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ASSESSMENT OF THE LIFE CYCLE OF NITROGEN AND CARBON COMPOUNDS EMITTED IN THE ARCTIC: THE EXAMPLE OF NATURAL GAS FIELDS OF GAZPROM DOBYCHA YAMBURG

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ABSTRACT

The paper is devoted to assessment of the integrated man-caused impact on ecosystems of the Far North, which is inevitable during HC production, requires regular and objective assessment that allows to monitor the dynamics of environmental changes with acceptable probability level.

Territories under extreme conditions (permafrost areas, etc.) with significant changes caused by gas production facilities to natural landscapes often cannot be naturally remediated within the time specified in standards. It should be noted that negative geoecological effects occur both in emergency situations and under normal operation. The zone of partial destruction of the plant cover caused by one-time passage of vehicles in the Far North areas on routes and field site adjacent territories accounts for the considerable part of developed areas. Over half of these territories are burned areas. The assessment of geoecological effects on ecosystems of the Far North requires a universal instrument, which is ensured by modeling and the impact of geoecological factors on the operation of the developed territory.

The historical and forecast assessment should be based on substantiated criteria and made using contemporary international scientific and technical methods. It will improve the efficiency of the environmental management at production facilities of Gazprom dobycha Yamburg. It is essential that the study of the environmental response to one-type impact allows to apply the method of analogues to other fields of the Far North.

The novelty of studies consists in the use of the life cycle assessment methodology for pollutants under Arctic conditions, which are emitted during natural gas production and transmission at fields of Gazprom dobycha Yamburg. This methodology comprises pollutant emission assessment, their short-term and long-term transformation and transfer in the “atmosphere – plants – soil – water” system, calculation of ecosystem stability criteria and pollutant supply using parameters “critical loads” and “geoecological risks”. It allows to carry out a comprehensive objective historical and forecast assessment of the geoecological situation on HC fields in the Far North.

At present there is no regulatory and procedural base for the unified approach to the integral estimation of the status and dynamics of the geoecological situation on the territory of Arctic fields. Normal operation of the environmental management system under these conditions is possible only using selected information criteria. The results of the carried out work will allow:

- to enhance accuracy and objectiveness of geological situation assessments;
- to meet global trends in environmental supervision of industrial activity;
- to improve environmental management system efficiency.

Thus, stable development of Gazprom dobycha Yamburg, its industrial facilities and Gazprom group companies requires consideration of all regional specific features of geoecological impact factors at all stages of field life cycle with account of their effects synthesis, using corresponding methods that take into account their synergistic nature.

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INTRODUCTION

Hydrocarbon production and other industrial activities in the Far North inevitably lead to environmental changes. The scope and nature of these changes depend on the intensity and specificity of exert impact, which locally and regionally determines one or another *geoecological situation*. According to presumption that any type of industrial activity may be potentially dangerous for the environment [1], estimation of the geoecological situation within the possible industrial impact area in terms of environmental acceptability and social and economic feasibility (effectiveness) is obligatory for successful addressing of environmental protection issues at all stages of construction and operation of industrial facilities, including long-term outlook.

Apart from that, in oil and gas production industry successful facilities operation strongly depends on geoecological situation (in particular, soil stability and drainage conditions in field development areas and along hydrocarbon transmission routes). It confirms how significant are retrospective and forecast estimates of geoecological situation alongside with estimation of different components of the life cycle of nitrogen and sulfur compounds at Gazprom dobycha Yamburg.

1 SCOPE OF INDUSTRIAL ACTIVITIES

Gazprom dobycha Yamburg LLC is a 100% subsidiary of Gazprom. The main lines of industrial activities of the company comprise: gas and gas condensate production, their treatment for transmission, geological exploration, development of new gas and gas condensate fields. The company's gas production volume amounts to 40% of the total Gazprom's gas production and over 31% of the total gas recovered in Russia. In 2010 Gazprom dobycha Yamburg produced more than 203 BCM of gas and about 1,5 mln tons of gas condensate. The company holds licenses for development of five fields located in Yamal-Nenets Autonomous District, namely Yamburg, Zapolyarnoye, Tazovskoye, Severo-Parusovoye and Yuzhno-Parusovoye (the last three fields are almost ready for development). In the short term it is planned to develop Severo-Kamennomysskoye and Kamennomysskoye-more offshore fields located in the Gulf of Ob, in the long term to develop other offshore fields of the Gulf of Ob and Taz Bay, and oil gas condensate fields of Gydan Peninsula. The history of Gazprom dobycha Yamburg began from development of Yamburg field followed by commissioning of Zapolyarnoye field.

1.1 Yamburg field

Yamburg oil gas condensate field is located to the North of the Arctic Circle region of the West Siberian Plain, in subarctic zone of the Taz Peninsula (Fig. 1).

