Send Orders for Reprints to reprints@benthamscience.ae

78 *The Open Ecology Journal,* **2015**, *8,* **(Suppl 1-M13) 78-85**

Open Access

Ecological Risk Challenge at Gazprom Dobycha Yamburg LLC

Anatoly K. Arabsky[1*], Vladimir N. Bashkin[2,3] and Rauf V. Galiulin[4]

[1]*Gazprom Dobycha Yamburg LLC, N-Urengoy, YANAO region, Russia*

[2]*Gazprom VNIIGAZ LLC, Razvilka, Leninsky district, Moscow region, 142719 Russia*

[3]*Institute of Physicochemical and Biological Problems of Soil Science RAS, Pushchino, Moscow region, 142292 Russia*

[4]*Institute of Basic Biological Problems RAS, Pushchino, Moscow region, 142292 Russia*

Abstract: The environmental peculiarities, biological resources properties and land stock for Gazprom Dobycha Yamburg LLC gas fields have determined the Company's long-term environmental policy based on the concept of gas industry sustainable development and is targeted at the stringent compliance with the Russian environmental laws and international ecological standards. The geo-environmental risk policy comprises a series of sequential efforts to be taken as well as R&D activities. So, it may be stated that the long-term experience of the Company in the sphere of environmental protection proves to be relevant and appropriate for replication by other Gazprom JSC subsidiaries developing hydrocarbon fields in the Far North.

Keywords: Gazprom Dobycha Yamburg LLC, gas production, polar areas, ecological risks, management

INTRODUCTION

The main topic of this paper is to consider step by step the (geo)ecological risk management in the Gazprom Dobycha Yamburg LLC bearing in mind the definition of such a type of risk. Numbering these obligatory steps and aiming the sustainable development of gas industry in the Polar Regions, we should postulate the following ones: a) addressing geo-environmental risk challenges & activities and research work; b) assessing risk management at the stage of gas field facilities operation, including industrial safety management and efforts to minimize industrial emissions into the atmosphere; c) assessment of natural complexes transformation; d) reclamation of damaged soils; e) environmental safety risk management at industrial facilities at the stage of new fields development, and f) assessment of geodynamic threats at the stage of trunk pipelines design and construction. The given approaches allow the company to manage the ecological risks and achieve the challenges of sustainable developments. So, the purpose of this paper is to show how the declared task is getting practically realizable.

ADDRESSING GEO-ENVIRONMENTAL RISK CHALLENGES & ACTIVITIES AND RESEARCH WORK

Successful handling of geo-environmental risks at Gazprom Dobycha Yamburg LLC is exemplified by a series of activities undertaken lately in the sphere of environment protection. They included intensification and identification of R&D areas enabling to meet the environmental challenges on the regional scale. The 2009-2014 efforts covered the following:

1. ecological and analytical control of ambient air, soil and water basin conditions in accordance with the license agreements;
2. construction of environmentally friendly production infrastructure;
3. restoration and reclamation of disturbed soil;
4. monitoring environmental status.

The key activities undertaken are listed in Table **1**.

The Company carries out research and development according to the R&D Plan for Subsidiary Companies annually adopted by Gazprom JSC. In order to perform the given efforts, it invites top branch, training and academic research institutes as contractors. The Company's specialists and scientists also take part in these activities to contribute to their performance.

The system was developed upon the Company's request, to monitor components of the environment, the Company's environmental management standards and inventory of greenhouse gas emissions (methane, carbon oxides and nitrogen oxides, etc.). In particular, the Company's specialists suggested that Gazprom VNIIGAS LLC (Russian Research Institute for Natural Gases and Gas Technologies) should develop computer software which will allow to draw up an inventory report (cadaster) on greenhouse gas emissions

*Address correspondence to this author at the Deputy Chief Engineer, Gazprom Dobycha Yamburg, LLC, N-Urengoy, YANAO region, 629306 Russia; Tel/Fax: +734494966015; E-mail: A.Arabsky@ygd.gazprom.ru

Table 1. Annual activities for protection of the environment (and its components) of Gazprom Dobycha Yamburg LLC.

