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THE ASSESSMENT OF THE RISKS FOR THE ENVIRONMENT FROM THE ACTIVITY OF THE HAYSYN LIAMP

M. Radomska, A. Yovenko, I. Horobtsov
National Aviation University
prosp. Kosmonavta Komarova, 1, Kyiv, 05380, Ukraine, E-mail: m.m.radomskaya@gmail.com

Purpose. To determine the most significant impacts on the natural components, environmental aspects and environmental risks conditioned by the activity of major pipelines and their infrastructure. ***Methodology*.** The definition of the impacts on the environment has been conducted using the standard approaches of environmental impacts assessment. The environmental aspects have been determined based on the recommendations of ISO 14001. To assess the probability of accidents at the studied facility we have applied direct and indirect methods. The direct method is based on the calculation of the possibility of failures repentance if they have happened before. The assessment of previously not manifested accidents has been conducted using original method of subjective and objective risk factors analysis. ***Results*.** Using the data provided by the enterprise we have defined the list of environmental aspects having the highest importance for the formation of environmental situation in the impact area. The analysis of possible emergency situations at major pipelines and their infrastructure has showed that the most severe damage is possible in case of depressurization of the major pipeline linear part; depressurization of the compressor station and gas distribution networks; or depressurization of storage vessels with odorant, methanol. The evaluation of the scenarios of the major accident types has allowed us to conclude that most serious damage is connected with air pollution with methanol, odorant and natural gas, while the intensity of flora, fauna and soils damage will be higher along the course of pipeline running, as it might cross valuable and vulnerable ecosystems. We have revealed that there is potential for the origination of depressurization of the major pipeline linear part, compressor station and gas distribution networks in next 10-20 years. ***Originality*.** For the first time, we have carried out comprehensive assessment of the risks associated with equipment involved in the transportation of natural gas, probability and significance of the major accident types with the application of original method. ***Practical value*.** We have developed recommendations for the efficient control and reduction of the probability of the significant accidents at major pipelines and their infrastructure. *References 8, tables 1*.

Keywords: gas transportation, environmental aspects, risk assessment, environmental impacts.

ОЦІНКА РИЗИКІВ ДЛЯ НАВКОЛИШНЬОГО СЕРЕДОВИЩА, ПОВ'ЯЗАНИХ З ДІЯЛЬНІСТЮ ГАЙСИНСЬКОГО ЛВУМГ

М. М. Радомська, А. І. Йовенко, І. В. Горобцов
Національний авіаційний університет
просп. Космонавта Комарова, 1, Київ, 05380, Україна, E-mail: m.m.radomskaya@gmail.com

У статті розглянуто вплив на навколишнє середовище інфраструктури та лінійної частини магістральних трубопроводів на прикладі Гайсинського ЛВУМГ. На основі вимог міжнародного стандарту ISO 14001 та спеціальної методики, розробленої ПАТ „Укртрансгаз" проаналізовано основні екологічні аспекти діяльності газотранспортного підприємства, а також оцінено основні наслідки штатного та аварійного функціонування технологічного обладнання підприємства для довкілля. Критичний аналіз наявних документів по оцінці впливів на навколишнє середовище ділянок магістральних трубопроводів та їх допоміжного обладнання виявив недостатню увагу до потенційних негативних змін у стані фітоценозів та мікрокліматичних параметрів в зоні дії даних промислових об'єктів. Визначено основні типи аварійних ситуацій на даному об'єкті та оцінено значення потенційної екологічної та економічної шкоди. Проведено оцінку ймовірності виникнення аварій та розроблено рекомендації для зниження інтенсивності прояву факторів реалізації ризиків.

Ключові слова: транспортування газу, екологічні аспекти, оцінка ризиків, впливи на навколишнє середовище.

PROBLEM STATEMENT. The efficient and effective movement of natural gas from the regions of extraction and production to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of final use. On this way natural gas, being a complex mixture of substances relocated under considerable pressure represents a serious threat for the natural environment and humans.

