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(Geo) Ecological Risk Assessment in Gas Industry Development Scenarios

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Abstract: In this paper the main attention is paid to the proposed methodology of assessing ecosystem risks associated with industrial emissions that not only allows to make quantitative estimation of potential changes in the ecosystem condition but also to calculate probability of their occurrence. It is also providing a detailed characterization of ecosystems as targets of man-induced impact. Finally it is shown that ecosystem risks qualitative assessment is feasible for environmental substantiation of gas projects in the areas with a low level of information supply and high level of uncertainty

Keywords: Ecological risk, geoecologocal risks, critical loads, exceedances, risk assessment and calculation.

INTRODUCTION

Geo-ecological risks assessment in the course of gas industry development strategy implementation is one of the key mechanisms for the prevention and minimization of the negative effects that human economic activity has on the environment.

Following the recommendation of the Convention on Biological Diversity specialists in environmental assessment pay particular attention to preservation of the biotic component of the natural environment. However, as shown by the practical analysis for investment projects environmental justification and gas industry analysis the impact on biota is a weak point of the sector (Treweek 1999, 2000; Bashkin 2010). Russia is no exception here as despite the regulations that require to include the bio-environmental factor in environmental impacts assessment, the quality of these studies is not high. One of the main reasons for this is insufficiency of the conventional assessment methods (Cherp 2001). The lack of 'ecosystem' approach and predominance of qualitative assessment methods over the quantitative ones tend to be its major deficiency. This part defines the concept of quantitative approach to assessment and probability analysis of geo-ecological risks. It has been developed with due regard to quantitative methods of estimating impacts on ecosystems based on the ecosystem's maximum permissible concentrations (MPC) – so-called critical loads of pollutants on ecosystems (Bashkin 2006).

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METHODOLOGICAL ASPECTS OF ASSESSING IMPACTS ON ECOSYSTEMS

In the sphere of environmental management today the impact on the environment is defined as any changes in the condition of environmental components (recipients) that occur fully or partially from production or other types of activities. Such impacts may be classified by the following criteria:

1) geographic scope - as local, territorial, regional, transboundary and global impacts;

2) duration - as non-recurring, periodic, continuous, short-term, medium-term and long-term impacts;

3) reversibility - as reversible and irreversible impacts;

4) intensity - as absolute or relative impacts;

5) probability - as high, medium and low ones;

6) uncertainty - as high, medium and low ones.

Given the structural and functional complexity of ecosystems, the forecast of changes in their condition is normally rather uncertain. This is due to inevitable simplification in the course of modeling the environmental processes, insufficiency of the baseline data used in forecast calculations, possible doubts about reliability or scientific data proofs and incompleteness of the algorithms applied.

The risk concept and methods of environmental risk assessment based on it are designated to minimize the problem criticality vis-à-vis uncertainty of forecasts for environmental impacts. Incorporation of risk assessment methods in the environmental impact assessments may contribute to a higher level of forecast reliability, facilitate analysis of project alternatives and ensure transparency in decision-making. The environmental risk assessment procedures include the following:

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1) hazard identification: identification of impact sources, characterization of hazard factors (chemical, physical, biological, radiological hazards), identification of potential recipients and possible negative changes in their condition;

2) exposure assessment: evaluation of the intensity of anthropogenic loads on the recipients;

3) impact assessment: determination of threshold levels for anthropogenic load on the recipients (reference doses or concentrations);

4) risk characterization: assessment of certain environmental risks, determination of their acceptability degree and uncertainty analysis of the investigations results.

More detailed studies on the environmental risk assessment involve investigation of the geo-ecological effects of pollution (Edujee 1999; Petts 1998; Suter 2000). To date, approaches to quantitative assessment of risk impact on the biota have been formed but they are mainly limited to the study of population and species (Smrchek & Zeeman 1998). Nevertheless, a mechanism for assessing ecosystem risks has been developed as a part of critical loads concept that forms the basis for controlling man-induced atmospheric pollution in consistency with the Convention on Long Range Trans-Boundary Air Pollution (Bashkin 2007).

