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Research Article

Viscous and heavy oils of Arctic zone

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Abstract

The paper presents the comparative analysis of physicochemical properties of oils in North American, Scandinavian, and Russian sectors of the Arctic. The analysis of oil reserve distribution in the arctic territory and aquatory shows that the Russian sector is much higher in oil reserves than North American and Scandinavian sectors. A study of physicochemical properties of viscous and heavy oils in the Russian part of the Arctic is presented in this paper. Using a global database on physical and chemical properties of oils, analysis of the distribution of viscous, heavy oils in terms of the volumes of their reserves was carried out. It is known, that heavy and viscous oils account for slightly more than 33 % of the total samples. The criteria necessary to classify oils as hard-to-recover oil reserves are determined. The features of the physico-chemical properties of these oils are studied under various conditions of the Arctic. The results of a comparative analysis of hard-to-recover oils from the main basin West Siberian of the Arctic zone of Russia are given, which made it possible to establish the features of the physicochemical properties of oil. The results of the research can be used to develop new and improve existing methods and technologies for oil production and refining.

Keywords

The Arctic, oil-gas resources, physic and chemical properties of oil, sulfur, waxes, resins, asphaltenes.

Introduction

In the 21st century, it has become apparent that further economic development in Russia is impossible without reclamation of the Arctic region based on the new quality approach accounting for ecological priorities. Presently, such arctic countries as Russia, the USA, Canada, Norway, Denmark on behalf of Greenland and non-arctic countries display as well the great interest to reclamation of this region (Askhabov et al. 2014, Bortnikov 2014, Kaminskii et al. 2014, Kontorovich 2014). The Arctic zone is divided into three large sectors, namely: North American, Scandinavian, and Russian. The oil-and-gas bearing zoning of the Arctic region is presented in Figure 1. The Arctic mineral resource base contains the main group of minerals, i.e. hydrocarbons. Russia is one of the leading Arctic countries in the field of oil-and-gas reserves.

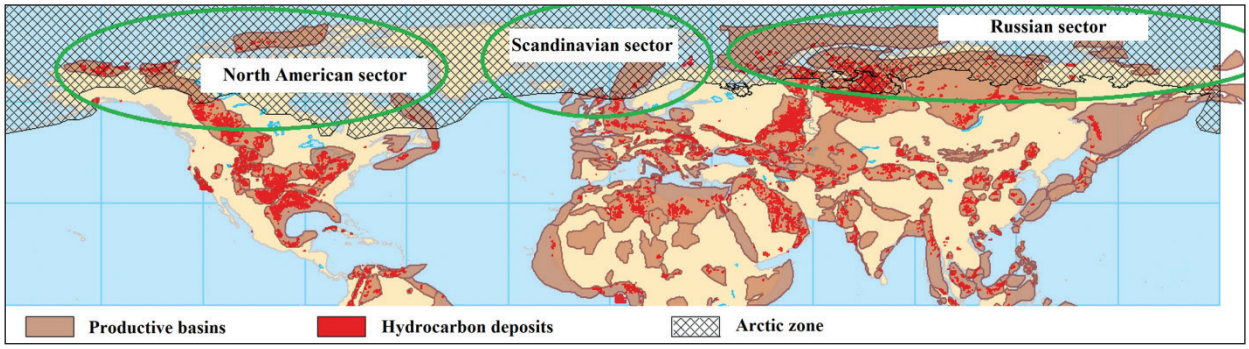

Fig. 1. Oil-and-gas bearing zoning of the Arctic region

The main aim of the study: to study the physicochemical properties of the viscous and heavy oils in the Arctic zone based on the information from the global database on the physicochemical properties of oils created in the Institute of Petroleum Chemistry, SB RAS, Tomsk, Russia.