Components of the Environment and Activities
Air
MPD instrumental monitoring of air pollutants in the atmosphere.
Air condition monitoring via leased automatic environmental monitoring station, etc.
Water
Construction of a sewage pumping station (SPS[1)]) for rainfall discharge in the area where the oil and methanol depots and gas filling station[2)] are located
Construction of intra-site sewage systems in the area where the oil and methanol depots and gas filling station are located
Construction of industrial waste containers in the area where the oil and methanol depots are located
Construction of an SPS in the area where gas processing plant, GPP-1C[3)] is located
Construction of an SPS in the area where gas-turbine power plant[4)] is located in the Zapolyarnoye Field
Construction of an SPS for industrial wastes in the area where gas processing plant GPP-2B is located etc.
Soil
Restoration of damaged soil in the area where preliminary gas processing terminal, PGPT-10[5)] at the Yamburgskoye Field is located
Restoration of damaged soils in the area where a number of gas processing plants are located
Restoration of the damaged soil in the area where a number of oil wells at different fields are located, etc.
Air, water, soil, resources
Departmental environmental laboratory chemical and analytical monitoring of air, water and soil
Laboratory chemical and analytical monitoring of potable water quality, microbiological monitoring of sewage and underground waters and soil, etc.
Environmental and resources monitoring at licensed field sites.

Note. 1) sewage pumping station; 2) gas filling station 3)gas processing plant; 4) gas-turbine power plant; 5) preliminary gas processing terminal.

Table 2. Annual environmental protection research and development activities of Gazprom Dobycha Yamburg LLC.

No	Contents
1	Development of the system for industrial ecological monitoring of environmental components.
2	Development of the concept "Regional-Branch Environmental Management System".
3	Cooperation procedures development for "Regional-Branch Environmental Management System" and the system of industrial and ecological monitoring of environmental components.
4	Development of the inventory, i.e. a systematized set of data on greenhouse gas emissions.
5	Water bodies investigation via bio-indication and bio-testing methods

based on the given data. At present options are being reviewed as how to draw up inventory reports in the English and Russian languages at a time. Special studies have also been carried out in the sphere of aquatic environment protection. The key research works are listed in Table **2**.

Development of the "Regional-Branch Environmental Management System" obviously falls beyond the scope of the Company's production activities and rather concerns its social accountability to the provinces of gas and gas condensate production. Therefore, these aspects and cooperation between Gazprom Dobycha Yamburg LLC and other agencies in the Yamalo-Nenets Autonomous Okrug are going to be presented in the next papper A. Arabsky & V. Bashkin (in this issue).

It is worth noting that its own EMS implementation and development as well as control establishment over all kinds of the Company's activity on the licensed sites and RBEMS would not be possible without certain technologies including geo-information systems (GIS). The Company's GIS was designed to utilize spatial data and was furnished with intuitive cartographic interface, i.e. a set of means, methods and rules of interaction between the system's elements (Vergeles *et al.* 2009). GIS provides real time access to external information systems data and allows to analyze information with regard to spatial and mutual positioning of objects and their geometrical characteristics.

Table 3. Perennial retrospective forecast assessment of the geo-environmental situation within the area of Gazprom Dobycha Yamburg LLC operations.

The assessment stages included the following findings: – assessment and monitoring of the geo-environmental situation in case of greenhouse gas emissions at the stage of natural gas production in the Far North provinces; – methodological approaches and criteria of retrospective and forecast assessment of the geo-environmental situation in the areas of the Company's operations; – software application for measurement of the Company's greenhouse gas emissions
Goal: To develop special criteria for geo-environmental situation assessment in the areas affected by the industrial facilities using international practices and software for greenhouse gas emissions measurement.
Deliverables: Report on the study "Retrospective and Forecast Assessment of the Geo-Environmental Situation within the Areas of Gazprom Dobycha Yamburg LLC Operations on the Basis of Well-Grounded Criteria", which consists of: – the system of assessment and monitoring of the geo-environmental situation in case of greenhouse gas emissions at the stage of natural gas production in the Far North provinces; – methodological approaches and criteria determination for retrospective and forecast assessment of the geo-environmental situation in the areas of the Company's operations; – software application to measure greenhouse gas emissions in the areas of the Company's operations.

