” field;

Base demulsifier: “Dissolvan V 5748” (Germany);

Cost of one ton of “Dissolvan V 5748”: 1,600,000 tenge;

The cost of one ton of “IKHLAS-1”: 1 200 000 tenge;

The volume of annual oil production: 116,340 t;

The average specific consumption of the base demulsifier “Dissolvan V 5748” 186 g / t;

The average specific consumption of the “IKHLAS-1” nano-demulsifier is 170 g / t;

The concentration of oil and oil products in the composition of “Dissolvan V 5748” formation water is 370-1290 mg / dm<sup>3</sup>;

The concentration of oil and oil products in the composition of the formation water “IKHLAS-1” does not exceed 46 mg / dm<sup>3</sup>.

#### Calculation of the actual annual economic effect of the introduction of “IKHLAS-1”:

The annual consumption of “Dissolvan V 5748” (186 x 116 340) / 1,000,000 = 21.6 t;

Cost of 21.6 t of “Dissolvan V 5748” 1,600,000 x 21.6 = 34,560,000 tenge

Annual consumption of “IKHLAS-1” (170 x 116 340) / 1,000,000 = 19.8 t

Cost of 19.8 t of “IKHLAS-1”: 1,200,000 x 19.8 = 23,760,000 tenge

Actual annual economic effect from the implementation of “IKHLAS-1”:

34 560 000 - 23 760 000 = 10 800 000 tenge (27 859 \$)

#### Conclusions:

1. The actual annual economic effect of the introduction of “IKHLAS-1” at the “Tenge Oil & Gas” field is 10,800,000 tenge (27,859 \$);

2. The level of reduction in the concentration of oil in the composition of formation water from 370-1290 mg / dm<sup>3</sup> to 46 mg / dm<sup>3</sup> (on the average a decrease is of 18 times) ) meets of the requirements of system reservoir pressure maintenance.

### V.III. Calculation of the actual economics effect for the “IKHLAS” nanodemulsifier at the “Phystech II” JSK field

#### Initial data:

In the period from 12.04.17-17.04.17, the EIT of the “IKHLAS-1” nanodemulsifier was carried out at the “Phystech II” JSK field. Since the beginning of 2018, the “IKHLAS-1” nano-demulsifier has been successfully Introduces at the “Phystech II” JSK field;

Basic demulsifier: “SNPX-4315D” (Russia);

The cost of one ton of “SNPX-4315D”: 1,550,000 tenge;

The cost of one ton of “IKHLAS-1”: 1 200 000 tenge;

The volume of annual oil production: 156 950 t;

The average specific consumption of the base demulsifier “SNPX-4315D” 221 g / t;

The average specific consumption of the “IKHLAS-1” nanodemulsifier is 100 g / t;

The concentration of oil and oil products in the composition of formation water “SNPX-4315D” is 200-470 mg / dm<sup>3</sup>;

The concentration of oil and oil products in the composition of the formation water “IKHLAS-1” does not exceed 47.8 mg / dm<sup>3</sup>.

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### Calculation of the actual annual economic effect of the introduction of "IKHLAS-1":

The annual consumption of "SNPX-4315D"  $(221 \times 156\,950) / 1,000,000 = 34.7$  t;

The cost of 34.7 tons of "SNPX-4315D"  $1\,550\,000 \times 34.7 = 53\,785\,000$  tenge

Annual consumption "IKHLAS-1"  $(100 \times 156\,950) / 1\,000\,000 = 15.7$  t

The cost of 15.7 tons of "IKHLAS-1":  $1\,200\,000 \times 15.7 = 18\,840\,000$  tenge

Actual annual economic effect from the implementation of "IKHLAS-1":

$53,785,000 - 18,840,000 = 34,945,000$  tenge (90,143 \$).

### Conclusions:

1. The actual annual economic benefit from the introduction of "IKHLAS-1" at the "Phystech II" JSK field is 34,945,000 tenge (90,143 \$)
2. The level of reduction in the concentration of oil in the composition of produced water from 200-470 mg / dm<sup>3</sup> to 47.8 mg / dm<sup>3</sup> (on the average a decrease is of 7 times) meets of the requirements of system reservoir pressure maintenance.

