Assessment of environmental damage to atmospheric air during development of oil and gas fields

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Abstract. At present, new tasks arise for the oil and gas producing industry in the Russian Federation. This is due to the geopolitical need to develop new oil and gas producing regions, in addition to the existing fields, in the coming years. These regions include, first of all, the Lena-Tunguska province with the most promising Dulisma, Yarakta, and Iktekh fields. The impact of extractive industry facilities on the environment is manifested both at the construction stage and at the stage of their exploitation. This makes it necessary to study geoeological risks for various facilities of the extractive industry. The authors studied the ecological situation in the production activity area of the fields and established the main environmental consequences of gas and oil production and their negative impact on the environment. Having measured the factors of the production environment, we established that the fields pollute the atmosphere mostly with emissions of hazardous substances, such as carbon monoxide, nitrogen and natural gas. The authors carried out an estimation of the economic damage to atmospheric air during the development of the fields. As a result, it was found that the Yarakta field causes the greatest economic damage to the atmospheric air.

1. Introduction

Russia is among the leading countries in terms of the natural gas resource potential. The total initial resource potential of natural gas is estimated at an approximate amount of 235.6 tn m$^3$, of which about 100 tn m$^3$ are in Western Siberia, 60 tn m$^3$ fall on other regions of the country and 75 tn m$^3$ on the continental shelf of the Arctic Ocean - the Kara and Barents seas. Natural gas reserves of the country amount to more than 100 years. Of the 942 fields containing free gas, as well as gas in gas caps, 465 are under development, geological exploration is carried out at 242 fields allocated among subsoil users, and 235 fields are in the non-allocated reserve fund [1].

The discovery in 1962 of the first oil and gas field in Markovo marked the beginning of the development of the Lena-Tunguska oil and gas province located in the western part [2] of Yakutia, in the northern and central areas of the Krasnoyarsk Territory, and in the western and northern areas of the Irkutsk Region. More than 40 (2 oil, 18 oil and gas, 18 gas condensate and gas) [3] fields were discovered in the territory of the province; industrial oil and gas inflows were obtained in more than 30 separate wells, mainly from subsalt terrigenous and carbonate sediments. The most significant identified fields are: Srednebetyuobinskoe, Verkhnevilyuchanskoe, Danilovskoye, Verkhnehonsk, Markovo, and Yarakta gas condensate and oil and gas condensate fields [4].

At all stages of the development life cycle of the field there is a negative impact on the environment. At the stage of exploration, field exploitation and transportation of oil and gas, land
areas are withdrawn, natural waters and the atmosphere become polluted [5]. The processes of exploration, drilling, production, preparation, transportation and storage of oil and gas require large volumes of water for technological, transportation, household and fire safety needs with simultaneous discharge of the same volume of highly mineralized waste waters containing chemical reagents, surfactants and petroleum products. At the construction stage of the drilling site, atmospheric pollution is observed mainly from vehicles [6].

The amount of environmental risks depends on the climatic conditions, the geological and technical features of the well installation, water system, reagents used, vehicles, production volumes, work organization and other factors [7].

Environmental risk assessment can be carried out on the basis of available scientific and statistical data on environmentally significant events, disasters, on the contribution of environmental factors to the state of sanitary and environmental well-being of the population, on the impact of environmental pollution on the state of biocenoses, etc. [8].

Environmental risk can be estimated as the probability of an adverse event for the environment, such as atmospheric pollution, convenient for comparing risks for a single object from different events or for different objects in typical conditions of functioning (activity) [9].

The second possible option for assessing the environmental risk caused by an enterprise to a certain element of the environment may be damage expressed in monetary terms. Environmental-economic damage is a monetary estimate of negative changes in the environment as a result of its pollution, reduction of the quality and quantity of natural resources, as well as the likely consequences of such changes [10].

The aim of this paper is a comparative assessment of the environmental risk (environmental and economic damage) for the atmosphere during the extraction and development of gas condensate fields located in the Lena-Tunguska oil and gas province in the Irkutsk Region.

2. Study objects and methods

As the objects of research, we chose the gas fields most promising in the development: Yarakta, Dulisma, and Iktek oil and gas condensate fields [11].

The Dulisma oil and gas condensate field is located in the Katangsky municipality, 90 km north-west of the city of Kirensk. The design capacity of the Dulisma field amounts to 400-450 thousand tons of oil per year. The license for the development of the field belongs to NK Dulisma, CJSC [12].