Due to the fact that transportation of natural gas is a strategic task related to national security and international obligations of Ukraine many environmental aspects of its work are often underestimated or even missed in the process of assessment. Currently, the PJSC "Ukrtransgaz" company is working on the improvement of the environmental performance, typical for its operational facilities. Among the major achievements the implementation of the risks assessment procedures and environmental aspects evaluation are the most important.

However, these facilities are still dangerous for the environment not only in emergency situations, but also during their normal exploitation, which is often missing in the analysis. In order to define important elements of

gas transportation system impacts on the environment, corresponding risks and damage the following study has been undertaken.

The definition of environmental aspects is an important element of the ISO 14001 environmental management system and its implementation [1]. According to the ISO 14001, "an environmental aspect is an element of an organization's activities, products, or services that has or may have an impact on the environment." Basically, an environmental aspect is any part of company's activities that can interact with the environment, either positively or negatively, this also include the use of resources and production of waste. Various approaches can be used to compile a comprehensive list of environmental aspects and impacts, including Value chain method and Process flow method.

The second step after the definition of the most complete list of aspects is to determine whether a company can control the aspect or only influence. The essence of the difference is in the real possibility to manage the aspect, in other words a company can do something to prevent or reduce the negative impact, or it just can choose some option which would have the minimal supposed or predicted consequences. From this point, aspects can be divided into *direct* and *indirect*. Direct environmental aspects are associated with activities, products, and services of the organization itself, over which it has direct management control. However, there are always subcontractors, distributors, chain managers and finally customer, who produce their own impacts due to provision of industrial process and consumption of final goods thus creating indirect environmental aspects of company's activities.

When the problem is learnt it is necessary to define whether this or that aspect is significant in terms of influence on environment. The significance of the impacts is valued against national (regional/local) regulations. The experience of similar companies within the specific field is also of a big value, especially if these companies have already implemented the corresponding standard. The other suitable way to define which aspects should be considered significant is expert opinions assessment.

Once defined the environmental aspects should be taken into account when establishing and maintaining the environmental management system at any level from the entire organization to its specific unit. In other words these aspects must be provided with monitoring and control procedures, so that their improvement would outcome in the maximal improvement of a company's environmental performance[2]. Control procedures might include establishing one or more of the following approaches: responsible person (ISO 14001; 4.4.1), training plan (ISO 14001; 4.4.2), or procedure, checklist and/or maintenance schedule (ISO 14001; 4.4.6) [1]. Level of control is chosen according to the nature and risk level of the significant aspect and it must become a part of the everyday work.

Therefore the list of aspects must be regularly updated, as this is crucial for the efficiency of the nature saving activities undertaken by the enterprise. By knowing and controlling the environmental aspects, an enterprise is able to control the environmental risks associated with its industrial activities, thus providing good risk assessment and management for the areas where a company processes can impact the environment [3]. From the other side a company doesn't have to control and improve somehow all aspects, only those considered important must be paid attention to.

It is important to note that there are no specific requirements in the standard about the need to document and trace the identified risks and opportunities. Therefore companies in most of cases do not have any special procedure to identify, track and monitor risks and opportunities. The most important thing to do is to develop a plan to address them and account in decision making process. As a result the risks could be determined, but targets, aimed at their prevention or reduction, are absent. However the standard includes the need to consider the changes in risks and opportunities during the review of the EMS sustainability, adequacy, and effectiveness.

To improve the situation it is offered to conduct the assessment of risks and opportunities with the following methodology.

EXPERIMENTAL PART AND RESULTS OBTAINED. The PJSC "Ukrtransgaz" developed special methodology of environmental aspects assessment and evaluation of their significance in 2008, substituted in 2015 [4]. The methodology is applied by all departments of the company and works for the harmonization of environmental performance of the PJSC "Ukrtransgaz" with the best practices of European and other international companies. The key findings of the environmental aspects assessment process are the basis for development and implementation of environmental management system at the enterprise.

The standard doesn't contain any recommendations on how to conduct the risks and opportunities analysis. According to the requirements of the newly introduced ISO 14001:2015 the EMS has to be analyzed from the point of the risks and opportunities that exist and should be addressed at present. So, the environmental aspects and risks and opportunities are interconnected, but the risks may arise not only internally, but also externally, namely from the environmental regulations (especially when they change constantly), information from consumers and providers, market analysis, or comparison with the similar companies abroad.

