Results of Environmental Monitoring of the Natural Environment of the License Area of Oil and Gas Production in the North of Western Siberia

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Abstract. This paper presents data of the local environmental monitoring carried out for environmental components within the license oil and gas production area located in Tazovskiy Raion, Yamalo-Nenets Autonomous Okrug, Tiumen Oblast. The local environmental monitoring of the license area includes analyses of all environmental components: atmospheric air (snow cover), soils, surface water, and bottom deposits. According to the analysis of data obtained in 2006-2018, regulatory limits and average regional values established for contents of hazardous substances in the soil profile were exceeded. Besides, MAC values in surface water were exceeded.

1. Introduction
During last decades, the active production of hydrocarbons has caused the pollution of the environmental components in northern regions of Tiumen Oblast. The Yamalo-Nenets Autonomous Okrug is a top producer of hydrocarbons, and thus, its territory has been to a greater extent impacted by man-made effects. Over 200 fields have been developed in this region [1, 2]. We shall note that all process stages of the oil and gas production pollute the environment [3, 4, 5].

In terms of its hydrocarbon resources, the Russkoie field located in Tazovskiy Raion, Yamalo-Nenets Autonomous Okrug, is one of the largest Russian fields [6, 7]. Its geological resources make up appr. 1.5 bln. tons, while recoverable resources – appr. 410 mln. tons. The Russkoie field was discovered in 1968. Its development has been started in 2007, and the full-scale production – in 2015. A relatively new drilling technique called the fishbone drilling is used in the license area. Hydrocarbons are transported by a pipeline, which connects the field with the Zapoliarie-Purpe Trunk Pipeline.

2. Subjects and Methods
The purpose of this study is to analyze data of the environmental monitoring, which was carried out during the development of the Russkoie field (license area).

Data of the environmental monitoring (2007-2018) were analyzed. During the monitoring, the Tiumenneftegaz Joint-Stock Company took samples of atmospheric air, snow cover and soil mantle and carried out the pollutant assay to obtain required data [8, 9, 10]. The samples were taken and the laboratory analyses were carried out according to common methods established by regulatory documents.
3. Results
Data of analysis. Major atmospheric air pollutants arising during the oil and gas production, transportation and refining/processing are hydrocarbons, hydrogen sulfide, nitrogen oxide, sulfur oxide, and suspended matters[11, 12].

To assess the atmospheric air quality within the license development area, air samples were taken according to GOST (State standard) 17.2.3.01-86 and RD (Regulations) 52.04.186-89. In 2007, samples were taken in 3 points, in 2013-2015 – in 9 points, in 2016 – in 5 points, and in 2018 – in 8 points. These samples were analyzed to determine contents of the following substances: nitrogen dioxide, nitrogen oxide, carbon oxide, sulphur dioxide, methane, benzopyrene, suspended matters, black, hydrocarbons, hydrogen sulfide, ethyl mercaptan, kerosene, and benzene [13]. The obtained data were compared with standards established for pollutant contents in atmospheric air in cities, towns and rural settlements.

Average contents of pollutants in atmospheric air samples taken during the whole development period are provided in Table 1.

Table 1. Average contents of substances in atmospheric air samples, Russkoie field (license area).

| Substance                     | Average content (mg/dm³) | MAC, mg/m³ |
|-------------------------------|--------------------------|------------|
|                               | 2007 2013 2014 2015 2016 2018 |           |
| Total, hydrocarbons           | 2.500 - - - - -           | -          |
| Nitrogen oxide                | 0.256 <0.1 0.058 0.056 0.055 <0.028 | 0.4        |
| Nitrogen dioxide              | 0.034 <0.1 0.047 0.048 0.047 0.034 | 0.2        |
| Sulphur dioxide               | <0.010 <0.013 0.033 0.037 0.033 0.084 | 0.5        |
| Black                         | <0.025 - 0.020 0.040 0.040 <0.03 | 0.15       |
| Carbon oxide                  | 2.700 <1 1.46 1.700 1.500 <2.0 | 5          |
| Suspended matters             | <0.260 - 0.130 0.200 0.180 0.281 | 0.5        |
| Methane                       | - <4 13.000 13.100 10.270 22.267 | 50         |
| Saturated hydrocarbons        | - <20 <0.8 <0.8 <0.8 <0.8 | -          |
| Benzopyrene                   | - - <0.000008 <0.000008 <0.000008 <0.0000005 | -         |
| Hydrogen sulphide             | - - - - - <0.006 | 0.008      |
| Ethyl mercaptan               | - - - - - <0.000015 | 0.000      |
| Kerosene                      | - - - - - <0.8 | -          |
| Benzene                       | - - - - - <0.0005 | 0.3        |

During the whole period of the field development, MAC values established for average contents were not exceeded. The highest content of nitrogen oxide was found in 2007 (0.256 mg/dm³), while the lowest – in 2018. Rapid increasing of the pollutant content in 2014-2016 can be caused by the increased number of vehicles and technical equipment used for the site pipeline construction during the above period.

