Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

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Abstract:

The aim of the paper is the development of a technique of assessment of possible ecological and economic damage to air resources during the development of offshore fields for ensuring sustainable development of the Arctic region of Russia.

The use of a modified temporary method for determining the prevented environmental damage is proposed to point out the possible environmental and economic damage by Monte Carlo mathematical modelling.

After calculations authors made a conclusion about the most rational method for calculating damage from the offshore Arctic oil and gas projects in the water of the Ob-Taz Bay in the Kara Sea.

The practical significance of this work is that the proposed methodology can be applied to all oil and gas fields on the Arctic shelf of Russia for measuring potential damages from air pollution as well as soil and water pollution.

Keywords: *Sustainable development, mathematical modelling, economic and ecological evaluation, Monte Carlo method, The Ob-Taz Bay.*

JEL code: C15, C51, C53, K32, L71.

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Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

424

1. Introduction

The implementation of the development program for the oil and gas fields of the Arctic shelf is becoming promising for the recent decades. With the normalization of the level of oil prices in the world market, an active exploration of this region with truly unique oil and gas reserves will begin. Application of new advanced and modern technologies is required. It includes creation of a complex infrastructure for all enterprises participating in this program. The most difficult part of it will be the construction of gas and oil producing complexes in the water area of the Kara Sea and the Ob-Taz Bay (Vasilev and Vasileva, 2017; Vasitsova, 2016).

On the state level one of the goals is ensuring sustainable development of the region. The concept of sustainable development have three main pillars: economy, the social environment and the environment. Excess of norms of maximum permissible emissions of harmful substances, air and environment pollution are repellent factors at the choice of the place of work. Thus, if there is a task not only to develop fields, but also to develop the region and to attract there human resources, it is necessary to consider basic provisions of the concept of sustainable development (Carayannis *et al.,* 2017; Cherepovitsyn, 2016; President of Russia official website 1995; Moyseychenko *et al.,* 2006).

The water area of the Ob-Taz Bay of the Kara Sea was chosen as the object of study. In this area there is a group of deposits that are extremely promising for development. This group includes such deposits as Severo-Kamennomysskoye, Kamennomysskoye-More, Tchugoryakhinskoe and Obskoye deposits (Figure 1). The depth of the sea in this area is approximately 6 meters.

Figure 1. *Location of the Kamennomysskoye-More, Severo- Kamennomysskoye, Tchugoryakhinskoe and Obskoye fields relative to the main pipeline*

This water area is the most vulnerable to the technogenic impacts of the development of gas fields. The most dangerous of these impacts is the construction

of gas wells. This is a large-scale and rather dirty production with a variety of complex technology and large volumes of liquid and solid waste. While drilling wells drilling muds with numerous chemical reagents are used; slurry in the form of pulp is washed from the wells which is stored in special settling tanks; heavy caterpillar transport is used on the construction works. On construction sites are situated warehouses of combustive-lubricating materials, workshops, household and subsidiary premises etc. As a result, the fragile balance of the underwater Arctic world can be disrupted. The situation can only be monitored through special ecological studies. The economic basis of these studies relies on the application of the developed methodology for assessing the possible environmental and economic damage (Ministry of Environment, 2008; Sultani (Nikulina), 2007).

2. Methodology

After the study of the normative legal acts on environmental damage assessment (President of Russia official website, 1995; 1998; 1999; 2002; Mingazprom USSR, 1986; Inf. Leg. Supp. Syst. "Garant", 2013) as well as various methods of determining the extent of environmental damage (JSC Gazprom. (n/d); NefteGazStroy, 2000; Kaledina *et al.,* 2016; Khalikova and Kirichenko, 2016; Kozlov, 2014; Institute for Energy and Finance, 1990) a decision was taken to assess the possible environmental and economic damage based on a temporary method for determining the prevented environmental damage (Rubino and Tuffin, 2009) and then modify it using mathematical modelling with the Monte Carlo method (Elepov *et al.,* 1980; Ermakov and Mikhailov, 1982; Fishman, 1999; Häyhä and Franzese, 2014; Robert and Casella, 2004; State Committee of the Russian..., 1999).