POLLUTANTS CRITICAL LOAD METHODOLOGY

Critical loads methodology focuses on the man-induced atmospheric impacts associated with anthropogenesis. So far, methods have been developed and applied to measure critical loads of major industrial pollutants such as sulfur, nitrogen, heavy metal compounds, as well as troposphere ozone impacting land and freshwater ecosystems.

Originally this methodology was applied on the global and national scale, nevertheless a fair amount of measurements and critical loads mapping have been made in the recent years at the regional scale. Studies have also been conducted as part of the initiative to enhance reliability of the baseline data for calculation and testing of new methods at a local level.

The critical loads concept is based on the idea of threshold effects that environmental hazards produce on ecosystems. The critical load is a maximum acceptable concentration of a pollutant whose annual atmospheric input to the ecosystem over a long period of time (50-100 years) will not cause irreversible changes to its structure and functions. This indicator characterizes the assimilation potential of ecosystems and is analogous to the reference dose for pollutants, a generally accepted impact standard in environmental risks assessment.

Unlike conventional quality standards applicable to natural environments (MPC, approximate acceptable level (APL), etc.), critical loads are standards that define significance of man-induced impacts on the ecosystems as a whole rather than their components. Calculation algorithms presuppose a selection of a limited number of biogeochemical parameters with threshold values ensuring the safety of man-induced loads on the recipients.

Based on the biogeochemical principles the critical loads methodology takes into the utmost account an internal heterogeneity of the territory affected by a developing facility. The critical loads are calculated for homogeneous areas (selected sites) of ecosystems. The main selection criteria are indicators that define specific features of pollutants migration in the environment: soil condition, vegetation cover, location within a catchment basin. The critical loads can be subsequently estimated for each target ecosystem and adopted as the local environmental impact standards.

CONCEPT OF ECOSYSTEM RISK ASSESSMENT AND POLLUTANTS CRITICAL LOADS METHODOLOGY

According to the critical loads methodology, the ecosystem risk is a two-dimensional factor that determines probability of adverse changes in the target ecosystems and values of these changes (Bashkin & Priputina 2010). The quantitative assessment of ecosystem risks is based on evaluation and dimensional analysis of the exceeded critical load for pollutant X ($E_x(X)$) within the area affected by a designed facility. Exceeded critical loads reflect the correlation between the exposure value (actual or expected load value of a pollutant) and the safe impact level (critical load value of a pollutant). The impact on ecosystems may be estimated as the percentage of allocated areas with exceeded critical loads within the selected sites (e.g. the sanitary protected area of the designed facility). The choice of the acceptability criteria for the expected changes depends on the features of the affected ecosystems. In the most valuable or sensitive ecosystems, the critical loads must not be exceeded by 100%. In other ecosystems '95% protection principle' should be applied. It means that permissible is considered to be the load of priority pollutants equivalent to $E_x(X) \leq 0$ for 95% of the territory.

Monte Carlo method-based probability models for exceeded critical loads may be applied to estimate ecosystem risks. Unlike the conventional way of evaluating exceeded critical loads the input data in the probability models are arrays of biogeochemical data values rather than single values (default values or average values). The arrays of input data can be obtained from the field-study data and from the prototype facilities analysis.

As a result, a set of values of $E_x(X)$ indicator is obtained for each particular area. Frequency distribution of these values allows for calculating the probability P (0 to 100 %) of achieving the positive values of $E_x(X)$ for each selected site within the field measured. Each value of $P(E_x(X)>0)$ will have the corresponding value of $M(E_x(X)>0)$ – the total area of selected sites with critical load exceedance. Based on the arrays of values (M; P), the ecosystem risk function ($R(X)$) is derived: $R(X) = F\{M, P\} = F\{M(E_x(X) > 0, P(E_x(X) > 0\}$, where M is the area of selected sites with exceeded critical load ($E_x(X)>0$); P is the probability of exceeded critical loads.