Within the 30 years of field development, Gazprom Dobycha Yamburg LLC gained a significant amount of spatial data stored on various data media, in various formats, cartographical projections and reference systems. However, the information used to be stored in different departments and its sharing was cumbersome and sometimes even impossible. So, the Company's own GIS allowed to overcome these difficulties. It was experimentally proved that it was unpractical and inefficient to introduce a typical GIS in an organization with a complex structure. The Company needed a GIS that would encompass all the aspects of its industrial activity and other types of activity using spatial and other types of data. The solution was found in establishing a spatial data infrastructure, normally used in GIS on the national or regional scales and such interrelated elements as:

1 information resources including spatial data in the form of distributed databases, file sets and descriptions (metadata);

2 regulatory and administrative documents in the form of the Company's standards, provisions, regulations and orders that determine working procedure with spatial data and metadata;

3 technology, software and hardware ensuring acquisition, storage and presentation of spatial data and metadata to end users.

In the course of the system implementation, the Company gained a positive experience which brought a new vision of the conventional cartography from the perspective of a gas production enterprise. At present the bulk of spatial data comes in digital format and includes topographical surveys, land surveys and design documentation. Spatial data acquisition is automated by means of opto-electronic geodesic tools, satellite positioning system and earth remote sensing data. Also the system allows modeling spatially dispersed processes and phenomena and forecast their changes time wise. For Gazprom Dobycha Yamburg LLC GIS application brought a brand new spatial data format comprising an integral part of the Company's information field.

Thus, GIS database is complemented with high-resolution images taken in space by earth satellites and showing the territory of the Company's licensed sites. Their simple analysis alone allows to assess the geo-environmental conditions of the licensed sites and adjacent territories as well as the cumulative environmental damage.

A good illustration of the Company's efficient GIS implementation is the 2010 retrospective and forecast assessment of the geo-environmental situation within the area of its industrial activity (Table **3**). The novelty of this effort is that the assessment criteria of the geo-environmental situation have been developed and special software has been designed for greenhouse gas emissions measurement. The latter relies on the advanced information technologies, a unit-of-delivery method, stratified architecture, client-server and intranet technologies related to software, systemization, storage and processing internal corporate information, etc.

Deliverables are designated to the structural divisions of Gazprom Dobycha Yamburg LLC and other Gazprom JSC subsidiaries, as well as JSC Gazprom Energy Saving and Ecology Directorate of Gas Transmission, Underground Storage and Utilization Department for the following purposes:

1. to assess sustainable development of Gazprom JSC and its subsidiaries using generally recognized international practices and criteria;

2. to reorganize the management system and optimize the environmental monitoring and admissible environmental impact assessment in the area of Gazprom JSC operations at the hydrocarbon fields under current and planned development;

3. to assess the geo-environmental situation in the areas of Gazprom Dobycha Yamburg LLC operations;

4. to compile the Company's statistical reports on greenhouse gas emissions, feasibility study of investments and implementation of projects aimed at reducing

greenhouse gas emissions from Gazprom Dobycha Yamburg LLC facilities.

It is worth mentioning that the Company for the first time managed to meet the challenge of drawing up an inventory report on greenhouse gas emissions in an automated mode, using special software designed by Gazprom VNIIGAZ LLC.

RISK MANAGEMENT AT THE STAGE OF GAS FIELD FACILITIES OPERATION

It's well known that fields of Gazprom Dobycha Yamburg LLC are technically reinforced with a great number of engineering gas-field facilities and other associated constructions on various basements, pile foundations and bearing structures ensuring gas production and preparation for long-distance transmission (Salikhov *et al.* 2006). All the Company's gas-field facilities are built on permafrost soils with their mean annual temperatures varying from -3 to -7^{o} C and thickness of the frozen ground of 300-400 m or more. Frozen soils are almost incompressible, high-tensile, with a high bearing capacity, while the thawed soils (at >0^{o} C) have their hard texture melted and their bearing capacity going to zero. Therefore only frozen soils may serve as a foundation for buildings and constructions. Thus, gas-field facilities operation in severe geo-technical Arctic conditions implies the risk of foundation failures in the solid permafrost zone. First and foremost, failures occur if the parameters of geo-technical systems exceed the tolerance limits adopted in design projects. In order to exclude potential risk, the Company has developed a special risk management system for gas-field facilities operation in permafrost conditions of the Arctic. One of its functions is to establish the required reliability level for different facilities foundations. At the input the system receives current parameters of the Company's territorial production complex and at the output forms adjusted values of the given parameters. The Company's territorial production complex is a set of engineering structures and units with different functions: gas-field and gas transmissions facilities, living quarters, motorways and railroads, etc. The system consists of two major blocks:

