Some Problems of Environmental Security of Territory of Oil and Gas Complex of the Republic of Sakha (Yakutia)

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Abstract. Oil and gas complexes sometimes use a method of cleaning soils from oil pollutions by covering polluted area with ground. An analysis of five years monitoring has shown that such method not only does not remove oil pollution, but also prevents further soil remediation using effective cleaning methods such as bioremediation, due to the absence at a depth of air oxygen and solar radiation which are necessary conditions for the life of hydrocarbon-oxidizing microorganisms. As a result oil pollution with thawed water annually seeps back to the soil surface, which leads to secondary environmental pollution by oil hydrocarbons.

1. Introduction

Sustainable socio-economic development of modern society is associated with high consumption of hydrocarbon raw materials. Hydrocarbons are primarily energy, heat, fuel and lubricants, raw materials for the chemical industry [1]. The efforts of the scientific community are currently aimed both at the search for alternative energy sources, and at the development of new technologies that allow more rational and comprehensive use of traditional (oil, gas, gas condensates) and non-traditional carbon-containing (coal, shale, bitumen) raw materials. Nevertheless, the demand for hydrocarbons continues to grow. As a result more and more new fields are searched and put into operation. The north-eastern part of the Arctic coast is of great interest from point of view hydrocarbon reserves. Here, according to many geologists, huge reserves of hydrocarbon raw materials are concentrated. The development these resources is a difficult task both as material costs and the need to work with minimal risk in extreme climatic conditions. In the conditions of low temperatures zone cold resistance of structures, equipment and materials sharply decreases, as a result of which the probability of emergency situations increases [2]. Oil production, transportation and refining even in regions with favorable climatic conditions are associated with numerous leaks, spills and accidents [3, 4]. According to the data [5], total oil losses may amount to 2–3 % of its production. The consequences of oil pollution are especially dangerous for the northern regions, where nature is very fragile and vulnerable [6-8]. During oil spills and leaks soil and aquatic ecosystems are the most vulnerable to the adverse effects. Soils and bottom sediments, being good geochemical barriers, absorb oil. Oil, falling into the soil, destroys the existing soil biocenosis, the remediation of which may take a long time. Typically, soils contain a certain amount of aboriginal hydrocarbon-oxidizing microorganisms (HOM) [9]. Oil trapped in the soil serves as a nutrient substrate for them, and the number of colonies of HOM increases. Biodegradation of oil contamination occurs under the influence of HOM, which leads to a gradual self-remediation of soils. The activity of biodegradation processes depends on the water-aeration regime, the amount of humus, the level of oil
pollution, the temperature of the soil layer and other factors [10]. Asphalt-resinous components of oil, as well as resinous components, formed during biodegradation, glue soil clumps. As a result, the water-aeration regime is destroyed. The lack of water and air oxygen negatively affects the activity of soil microflora. In many cases, especially at high levels of oil pollution, soil microflora almost perishes. In the northern regions due to a very short period of positive temperatures, a small amount of humus the activity of soil microflora itself is not large. Oil pollution further more inhibits the microbiological activity of soils, and self-remediation processes can last for a long time. As a result, it is necessary to monitor the timely detection of oil pollution [9, 11] and carry out special remediation works for the remediation of oil-polluted soils.

Sustainable functioning and restoration of ecosystems disturbed by the activities of oil and gas complexes is a priority for environmental protection. Despite the high requirements to minimize pollution and the transition to the most environmentally safe purification technologies of oil-polluted soils and ground, there is a risk of disturbance and pollution of soils with oil and oil products, which causes negative consequences for the environment. Unfortunately, oil spill response methods such as burning, covering contaminated areas with ground or sand are still used, which is not acceptable [12-14].

Observations have shown that sometimes even in the first spring-summer season, when the oil-polluted area is covered with ground, oil seeps to the surface of the earth. Consider what happens to pollution in the case of carrying out such purification activities.

2. Objects and methods
The object of research was an area of oil and gas complex object of the Republic of Sakha (Yakutia), it was the tank farm. Two sites were taken: the first – with fresh pollution and the second – with fresh pollution covered by ground, and at the latest oil had seeped again. In early June the recovery works on bioremediation of soil were carried out in both sites. In early September soil samples were collected for analysis. The observations were carrying out for 5 years, samples were sampled every year on the twentieth of May and early September.