The Yarakta oil and gas condensate field is geographically located 140 km north-east of the city of Ust-Kut, closer to the northern part of the Ust-Kut municipality and the southern part of the Katangsky municipality of the Irkutsk region of the Russian Federation. The oil and gas potential of the field is primarily associated with sediments of the Vendian and Cambrian ages, namely, sandstones of the Yarakta horizon with a total thickness of up to 40 m. The resource oil reserve is estimated at 102.5 million tons, and its density is 0.830 g/cm³ or 34° API. The density of the condensate is the same as 0.67–0.71 g/cm³. The license holder for the development of the Yarakta field is a subsidiary of INK LLC – Ust-Kutneftegaz OJSC [13].

The Iktek oil and gas field is located on the eastern slope of the Mirny ledge in close proximity to the Vilyuchanskaya saddle and is confined to the eponymous brachyanticline of the north-east strike. Reserves of oil (extr.) amount to: category C2 - 6.248 mn tons [14], category D1l (as of January 1, 2009) - 3.24 mn tons; gas: category C1 - 6.201 bn m³, category C2 - 10.535 bn m³, category D1l (as of January 1, 2009) - 11 bn m³; condensate (extr.): category C1 - 0.147 mn tons, category C2 - 0.248 mn tons [15].

The initial data for assessing environmental risks were the results of production control of enterprises, as well as EIA materials. For comparison, we chose similar technological processes, namely, the well construction and development stage [16].

Construction work on the arrangement of sites is accompanied by some increase in the existing level of air pollution. The main sources of air pollution are mobile diesel power stations, construction equipment and vehicles, welding units, pressure pulverizers of paintwork materials, loading and
unloading platforms. Construction work is performed stagewise. Each stage of construction is characterized by a specific set of atmospheric pollution sources. The work of motor transport and road-building machinery is accompanied by a constant change in the location of equipment at construction sites and the number of simultaneously operated transport units, different mode and time of operation of the engine. Operation of construction equipment and motor transport is associated with atmospheric pollution from exhaust gases of internal combustion engines. Oxides of nitrogen, carbon, sulfur, soot, and hydrocarbons enter the atmosphere with exhaust gases from vehicles and special equipment. The volume of exhaust gases and the content of harmful substances in them depends on the amount of fuel consumed and the technical condition of the engines. Welding work is periodic. The degree of impact on the atmospheric air caused by welding depends on the number and brand of electrodes used and the operation time of welding stations. During the operation of mobile welding stations that perform welding and cutting work, atmospheric air is polluted by welding aerosol, which contains hazardous metal (iron, manganese) oxides, inorganic dust, fluorides, and gaseous compounds (nitrogen dioxide, carbon monoxide, hydrogen fluoride). Atmospheric pollution during paint and varnish work depends on the brand and quantity of paintwork materials used. When carrying out paint and varnish work, vapors of solvents and paint aerosol enter the atmosphere [17].

The environmental-economic caused by the emission of pollution into the air for any source is determined by the aggregate account method according to the formula

\[ D_{\text{atm}} = k \cdot t \cdot f \cdot M, \]  

where \( k \) is a constant, the numerical value of which may vary depending on the increase in prices, rub/toe; \( t \) is the relative hazard coefficient, depending on the type of territory; \( f \) is a dimensionless coefficient taking into account the dispersion of the impurity in the atmosphere. Its value depends on the sedimentation rate of particles, the height of their emissions from the ground; gas temperature [18]; \( M \) is the reduced mass of the gas pollution emission from the source, toe/year [19].

The magnitude of the reduced mass of pollution emissions into the atmosphere was determined by the formula

\[ M = \sum_{i=1}^{n} A_i \cdot m_i, \]  

where \( N \) is the total number of pollutants; \( A_i \) is the dimensionless coefficient of the relative activity of the \( i \)-type impurity; \( m \) is the mass of the annual \( i \)-type emission into the atmosphere, tons/year [20].

3. Results of the study and their discussion

We assessed the environmental risk in relation to oil and gas companies. Based on data from the results of production control and draft standards for maximum allowable emissions, we calculated the API values for the study subjects. For the enterprises, we chose ecosstressors of the same chemical nature, namely oxides of nitrogen, sulfur, carbon, inorganic dust with 70-20% free silica, and hydrocarbons.

Figure 1 shows the ranking of the studied enterprises by air pollution index. As can be seen from the above data, the highest atmospheric pollution index is typical for the Yarakta field, the value of which corresponds to the “highly polluted” state of the atmosphere. This is due to the high degree of atmospheric gas pollution by exhaust gases of internal combustion engines.

When assessing the impact of the studied enterprises on the environment, we used the amount of the environmental risk expressed in monetary terms, and found that the construction of the Yarakta field caused the greatest damage (Figure 2). According to the results of the calculation, it was found that the total economic damage to the atmospheric air during the construction work at the sites of the enterprises under consideration amounts to 26.2 thousand rubles.