1. Geo-information block or technical auditing block, which monitors the condition of basements and foundations of facilities under construction or in service, and provides database support and analysis. The block aligns R&D permafrost laboratory and a surveyor service which performs geotechnical monitoring, namely:

a) compilation of geological engineering survey results obtained on gas-field and infrastructure facilities in different years;

b) engineering and geological study of gas-field facilities foundations along with soil analysis to determine physical and mechanical parameters of the soil;

c) regular thermometric surveillance within wells drilled at the field sites and inside the facilities.

2. Production and technical block includes emergency repair and rehabilitation service, buildings and facilities operation service that performs engineering and technical work and ensure operational risk reduction below the given level. To guarantee foundations reliability the block performs the following preventive and structural tasks:

a) summer and winter operations modes shifts for basements and foundations on a timely basis;

b) basements and foundations operation in pursue to the regulatory requirements unless specified otherwise on the operating mode shift;

c) strengthening the sagged foundations using backup piles;

d) application and testing of new pile foundation structures if there is sound basis for this;

e) seasonal cooling units installation, thermal probing and heat improvement of the foundation soil near the piles;

f) soil hydrophobization;

g) application of plastic, bituminous and wax anti-heaving coating of piles when recommended.

The risk management system of gas-field facilities operation guarantees sustainable operation of the Company's territorial production complex in a permanently changing Arctic environment affected by stochastic (random) natural processes. Meanwhile, risk management results obtained in the course of the Yamburgskoye Field development have been applied to project designs and at the Zapolyarnoye Field construction stag, and may be further utilized in new gas-field complexes operation in the permafrost conditions of the Arctic.

INDUSTRIAL SAFETY MANAGEMENT

Among Gazprom Dobycha Yamburg LLC facilities which may induce geo-environmental risks are gas processing plants and gas pretreatment units, booster compressor stations, re-injection gas pipelines (intrafield gas pipelines) as well as gas and gas condensate wells (Salikhov *et al.* 2010). The key factors leading to emergency situations in the course of the facilities operation are:

3. natural gas explosiveness and flammability;
4. significant amount of explosive and flammable materials;
5. high pressure in re-injection gas pipelines of 1.7-25.0 MPa and gas temperature varying from -10 to +35°C in the course of gas field preparation and transmission;
6. poor accessibility of indoor re-injection gas pipelines;
7. numerous hazardous substances involved in the technological process in the form of natural gas, methanol, diethyleneglycol – $(HOCH_2CH_2)_2O$, fuel and lubrication materials, etc.;

8. high concentration of equipment in a confined space, etc.

Analysis of similar facilities operating with hazardous substances proves that accidents are likely to occur accompanied by explosions, fire and environmental pollution. Thus, the Company introduced a system for industrial safety management technical supervision which not only enables to identify duties and responsibilities of the top management and company departments but to streamline their interaction with supervisory bodies and top controlling authorities of Gazprom JSC. The system urges upon abiding by the following requirements:

1. adherence to the order and conditions of applicability of technical equipment at industrial facilities which potentially may induce the risk of emergency situations; carrying out tests and technical examinations of these facilities;
2. establishment of the Company's own professional emergency repair and rehabilitation teams composed of staff operating at potentially hazardous facilities;
3. establishment of a surveillance system, alarm system, system of actions support in case of emergency;
4. performance support of equipment and process supervisory systems, ensuring compliance with the requirements for hazardous substances storage;
5. planning and running operations of emergency response actions and post-accident clean-up, etc.
6. Among the key activities aimed at ensuring industrial safety at the operating facilities within the Company and its different services the following may be singled out:

a) target inspections to check compliance with industrial safety requirements in the course of potentially hazardous facilities operation;

b) industrial safety expert review of equipment and technical devices applied in the potentially hazardous facilities to extend their service life; carrying out technical examination and check tests;

c) calibration and verification of gas analyzers and gas fumes annunciator, etc.