### V.IV. Calculation of the actual economics effect for the "IKHLAS" nanodemulsifier at the "Akkulka" field of "TetisAralGaz" LLP.

#### Initial data:

In the period from 08.14.17-26.08.17 at the "TektisAralGas" LLP "Akkulka" field, the EIT of the "IKHLAS-1" nanodemulsifier was held. Since October 2017, "IKHLAS-1" is successfully introduced at the "Akkulka" field. of "TetisAralGaz" LLP;

Basic demulsifier: "DMO-86520" ("Baker Hughes", USA);

The cost of one ton of "DMO-86520" 2 100 000 tenge;

The cost of one ton of "IKHLAS-1". 1 200 000 tenge;

Annual oil production: 254,405 tons;

The average specific consumption of the base demulsifier "DMO-86520" 69.6 g / t;

The average specific consumption of the "IKHLAS-1" nanodemulsifier is 40.4 g / t;

The concentration of oil and oil products in the composition of formation water "DMO-86520" is 62-137 mg / dm<sup>3</sup>;

The concentration of oil and oil products in the composition of the formation water "IKHLAS-1" does not exceed 28 mg / dm<sup>3</sup>

### Calculation of the actual annual economic effect of the introduction of "IKHLAS-1":

The annual consumption of "DMO-86520"  $(69.6 \times 254\,405) / 1,000,000 = 17.7$  t;

The cost of 17.7 tons of "DMO-86520"  $2\,100\,000 \times 17.7 = 37\,170\,000$  tenge

Annual consumption "IKHLAS-1"  $(40.4 \times 254\,405) / 1\,000\,000 = 10.2$  t

The cost of 10.2 tons of "IKHLAS-1":  $1,200,000 \times 10.2 = 12,240,000$  tenge

Actual annual economic effect from the implementation of "IKHLAS-1":

$37,170,000 - 12,240,000 = 24,930,000$  tenge (64,309 \$)

### Conclusions:

1. The actual annual economic benefit from the introduction of "IKHLAS-1" at the "Akkulka" field of "TetisAralGas" LLP is 24,930,000 tenge (64,309 \$).
2. The level of reduction in the concentration of oil in the composition of formation water from 62-137 mg / dm<sup>3</sup> to 28 mg / dm<sup>3</sup> (on the average a decrease is of 3.5 times) meets of the requirements of system reservoir pressure maintenance.

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### V.V. The calculation of the expected annual economic effect for the nanodemulsifiers “IKHLAS-1” and “IKHLAS-2” at the OGPD “Zhaikmunaygaz” JSC “Embamunaigas”

#### Initial data:

In the period 06.01.18-25.01.18, at the oil fields and ShPPO of the OGPD "Zhaikmunaygaz JSC "Embamunaigas" were conducted EIT of the nanodemulsifiers "IKHLAS-1" and "IKHLAS-2". Starting from July 1, 2019, "IKHLAS-1" and "IKHLAS-2" successfully are being introduced at the OGPD "Zhaikmunaygaz JSC "Embamunaigas"

Basic demulsifiers: “Dissolvan V 4795” and “Dissolvan V 4397” (Germany);

The cost of one ton of “Dissolvan V 4795” and “Dissolvan V 4397” 1 600 000 tenge;

Cost of one ton of “IKHLAS-1” and “IKHLAS-2”: 1 200 000 tenge;

Annual oil production: 931,115 t;

The average daily consumption of basic demulsifiers is  $89.94 \times 2 = 179.88$  kg;

Average daily consumption of nanodemulsifiers “IKHLAS-1” and “IKHLAS-2”: 89.94 kg;

The concentration of oil and oil products in the composition of the “Dissolvan V 4795” and “Dissolvan V 4397” formation waters is 50-400 mg / dm<sup>3</sup>;

The concentration of oil and oil products in the composition of the formation water “IKHLAS-1” does not exceed 15-50 mg / dm<sup>3</sup>.

