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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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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:

$$У^{в}_{пр\,r} = \sum_{j=1}^{N} У^{в}_{удхj} \cdot M^{в}_{r} \cdot K^{в}_{э} \cdot J_{д} \cdot \frac{1}{(1+i)^{t}} \qquad (1)$$

$У^{в}_{пр\,r}$ - Environmental damage from atmospheric air pollution by emissions from stationary sources in the r-th region during the reporting period, thousand roubles; $У^{в}_{удхj}$ - 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; $M^{в}_{r}$ - The resulted mass of a dump of polluting substances in atmosphere of a considered region, for the accounting period, thousand cond.t; $K^{в}_{э}$ **-** Coefficient of 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:

$$M_K^B = \sum_{i=1}^{N} m_i^B K_{эi}^B \tag{2}$$

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; $K_{эi}^{в}$ - 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 m^3 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	ental damage	project implementation
	Carbon monoxide	Oxides of nitrogen	Methane	Sulphur dioxide				

40,56910	41,67652	42,62898	42,033393	40,06041	43,77486	39,73910	41,87933	41,08426	33,69853	
4,26429	3,34778	4,25531	3,98894	4,21424	4,95352	4,194405	4,624283	2,242593	4,093138	Actual emission mass, thousand t
0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	Coefficient of relative ecological and economic damage
4,70473	4,76165	4,61266	4,19709	4,29687	4,16905	4,30486	4,17883	4,27389	4,38979	Actual emission mass, thousand t
16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	Coefficient of relative ecological and economic damage
0,78423	1,00562	0,95612	0,82233	0,78423	0,89628	0,98220	0,89588	1,02472	0,75361	Actual emission mass, thousand t
1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	Coefficient of relative ecological and economic damage
0,04228	0,05509	0,05908	0,06036	0,07274	0,05455	0,06047	0,03834	0,04902	0,06759	Actual emission mass, thousand t
20	20	20	20	20	20	20	20	20	20	Coefficient of relative ecological and economic damage
1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	1,4	
100,895	105,473	103,470	105,941	104,948	104,690	103,254	104,463	107,600	108,052	
464864442,8	508418001,9	494880945,9	455365172,3	4413313227,5	467964903,8	431315567,5	444919854,6	4606221561,9	389081037,8	
7 659 511 497,22	8 377 137 875,08	8 154 089 548,09	7 502 993 241,32	7 271 759 389,81	7 710 597 393,29	7 106 731 003,28	7 330 887 087,66	7 589 602 094,87	6 410 838 102,84	

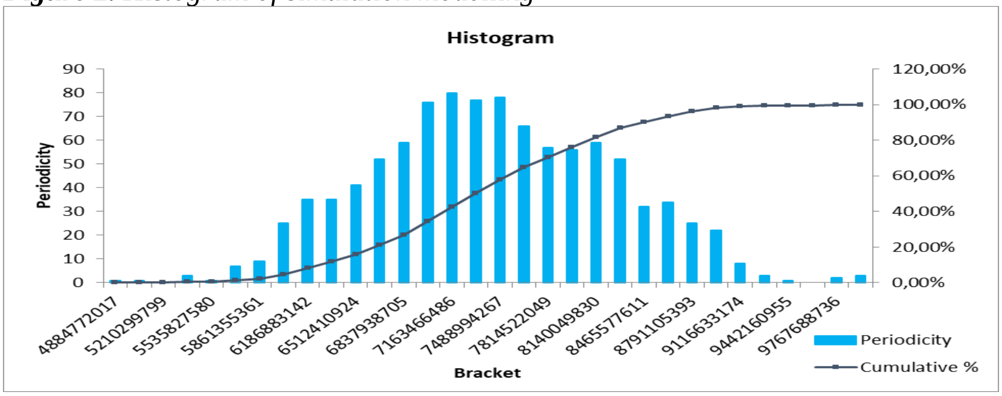
Based on the initial data, we perform an imitation. To implement the simulation it is recommended to use a normal distribution since the practice of risk analysis showed that it is found in the overwhelming majority of cases. The number of simulations can be arbitrarily large and is determined by the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

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.