EFFORTS TO MINIMIZE INDUSTRIAL EMISSIONS INTO THE ATMOSPHERE

Production wells are drilled, tested and put into operation at the field construction and development stage (Raykevich & Minigulov 2007; Sustainable… 2013). Some of these operations are related to natural gas release and combustion at the maximum possible production rate. Thus, the duration of operation largely depends on the gas deposit geological structure, construction conditions and means of well development. The released gas is burnt in a gas flare unit, as a result, combustion products are discharged into the air, such as carbon oxide, nitrogen oxide, sulfur oxide and benzo(a)pyrene.

Systematic scientific research was conducted at the Zapolyarnoye Field starting from 2001 in order to cut the well development period and accelerate the start-up and introduce new methods of gas-dynamic well survey requiring no gas burning (Arabsky *et al.* 2005). As a result, the Company developed and introduced a two-stage secondary recovery method involving reservoir drawdown and maintenance of pressure equilibrium in 'well-reservoir' system (Andreev *et al.* 2005). According to this method the well is filled with condensate prior to well bottom perforation (strikethrough) with further emptying the well to clear gas level; and then well perforation is performed along the entire pay zone in gaseous area by equilibrium of formation pressure and well bottom pressure. This method allows to shorten the well development period and the start-up time from 3 to 2 days. It enables to reduce by 1/3 the gas volume needed for the process implementation. Combustion gas emissions were reduced in the same proportion.

Another way of minimizing combustion gas emissions into the atmosphere is a well start-up and conversion to a thermal regime without gas flaring (Raykevich & Minigulov 2007). It was suggested to heat and convert the well to a thermal mode and supply gas at start-up phase through a gas collector directly to the re-injection gas pipeline. Thus, the well is converted to optimum performance without gas burning. This technology required injection of hydrate formation inhibitor, methanol into the borehole of the well after its development but before the start-up. Methanol heats up in the well bottom reaching reservoir temperature and gradually evaporates into the gas flowing from the formation. Vapors of hot methanol in the well bottom and in the borehole mix up with gas from the formation and flow out to the surface along the borehole in a vaporous state. This allows to efficiently prevent gas hydrates formation in the well as well as in gathering facilities and gas processing plant at lowest temperatures and to bring wells to operational mode without gas burning. Further on if the well operates at wellhead temperature which is lower than the temperature of hydrate development, methanol is additionally injected through annular space into the well prior to its conversion to a hydrate-free thermal mode.

The Company also developed and introduced a new method of permanent gas-dynamic well surveys which completely excludes gas release and burning (Raykevich & Minigulov 2007). For this telemetry systems data are used, which allow to register gas production rate, pressure and temperature at the wellhead and simultaneously measure well bottom pressure with borehole tools. All that allows to assess well performance without gas release. Surveying modes are set by way of adjusting choke valves, owing to the fact that all production wells in the Zapolyarnoye Field are equipped with telemetry sensors that register wellhead production parameters, namely pressure, temperature and gas flow rate.

ASSESSMENT OF NATURAL COMPLEXES TRANSFORMATION

In the north of Western Siberia it is essential to reconstruct the process of its natural complexes transformation at the very early stages of fields' development (Kornienko & Yakubson 2005). These data are needed to establish the environmental management system on the long-operating Yam-

burgskoye Field and a relatively new Zapolyarnoye Field, as well as some other fields in the wake of development. The archive data on aerospace and ground observations obtained in the past 20-30 years may be sufficient to characterize natural complexes transformation in the Yamburgskoye Field. But for other fields the updated, complete and more specific space information is required.