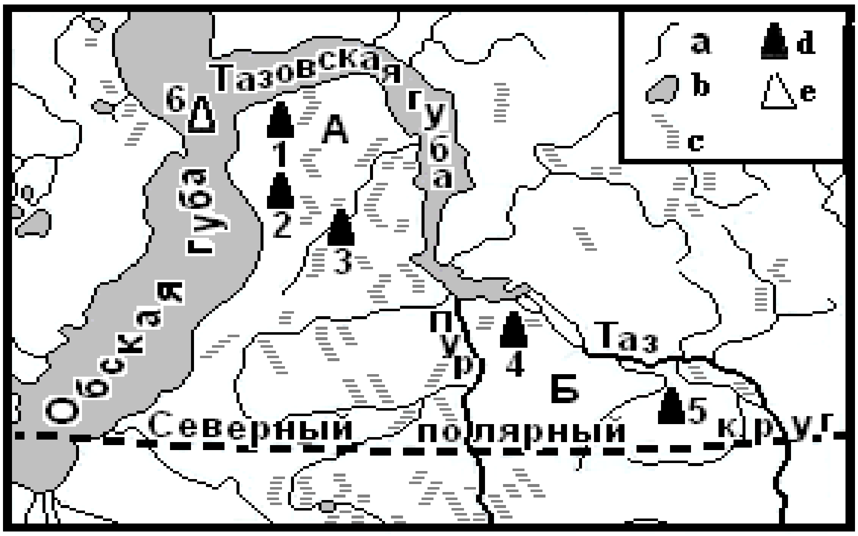

Fig. 1 – Location map of oil gas condensate fields.

A – Taz Peninsula; Б – interfluve of Pur and Taz rivers; a – rivers; b - lakes; c - marsh; d – fields under development or planned for development; e – promising fields. Fields 1 - Severo-Parusovoye 2 - Yuzhno-Parusovoye; 3 – Yamburg; 4 – Tazovskoye; 5 – Zapolyarnoye; 6 – Severo-Kamennomysskoye.

This field is located in West-Siberian oil and gas bearing province, the largest province in the world in terms of gas and oil resources and reserves. Natural gas was discovered on the field in 1969, oil – in 1990 [1]. In 1986 the field was developed for gas condensate and in 1987 – for natural gas. The field is confined to asymmetric north-to-west oriented semiclosed structure of the same name. Cenomanian (Upper Cretaceous) and Neocomian (Lower Cretaceous) deposits represent pay intervals. Pay Cenomanian deposits with alternating sandstones, siltstones and clays occur at the depth of 1000-1211 m. Net gas pay amounts to 175 m, porosity to 27-33% and permeability 0,01-2,2 μm^2. Gas deposit is of anticline type and has large sizes: 175x50 km and 213 m high. Gas composition (%): methane 98,6, its homologues up to 0,07, nitrogen 1,14 and carbon dioxide 0,19. Gas initially in place amounted to 5,4 trillion m^3, and by the beginning of 2002 maturity of the deposit exceeded 40%.

In Low Cretaceous deposits 15 pay intervals were detected at 2500-3350 m depth. They revealed 23 gas condensate deposits with alternating sandstones, siltstones and clays. Deposits are predominantly lithological and lenticular with net pay of 1,2-11,1 m, porosity 15,6-17,7% and initial formation pressure 23,5-34,4 MPa. Gas composition (%): methane 89-90, ethane 4,5-4,9, propane 2,1-2,2, butane 1,0-1,1, pentane and higher hydrocarbons 2,7-2,9, nitrogen 0,36-0,55 and carbon dioxide 0,17-0,42. Concentration of condensate in formation gas amounts to 107-126 g/m^3.

By the beginning of 2002 explored gas reserves (category $A+B+C_1$ of the Russian classification) totaled 4184,5 BCM, inferred gas reserves (category C_2) – 476,2 BCM, cumulative production – 2331 BCM. More than 4 trillion m^3 of gas and about 24 million tons of gas condensate have been produced since the field commissioning. The field gives nearly 50% of the total company's gas production, however maximum reserves concentrated in its central part are already depleted. Today under development are peripheral areas of the field.

1.2 Zapolyarnoye field

Zapolyarnoye oil gas condensate field is located in the same named part of the West Siberian Plain, in subarctic zone, in interfluve of Pur and Taz rivers (Fig. 1). This field is also the part of the West Siberian oil and gas bearing province. It was discovered in 1965. Field development started in 2001 [1]. The field is confined to the same named elevation at the north-west slope of Taz anticline of the West Siberian Plate. It is composed of Jurassic, Cretaceous and Paleogene deposits.

Commercial gas bearing capacity of the field is related to Turonian and Cenomanian deposits of the Upper, Hauterivian and Barremian Stages of the Lower Cretaceous period. Main gas reserves are confined to Cenomanian deposits. Pay horizon occurs at the depth of 1130-1330 m. It predominantly contains sandstones and siltstones with sparse clay interlayers. Net pay is 64,4 m, porosity 33,2%, permeability 1-5 μm^2. The deposit represents a bottom water-drive massive anticline reservoir 47x29 km in size and gas column of 224 m. Gas production rate is 0,9-6,9 mln m^3/day with initial formation pressure of 13,03 MPa.