The ecosystem risk function is a distribution function. If there is a large number of selected sites the array of values

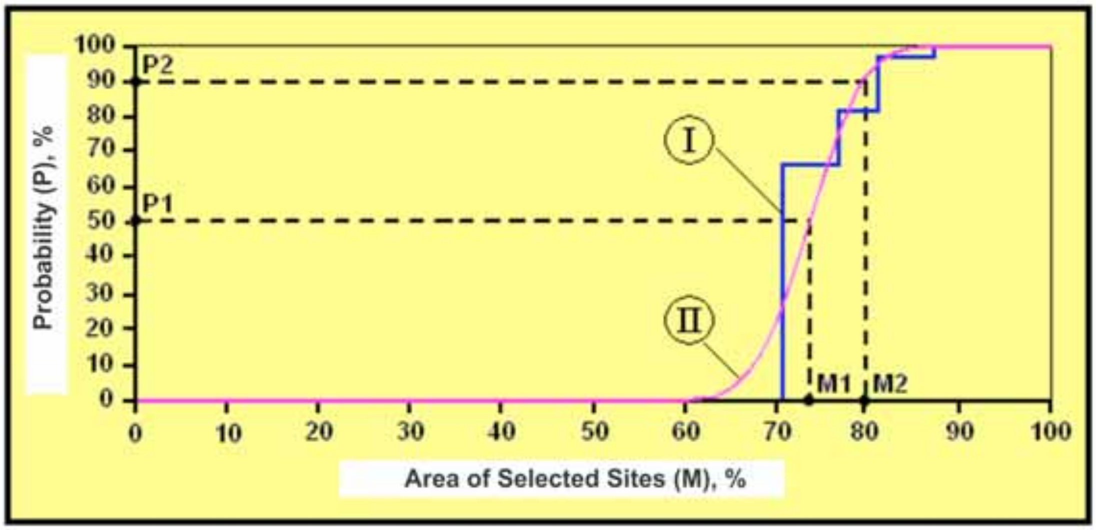

Fig. (1). Ecosystem risk function ($R(X)$) based on step distribution function (I) and continuous normal distribution function (II).

(M; P) will be well-approximated with a continuous normal distribution function. If the number of selected sites is low it is not possible to pass to normal distribution and the function will have a stepwise shape (Fig. **1**).

The distribution function allows to estimate the probability P_1 of exceeded critical loads in the area less than M_1 and the probability of exceeded critical loads for the fixed value interval of M ($M_1 \leq M_i \leq M_2$): $P=P_2 - P_1$.

ECOSYSTEM RISK ASSESSMENT BASED ON CRITICAL LOADS METHODOLOGY

Ecosystem risk assessment based on critical loads of pollutants normally relies on the formal risk assessment procedure (see above). The stage of hazard identification involves localization of emission sources, determination of possible scenarios of man-induced impact and making a comprehensive list of pollutants contained in emissions from a designed facility. It is also worthy to outline and classify potential recipients of the impact (ecosystems within the area affected by a facility under design). The obtained information on hazard factors and recipients is then used to make a qualitative characterization of impacts and specify the list of pollutants requiring comprehensive risk evaluation (priority pollutants). Exposure assessment should involve a detailed description of recipients (including division of the target ecosystems into receptor sites) along with determination of the background and the estimated loads for priority pollutants (values of pollutant deposition) (g/ha/yr or eq/ha/yr). The ecosystem impacts assessment should incorporate mapping and measurement of critical load values that refer to the maximum acceptable level of pollution loads for the selected recipients. Ecosystem risk characterization should involve estimation of change values for the recipients condition, assessment of changes probability and determination of their acceptability level under the selected criteria.

Risk characterization is a two-phase process. The first phase involves deterministic calculation of exceeded critical loads on the basis of the averaged input data. The second phase includes ecosystem risks assessment using modeling methods in cases when the receptor sites with $E_x(X)>0$ are identified (see above).