The information basis developed for this purpose is a time series of updatable high resolution satellite images compatible in GIS with geo-environmental and permafrost maps of 1:100000 scale. They are used to indicate natural complexes transformation types and zones with due regard to the system of landscape indicators characterizing the cryolithic zone condition. These data include:

1. species composition and vegetation cover condition;
2. physical properties of soils;
3. area of water basins, taliks (thawed zones), waterlogged and bogged zones;
4. snow cover condition in spring season;
5. water optical properties and temperature;
6. meanders and waterside character;
7. optical properties and chemical composition of air;
8. terrain (relief) micro- and macroforms.

Among the major requirements for information basis are reproducibility of space data processing and interpretation results, estimation and forecast of natural complexes transformation on the regional and local scale, including licensed sites and certain industrial facilities.

The research proved a real opportunity of setting an information basis for space geo-environmental and permafrost monitoring in the form of the above-mentioned thematic maps. It is worth noting that natural complexes transformation assessment has a number of features related not only to specific impact of industrial facilities, but to permafrost fields' conditions. They include high spatial variability of ice and temperature patterns of frozen soils as a lithogenic basis of landscapes in the north of Western Siberia, extensive development of talik ground waters and cryogenic processes. Numerous features of the cryolithic zone are reflected in the existing landscape and may be revealed and controlled via remote sensing of the Earth. On the whole, the satellite data-based study and quantitative assessment of natural complexes transformations in the areas of intensive gas fields development in the cryolithic zone, is needed to assess the geo-environmental risks at the stage of new prospective fields development in the Far North.

RECLAMATION OF DAMAGED SOILS

Protection of the cryolithic zone surface is the prerequisite of the production sites environmental safety and natural gas transmission safety. Field surveys and aero survey data analysis show that gas fields territories in the Far North are characterized by widespread thermal erosion as a combination of thermal and mechanical effect of streaming water on frozen rocks and ice (Andreyev *et al.* 2003). Thermal erosion is marked by high development rate with focal points arising even on slight slopes of the terrain as a result of vegetation cover partial damage and permanent or temporary stream flow. It causes terrain and landscape modifications and an extensive ravine networks formation, which may endanger the stability of gas reservoirs.

Earlier at the Yamburgskoye Field the Company developed and implemented a system of permafrost monitoring and analysis of technogenic factors that affect it. Also it performed reclamation of soils damaged by thermal erosion. When developing methods of thermal erosion minimization and control of consequent ravine formation, the key priority was to increase erosion resistance in soil systems. To achieve this, soil was reinforced via remediation means composed of local dust sand added with aggregating agent "universin-V" (4% of the weight) and mineral constituents. This allowed to increase the cryolithic zone erosion resistance by 4-5 orders of magnitude. Thus, 2.5-4.0 cm thick soil cover had no negative impact on vegetation but provided a positive agrochemical effect due to temperature increase by 2-3°C in the root layer and acidic tundra soils alkalization. Among other damaged soils reclamation methods are algal phytomelioration with the use of native soil microalgae for soil densification, higher plants growth stimulation, etc.

ENVIRONMENTAL SAFETY RISK MANAGEMENT AT INDUSTRIAL FACILITIES AT THE STAGE OF NEW FIELDS DEVELOPMENT

Gazprom Dobycha Yamburg LLC is actively designing a master scheme for its short-term and mid-term development within the framework of Gazprom JSC plans (Andreyev *et al.* 2010). Since all the developed hydrocarbon fields and those under development or projected are located in a natural environment which is highly sensitive to technogenic impact. Therefore, environmental safety at field construction and gas production stages is given a top priority.

Several fields with sizeable gas and gas condensate reserves are located in the offshore area of the Ob and Taz Bay. This causes certain difficulties related to offshore infrastructure development and field exploitation, gulf depths and bottom peculiarities, ice drifts, etc. Development of the offshore fields requires a comprehensive approach to ensure environmental safety of industrial facilities at the stages of their design, construction, operation and decommissioning in the future. The key components of this approach in the offshore fields of the Ob Bay including the Severo-Kamennomysskoye and Kamennomysskoye-Sea Fields are the following (see Fig. **5**, Arabsky, this issue):

1. advanced technical and process solutions;
2. availability of warning and accident response system;
3. industrial environmental monitoring;
4. navigation restriction in the area of hydrocarbon production complexes;
5. compliance with work performance requirements at the field development and operational stages;

6. stabilization of foundations, adequate protection of hydrocarbon-production complexes;
7. outer (condition monitoring) and inner inspections in the course of construction, testing and operation of hydrocarbon-production complexes;
8. control over the quantity and composition of biological resources.