Turonian pay horizon occurs 70-100 m higher than Cenomanian and contains sandy siltstone and argillaceous rocks. Net pay amounts to 7,1 m, porosity - 20%, initial formation pressure 12,36 MPa. Gas anticline deposit is 38x20 km in size and 184 m high. Cenomanian and Turonian gas is dry and has the following composition (%): methane 98,80, its heavy homologues 0,08, nitrogen 1,0 and carbon dioxide 0,12.

Lower Cretaceous deposits reveal gas condensate intervals at the depth of 2477-3282 m in formations of $BT_{2\text{-}3}$ and $BT_{11\text{-}2}$ groups, oil gas condensate intervals in formations of $BT_{6\text{-}8}$, BT_{10} and $BT_{11\text{-}1}$groups. Pay zones are represented by sandstones and siltstones with argillites. Gross pay amounts to 14-60 m, net pay 4,8-46,0 m, porosity is 14-17%, initial formation pressure - 24,7-33,0 MPa, gas saturation 0,67-0,72. Gas composition (%): methane 87,2-88,0, its homologues 11,77-11,93, carbon dioxide 0,06-0,22 and nitrogen 0,30-0,67. Condensate content in gas amounts to 172,3-197,0 g/m^3.

In the beginning of 2002 explored gas reserves (category C_1) were estimated at 3532,4 BCM, 2797,0 BCM of this volume pertained to Cenomanian and Turonian deposits; inferred reserves (category C_2) were estimated at 31,4 BCM, cumulative production - 8,2 BCM.

2 ENVIRONMENTAL POLICY

Gazprom dobycha Yamburg LLC follows triune concept of sustainable development and in all its activities tries to maintain the balance between economic, social and ecological constituents [2]. The society not only fulfils the requirements of environmental protection legislation of the Russian Federation, but also makes all efforts to get as closer to the international environmental standards as possible. In 2009 the company put into force “Environmental Policy”. Introduction and maintenance of the environmental management system was claimed to help to achieve environment protection targets. This system is based on recommendations of the universally recognized international standard ISO (International Standards Organization) 14001 (its Russian version GOST R ISO 14001), which defines guidelines for control and improvement of ecological indicators of the company’s environmental protection activities. Integrated approach towards environmental protection management based on recommendations of this standard must at least ensure balance between cost-effectiveness of gas production and mitigation of the environmental impact. The structure of the environmental management within the company is given in Fig. 2.