2.1 Determination of the magnitude of possible environmental and economic damage to atmospheric air

Estimation of the magnitude of possible environmental and economic damage from air pollution is carried out on the basis of regional indicators of specific damage, which are specific cost estimates of damage per unit (1 conventional tonne) of a reduced mass of pollutants. The calculation formulas have the following form:

$$Y_{np\,r}^{в} = \sum_{j=1}^{N} Y_{уòxj}^{в} \cdot M_r^{в} \cdot K_э^{в} \cdot J_д \cdot \frac{1}{\left(1+i\right)^t} \qquad (1)$$

$Y_{np\,r}^{в}$ - Environmental damage from atmospheric air pollution by emissions from stationary sources in the r-th region during the reporting period, thousand roubles; $Y_{уòxj}^{в}$ - An indicator of specific damage to atmospheric air caused by the emission of a unit of a reduced mass of pollutants at the end of the reporting period, roubles / cond.t; $M_r^{в}$ - The resulted mass of a dump of polluting substances in atmosphere of a considered region, for the accounting period, thousand cond.t; $K_э^{в}$ - Coefficient of

Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

426

the ecological situation and ecological significance of the state of atmospheric air of the territories within the economic regions of Russia; J_{∂} **-** Index-deflator by industry, established by the Ministry of Economics of Russia for the period under review and brought to the State Environmental Protection Committee of the State Environmental Committee. i - the level of inflation in the RF for the period under study; t – project implementation period. The resulted mass of polluting substances is calculated by the following formula for the specific object in the region:

$$M_K^B = \sum_{i=1}^{N} m_i^B K_{\ni i}^B \qquad (2)$$

where: m_i^B **-** The mass of the actual emission of the i-th pollutant or group of substances with the same coefficient of relative environmental and economic hazard in the atmosphere of the region in question, t / year; $K_{\ni i}^{\text{в}}$ **-** Coefficient of relative ecological and economic hazard for the i-th pollutant or group of substances. i - Number of pollutant or group of substances. N - The number of pollutants. The indicator *m* is determined on the basis of statistical reporting data of enterprises and organizations, data of hydrochemical laboratories, certified for the right to conduct appropriate analyses, materials of control services of territorial environmental agencies and hydrometeorology, design data, etc. Based on the proposed methodology, a model is formed for determining the conditionally possible environmental and economic damage and simulation is carried out according to the developed algorithm (Danilov *et al.,* 2016; Ministry of Environmental…, 1996; Patin, 2001).

2.2   Algorithm for carrying out simulation

- 1st step. Creating a model for determining the conditionally possible environmental and economic damage in Excel.
- 2nd step. Setting the distribution function of each variable which affects the formation of the magnitude of the total possible ecological and economic damages and the introduction of its minimum and maximum values. For doing this we assign the probability distribution to the variable, based on estimates or our expectations (for example, in our case a normal distribution was chosen).
- 3rd step. Conducting design iterations which is a fully computerized part of the analysis. 1000 iterations are usually sufficient for a good representative sample. During each iteration random selection of the values of key variables from the specified interval occurs in accordance with probability distributions and correlation conditions. Then the resulting indicators are calculated and saved (for example, possible environmental and economic damage).
- 4th step. Conducting a statistical analysis of the results obtained and constructing a histogram of the distribution of the resulting indicator from which it is possible to estimate the possible environmental and economic damage from the

implementation of the actions described in the development program of the Arctic zone, the range of possible outcomes.

3. Results

The object of the analysis was a project to develop Kamennomyssky group of gas fields located in the Ob-Taz Bay of the Kara Sea in the Arctic region. These deposits are supposed to be worked out all together while the designed production capacity will be 21 billion m³ of gas per year. The term of the project is 40 years. Based on a statistical analysis using data from Sakhalin Energy (Ministry of Environment, 2008), as well as various sources of emission data (Abashidze *et al.,* 2009, Bagramov, 1997, State Committee of the Russia, 1997) and taking into account the specifics of the development of oil and gas fields (JSC "GAZPROM", 2009; Kuskov and Kuskova, 2017; Nikulina and Kruk, 2016; State Committee of the USSR, 1987; Sakhalin Energy 2015), the minimum and maximum values, the average values and standard deviation are calculated. The values of the indicators and the calculations are presented in Table 1.