For nitrogen dioxide, the highest value was determined in 2015 (0.048 mg/dm³), and the lowest – in 2007 and 2018 (0.034 mg/dm³). The highest sulphur dioxide value was determined in 2018 (0.084 mg/dm³), and the lowest – in 2014 and 2016 (0.033 mg/dm³). Black concentrations varied from 0.02 to 0.04 mg/dm³. The highest carbon oxide content was found in 2007 (1.7 mg/dm³), and the lowest – in 2014 (1.46 mg/dm³). Suspended matters varied from 0.13 mg/dm³ to 0.281 mg/dm³. The highest methane concentration was determined in 2018 (22.267 mg/dm³), and the lowest – in 2014 (13 mg/dm³).
For the assessment of environmental impacts of the oil and gas production facilities, data of snow cover analyses, which indicate the atmospheric pollution, are of great importance.

The field snow cover was monitored according to GOST (State Standard) 17.1.5.05-85, recommended practices for the assessment of metal pollution degrees carried out for community atmospheric air based on metal contents available in snow cover and soils, as well as according to RD (Regulations) 52.04.186-89. In 2007, samples were taken on 3 sites, in 2013–2015 on 8 sites, in 2016–2017 on 3 sites, and in 2018–2019 on 7 sites.

Since hygienic standards regulating the snow quality are not available, data of snow analysis were compared with average regional values (Table 2). Besides, these data were compared with MAC values established for atmospheric air based on metal contents available in snow cover and soils, as well as according to RD (Regulations) 52.04.186-89. In 2007, samples were taken on 3 sites, in 2013–2015 – on 8 sites, in 2016–2017 on 3 sites, and in 2018–2019 on 7 sites.

Table 2. Average pollutant contents in snow samples, Russkoie field (license area).

| Substance          | Average content (mg/dm³) | MAC, mg/m³ | Average regional value |
|--------------------|--------------------------|------------|------------------------|
|                    | Sampling year 2007 | 2013 | 2014 | 2015 | 2016 | 2018 |                  |
| Suspended matters  | <3.0                | -    | -    | -    | -    | -    | 10.0             |
| Ammonium ions      | 0.020               | 0.097 | 0.230 | 0.260 | 0.116 | 1.5   | <0.5             |
| Nitrate ions       | -                   | -    | 0.860 | 1.620 | 1.413 | 0.723 | 45    | 1.398            |
| Sulfate ions       | 0.467               | 0.890 | 2.045 | 1.650 | 1.801 | 500   | 0.88             |
| Chloride ions      | -                   | 0.490 | 8.570 | 6.313 | 0.894 | 350   | 1.04             |
| Oil products       | 0.020               | 0.080 | <0.04 | 0.118 | 0.082 | 0.084 | 0.3   | 0.041            |
| Phenols            | 0.001               | 0.004 | <0.005 | <0.0005 | 0.002 | 0.004 | 0.001 | 0.0048           |
| Total Fe           | 0.152               | <0.05 | 0.055 | 0.163 | 0.108 | 0.15  | 0.3   | 0.15             |
| Pb                 | 0.006               | 0.003 | <0.010 | <0.0005 | <0.0005 | <0.0005 | 0.01 | <0.0002         |
| Zn                 | 0.015               | 0.070 | 0.009 | <0.05 | 0.079 | 0.028 | 1     | 0.012            |
| Mn                 | 0.050               | -    | 0.002 | <0.0005 | 0.020 | 0.018 | 0.1   | 0.008            |
| Cu                 | -                   | 0.049 | <0.001 | <0.005 | <0.005 | <0.005 | 1     | 0.0028           |
| Ni                 | 0.001               | <0.001 | <0.001 | 0.002 | <0.001 | 0.02 | 0.02 | 0.0016         |
| Cr                 | 0.001               | <0.001 | <0.001 | <0.025 | <0.025 | 0.5 | <0.008     |
| Hg                 | 0.00005             | -    | -    | -    | -    | -    | 0.005 | -               |
| Benzopyrene        | <0.0010             | -    | -    | -    | -    | -    | -    | -               |

Notes
1. 1.620–exceeded average regional values
2. 0.004–exceeded MAC values

When analyzing average concentrations in snow samples, we shall note that phenol concentrations four-fold exceeded MAC values in 2013 and 2018, and twicely exceeded them in 2016. These exceedances can be caused by the increased oil and gas production at the field, as well as by the construction of production sites and an oil pipeline carried out during the above periods.

Interannually, average regional values determined for the following contents were exceeded: nitrate ions, sulfate ions, chloride ions, oil products, iron, zinc, manganese, and copper. The highest exceedances were determined in 2015–2016, for chloride ions and sulfate ions.