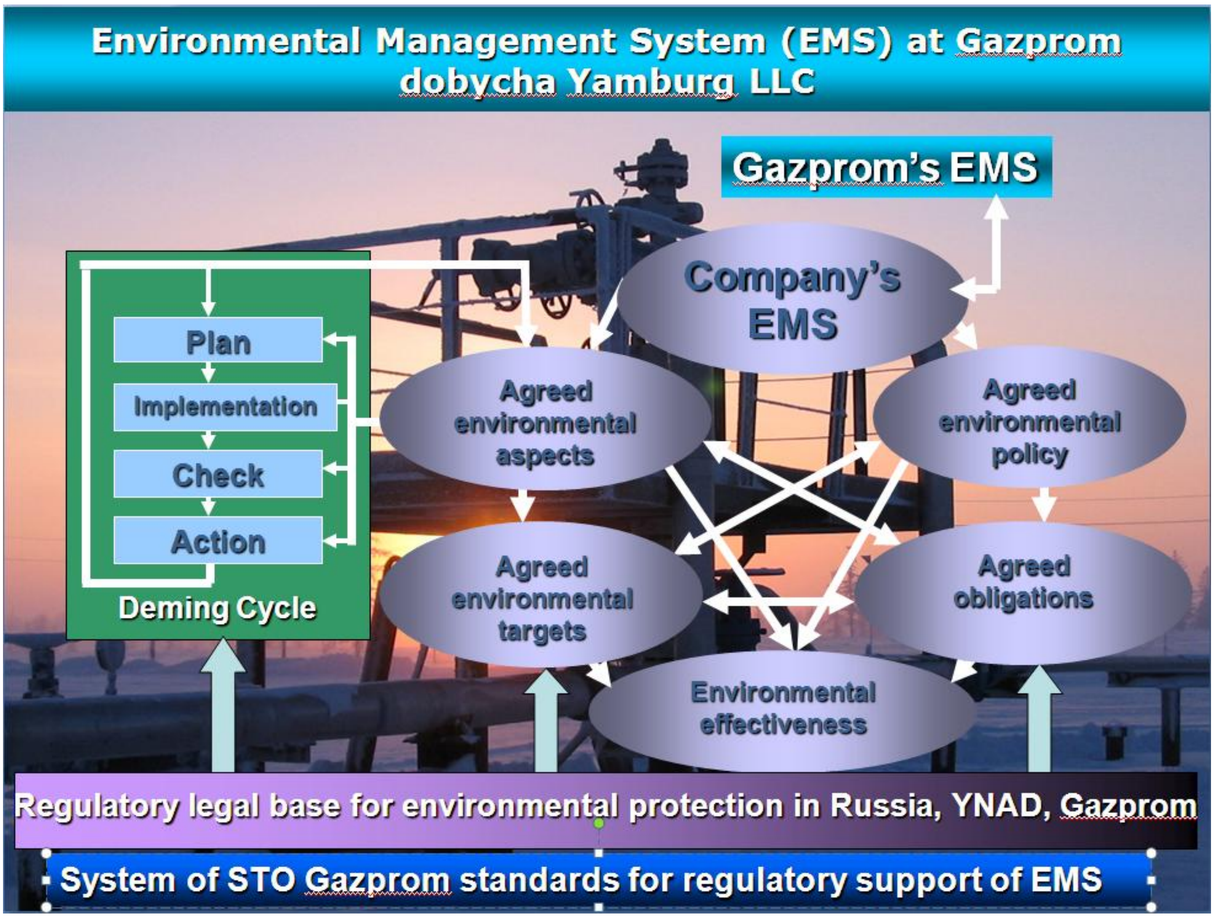

Figure 2 – Structure of the environmental management system at Gazprom dobycha Yamburg

The company follows the main provisions of the Environmental Policy approved by Gazprom’s Management Committee Resolution No. 45 dd. 25 September 2008 and takes efforts to ensure simultaneously reliable operation of hydrocarbon production facilities and maximally rational use of natural resources and preserving favorable environment in the Far North. According to the Ecological Doctrine of the Russian Federation, the Concept of the Country’s transition to sustainable development and generally recognized principles of social responsibility, fundamental principles of the company’s Environmental Policy include:

a) minimization of the negative impact and environmental conservation at the company's industrial facilities location sites;

b) enhancement of effectiveness natural and energy resources use;

c) effective management of nature protection activities based on national and international standards;

d) ensuring industrial and environmental safety during operation of natural gas and gas condensate production facilities.

Environmental policy, which reflects the company's view on the environment protection and implementation of the principles of sustainable development and social responsibility is the basis for goal-oriented short-term and mid-term planning of the company's activities in this area. However Environmental policy will inevitably be subject to updating, adjustment and improvement in case of any changes in development priorities or operation conditions of Gazprom's subsidiary.

3 EMISSIONS OF NITROGEN AND CARBON COMPOUNDS: ANALYSIS OF GEOECOLOGICAL RISKS

Analysis of geoecological situation in the context of environment contamination by industrial pollutants as a rule uses the following indicators that:

- (a) specify the quality of separate natural environments (soils, waters, etc) in terms of environmental safety for people and biota (maximum allowable concentrations, approximate permissible concentration, etc.),
- (b) specify resource potential of natural-territorial habitats (for example, productivity parameters of phytocenosis);
- (c) have environment or industrial function (for example, species composition of the vegetation cover from a perspective of maintaining the thawing depth of soils).

However complexity of relationships and availability of multiple factors that influence cause-effect relationships in the system «industrial facility – environment» in the majority of cases determine not unambiguous (deterministic), but *probabilistic (stochastic) nature* of the response of life forms and environment changes caused by the human impact. Thus, *geoecological situation evaluation criteria* also must include indicators that will specify probability and significance of possible unfavorable changes in the environment. Such criteria comprise *risk factors*.

According to the general idea and nature of the human impact on the environment, risk appears when the maximum (threshold) impact level specific for different groups of recipients or natural components is exceeded. It means that evaluation of risks of geoecological situations requires comparing parameters of existing or planned impacts of acceptable level, which quantitative increase determines risk factors.

As opposed to other approaches and methods of environmental impact assessment (often based on so called universal or integral indicators), the risk evaluation methodology focuses on obtaining retrospective and forecast data related to specific environmental effects and recipient groups or industrial facilities. Risk factors being evaluation criteria of geoecological situation allow to determine, classify and rank natural-territorial habitats located within pollutant impact areas by their level of susceptibility to different types of ecological hazards or by the danger level of failures of industrial facilities located within such areas. These estimates may be represented as threshold values for the most probable environmental or social-economic damage or probability of its occurrence.

Risk factors as evaluation criteria for geoecological situation do not cancel standard indicators, which are usually used to substantiate (calculate parameters) acceptable exposure levels depending on specific nature protection and production goals.

3.1 Main stages and the procedure of quantitative assessment of risks related to the impact of atmospheric pollutants on the environment

Risk methods are widely used in many areas of industrial activities. Typically risk analysis includes the following two blocks of tasks related to the human-induced pollution of the environment:

- *Risk evaluation* – quantitative determination of risk factors (levels) associated with different man-induced factors (covered by present recommendations);
- *Risk management* related to decision-making in the field of natural resources use aimed at mitigation and minimization of negative consequences of industrial activities on the environment.

Maximum allowable exposure limits, which characterize quantitative dependencies between emissions of different pollutants into the atmosphere and corresponding unfavorable environmental and/or geoecological effects, which declare themselves by disturbance of the physiological state of biota or its structure and functioning of natural-territorial habitats are determined by **estimation of the life cycle**. For recipients (i.e. certain types (groups) of life forms) these threshold values are called *reference doses* (RfD). *Critical loads* are their ecosystem analogues (i.e. admissible level of pollutant emissions into natural-territorial habitat)[3].