#### Calculation of the expected annual economic effect for “IKHLAS-1” and “IKHLAS-2”:

The total annual consumption of basic demulsifiers:  $179.88 \times 365 = 65\,656$  kg = 65, 656 t;

The total annual consumption of demulsifiers “IKHLAS-1” and “IKHLAS-2”:  $89.94 \times 365 = 32\,828$  kg = 32, 828 t;

The cost of 65, 656 tons of base demulsifiers “Dissolvan V 4795” and “Dissolvan V 4397”:  $65,656 \times 1,600,000 = 105,049,600$  tenge;

Cost of 32.828 tons of “IKHLAS-1” and “IKHLAS-2” nanodemulsifiers:  $32,828 \times 1,200,000 = 39,393,600$  tenge;

Annual expected economic effect:  $105,049,600 - 39,393,600 = 65,656,000$  tenge (169,365 \$).

#### Conclusions:

1. The expected annual economic effect for the “IKHLAS-1” and “IKHLAS-2”: nanodemulsifiers at the fields and ShPPO of OGPD "Zhaikmunaygas" "Embamunaigas" JSC is 65 656 000 tenge (169 365 \$).
2. The level of reduction in the concentration of oil and oil products in the composition of formation water from 50-400 mg / dm<sup>3</sup> to 15-50 mg / dm<sup>3</sup> (on the average a decrease is of 6.9 times) meets of the requirements of system reservoir pressure maintenance.

### V.VI. The calculation of the expected annual economic effect for the “IKHLAS-1” nanodemulsifier at the “Karsak” ShPPO and at the “Botahan” field of OGPD “Dossormunaigas” of “Embamunaigas” JSC

#### Initial data:

In the period 02.02.2019 - 12.02.2019 at the “Karsak” ShPPO and at the “Botahan” field of OGPD “Dossormunaigas” of “Embamunaigas” JSC, were conducted EIT of the nanodemulsifier “IKHLAS-1”. Starting from July 1, 2019, “IKHLAS-1” is successfully being introduced at the “Karsak” ShPPO and at the “Botahan” field of OGPD

“Dossormunaigas” of “Embamunaigas” JSC;

Base demulsifier: “Dissolvan V 4795” (Germany);

Cost of one ton of “Dissolvan V 4795” 1,600,000 tenge;

The cost of one ton of “IKHLAS-1”. 1 200 000 tenge;

The volume of annual oil production: 151 840 t;

The average daily consumption of the base demulsifier is  $78.1 + 16.9 = 95$  kg.

Average daily consumption of the “IKHLAS-1”. nanodemulsifier:  $46.1 + 14 = 60.1$  kg

The concentration of oil and oil products in the composition of the “Dissolvan V 4795” formation water is 73 mg / dm<sup>3</sup>;

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The concentration of oil and oil products in the composition of the formation water "IKHLAS-1" does not exceed 29 mg / dm<sup>3</sup>

### Calculation of the expected annual economic effect for "IKHLAS-1":

The total annual consumption of the base demulsifier "Dissolvan V 4795":  $95 \times 365 = 34\,675$  kg = 34, 675 t;

The total annual consumption of the demulsifier "IKHLAS-1":  $60.1 \times 365 = 21\,936$  kg = 21, 936 t;

Cost 34, 675 t base demulsifier "Dissolvan V 4795":  $34,675 \times 1,600,000 = 55,480,000$  tenge;

Cost of 21, 936 t of "IKHLAS-1" nanodemulsifiers:  $21,936 \times 1\,200\,000 = 26\,323\,200$  tenge;

Annual expected economic effect:  $55,480,000 - 26,323,200 = 29,156,800$  tenge (75,212 \$).

### Conclusions:

1. The expected annual economic effect for the "IKHLAS-1". nanodemulsifier at "Karsak" ShPPO and at the "Botahan" field of OGPD "Dossormunaigas" of "Embamunaigas" JSC is 29 296 800 tenge (75,212 \$).

2. The level of reduction in the concentration of oil and oil products in the composition of formation water from 73 mg / dm<sup>3</sup> to 29 mg / dm<sup>3</sup> (on the average a decrease is of 2.5 times) meets of the requirements of system reservoir pressure maintenance.

### Summary conclusion on economic efficiency

The sum of annual actual and expected economic effects according results to the EIT and introduction of "IKHLAS". nanodemulsifiers at some oil fields of the Republic of Kazakhstan, make up respectively: 139,489,760 tenge (359,825 \$) and 975,812,800 tenge (2,517,187 \$).