Table 1: *Results of statistical analysis*

The name of the indicator	Minimum	Maximum	Average	Standard deviation
Specific damage to atmospheric air, roubles / cond. t.	35,6	46	40,800	4,245782221
Gross emissions of pollutants into atmospheric air, thousands t.				
Carbon monoxide	4	4,51	4,255	0,208206628
Oxides of nitrogen (In terms of NO_2)	4,1	4,8	4,450	0,285773803
Methane	0,86	1,1	0,980	0,09797959
Sulphur dioxide	0,04	0,07	0,055	0,012247449
The deflator index	102,7	105,3	103,960	1,067533653

Then a model was constructed in Excel for determining the magnitude of the conditionally possible environmental and economic damage from atmospheric air pollution, based on formulas 2 and 3. 1000 iterations were made using the function "Generating random numbers" and the normal distribution with the data obtained in Table 1. A fragment of the calculation table with the model is shown in Table 2.

Table 2: *Model of an estimation of conditionally possible ecological and economic damage*

to athmospheric air	The mass of the pollutants discharged into the athmosphere				ecological	significance of the	deflator	damage	project implementation
	Carbon monoxide	Oxides of nitrogen	Methane	Sulphur dioxide					

Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

428

	Actual emission mass, thousand t	Coefficient of relative ecological and economic damage	Actual emission mass, thousand t	Coefficient of relative ecological and economic damage	Actual emission mass, thousand t	Coefficient of relative ecological and economic damage	Actual emission mass, thousand t	Coefficient of relative ecological and economic damage			
33,69853	4,093138	0,4	4,38979	16,5	0,75361	1,2	0,06759	20	1,4	108,052 38908103 7,8	6 410 838 102,84
41,08426	2,242593	0,4	4,27389	16,5	1,02472	1,2	0,04902	20	1,4	107,600 4606215 61,9	7 589 60 2 094,87
41,87933	4,624283	0,4	4,17883	16,5	0,89588	1,2	0,03834	20	1,4	104,463 44491985 4,6	7 330 887 087,66
39,73910	4,194405	0,4	4,30486	16,5	0,98220	1,2	0,06047	20	1,4	103,254 43131556 7,5	7 106 731 003,28
43,77486	4,95352	0,4	4,16905	16,5	0,89628	1,2	0,05455	20	1,4	104,690 46796490 3,8	7 710 597 393,29
40,06041	4,21424	0,4	4,29687	16,5	0,78423	1,2	0,07274	20	1,4	104,948 44133132 27,5	7 271 759 389,81
42,033393	3,98894	0,4	4,19709	16,5	0,82233	1,2	0,06036	20	1,4	105,941 45536517 2,3	7 502 993 241,32
42,62898	4,25531	0,4	4,61266	16,5	0,95612	1,2	0,05908	20	1,4	103,470 49488049 945,9	7 377 13 89 548, 09
41,67652	3,34778	0,4	4,76165	16,5	1,00562	1,2	0,05509	20	1,4	105,473 5084180 01,9	8 154 0 8 377 13 89 548,
40,56910	4,26429	0,4	4,70473	16,5	0,78423	1,2	0,04228	20	1,4	100,895 4648644 42,8	7 659 51 1 497,22 7 875,08

Based on the initial data, we perform an imitation. To implement the simulation it is recommended to use a normal distribution since the practice of risk analysis showed that it is found in the overwhelming majority of cases. The number of simulations can be arbitrarily large and is determined by the required accuracy of the analysis. In this case, we limit ourselves to 1000 imitations. Based on the results of the

simulation, using standard MS Excel functions, we perform economic statistical analysis (the results of the analysis are presented in Table 3).