As opposed to sanitary and epidemiological studies and production industry with large statistical database, which characterizes cause-and-effect relationship between safety factors and their occurrence, establishment of dose-response dependencies in the area of natural resources management is much more complex. Among causes that complicate such estimates and depend on specific features of natural sites are the following:

(i) availability of multiple components and internal complexity of natural-territorial habitats (related to species, structural, spatial, etc.);

(ii) non-linear and as a rule stochastic dynamics of their natural development taking into account variety and uniqueness of certain sites;

(iii) availability of mechanisms of adaptation and resistance of some specimens, populations and ecosystems to environmental conditions changes, which are identified by different responses to similar impacts;

(iv) some degree of novelty of problems related to industrial impact on the environment, which results in absence of statistically representative monitoring data.

Estimation of environmentally safe reference doses (RfD) of different pollutants for certain biological species is an individual line of environmental studies based on laboratory tests or special monitoring observations. The procedure of evaluation of environmental risks as a rule uses available literature or reference data.

The most validated method to determine acceptable impact of pollutants on the environment is to *calculate critical loads* [3]. Estimation of critical loads is based on quantitative parametrization of the main migration routes of ecosystem elements specific for different bioclimatic and landscape conditions. Critical loads are calculated by simple biogeochemical models that use two types of equations:

- equilibrium equations of balance of elements and their compounds in soil (as soil cover is considered to be the main medium for deposition of the majority of industrial compounds);
- equations that characterize intensity of the main migration flows from soils to adjacent media.

Critical load calculations take into account variety of possible impact effects of the same pollutants on different recipient groups and different types of ecosystems. Usually critical loads are estimated for environmental effects associated with long-term impact on the environment (25-50 years and more). In case of availability of required data it is possible to estimate critical loads (CL) for short-term impacts. Thus, several CL values of the same pollutant can be obtained for one ecosystem depending on selected recipients and/or priorities of the environmental protection policy. CL may also be targeted at preserving of geoecological situation favorable for industrial activities. Such approach is similar to method used to define maximum and approximate permissible concentrations, when there are sanitary, hygienic, translocation, production and other quality standards of natural media.

Afterwards, at the stage of risk characterization calculations may include all obtained CL values or only minimum CL values estimated for the most sensitive recipients. The second option meets the principle of the maximum protection status of ecosystems, as their sensitivity to industrial impact is deemed to be determined by resistance of the most sensitive species. If we preserve species composition (biodiversity) of ecosystems, we will also preserve their main functions.

CL calculation methods are widely used in evaluations of regional impact of industrial activities on the environment, as they can be spatially tied to certain territories, which is important in terms of identification of possible environmental damages (see 6.5). Landscape maps or special GIS-projects can be regarded as a basic material for spatial tie of critical loads. The second option can significantly simplify required CL calculations.

Risk characterization is the final stage of risk evaluation. It determines risk factors by comparing actual and forecast exposure levels with acceptable exposure parameters (RfD or CL).

According to the definition of “environmental risk” given in [1], formula for risk calculation can be written as:

$$R(Exp(X)) = P((ExpD(X)/RfD) > 1) \quad (1)$$

where *R(Exp(X))* is environmental risk for biotic components of ecosystems related to the impact of a certain pollutant *(X)* and typical for certain environmental effects; *ExpD(X)* – actual or planned impact level (exposure dose); *RfD* – safe impact level (reference dose) of the considered pollutant; *P* – the probability that exposure level will exceed acceptable level.

If critical load is used as ecosystem indicator of acceptable exposure, the formula can be slightly modified:

$$R(Exp(X)) = P(Ex(KH(X)) > 0) = P((ExpH(X) – KH(X)) > 0) \quad (2)$$

where *R(Exp(X))* is environmental risk for ecosystems related to the entry of pollutant (X) and typical for certain environmental effects; *P(Ex(KH(X)))* **–** the probability that actual (or planned) impact *(ExpH(X))* will exceed acceptable impact level (*KH(X))*.

Calculations by formulae 1 and 2 are made with the use of stochastic methods, for example Monte Carlo (see Appendix D).

Parameter that describes *ExpD(X)/RfD* relationship in equation 1 may be considered as *danger coefficient* for a certain recipient group. When *ExpD(X)/RfD < 1* there is no danger and no risk. When danger coefficient is > 1, comparative analysis of these values calculated for different recipient groups within one ecosystem or for one group, but for different ecosystems, or for different exposure time may be used for additional analysis and substantiation of priority of nature protection measures and/or variation of exposure intensity.

Similarly analysis of absolute values when CL is exceeded, i.e *Ex(KH(X)) > 0*, also provides additional information required for decision-making in the field of environmental protection and environmental-economic validation of industrial activities. For example, value of CL exceeding can be taken into account when calculating fees for environment contamination.