Materials and methods

The analysis of oil reserve distribution in the arctic territory and aquatory was carried out using the petroleum chemistry database created in the Institute of Petroleum Chemistry, SB RAS, Tomsk, Russia (Yashchenko and Polishchuk 2014), which contains over 32800 oil types. The comparative analysis was conducted to study the physicochemical properties of oils of North American, Scandinavian, and Russian sectors. A special attention was paid to studying the properties of viscous and heavy oils of the Russian sector.

In order to provide the compositional analysis, the properties of oil from large, unique and hard to recover reserves of North-West Siberia were studied, namely: Arctic, Bovanenkovo, Zapolyarny, Novopotovskoe, and Russkoe fields. Both physicochemical properties.

The methods used in the study: methods of statistical analysis and classification of data to study the characteristics of viscous and heavy oils and methods of geoinformation systems for spatial analysis of data on the physico-chemical properties and conditions of their occurrence in various oil-bearing basins in the Arctic zone.

Results and discussion

The article presents new results of the investigation of the peculiarities of physicochemical properties of hard-to-recover oils of low quality in the Arctic zone of Russia. The analysis was carried out using a vast array of data on the properties of oils obtained from the database of the Institute of Petroleum Chemistry of the SB RAS. The sample size was 2900 samples of Arctic oil, more than half of which (about 1500) belonged to hard-to-recover oils. For this subarray of data, the average values of the physico-chemical characteristics were determined, the comparison of which made it possible to reveal features of the properties of hard-to-recover oils. It is shown that, on average, such oils are heavy, high-viscosity, sulphurous, medium-paraffinic, medium-resins and medium-asphaltenic, with a high content of heavy metals. A comparative analysis of hard-to-recover oils for the West Siberian basin of the Arctic zone of Russia has been carried out, and features of the physicochemical properties of oil have been established.

Table 1 contains information about hydrocarbon deposit and resource distribution in the Arctic zone. In the Russian sector, the number of hydrocarbon deposits is 4 and 8 times higher than that of North American and Scandinavian sectors, respectively. The amount of hydrocarbon reserves in the Russian sector is also large and comes to almost ¾ of all arctic reserves.

Physicochemical properties of arctic oils are presented in Table 2 for the sectors under study. The

Table 1. Hydrocarbon deposit and resource distribution in Arctic zone

Arctic zone	Productive basins	Number of hydrocarbon deposits	Hydrocarbon reserves (%)
North American sector	Alaska Arctic Slope, Beaufort, West-Canadian, Labrador Region, Sverdrup Island	165	18.50
Scandinavian sector	West-Scotland, Norwegian Sea, Hatton, Middle Europe, Shetland-Faeroes	91	8.30
Russian sector	Anadyr'-Navarinskii, Barents-Kara, East-Arctic, Yeniseian-Anabar, West Siberian, Lena-Vilyuysk, Lena-Tunguska, Penzhinsk, Pacific Ocean region, Timan-Pechora, Ust'-Indigirsk, South-Chukot	731	73.20

Table 2. Physicochemical properties of oils in Arctic zone

Indicators	North American sector	Scandinavian sector	Russian sector
Density (g/cm^3)	0.8880	0.8471	0.8370
Viscosity at 20 °C, (mm^2/s)	26.27	7.89	421.16
Viscosity at 50 °C, (mm^2/s)	12.23	5.54	16.29
Sulfur (wt. %)	0.99	0.36	0.59
Paraffine (wt. %)	1.26	5.82	4.81
Asphaltene (wt. %)	11.30	0.48	1.52
Fraction boiling point ≤200 °C, (wt. %)	10	34	28.15
Gas m^3/t	219.67	187.45	142.27
Vanadium (wt. %)	0.004	0.0002	0.004
Nickel (wt. %)	0.001	0.0001	0.007

statistical analysis shows that average values differ and reflect their changes in different sectors of the Arctic zone. Oils from North American sector are the heaviest as compared to those from Scandinavian and Russian sectors and contain more sulfur, asphaltenes and less paraffines and light fractions with boiling points ≤200 °C. Oils from Russian sector refer to light oils, although are characterized by the high viscosity and the high content of such heavy metals as vanadium and nickel which corresponds to their profitable extraction. Scandinavian oils possess higher quality and are described by the average density, low viscosity, sulfur, asphaltenes, and metals, but are high in paraffines.