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References:

Abashidze, A.H., Vasiliev, Yu.G. and Solntsev, A.M. 2009. International Environmental Law: Documents and Commentaries, Issue. II: Protection of the environment during armed conflicts, RUDN, Moscow. Available at: http://dspace.vniro.ru/handle/123456789/1478. Revised September 28, 2017, Accessed March 20 2018.

Bagramov, R.A. 1997. The main requirements for drilling rigs, and the methodology for assessing their quality: Textbook. Moscow, Federal State Unitary Enterprise Publishing House "Oil and Gas". Gubkin Russian State University of Oil and Gas.

Carayannis, E.G., Cherepovitsyn, A.E. and Ilinova, A.A. 2017. Sustainable Development of the Russian Arctic zone energy shelf: the Role of the Quintuple Innovation Helix Model. Journal of the Knowledge Economy, 8(2), 456-470.

Cherepovitsyn, A.E. 2016. Socio-economic potential of large-scale projects to develop offshore oil and gas: risks and stakeholder expectations. Journal of Mining Institute, 215, 140-149. http://pmi.spmi.ru/index.php/pmi/article/view/125/146.

Danilov, A.S., Smirnov, Y.D. and Korelskiy, D.S. 2016. Promising method of remote environmental monitoring of Russian oil and gas industry facilities, Neftyanoe Khozyaystvo [Oil Industry], 2, 121-122.

Elepov, B.S., Kronberg, A.A., Mikhailov, G.A. and Sabelfeld, K.K. 1980. Solution of boundary value problems by the Monte Carlo method. Novosibirsk. Nauka.

Ermakov, S.M. and Mikhailov, G.A. 1982. Statistical modelling, 2nd edition, Moscow, Nauka.

Fishman, G.S. 1999. Monte Carlo. Concepts, Algorithms, and Applications, 3rd ed., Berlin, SpringerVerlag.

Häyhä, T. and Franzese, P. 2014. Ecosystem services assessment: A review under an ecological-economic and systems perspective. Ecological Modelling, 289, 124-132.

Information and Legal Support System "Garant". 2013. Resolution of the Government of the Russian Federation No. 380 from April 29, 2013 "On the Approval of the Regulation on Measures for the Conservation of Aquatic Biological Resources and their Environment". Available at: http://www.garant.ru/products/ipo/prime/doc/71293672/.

Institute for Energy and Finance. 1990. Problems of scientific and methodological support of assessments of damage to fisheries from the development of oil and gas fields on the sea shelf. Moscow: RAS-MSU. Available at: http://www.fief.ru/presentation/read.134.htm

JSC "GAZPROM". 2009. Methodological instructions for conducting a risk analysis for hazardous industrial objects of gas enterprises of JSC Gazprom. Moscow, STO Gazprom 2-2.3-351-2009. Available at: https://es.scribd.com/document/367494733/sto-gazprom2-2-3-351-2009

JSC Gazprom. (n/d). Departmental Guidance Document of JSC Gazprom. http://www.snti.ru/snips_rd51.htm (Accessed on March 20 2018).

Kaledina, N.O., Kobylkin, S.S. and Kobylkin, A.S. 2016. The calculation method to ensure safe parameters of ventilation conditions of goaf in coal mines. Eurasian Mining, 41-44. DOI:10.17580/em.2016.01.07

Khalikova, M.A. and Kirichenko, Y.A. 2016. Methodology of assessing the fair value of the development of reserves of oil and gas fields. Internet-Journal Naukovedenie, 8(6), 56. Available at: https://naukovedenie.ru/PDF/56EVN616.pdf.

Kozlov, M.V. 2014. Planning of ecological research. Moscow: KMC. Available at: http://www.ievbras.ru/ecostat/Kiril/Article/A30/12/12_r.htm.

Kuskov, V.B. and Kuskova, Ya.V. 2017. Development of technology for the production of natural red iron oxide pigment, Inzynieria Mineralna (Mineral Engineering) 1(39), 217-220.

Mingazprom USSR. 1986. Guidance normative document RD 51-01-11-85 "Environmental studies in engineering surveys on the continental shelf. Requirements for methods and results", Moscow, VNIPImorneftegas.

Ministry of Environmental Protection and Natural Resources of the Russian Federation, Samara Regional Committee for Environmental Protection and Natural Resources of the Russian Federation. 1996. Method for calculating emissions of harmful substances into the atmosphere with free burning of oil and oil products. Samara. Available at: http://aquagroup.ru/normdocs/14015.