Thus, MAC values established for atmospheric air samples were not exceeded during the development of the Russkoie field. For the snow samples, phenol MAC values were exceeded, as well as average regional values of a number of hazardous pollutants.
During the local environmental monitoring, soil samples were taken (14 points in 2007, 9 points in 2013-2015, 11 points in 2016, and 16 points in 2018). The soil quality was assessed according to GN (Hygienic Standard) 2.1.7.2041-2006 and GN(Hygienic Standard) 2.1.7.2511-09.

Table 3 provides average concentrations of pollutants in soil samples taken within the license area.

| Determined parameters | Average content, mg/kg | MAC region value, mg/kg |
|-----------------------|------------------------|-------------------------|
|                       | Sampling year          |                         |
|                       | 2007  2013  2014  2015| 2016  2018              |
| Aqueous extract       | -  -  -  -            | 5.555  5.138 -  5.46    |
| pH                    | -  -  -  -            | 0.00120  0.005 0.00120  |
| Total nitrogen        | -  -  0.036  0.061   | 0.048  0.018 -  0.1     |
| Nitrate ions          | -  -  -  -            | 14.2  0.2 -  -         |
| Phosphate ions        | -  -  -  -            | <1.0  <1 -  -         |
| Sulfate ions          | -  -  -  -            | 11.909  <1 -  -       |
| Chloride ions         | -  -  -  -            | 2.77  4.376 -  -      |
| Oil products          | 11.928  324.38  21.4  | 5.4  59.273  38.75  -  |
| Benzopyrene           | -  -  -  -            | <0.005  <0.005 0.005  |
| Phenols               | -  -  0.05  0.2  0.3 | <0.05  <0.05 -  0.22   |
| Anionic surfactants   | -  -  -  -            | <0.02  <0.2 -  2.6    |
| Total Fe (total form) | 2333.07  <1000  3366  | 3000  2969.091  3081.25| 13113 |
| Pb (total form)       | 13.446  <20  8.2  5.2 | 6.264  3.594 32  7.9   |
| Zn (total form)       | 13.598  <55  4.5  18.46 | 5.052  7.075 55  41.9 |
| Mn (total form)       | -  -  98  76.1  | 24.727  18.319 150  0  |
| Ni (total form)       | 10.679  <35  3.9  4.7 | 7.227  1.429 20  20.6 |
| CrVI (total form)     | -  -  -  -            | 5.200  5.563 0.0  44  |
| Cd (total form)       | 0.331  <2  0.6  0.8 | 0.001  0.213 0.5  0.42 |
| Hg (total form)       | -  <0.1  <0.1  0.026 | 0.046  0.003 2.1  0.013 |
| Cu (total form)       | -  <10  2.9  2.4  | 2.573  2.071 33  12.5 |
| Ba                    | -  -  -  -            | <5.0  2.55 -  -      |
| NO3-N                 | -  -  1.9  <1.0       | -  -  -  -         |

Notes
1. "-" - samples were not analyzed for this substance
2. 1.620 - exceeded average regional values
3. 0.004 - exceeded MAC values

According to the chemical analysis, pH values determined for the aqueous extract of analyzed soil samples correspond to strongly acid-neutral soils [14, 15, 16, 17]. MAC values were exceeded for chrome in 2016 (5.2 mg/kg) and in 2018 (5.563 mg/kg); besides, cadmium contents were exceeded in 2014 (1.2 MAC) and in 2015 (1.6 MAC).
Averageregionalvaluesestablishedforoilproductswereexceededin2013-2014 and in 2016-2018, for phenols – in2015, for lead – in 2007 and in2014,and for mercury – in 2015-2016.

Soil concentrations of oil products vary significantly within the area; the highest concentrations were determined in abandoned sludge pits. However, high contents of oil products were also found at field boundaries.

Duringanalysisofthevaluesexceedingallowablelimitsestablishedforoilssamples, the cumulative soil pollution (Zc) [18] was calculated in each sampling point, individually for each stage of the field development [10].Calculation results shown that the increased oil and gas production volumes cause the deteriorated soil quality. In 2007, Zc in all sampling points was zero, “pure” category of chemical pollution; in 2016, Zc was within limits 23 до 319, “hazardous” and “extremely hazardous” category of chemical pollution; in 2018 году, Zc was from 63 to 219, “hazardous” and “extremely hazardous” category of chemical pollution.

Thus, maximum allowable concentrations established for atmospheric air samples were not exceeded during the development of the Russkoie field. In the snow samples, MAC values of phenols were exceeded, as well as average regional values established for a number of hazardous pollutants. Soils within the considered site have been polluted with chemical substances (nitrogen, oil products, phenols, lead, cadmium, chrome, mercury) during the development of the license area. The soil pollution in close proximity to water bodies shall be considered as the most hazardous impact [19, 20].

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