It should be noted that Scandinavian region is rich in heavy (over 0.88 g/cm^3 density) and viscous (over 35 mm^2/s at 20 °C) oils that can be rather efficient for the production of arctic oils and paving bitumen (Kontorovich 2014). Table 3 contains information about physicochemical properties of heavy and viscous oils in sectors under review.

The statistical analysis shows that heavy and viscous oils in the Russian sector are heavier and more viscous as compared to those from North American and Scandinavian sectors, and almost 1.5–2 times higher in sulfur and praffines. Heavy oils of North American sector are characterized by the higher asphaltene aggregation (3–10 times higher). Scandinavian oils possess higher quality, i.e. the lowest density and viscosity, low sulfur and asphaltenes.

The total area of the Russian sector is 30 % larger than the territory of the whole Russia (Bortnikov 2014). In compliance with the regulatory documents, it includes the part of the Sakha Yakutia Republic, Murmansk and Arkhangelsk regions, Novaya Zemlya Archipelago, Autonomous Areas of Taimyr, Yamalo-Nenets and Chukot, Republics of Karelia and Komi, and also territories and islands and adjacent continental waters, the territorial sea and continental shelf (Fig. 1).

The Russian Arctic region is of geopolitical, economical, defence, scientific, and socio-economic in-

terests of the Russian Federation. The Russian sector is the largest petroleum reserve of the country after West and East Siberia regions that have been explored for the last time. This sector should be seriously prepared for reclamation during the next 10–15 years. The estimation of hydrocarbon potential of territories and aquatories of the Russian sector is given in Table 4.

According to Table 4, hydrocarbon deposits in the Russian Arctic zone are so significant that without the reclamation of this region the country will not be able to succesfully develop and exist. The estimation of hydrocarbon potential of territories and aquatories of the Russian sector of the Arctic requires considerable detailing and corrections since geologic-geophysical state of north territories and aquatories has not yet been well investigated. In specialists' opinion, the estimation of oil reserves of the Russian sector can be rather higher and comparable with productive basins of Near East (Kontorovich 2014). Thus, the unique oil reserve Pobeda was discovered in Kara Sea by Rosneft Company. Research results on fluid, drilling sludge, and core samples obtained by OAO 'TomskNIPIneft' proved prognosis evaluations of the oil quality. The quality of this superlight oil surpasses that of Brent oil benchmark. It was found that the density of this oil is 0.808–0.814 g/cm^3. The weight content of sulfur in oil reserve Pobeda is only 0.02. Moreover, this oil type is characterized by the high output of light fractions (60–70 %) and the low resin content (1.5 %). At the same time, oils from northern and eastern territories and aquatories are hard to recover reserves due to difficult mining-and-geological conditions such as permafrost.

As was mentioned above, the Russian sector is very high in hydrocarbon deposits, especially heavy and viscous oils. These are oils from the unique and large fields, namely: Russkoe, Novopotovskoe, Komsomol'skoe, Vyngapur, Zapadno-Messoyakhskoe, Tazovskoe in West Siberian basin; Naul'skoe, Yaregskoe, Medynskoe-More, Prirazlomnoe, Syurkharatinskoe, Toraveiskoe in Timan-Pechora basin; Olenekskoe in Lena-Tunguska basin, and others (Chirkova et al. 2015, Lur'e and Shmidt 2009, Polishchuk and Yashchenko 2006, Yashchenko 2013, Yashchenko 2012). In connection with the interest to heavy and viscous oils (Canada, Venezuela) increased in the world, the problem of rationale for the optimum technologies and production models, transportation and processing of oil in Russia becomes very relevant. Heavy and viscous oils presented in Table 5 are medium -sour, -resinous, -asphaltene and low in sulfur diesel and associated gas. Also, a high content of vanadium and nickel is present.