## VI. CONCLUSIONS

1. The numerous conclusions of the analytical review of the data available in the literature, mainly over the past 10 years, made it possible to formulate the relevance, purpose and objectives of the work at the level of oilfield nanotechnology. The known requirements for demulsifiers were reviewed, with numerous additions, at the also level of oilfield nanotechnology;

2. The revealed correlation relationships for the components of the demulsifiers "property-property", "property-structure", "property-structure-efficiency of use" made it possible not only to optimize the composition of the most effective compositions, but also to establish some new properties within the corresponding homological series. For example, for the dependence of the viscosity ( $\mu$ ) of n-aliphatic alcohols on the number of carbon atoms (m) in the molecule, it was found for the first time that at  $m = 9$  the viscosity increases by 16 times compared to  $m = 8$  (fig. 2). In previous similar transitions (for example, from  $m = 7$  to  $m = 8$ ;  $m = 6$  to  $m = 7$ ;  $m = 5$  to  $m = 6$ ;  $m = 4$  to  $m = 5$ , etc.), the viscosity increases on average by 1, 5 times. The reason for the sharp increase in viscosity at  $m = 9$  in our opinion is a sharp increase in the number of aggregations (g) in nonyl alcohol clusters. Therefore, in accordance with the concept of "critical micellization concentration" (CMC) for colloidal surface-active substances (surfactants), there may exist the concept of "critical length of the hydrocarbon radical of cluster formation" (CLHRCF) for non-colloidal surfactants, in this case for n-aliphatic alcohols. The concept of CLHRCF was first introduced into colloidal chemistry. It is known that in solutions of colloidal surfactants before CMC, there are pre-micellar aggregates with insignificant values of g [12-13]. Similarly, in our opinion, precluster aggregates with insignificant g values exist before CLHRCF. The cluster structure for some n-aliphatic alcohols was studied by Ukrainian scientists [12-14] and found that for n-hexyl alcohol at 20-50K,  $g=4$ . Therefore, under normal conditions, the dominant pre-cluster aggregates consist mainly of dimers. In general, with the concept of CLHRCF, the research prospect of formation cluster opens up not only for n-aliphatic alcohols, but also for other homologous series of non-colloidal surfactants;

3. The results of EIT and the introduction of nanodemulsifiers in some oil fields of the Republic of Kazakhstan:

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3.1. The results of the EIT of the “IKHLAS-1”. nanodemulsifier at the Zhetybay field of Mangistaumunaigas JSC compared to the base demulsifier Randem-2219 (Rauan Nalko company): the specific consumption of the demulsifier is reduced by 21.6%; dominant concentrations of formation water and chloride salts are reduced by 2.1 and 12.3 times, respectively; the oil concentration in the formation water is reduced by 20-28 times (from 600-1400 to 30-50 mg / dm<sup>3</sup>);

3.2. The results of the EIT of the “IKHLAS-1”. nanodemulsifier at the Tenge Oil & Gas field compared to the base demulsifier Dissolvan V 5748 (Germany): the specific consumption of the demulsifier was reduced by 18%; the preparation temperature is reduced by 14 ° C; at the GP-2 site, the water concentration in the oil is reduced by 9%, and chloride salts are reduced by 2.6 times; at the GU-1 site, the concentrations of water and chloride salts in the oil are reduced by 14 and 18 times, respectively; the oil concentration in the composition of formation water is reduced by 18 times (from 370-1290 to 46 mg / dm<sup>3</sup>); since 2018, “IKHLAS-1”. has been successfully introduced at the “Tenge Oil & Gas” field;

3.3. The results of the EIT of the “IKHLAS-1” nanodemulsifier at the “Phystech II” JSK field compared to the basic demulsifier “SNPCH-4315D” (Russia): in PPO technologies, the specific consumption of the demulsifier is reduced by 2.2 times; preparation temperature is reduced by 5 ° C; the oil concentration in the composition of formation water is reduced by 7 times (from 200-470 to 47.8 mg / dm<sup>3</sup>); since 2018, “IKHLAS-1” with a specific consumption of 100 g / t is successfully introduced at the “Phystech II” JSK field;