The content of oil pollution in soils has been determined by the yield of cold chloroform extracts (CE) [15]. Using this method of determination oil pollution allows studying not only fresh, but also old pollution, as well as products of the transformation of oil pollutants [16-19]. Composition of extracts has been studied by methods of liquid adsorption chromatography [15] and IR-Fourier spectroscopy.

3. Results and discussion
Investigations have shown, that over the summer season in both sites due to biodegradation the content of oil pollution significantly decreased (figure 1). However, in May of next year the content of oil pollution increased again. At the first site, where the pollution was not covered, there was only a slight increase, while in the site with buried oil pollution the pollution content was even higher than last year (figure 1).
Figure 1. Dynamics of changes in the level of oil pollution of soils with sampling time.

A similar picture was observed in subsequent years. At the first site with the initial fresh pollution a decrease of the amplitude of fluctuations of the content of oil pollution is noted over time. Then pollution gradually decreases. At the second site strong seasonal fluctuations of the content of oil pollution continued. It increased in May and decreased by the beginning of September. This is probably due to the fact that in the summer time biodegradation processes are occurs and by September the content of oil pollution in the surface layers of the soil decreases. At a depth, where pollution is buried, the activity of the HOM even in the summer time is too low (absence of air oxygen and solar heat), and the biodegradation processes attenuate. Oil pollution occurred in deeper layers of the soil is capable to migration with rain and thawed water. As result, after spring thawing of soils an increase of the content of oil pollution in the surface soil layers is again observed.

For confirmation this assumption soil samples from the second site were analyzed from various depths: from the surface to 100 cm. As shown in the table 1, the oil content in the soil increases with depth, and the amount of hydrocarbon components in the composition of CE increases, and among them – methane-naphthenic (Me–Na) hydrocarbons, the content of resins and asphaltenes decreases, which is typical for the composition of fresh pollutants. That means the components of oil pollution with depth are less undergone to biodegradation processes. This is also indicated the relative absorption coefficients of the structural groups calculated according to IR-Fourier spectroscopy as the ratio of the optical densities of the absorption bands of the certain structural groups to the optical density of the band at 1460 cm$^{-1}$. The relative coefficient $D_{720}'$ characterizes the presence methylene groups in the structure of oil contamination, $D_{1710}'$ points to carbonyl groups (table 1). An increase of hydrocarbon groups ($D_{720}'$) in the composition of CE and a decrease of oxygen-containing groups ($D_{1710}'$) with depth indicate a greater preservation of oil contamination components.
Thus, oil pollution is more oxidized or transformed near the surface. The processes of oxidative degradation, apparently, practically do not proceed from a depth of 50 cm and below. As it is known, HOM are most active in the upper soil layer (0–20 cm). Oil hydrocarbons are not available for the action of a biological degradation at depth, since aerobic HOM in composition of preparation can only degrade oil in an aerated soil layer [20]. Due to the lack of air oxygen and ultraviolet radiation their activity sharply falls and the biodegradation processes almost attenuate, which is confirmed by the results of the analyzed soil samples (table 1). Thus, the increase of content of oil pollution in the investigated site No. 2 in the spring time is the result of vertical oil migration along the soil profile. For example, the ability of polycyclic aromatic hydrocarbons to migrate deep into the soil in the autumn time and up to the surface in spring time was noted in work [6]. This vertical migration is probably due to the processes of freezing and thawing of soils in the autumn and spring seasons. Aromatic hydrocarbons are more soluble in water, than aliphatic. As a result of this, perhaps they are more involved in the processes of migration associated with freezing and thawing of water. Also, a season permafrost thawing can influence on processes of migration.

4. Conclusion
An analysis of the results of five-year monitoring has shown that burred oil pollution is poorly exposed to biological remediation methods, by reason of an absence of air oxygen and solar radiation at a depth necessary for the life of HOM. As a result, an annual increase of the concentration of oil pollution in the surface layers of the soil in May is observed, due to the migration of oil pollution from deeper layers with thawed water. Probably oil pollution spreading is also facilitated by rainwater and seasonal thawed water formed during permafrost thawing. As a result, burred oil pollution can become a secondary source of environmental pollution for many years, reducing the effect of carried out purification activities.

Thus, covered oil-polluted areas with ground not only does not eliminate oil pollution, but also prevents to the carrying out of remediation activities with using the most effective cleaning methods such as bioremediation.

5. References
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