This part of the work on environmental impacts management basically reflects the process of developing an industrial site environmental safety system (ISESS), that is an ordered sequence of stages of scientific and practical research aimed at identification of the major threats and risk factors for the given facility to develop the instruments and goals for their management. On the basis of the analysis of the works [5-8], the steps of ISESS development can be divided into two blocks: assessment and management.

The identification phase of environmental hazard sources includes the definition of the list of events, phenomena and processes that cause degradation of the environment quality and directly or indirectly damage the site or, on the contrary, is a source of threats from this facility to other components of the environment,

including humans.

At the second stage, it is necessary to evaluate the impacts associated with the identified sources of threats and their consequences. The obtained results are used for carrying out two studies of different directions – evaluation of the current environmental situation in priority areas and assessment of environmental risks, based on the factors of environmental safety.

These steps have been performed at the JSC "Ukrtransgaz" in the form of environmental aspects assessment. However, the next stage, which should be the formation of the integral ISESS concept, is currently under development.

The concept of environmental safety is designed to ensure the organization of nature use in the form that does not cause irreversible damage to the environment and public health. So, the first block of ISESS development is practically completed, while the management block misses some elements, as it was mentioned above.

The phase of development of the methods and mechanisms for providing the ISESS includes the development of methods to avoid, reduce probability, mitigate and limit the propagation of adverse effects of the object. So, based on the environmental aspects defined and the corresponding risks assessed the targets for EMS must be clearly set.

The assessment of environmental risks due to potential accidents at pipelines includes:

1) characteristics of technical condition of the pipeline;

2) frequency of defects formation;

3) analysis of the factors, having influence on pipeline safety;

4) expected average losses of petrochemicals due to accidents;

5) expected areas of pollution propagation.

The analysis of the probability of the given type of accidents is assessed in two ways: direct and indirect.

The direct method is applied for those accidents, which had already happened before.

The indirect method is suitable for those accidents, which have no history of manifestation and the probability of the accident is evaluated based on the original methodology of risk factors analysis.

The analysis of the obtained results is the basis for making conclusions about the potential consequences for the environment and adjoining settlements, and the potential period of environment restoration.

Characteristics of the major pipelines impacts on the environment. The major impacts of the gas transportation networks on the environment should be differentiated into constructional and exploitation. Constructional impacts are in most cases the same for all types of industrial facilities and are defined by modern constructional technologies. As for exploitation impacts they are more specific and have certain peculiarities depending on the conditions of origination, which are normative and emergency.

The list of the technological processes, which impose threats for the environment, includes:

– operation and maintenance of gas pumping aggregates;
– operation and maintenance of gas preparation, heating and drying facilities;
– operation and maintenance of boiler house and heating boilers;
– transportation and distribution of gas;
– transportation of odorant, methanol;
– activities of the maintenance section;
– mechanical processing of metals;
– welding of metals;
– distribution of liquid fuel;
– operation and maintenance of motor transport, work with fuels and lubricants;
– land excavation works;
– painting of surfaces, application of protective coating on pipelines.

The impacts of these technological processes on the environment include air, water and soils pollution, waste accumulation. Thus, normative impacts include pollution of air with carbon and nitrogen oxides of the emissions from boiler and heating plant, and with methane due to the losses at gas distribution joints. In most cases such level of air pollution is considered to be minor and negligible, which is not acceptable from the point of the modern EMS application not only in terms of environment quality reduction, but also as a factor of resource saving strategy implementation. The emissions of the methane are also possible in the course of normative and especially emergency situations.

Surface and underground waters are of no or minimal influence as the transported medium is in gaseous condition under pressure and in case of escape will lead to air pollution. However maintenance and repair works might lead to the pollution of waters in case of proximal location.