Risk values themselves calculated by formulae 1 and 3 can be expressed in units or more frequently in percents (from 0 to 100%) as they are probability indicators. Obtained risk values for ecosystems related to one or another unfavorable effects are ranked (Table 1). When the probability of CL exceeding is < 5%, environmental risk is at its minimum and it can be disregarded. Risk of 5-25% in some cases can be regarded as acceptable. When probability of CL exceeding is 75-95%, we deal with increased risk. High risk level corresponds to the probability of CL exceeding > 95%.

Table 1. Principles of risk level ranking

Risk levels	Probability of CL exceeding (%)
Almost no risk	< 5%
Low risk level	5 - 25%
Medium risk level	25 - 75%
Increased risk level	75 - 95%
High risk level	> 95%

The next step is to gather all information on partial risks and perform comparative analysis of obtained results to identify priority risks and indicate maximum risk zones within the considered territory. The major attention is given to geoecological risks, which impact operation conditions of industrial facilities.

4 EVALUATION OF GEOECOLOGICAL SITUATION ON THE BASIS OF RISK CRITERIA

Classification and subsequent analysis of gathered data on risks allows to perform retrospective, current and/or forecast evaluation of geoecological situation within the zone of company's responsibility. Apart from obtained risk parameters, land status is also taken into account in evaluation of geoecological situation (Table 2).

Table 2. Geoecological situation in the Far North: evaluation principles based on risk criteria

Ecosystem (land) status	Risk level	Evaluation of geoecological situation
Specially protected natural sites	*Almost no risk*	Favourable
	Low risk level	Acceptable/ Satisfactory
	Medium risk level	Unfavourable
	Increased risk level	Dangerous
	High risk level	
Traditional land use areas *(deer grazing areas and hunting lands)* ***Wet lands***	*Almost no risk*	Favourable
	Low risk level	
	Medium risk level	Acceptable / Satisfactory
	Increased risk level	Unfavourable

	High risk level	**Dangerous**
Natural sites *(natural tundra ecosystems)* ***outside industrial sites and sanitary protection zones of companies***	*Almost no risk*	**Favourable / Acceptable**
	Low risk level	
	Medium risk level	
	Increased risk level	**Unfavourable**
	High risk level	**Dangerous**
Lands within sanitary protection zones of companies or assigned to oil and gas production companies for temporary use	*Almost no risk*	**Favourable**
	Low risk level	
	Medium risk level	
	Increased risk level	**Satisfactory / Unfavourable**
	High risk level	**Unfavourable / Dangerous**

5 ADDRESSING GEOLOGICAL RISK ISSUES BASED ON LIFE CYCLE ANALYSIS

5.1 Measures and research activities

The Company carries out research activities in the field of ecology with contractors represented by the leading industry, educational and academic institutions. These activities are included in the Research and Development plan approved by Gazprom. Some of such measures included development of the system of monitoring for environmental components, environmental protection management, and development of greenhouse gas emissions inventory (methane, carbon oxides, nitrogen, etc.). The Company also conducted special studies in the field of water environment protection [4-7].

The Company came forward with an initiative to develop in Yamalo-Nenets autonomous district (YNAD) regional environmental protection management system (REPMS). This initiative was based on the Memorandum for development of hydrocarbon fields of Yamal Peninsula and adjacent water areas signed in 2002 by administration of YNAD and JSC Gazprom. R&D plan was drawn up to address the issue of REPMS development concept.

The main targets of REPMS are as follows [3]:

a) formulation and enforcement of regional environmental policy (harmonized with interests of all system participants);

b) coordination of activities of executive government bodies, local government authorities, fuel and power companies that use natural resources and non-government nature protection organizations;

c) development of mechanisms to minimize damage to the environment, optimization of expenditures for nature protection, resource saving, etc.;

d) optimization of environment protection management functions based on joint coordinated solutions agreed by all REPMS participants;

e) improvement of regulatory legal base and organizational-administrative documentation on environment protection at regional and federal levels;

f) increase of transparency of natural use and environment protection activities, providing population, economic entities, social organizations and government authorities with reliable information.

REPMS is an organizational management system (system of administration and management of environment protection as specified in GOST R ISO 9000) based on regulatory and legal documents and information technologies. Generally accepted principles of ISO 14000 international standards on development and introduction of environment protection management system were used to address set targets within R&D program. Basic principles of gas industry sustainable development suggested and developed by the International Gas Union together with social responsibility principles included in ISO 26000 “Guidance on social responsibility” drawn up in 2010 are also used.

REPMS is based on provisions of the system of Russian national standards GOST R ISO 14000:2007 (harmonized with ISO 14000-2004), which envisage periodic analysis and assessment of the results of system management and administration to define ways to improve environmental activities in the region. REPMS is aimed at constant improving of nature protection measures in the region on the basis of generally accepted management model, which contains 5 basic elements: 1) environmental policy, 2) planning, 3) implementation, 4) measurement and assessment, and 5) analysis and improvement.

REPMS operation mechanism complies with the structure of environmental management protection system recommended by ISO 14000. The most significant difference consists in the fact that basic provisions of this system must be agreed between all participants, beginning from development of a joint environmental policy based on the own and regional policies.