Table 3. *Economic and statistical analysis of simulation results*

№	Indicators	Specific damage to atmospheric air, roubles / cond. t.	Carbon monoxide, thousand t	Oxides of nitrogen, thousand t	Methane, thousand t	Sulphur dioxide, thousand t	The deflator index	Ecological and Economic damage for the entire project implementation period brought to the present value, roubles
1	Minimum	28,91580	3,56852	3,59973	0,5874	0,01024	97,374 37	4884772017,2
2	Maximum	53,76732	4,95352	4,94147	1,2575	0,08905	112,13 04	9930452627,0
3	Average	40,80438	4,25119	4,24513	0,9776	0,05426	105,61 18	7352827949,9
4	Standard deviation	4,112689	0,21649	0,21628	0,1023	0,01231	2,3689 53	815737394,56
5	The coefficient of variation	0,100790	0,050926	0,05094	0,1047	0,22693	0,0224 30	0,11
6	Number of cases <0							1000,00
7	Number of cases >0							0,00

After the analysis of the data obtained in the course of simulation, a histogram was constructed. The results of NPV estimation by the Monte Carlo method are graphically presented in Figure 2.

Figure 2. *Histogram of simulation modelling*
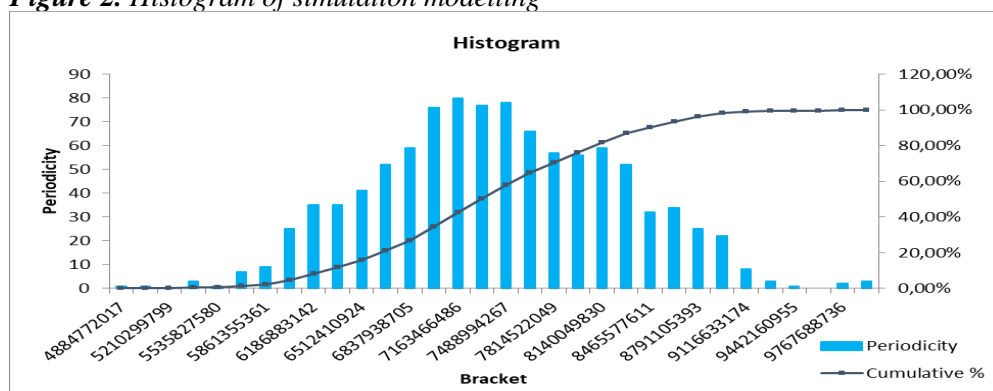
Simulation modelling demonstrated the following results:
1. The average value of conditionally possible damage is 7.35 billion roubles.
2. The minimum value of conditionally possible damage is 4.88 billion roubles.
3. The maximum value of conditionally possible damage is 9.93 billion roubles.
4. The coefficient of variation of the conditionally possible damage is 11%.
5. The number of cases of conditionally possible damage <0 - 0.

Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

430

Thus, the total amount of conditional-possible environmental and economic damage caused by the development of deposits of the Kamennomyssky group of deposits is 7.35 billion rubles. This result allows us to speak about the high degree of riskiness of the project due to damage to the environment.

The Monte Carlo method (simulation) cannot be considered optimal. Monte Carlo simulations have the following drawbacks:

• in the process of modeling there is a lot of routine work, forming a consistent system of all factors becomes a very laborious task;

• due to the presence of a large number of such connections, the solution turns out to be unstable;

• the relationships between the phenomena and errors of the forecast as well as the expected probability distributions by main parameters are built with the use of expert information. So increasing the complexity of calculations is not always accompanied by an adequate increase in their accuracy.

However, in the conditions of a limited amount of initial information for conducting detailed analysis with a view to detailed forecasting of the values of indicators during the implementation of large-scale projects, this method can be considered as the most acceptable.

4. Conclusions

The proposed methodology is a universal method and it can be used to calculate the environmental damage of any industrial project. Further work on this topic assumes the continuation of the study of the topic of damage and the development of methods for assessing the eventual possible environmental and economic damage to water, biological and soil resources. This method of assessment of potential damage will allow to prevent it.

Acknowledgments:

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Environmental and Economic Damage from the Development of Oil and Gas Fields in the Arctic Shelf of the Russian Federation

432

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