Notably, assessment of the Severo-Kamennomysskoye Field development and operation effect on the Ob Bay with its diverse ichthyo-fauna proved that the following factors may be involved:

1. breaking away of the bottom area intended for hydrocarbon production facilities;
2. suspended substances cloud formation as a result of puddling bottom sediments in the course of offshore drilling, dredging, etc.;
3. noise factor;
4. water intake for process needs, etc.;

In this respect reimbursement costs were calculated for the construction activities impact on aquatic biological resources. The Company also coordinated with Nizhneobsk Territorial Administration of the Federal Fishery Agency a set of actions on fish resources recovery in the framework of mitigating adverse impact on ichthyo-fauna. Finally, a permanent industrial environmental monitoring system was implemented to ensure surveillance over the environmental components, to process, accumulate and analyze the obtained data and to reveal the environmental trends at the stage of field development. This will allow accumulate relevant information sufficient for managerial or other decisions and implement preventive measures enabling to comply with the permissible limits specified in legal-regulatory acts.

ASSESSMENT OF GEODYNAMIC THREATS AT THE STAGE OF TRUNK PIPELINES DESIGN AND CONSTRUCTION

To successfully implement its development plans, Gazprom Dobycha Yamburg LLC gives high priority to assessment of geodynamic hazards arising in the course of trunk pipelines design and construction of newly developed fields. Significantly hazardous consequences of the geodynamic processes adverse impact naturally revealed in surface facilities deformation, filed pipeline ruptures, waterlogging and flooding of sinking or subsiding lots, and land sliding. This subchapter (Ishkov *et al.* 2011) describes the assessment procedure for current geodynamic threat as a part of project design documentation development to justify investments for the trunk pipeline in the Severo-Kamennomysskoye Field, as an example (see Fig. **5**, Arabsky, this issue). Geodynamic threat assessment at the gas pipeline involves estimation of the present-day deformation activity at fault zones and reveals their type and order on the basis of detailed analysis:

1. the Earth remote sensing data;
2. geological and geophysical data;
3. information on occurrence and location of emergency pipeline ruptures;
4. data on vertical crustal movements;

Integrated assessment of geodynamic threat is exercised in four stages.

The first stage involves fracture and fault zones identification on the regional scale, as a result of geological and geophysical (G&G) archive data analysis and Earth remote sensing data analysis. The second stage includes comparison of the data obtained and processed as a result of G&G survey and Earth remote sensing data, thus determining the basic characteristics of fault zones. The third stage consists of collecting and analysis of supplementary data. The fourth stage deals directly with the present-day geodynamic threats assessment involving zoning of the area under review according to the current status of the geological environment i.e. detection of fault zones according to their hazard rate. These efforts result in the cartographic zoning scheme production for the gas pipeline with due regard to geodynamic threat scale. Unlike the existing approaches which only allow to identify the fault zones deemed to be active in terms of long-running geological processes, this method structures fault zones identification according to the current geodynamic status on a real time basis. The obtained cartographic scheme depicts dangerous faults pattern, allows to choose the optimal observation schedule, i.e. to set accuracy and details level, measurement techniques, configuration of measuring profiles, etc.

It is not a coincidence that Gazprom Dobycha Yamburg LLC was chosen as an example of successful geo-environmental risks tackling in gas industry. This was due to the Company's substantial contribution into the total volume of gas produced by Gazprom JSC in the Yamburgskoye and Zapolyarnoye Fields. The natural peculiarities of the field territories combined with their biological resources and soil reserves give the Company solid grounds to pursue scientifically based environmental policy. Geo-environmental risks challenges imply certain environmental activities and intensified research and development in this area. Accidents prevention is effected by the Company by means of: gas-field facilities maintenance risk management; industrial safety management; environmental management, etc. It ensures implementation of efforts aimed at reducing the atmospheric emissions; assessment of natural complexes transformation and reclamation of damaged soils, etc. The Company gives high priority to tackling issues of environmental safety at industrial facilities in the course of new offshore hydrocarbon fields' development, as well as to assessing geodynamic threats at the stage of trunk pipelines design and construction in these fields.