The key factor of REPMS successful operation is its constant improvement, which is described by Deming Cycle customized for solution of the set target, Fig. 3.

Deming cycle here means cyclic decision making process. The set target is achieved because the system envisages strong feedback during operation. From the moment of REPMS introduction participating companies must evaluate its environmental effectiveness by confirmation of its compliance with requirements of the environmental policy, targets and planned values. This will allow to increase accuracy of quantitative assessment of geoecological risks and if required indicate ways to improve the system and specify environmental aspects of companies’ activities. This will help to adjust system operation and eliminate incompliance with approved requirements.

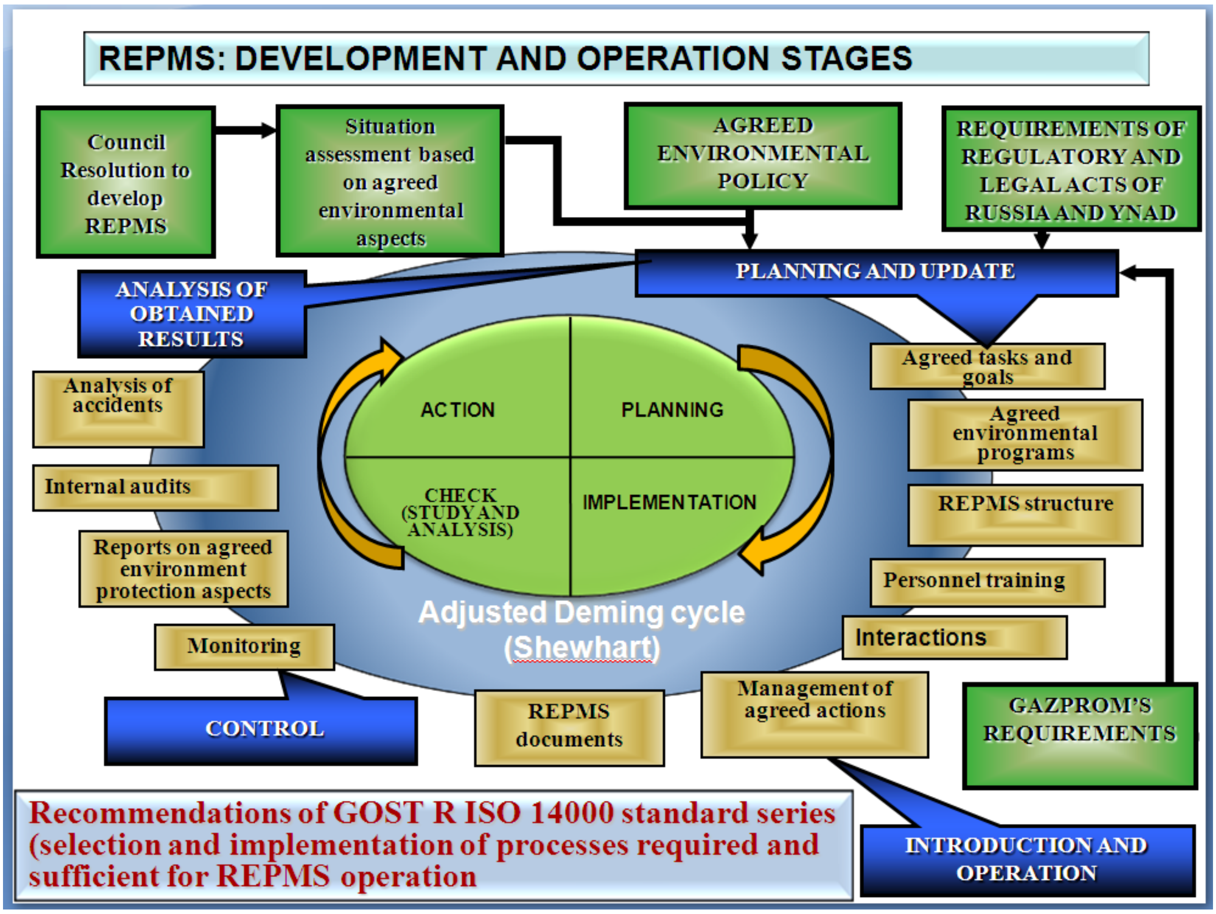

Fig. 3. Deming cycle customized for YNAD regional environmental protection management system

It is worth mentioning that for the first time ever report on greenhouse gas emissions inventory was done automatically by special software.

5.2 - Measures for atmospheric emission reduction

It is well-known that during gas field facilities construction and development production wells are drilled, developed and commissioned. These operations are connected with release and flaring of natural gas with maximum possible flow rate; their duration is determined by the geological structure of the specific deposit, well construction conditions and development methods. Released gas is flared on the gas flare unit, which causes atmospheric emissions of such combustion products as carbon and nitrogen oxides, sulphur oxide and benzapyrene.