The final stage of ecosystem risk assessment should involve uncertainty analysis of the results obtained. For this, uncertainty sources should be described at each stage and reliability of the calculation results to be evaluated. The ecosystem risk assessment results are to be applied to classify certain project alternatives and develop environmental impact mitigation approaches as a part of assessment of the planned economic activities' impact on the environment.

CONCLUSION

Therefore, the proposed methodology of assessing ecosystem risks associated with industrial emissions not only allows to make quantitative estimation of potential changes in the ecosystem condition but also to calculate probability of their occurrence. It also allows to provide a detailed characterization of ecosystems as targets of man-induced impact. Moreover, this methodology takes into account a close correlation between individual components of the land and water ecosystems and natural variability of parameters that feature their condition.

Ecosystem risks qualitative assessment is feasible for environmental substantiation of gas projects in the areas with a low level of information supply and high level of uncertainty (Demidova, 2007; Bashkin *et al.*, 2013; Bashkin, 2014).

CONFLICT OF INTEREST

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

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REFERENCES

Bashkin, VN (2006) *Modern Biogeochemistry: Environmental Risk Assessment*, 2nd Edition, Springer, Dordrecht.

Bashkin, VN (2007) Environmental risk: assessment, management, insurance, Higher School, Moscow.

Bashkin, VN (2010) Environmental risk assessment in master plan for gas industry development. *Science and Technology in Gas Industry*, 2(42), 72-81.

Bashkin, VN (2014) *Biogeochemistry of Polar Ecosystems in the Impacted Zones of Gas Industry*, Gazprom VNIIGAZ, Moscow.

Bashkin, VN, Priputina, IV (2010) *Ecological Risk Management at Emission of Pollutants*, Gazprom VNIIGAZ Moscow.

Bashkin, VN, Arno, OB, Arabsky, AK, Barsukov, PV, Priputina, IV & Galiulin, RV (2013) *Retrospective and Prognosis of Geoecological Situation in the Gas-condensate Fields of the Polar Regions*, Gazprom VNIIGAZ Moscow.

Cherp, A, Vinichenko, V, Khotuleva, M (2001) *Ecological Assessment and Ecological Expertise*. 3rd ed., Ecoline, Moscow.

Demidova, OA (2007) Critical loads approach in ecosystem risks assessment. *Problems of Risk Analyses*, 3, 50-2.

Eduljee, G (1999) Risk Assessment. In: Petts, J (Ed) *Handbook on Environmental Impact Assessment: 2 volumes*, Oxford: Blackwell Science Ltd 374-404.

Petts, J (1998) Risk Assessment and Management for Waste Treatment and Disposal. In: Calow, P (Ed) *Handbook of Environmental Risk Assessment and Management*, Oxford, Blackwell Science, 417-52.

Samsonov, RO, Kazak, AS & Bashkin, VN (2007) Systems analysis of geoenvironmental risks in gas industry. *Safety and Emergency Situations*, 2, 25-37.

Smrchek, JC & Zeeman, MG (1998) Assessing Risks to Ecological Systems from Chemicals. In: Calow, P (Ed) *Handbook of Environmental Risk Assessment and Management*, Oxford, Blackwell Science, 453-87.

Suter, GW II (2000) Developments and trends in ecological risk assessment. In: Linkov, I. & Palma-Oliveira, J. (Ed) *Proceedings of the NATO Advanced Research Workshop "Assessment and Management of Environmental Risks: Cost-Efficient Methods and Applications*", Kluwer Academic Publishers, Dordrecht, 3-10.

Treweek, J (1999) *Ecological Impact Assessment*, Blackwell Science, Oxford, UK.

Treweek, J (2000) Evidence from Dr Jo Treweek to the Environmental Planning Study, 14 June 2000. *Index of Evidence Submitted to the Environmental Planning Study*, Royal Commission on Environmental Pollution. Available at: http://www.rcep.org.uk/epevid/-P2-JT.htm

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