CONCLUSION

Thus, the environmental peculiarities, biological resources properties and land stock for Gazprom Dobycha Yamburg LLC gas fields have determined the Company's long-term environmental policy based on the concept of gas industry sustainable development and is targeted at the stringent compliance with the Russian environmental laws and international ecological standards. The geo-environmental risk policy comprises a series of sequential efforts to be taken as well as R&D activities. So, it may be stated that the long-term experience of the Company in the sphere of envi-

ronmental protection proves to be relevant and appropriate for replication by other Gazprom JSC subsidiaries developing hydrocarbon fields in the Far North.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

The author expresses his deep appreciation and gratitude to Dr. O. Makluk, head of environmental protection department of Gazprom Dobycha Yamburg LLC, for helpful discussion and useful support.

REFERENCES

Andreyev, OP, Stavkin, GP, Levinzon, IL, Perepelkin, IB & Lobastova, SA (2003) Soils and landscapes protection and restoration at the stage of gas production in the far north. *Ecology and Industry of Russia*, 6, 4-9.

Andreyev, OP, Mazanov, SV, Akhmedsafin, SK, Arabsky, AK, Ishkov, AG, Rusakov, SY & Yarygin, GA (2010) Environmental safety issues at the stage of first gas fields development in the ob-taz bay. *Science and Technology in Gas Industry*, 4, 32-8.

Ishkov, AG, Andreyev, OP, Arabsky, AK, Yarygin, GA, Khvastina, AS & Bayukin, MV (2010) Key principles of the regional-branch environmental management system. *Environment Protection in Oil and Gas Complex*, 4, 4-9.

Ishkov, AG, Yarygin, GA, Kuzmin, YO, Lukyanov, OV & Farafonov, AS (2011) Present day geodynamic hazards assessment at the stage of trunk pipelines design and construction. *Science and Technology in Gas Industry*, 1, 66-71.

Kornienko, SG, Yakubson, KI & Maslennikov, VV (2005) Satellite investigation of natural complexes transformations in oil and gas-bearing areas of the cryolithic zone. *Science and Technology in Gas Industry*, 3, 71-7.

Andreyev, OP, Raykevich, SI, Raykevich, AI & Minigulov, RM (2005) Method of Secondary Recovery from Gas Well Pay Zones. Patent of Invention No. 2289681, Russian Federation, Application as of 28.07.2005. Published on 20.12.2006. Bulletin No 35.

Physical and Geographical Zoning of the Tyumen Region (1973) Moscow University, Moscow.

Raykevich, SI & Minigulov, RM (2007) Reducing greenhouse gas emissions in the atmosphere at oil and gas fields development stage. *Science and Technology in Gas Industry*, 2, 8-15.

Salikhov, ZS, Andreyev, OP, Arabsky, AK, Kondratyev, SD, Pavlunin, VB & Stavkin, GP (2006) Risk management at the stage of gas-field facilities operation in permafrost conditions of arctic areas and the yamal peninsula. *Science and Technology in Gas Industry*, 3, 18-25.

Salikhov, ZS, Mazanov, SV, Kumushbayev, AM & Kozlov, VM (2010) Operating Hazardous production facilities at gazprom dobycha yamburg, LLC in the far north. *Gas Industry*, 8,74-7.

Markelov, VA, Andreev, OP & Kobylkin DN, (Eds) (2013) Sustainable Development of Gas Industry, Nedra, Moscow.

Vergeles, SP, Bukhtoyarov, BN, Olimpiev, IV & Kiselevsky, EV (2009) Integration of geo-information technologies at gazprom dobycha yamburg LLC. *Science and Technology in Gas Industry*, 2, 48-57.

Received: November 22, 2014 Revised: February 02, 2015 Accepted: March 24, 2015