In Russia, heavy oils are referred to hard to recover hydrocarbon reserves. They differ from

Table 3. Physicochemical properties of heavy and viscous oils in Arctic zone

Indicators	North American sector	Scandinavian sector	Russian sector
Density (g/cm^3)	0.9107	0.8955	0.9250
Viscosity at 20 °C, (mm^2/s)	37.68	22.67	621.40
Viscosity at 50 °C, (mm^2/s)	30.30	10.14	60.53
Sulfur (wt.%)	1.16	0.48	1.60
Paraffine (wt.%)	1.07	1.60	2.68
Asphaltene (wt.%)	12.85	1.00	3.57

Table 4. Hydrocarbon deposits in territories and aquatories of the Russian Arctic zone

Territories and aquatories	Initial recoverable reserves of oil, condensate, associated and free gas				
	Oil (bln t)	Associated gas (bln m^3)	Free gas (trn m^3)	Condensate (mn t)	Total hydrocarbon (bln t)
Territories	51.2	2876.0	94.6	1378.0	150.1
Aquatories	19.4	2553.8	107.6	6325.2	135.7
Total	70.6	5429.8	202.2	7703.2	286.0

Table 5. Physicochemical properties of heavy viscous oils in Arctic zone of Russia

Indicators	Heavy viscous oils
Density (g/cm^3)	0.9250
Viscosity at 20 °C, (mm^2/s)	621.40
Viscosity at 50 °C, (mm^2/s)	60.53
Sulfur (wt. %)	1.60
Paraffine (wt. %)	2.68
Resins (wt. %)	9.99
Asphaltene (wt. %)	3.57
Fraction boiling point ≤200 °C, (wt. %)	11.86
Fraction boiling point ≤300 °C, (wt. %)	24.21
Fraction boiling point ≤350 °C, (wt. %)	33.13
Gas m^3/t	43.42
Vanadium (wt. %)	0.0067
Nickel (wt. %)	0.0141

traditional oil types not only by their high density but also composition. Moreover, heavy oils comprise naphthenic acids, sulphonated acids, simple and compound ethers which can be extracted by a special refining technology. The cost of these components in terms of marketable products obtained after the oil refinement can exceed the cost of oil products. The content of heavy metals in arctic oil satisfies the level of normal concentrations. Currently, oil companies neglect the extraction of associated components from heavy viscous oil. Besides, there are no efficient technologies for the extraction of associated components that could render a significant profit to oil companies.

Thus, for example, the quality of vanadium and nickel extracted from heavy viscous oil considerably exceeds the quality of analogs obtained from ore. Therefore, it is metal extracted from oil that the developed countries prefer to use in innovative technologies which provide the purity higher than in casthouse production. Canada and Japan produce vanadium completely from heavy viscous oils; the USA extracts over 80 % of vanadium from oil as well (Yakuzeni 2005). Since 2003, the demand for vanadium has been outstripped, and, obviously, will be continued despite the economy crisis.

In order to provide the compositional analysis, the properties of oil from large, unique and hard to recover reserves of North-West Siberia were studied, namely: Arctic, Bovanenkovo, Zapolyarny, Novopotovskoe, and Russkoe fields.

The comparative analysis of physicochemical properties shows that by its density this oil can be referred to light (Bovanenkovo, Zapolyarny and Arctic fields), medium and heavy (Novopotovskoe field), and bitumen (Russkoe field) having over 0.895 g/cm^3 density. By contrast to other types, the oil from Russkoe field is high viscous. The properties content of oils from North-West Siberia is given in Table 6.

Novopotovskoe and Russkoe fields possess large reserves of heavy and viscous oils, the average physicochemical properties of which are given in Table 7. Physicochemical properties of these oils slightly differ. On the average, oils are low in sulfur, resin, asphaltenes, and diesel fractions. Oils from Russkoe field possess higher viscosity and are twice as high resins and asphaltenes as oils from Novopotovskoe field at a lower amount of end point fractions in comparison with Novopotovskoe field.