3.4. The results of the EIT of the “IKHLAS-1” nanodemulsifier at the “Akkulka” field of “TetisAralQaz” LLP in comparison with the base demulsifier “DMO-86520” (USA, Baker Hughes): the specific consumption of the demulsifier is reduced by 2 times; the concentration of chloride salts in the composition of the delivered oil is reduced by 2.8 times; the oil concentration in the composition of formation water is reduced by 3.5 times (from 62-137 to 28 mg / dm<sup>3</sup>); Since October 2017, “IKHLAS-1” is successfully introduced at the “Akkulka” field. In 2019 “IKHLAS-1” also successfully introduced at the “Anaka” field;

3.5. The results of the test results of the “IKHLAS-1” and “IKHLAS-2” nanodemulsifiers at the ShPPO and at individual fields of OGPD “Zhaikmunaygaz” of “Embamunaigas” JSC in comparison with the basic demulsifiers “Dissolvan-4795” and “Dissolvan-4397” (Germany) with formation various types of oil colloids (viscoelastic systems, gas hydrates, etc.) in the conditions PPO: the specific consumption of the demulsifier is reduced by 2 times; the concentration of chloride salts in the composition of crude oil is reduced by 1.4 times; the oil concentration in the composition of formation water is reduced by 6.9 times (from 50-400 to 15-50 mg / dm<sup>3</sup>); since July 1, 2019 “IKHLAS-1” and “IKHLAS-2” are successfully introduced at the ShPPO and at individual fields of the OGPD “Zhaikmunaygaz” of “Embamunaigas” JSC.

3.6. Results of the “IKHLAS-1” nanodemulsifiers EIT at the “Karsak” ShPPO and at the “Botahan” field of OGPD “Dossormunaigas” of “Embamunaigas” JSC compared to the basic demulsifier “Dissolvan-4795” (Germany): the specific demulsifier consumption is reduced by 1, 7 times; the concentration of residual water in the oil of the commodity tank is reduced by 3 times; the oil concentration in the composition of formation water is reduced by 2.5 times (from 73 to 29 mg / dm<sup>3</sup>); since July 1, 2019 “IKHLAS-1” is successfully introduced at “Karsak” ShPPO and at the “Botahan” field of OGPD “Dossormunaigas” of “Embamunaigas” JSC JSC.

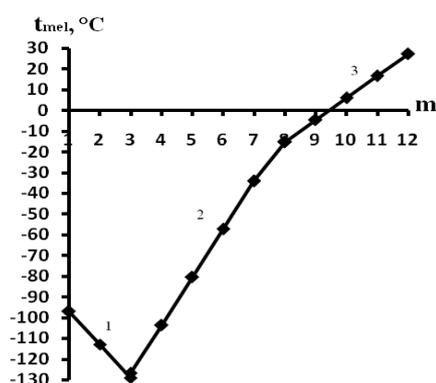
4. Actual and expected annual economic efficiency from the use of IKHLAS nanodemulsifiers at the above listed oil fields are 359,825 \$ and 2 517 187 \$, respectively.

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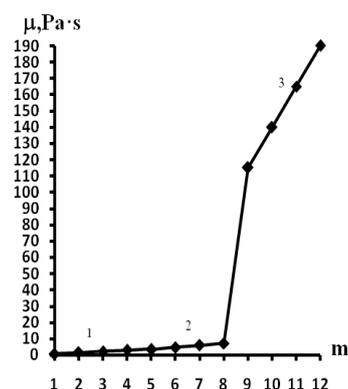
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**Fig. 1.** Depends  $t_{mel} = f(m)$  for n-aliphatic alcohols ( $C_mH_{2m+1}OH$ ):  $t_{mel}$  - melting temperature; 1 - (m = 1-3); 2 - (m = 3-7); 3 - (m = 8-12)



**Fig. 2.** Depends  $\mu = f(m)$  for n-aliphatic alcohols ( $C_mH_{2m+1}OH$ ):  $\mu$  - dynamic viscosity, mPa·s; 1 - (m=1-5); 2 - (m=5-8); 3 - (m=9-12)

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