Figure 3 shows a chart comparing the economic assessment of the damage to the atmospheric air for the production capacity in m³ of hydrocarbon raw material produced. When recalculated to the
production capacity, the Yarakta field strengthened its position as the one that caused the most serious
damage to the atmospheric air from all the fields under consideration.

![Figure 1. Comparative chart of the air pollution index of the studied enterprises.](image1)

![Figure 2. Chart ranking damage from work on the development of deposits, by main pollutants.](image2)

![Figure 3. Chart ranking damage to the atmospheric air equivalent to 1 m³ of hydrocarbon raw material produced.](image3)

4. Conclusions
Based on the environmental risk assessment, we ranked the enterprises in question located in the
Irkutsk Region and operating the fields of the Lena-Tungusska province with assignment of corresponding ranks per 1 m³ of gas or oil. It was found that specific environmental risks at the development stage differ insignificantly. However, at the stage of operation, especially in the event of an emergency, the difference is colossal. Predictive assessment of atmospheric pollution during fires showed that environmental and economic damage increases from 10 to 100 times.
References

[1] Kozhukhova O S 2011 Oil and gas sector of Russia: condition and directions of development Economics and law issues 7 174–177

[2] Lukyanchikov N N and Potravny I M 2012 Economy and organization of environmental management: electronic textbook (Moscow: UNITY-DANA) p 687

[3] Burenina N S 2010 Atmospheric air protection: collection of regulatory legal documents (St. Petersburg: Research Institute Atmosphere, LLC Integral) p 295.

[4] Karakeyan V I 2011 Environmental economics: textbook (Moscow: Publ. house Yurayt) p 576

[5] Yankevsky A V and Abdurazakova K N 2017 The role of the introduction of innovative technologies in the oil and gas sector Collection of articles Innovations in technology and education 176–179

[6] Vorobev A E and Yankevsky A V 2013 Distinctive features of regulatory and legal aspects of subsoil use in foreign countries Proceedings of the VII International Conference dedicated to the 80th anniversary of the Kulatov Kyzyl-Kii Mining Technical College “Mining, oil, geological and geo-ecological education in the XXI century” 126–132

[7] Solovyanyov A A 2014 Ecological consequences of the development of shale gas deposits (Moscow: Green Book) p 60

[8] Makarov A A 2012 Forecast of energy industry development in the world and Russia until 2035 (Moscow: Institute for Energy Studies of RAS, REA) p 196

[9] Zhiltsov S S 2012 Shale gas (Simferopol: Publishing house Tavria) p 136

[10] Gavrilo V P and Grunis E B 2012 The state of the oil production resource base in Russia and the prospects for its increase Geology of oil and gas 5 1–17

[11] Muslimov R H 2014 Innovation and wide modernization of the oil and gas sector is an objective necessity for the modern development of Russia Georesources 1 (56) 3–10

[12] Sultanova K S 2015 Influence of lithofacial conditions on filtration and capacity properties of the YK1 collector layer of the Talinsky oil field Proceedings of the XIX International Usov Symposium of students and young scientists dedicated to the 70th anniversary of the Victory of the Soviet people over Nazi Germany “Problems of geology and development of the subsoil” 301–303

[13] Hou B, Xie S X, Chen M, Jin Y, Hao D and Wang R S 2013 The Treatment of Refinery Heavy Oil Sludge Petroleum Science and Technology 31(5) 458–464

[14] Olaquer E 2016 Atmospheric Impacts of the Oil and Gas Industry (Amsterdam: Elsevier) p 170

[15] Stanley N, Tota-Maharaj K, Eke P and Hills C 2016 Environmental and Economic Impacts of Crude Oil and Natural Gas Production in Developing Countries International Journal of Economy, Energy and Environment 1(3) 64–73

[16] Vasilyev A V 2018 Experience, Results and Problems of Ecological Monitoring of Oil Containing Waste Proceedings of the 2018 IEEE International Conference “Management of Municipal Waste as an Important Factor of Sustainable Urban Development WASTE 2018” 98–101

[17] Jin C and Zhang Z 2018 Regarding the role of oil & gas industry on social infrastructure development in Azerbaijan and the solution of ecological problems IOP Conference Series: Earth and Environmental Science 189(5) 052004

[18] Piet G J, Knights A M, Jongbloed R H, Tamis J E, de Vries P and Robinson L A 2017 Ecological risk assessments to guide decision-making: Methodology matters Environmental Science and Policy 68 1–9

[19] Zemenkova M, Shalay V, Zemenkov Y and Kurushina E 2016 Improving the Efficiency of Administrative Decision-Making when Monitoring Reliability and Safety of Oil and Gas Equipment MATEC Web of Conferences.

[20] Sharf I, Tsibulnikova M and Dmitrieva N 2016 Economic evaluation of the approaches to associated petroleum gas utilization International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management 3 153–160