Since 2001 the integrated scientific works aimed at reduction of the timeframes of well development and their accelerated commissioning have been carried out at the Zapolyarnoye field; new methods of gas dynamic studies of wells that are not connected with gas flaring have been worked out as well. These studies resulted in development and implementation of the method of pay formation secondary penetration, which is carried out in two stages under pressure drawdown and pressure balance in the “well-formation” system. It is achieved by well shifting to condensate, perforation (penetration) of lower interval with further well drawdown to pure gas and pay formation perforation in the gas media under formation and bottomhole pressure balance. This method allowed to reduce well development and commissioning timeframe from 3 to 2 days. Gas volume needed for this process was reduced by 1/3 respectively. Emissions of gas combustion products to the atmosphere were reduced in the same proportion. This technology is patented by the RF, No. 2289681.

Another method for reduction of atmospheric emissions of gas combustion products is well commissioning and bringing to the temperature mode without gas flaring. It was proposed to warm the well up and bring it to the temperature mode with gas feed via the gas gathering reservoir directly to the gas flowline. In such case the well is brought to the best operating mode without gas flaring. The implementation of this technology required preliminary injection of hydrate growth inhibitor – methanol to the wellbore after well development and before commissioning. The methanol is heated at the bottomhole to the formation temperature and gradually vaporizes to the formation gas flow. Warm methanol vapor in the bottomhole area and wellbore mixes with the flowing gas from formation and comes to the surface by the wellbore in the vaporized condition. It allows to more efficiently prevent gas hydrate growth both in wells and gathering systems and gas treatment units under very low temperatures. This method allowed to bring wells to the operating mode without gas flaring. Later on, if the wellhead gas temperature is lower than hydrate growth temperature, additional methanol is fed to the well through the annulus until the well is brought to the hydrate-free temperature mode.

Specialists of the Company have also worked out and implemented the method for stationary gas dynamic studies completely without gas release and flaring. This method employs the data of telemetric systems that can determine gas production rate, wellhead pressure and temperature with simultaneous measurement of bottomhole pressure by bottomhole devices, which allows to determine the productivity without gas release. Study modes are regulated by chokes. Thus, all production wells of the Zapolyarnoye field are equipped with telemetric sensors that register wellhead gas pressure, temperature and flow rate.

5.3 - Assessment of natural complexes transformation

The most important for West Siberia is the reconstruction of its natural complexes transformation from the very beginning of field development. This information is necessary for the development of environmental protection management system at both the Yamburg field, which has a long development history, and recently commissioned Zapolyarnoye field and other fields planned for development. If the transformation of natural complexes of the Yamburg field can be characterized based on the data of air space and surface surveys for 20-30 years, for other fields this issue can be addressed by more modern and detailed space data.

The developed for these purposes information base is a time-series of updated high resolution space images compared with geoecological and geocryological maps of scale 1:100000 in GIS. Types and areas of natural complexes transformation are plotted on them according to the system of landscape indicators that determine the condition of the permafrost area and include:

a) species composition and condition of vegetation cover;

b) physical properties of soils;

c) area of water bodies, thawed ground, flooding and bogging zones;

d) snow cover condition in the spring period;

e) optical properties and temperature of water;

f) location of river bends and coastal line;

g) optical properties and chemical composition of air;

h) micro and megaforms of terrain.

The main requirements for the information base include the reproducibility of results of space data processing and interpretation as well as the possibility to assess and forecast natural complexes transformation at regional and local territories, including license blocks and separate production sites.

The performed studies showed the real possibility of the development of the information base for geoecological and geocryological monitoring in the form of maps mentioned above. It should be noted that the assessment of natural complexes transformation in the permafrost area has certain distinctive features related to the typical impacts of industrial facilities and specific features of field geocryological conditions. The latter comprise spatial icing and temperature field variability of permafrost, the lithogenic basis of northern landscapes of West Siberia, extensive development of thawed ground waters and active development of contemporary cryogenic processes. Many features of the permafrost zone are reflected in the modern landscape and can be identified and controlled by remote Earth sounding. In general, the issue of quantitative assessment and analysis of natural complexes transformation in the areas of active permafrost gas field development based on the data of space surveys is conditioned by the need for assessment of geoecological risks of development of new promising field in the High North.

CONCLUSION

Thus, geoecological risks in gas industry revealed in the form of emergency emissions or spills of various chemical agents to the environment can have negative impact on people. Therefore, accident prevention, including engineering and monitoring means, becomes very important. As for remediation of consequences of accident situations, it consists in rehabilitation of lands disturbed due to various reasons using biological means. Gazprom dobycha Yamburg was selected as an example of successful addressing of the issue of geoecological risks in the gas industry. Distinctive features of the territory of the Company’s fields determine the need for pursuing scientifically substantiated environmental policy by using measures for emergency situations prevention. Provision of environmental safety of production facilities at new hydrocarbon fields development is very important in the Company. The long-term experience of the Company in the environmental protection area allows to use it in other subsidiary companies of Gazprom involved in hydrocarbon field development in the Far North.

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Figure 2 - Structure of the environmental management system at Gazprom dobycha Yamburg

Figure 3 - Deming cycle customized for YNAD regional environmental protection management system