Oils from Russkoe field can become the main natural source of deficient naphthene oil production. According to Table 7, oils from Russkoe field is the unique raw material since it refers to heavy oils low

Table 6. Properties content of oils from North-West Siberia

Area	Zapolyarny	Arctic	Bovanenkovo	Novopotovskoe	Russkoe
Density (g/cm^3)	0.7942	0.8119	0.7923	0.8495	0.9375
Viscosity (MPa · s)	2.33	4.69	5.55	10.57	515.86
Sulfur (wt. %)	0.05	0.06	0.06	0.11	0.34
Paraffine (wt. %)	2.06	4.96	6.44	5.32	1.12
Resins (wt. %)	2.63	2.40	1.92	3.27	11.43
Asphaltene (wt. %)	0.09	0.23	0.24	0.27	0.89
Fraction boiling point ≤200 °C, (wt. %)	57.04	27.17	–	28.53	4.09
Fraction boiling point ≤300 °C, (wt. %)	91.35	55.33	–	56.03	13.33
Fraction boiling point ≤350 °C, (wt. %)	99.98	–	–	57.66	30.90
Vanadium (wt. %)	–	–	0.00001	0.00007	0.0017
Nickel (wt. %)	–	–	0.00001	0.00005	0.0005

Table 7. Physicochemical properties of heavy viscous oils of Novopotovskoe and Russkoe fields

Indicators	Novopotovskoe field	Russkoe field
Density (g/cm^3)	0.9147	0.9396
Viscosity at 20 °C (mm^2/s)	38.99	560.00
Sulfur (wt. %)	0.18	0.35
Paraffine (wt. %)	1.11	1.16
Resins (wt. %)	4.81	11.02
Asphaltene (wt.%)	0.33	0.74
Fraction boiling point ≤200 °C (wt.%)	0.90	0.72
Fraction boiling point ≤300 °C (wt.%)	45.74	18.35
Fraction boiling point ≤350 °C (wt.%)	46.52	28.21

in paraffines and sulfur with the minimum content of light fractions with boiling points ≤200 °C (> 1.0 wt.% boils off). Today, naphthene oils having a high viscosity index produced from low-paraffine oils of Russkoe field is rather difficult and implies the application of up-to-date hydro-catalytic technologies. However, a wide range of their applications (the production of industrial, dielectric, hydraulic, transmission, refrigerator and other oils) provides the efficient use of hard to recover reserves of the Arctic. For example, in the USA and Canada, 20 % of base oils are based just on heavy hydrocarbon feedstock refining. In the Russian part of the Arctic, it is important and expedient to bring industry nearer to the heavy oil output that will allow the development of the petroleum chemistry production and efficient and high-performance technologies. The Arctic has opportunities to become the largest manufacturer of diverse petroleum products and perform its sustainable delivery to the home and, in the future, international market as well.

Conclusions

It is shown that the Russian sector of the Arctic zone is much richer in oil and gas than other sectors. Oils of the Russian sector belong to the light oil type, but are characterized by high viscosity and high content of heavy metals, such as vanadium and nickel the content of which corresponds to their profitable extraction. There are no currently efficient extraction technologies for such associated components as naphthenic acids, sulphonated acids, simple and compound ethers, heavy metals that could render a significant profit to oil companies. The properties and composition of heavy viscous oils from West Siberia is the main rec-

ommendation for their refining using the advanced technologies and production models for a wide range of petroleum products. The use of these data for advanced oil processing, efficient and economical use of hydrocarbon deposits will allow not only to improve such processes as thermal and catalytic cracking, but also change the viewpoint concerning the existing oil refining technologies. In General, the results of the research can be used to develop new technologies for oil production and transportation, as well as to assess prospects and determine the direction of development of the domestic oil and gas production complex.

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