The analysis of available EIA materials and EIS provided for the projects of development of pipeline networks in Ukraine has showed a range of disadvantages. First of all, it should be mentioned that the assessment of impacts doesn't cover the influence on microclimate and biota. The first issue must be considered due to the fact that emissions of the pipelines exploitation include components with high radiative forcing, namely methane, as well as products of hydrocarbons decomposition – carbon dioxide and water vapor. The intrusion of these gases has the total potential of the temperature increase of 0.75 to 1.15ºC, producing thermal abnormalities and physical pollution along the route pipelines [9]. This may have certain influence on air circulation and thus the efficiency of mixing and distribution patterns of air emissions from the pipeline facilities would be changed.

Biota, first of all plant associations, is potentially affected in case of major accidents which include fires, explosions and gross emissions of natural gas. But the modification of the microclimate parameters, especially thermal and emission distribution mode, might cause the shift of phytocenosis living cycles and even prevent the full development of vegetative period. The morphological signs might also have some deviations from the normal parameters: reduced crown density, defoliation, reduced level of foliation, abnormal size and color of leaves (needles), deformation of trunk, crown and sprouts, increased proportion of dry sprouts

in the crown or dry top. All these signs are not normally predicted and considered in the EIA materials; however, they should be included into the plan of environment monitoring developed specially for the facility. It will be an important indicator of the environmental situation and a mean of tracing losses of transported product.

Analysis of the potential risks for the environment quality. The most important types of emergency situations, which should considered in the process of the risks assessment are:

1) depressurization of the major pipeline linear part;

2) depressurization of the compressor station and gas distribution networks;

3) depressurization of storage vessels with odorant, methanol;

4) leakage of sealing or equipment;

5) fire in buildings or on the pipeline.

The potential damage in case of these emergencies is not limited to the destruction of buildings and equipment, included into the pipeline facility. Serious consequences of the possible fires and explosions, as well as releases of transported product and reagents (methanol and odorant) are:

- pollution of the atmosphere with methane, odorant and methanol vapors;
- pollution of the atmosphere with products of combustion;
- pollution of surface waters and soils with liquid components and products of combustion;
- destruction of flora and fauna;
- injuries and traumas of the personnel.

Based on the significance of the expected damage the most important types of accidents are those involving depressurization (DP). The intensity of potential losses is presented in Table 1.

So, the most serious damage is connected with air pollution with methanol and odorant due to their toxicity and natural gas release into the air due to vast area of propagation along the pipeline. The intensity of flora, fauna and soils damage should be assessed separately in the area of the affected equipment location and along the course of pipeline running.

Thus, the depressurization of vessels and local networks is not supposed to cause considerable damage to flora, fauna and soils, due to local distribution (mostly within the sanitary zone) and the fact that it will not damage valuable soils, being located on non-agricultural land, or species under protection, which are normally absent within and in the vicinity of industrial facilities. While the pipeline runs for dozens of kilometers crossing both valuable soils and areas under protection. Therefore, its depressurization will have more significant effect on these components of environment. This must be accounted in the assessment of potential damage of such accidents.

As for the probability of these accidents, the direct methods of assessment could be applied to the first and the second type, as they had been previous manifested.

The statistical information from the data about failures of major pipelines states that depressurization of their linear part might take place every 20 years, causing noticeable damage over $5 \cdot 10^5$ minimal salary rates (MSR), disturbance of living condition for over a few hundreds of people, injuries and traumas, depending on the location of the breach. [10] These parameters refer this type of accident to possible with the expected intensity of 10^{-2}–10^{-4} 1/year and critical severity of consequences: critical risk may cause human death, damages material assets and causes considerable harm to the environment [11]. It means that detailed risk analysis is advisable at risk and opportunities analysis to be performed according to the ISO 14001:2015. The given threat should undergo strict control, risk control and safety provision measures are necessary.

Table 1 – Damage assessment for the basic accident scenarios

Type of accident	Sources of impacts	Direct con-sequences	Level of propa-gation	Value of damage
DP of the major pipeline linear part;	air emissions	air pollution	regional	significant
	natural gas burning	damage to flora, fauna, soils	regional	significant
		air pollution	regional	significant
	formation of explosive mixture, explosion	damage to flora, fauna, soils	local	significance depends on type of soil and species protective status
DP of the com-pressor station and gas distribu-tion networks;	natural gas burning	air pollution	local	important
	formation of explosive mixture, explosion	injuries and traumas of personnel; equipment failure; damage to flora, fauna, soils	local	important
		air pollution	local	important
DP of storage vessels with odorant, methanol;	emissions of toxic substances	poisonings of the personnel, local population and fauna	trans-regional	very significant
		air pollution	regional	significant
		damage to flora, fauna, soils	local	significance depends on type of soil and species protective status

The register of emergency situations shows that the accident, involving depressurization of compressor

station and gas distribution networks, has taken place 2 times over the last 30 years, producing damage of 950 MSR on average. Thus, the probability of the same accident in the next two decades is 34%.