Ministry of Environmental Protection of the Republic of Kazakhstan. 2008. Order from January 30, 2007 No 23-p “The methodology for calculating the parameters of emissions and gross emissions of harmful substances from flare plants burning hydrocarbon mixtures”. Available at: http://online.zakon.kz/Document/?doc_id=30198720.

Moyseychenko, G.V., Zuenko, Yu.I. and Ogorodnikova, A.A. 2006. Ecological and economic assessment of the impact of seismic exploration on the bioresources of the Magadan shelf. Materials of the Far Eastern regional conference “Geology, geography and biological diversity of the northeast of Russia”, SSC, FEB RAS, Magadan, pp. 243

NefteGazStroy. 2000. Environmental justification for drilling operations in the water areas of the Far East and North-Eastern seas of the Russian Federation. Moscow: LLC "NefteGazStroy Consulting & Engineering" Publication.

Nikulina, A.Y. and Kruk, M.N. 2016. Organizational and economic mechanism of oil and gas projects in the Russian arctic shelf. Journal of Internet Banking and Commerce, Special Issue -- S6(003). Available at: http://www.icommercecentral.com/open-access/organizational-and-economic-mechanism-of-oil-and-gas-projects-in-the-russian-arctic-shelf.php?aid=82672.

Patin, S.A. 2001. Oil and ecology of the continental shelf. Moscow: VNIRO Publishing.

President of Russia official website. 1995. Federal Law of the Russian Federation No 174-FZ from November 23, 1995 “On Environmental Expertise”. http://www.kremlin.ru/acts/bank/8509.

President of Russia official website. 1998. Federal Law of the Russian Federation No 89-FZ from June 24, 1998 “On production and consumption wastes”. Available at: http://kremlin.ru/acts/bank/12555.

President of Russia official website. 1999. Federal Law of the Russian Federation No 96-FZ from May 04, 1999 “On Environmental Protection”. Available at: http://www.kremlin.ru/acts/bank/13789.

President of Russia official website. 2002. Federal Law of the Russian Federation No 7-FZ from January 10, 2002 “On Environmental Protection”. http://kremlin.ru/acts/bank/17718

Robert, C.P. and Casella, G. 2004. Monte Carlo Statistical Methods, 2nd edition, Springer, Berlin, 2004.

Rubino, G. and Tuffin, B. (eds). 2009. Rare event simulation using Monte Carlo methods. London, Wiley.

Sakhalin Energy 2015. Sustainability report. Available at: http://www.sakhalinenergy.ru/media/user/otchety/SD_report_2015_rus.pdf

State Committee of the Russian Federation for Environmental Protection. 1999. Temporary technique for determining prevented environmental damage from March 9, 1999. Moscow. Available at: http://aquagroup.ru/normdocs/1406.

State Committee of the Russian Federation for the Protection of the Environment. 1997. Order No 90 from March 5, 1997 “Methodology For Calculation of Emissions from Sources of Combustion During oil and oil Products Spills. Available at: http://eco.com.ua/content/metodika-rascheta-vybrosov-ot-istochnikov-goreniya-pri-razlive-nefti-i-nefteproduktov.

State Committee of the USSR for Hydrometeorology and Natural Environment Control No OND-86. 1987. Method for calculating the concentrations in the air of harmful substances contained in the emissions of enterprises. Leningrad: Gidrometeoizdat. Available at: http://aquagroup.ru/normdocs/16398.

Sultani (Nikulina), A. 2007. Economic problems of sustainable development, Journal of Mining Institute 170(1), 275-277. Available at: http://pmi.spmi.ru/index.php/pmi/article/view/2811/2913

Vasilev, Y. and Vasileva, P. 2017. Improving efficiency of coal provision of TPS in the Russian federation, Proceeding of 17th International multidisciplinary scientific geoconference "SGEM 2017", Albena, Bulgaria, 29 June – 5 July, Ecology, economics, education and legislation, 17(53), 479-486.

Vasitsova, V.M. 2016. Problems development of the offshore oil and gas fields deposits, Journal of Mining Institute, 218, 345-350. Available at: http://pmi.spmi.ru/index.php/pmi/article/view/25.