The expected cost of the damage is 1000 MSR, which means there is a need for the analysis of the reasons of these accidents to define the driving factors and develop efficient prevention plan. Due to the essence of the process, the combination of technological and technical factors out of human control is the reason of this type of accident. Therefore more frequent non-destructive diagnostics and maintenance are the potential ways to reducing the level of accidents probability.

As for the last type of serious risk – depressurization of storage vessels with odorant and methanol, - it cannot be analyzed directly due to absence of data about such accidents. So, the analysis of objective and subjective factors is the way to conduct evaluation.

Among the variety of technogenic risk the most common are the following: low level of research and development works, violation of the rules and technological regulations of technical systems safe operation, and personnel errors. In fact, technogenic risks depend on the level of professionalism of employees and management efficiency, as well as the technological features of this facility. These factors can be characterized with relative categories and thus receive qualitative assessment of technogenic risks for the investigated object.

It is proposed to divide the factors into two groups: subjective (human factor) and objective (geographical, technological, structural and other properties of the object). Each group is characterized with the parameters that need to be evaluated in points from 1 to 5 with specially developed scale for their comparison, and these factors are ranked according to their significance in the formation of the final risk level from 1 to 3. This assessment can be carried out on each object during scheduled or unscheduled inspection, and the results obtained should be used to develop recommendations for improving the safety of the object.

When evaluating subjective factors, it is necessary to analyze parameters such as personnel knowledge and compliance with licensing requirements (index of importance 1); personnel management and efficiency of the division of production and management responsibilities (2); education and staff training (3); documentation (1); timeliness, completeness and regularity of maintenance and equipment repair (3); stability and efficiency over control of technological operations (3); causes, consequences of emergencies and other accidents, as well as the efficiency of overcoming the consequences of such situations, especially for the environment (2).

Objective risk factors completely depend on the specifics of the technological processes of the studied object. But in general case, the following parameters should be considered: assortment of stored, used and/or produced hazardous substances at the facility (1); storage volumes of hazardous substances (2); frequency of execution of technological operations (3); measures to increase the general safety of the object – fire safety, personnel safety, etc. (2); measures for the environment protection efficiency (3); waste management efficiency (2); location of the object in relation to other industrial, residential and recreational facilities (2).

The final evaluation of all parameters allows determining the level of risks associated with the human factor, and to characterize the level of the object environment hazard, due to its physical characteristics. At the same time, the interpretation of the results obtained (in points) is opposite: the greater the score on the subjective parameters is, the higher the level of safety is, and vice versa higher overall score for the objective parameters indicates the increased level of threat for the environment. For the final assessment of the level of technogenic risks, one should consider the difference in points for each group of parameters, since the efficient organization of the personnel's activity can reduce the objective risks associated with the technological properties of the object.

Thus, the analysis of the data available on the studied object shows that the total score of objective factors is 51 points, which corresponds to increased level of risk, and subjective factors represent 45 points, which are at the edge between moderate and low level of risk. This could be interpreted as the presence of significant hazardous factors (toxic substances under pressure), which are currently under efficient control. In other words this score defines that the level of safety organization at the enterprise is sufficient, accounting both technological potential of risks prevention and control and the efficiency of management and exploitation by the personnel. However, the high significance of the damage to be caused in case of the depressurization of storage vessels with odorant and methanol should make this environmental aspect one of the most controlled and the periodicity of inspections must be increased.

Recommendations for the improvement of the environmental safety and formation of isess.

1. Increase the volume and improve the quality of environmental impact assessment process when developing the project documentation for the construction of new facilities: include the assessment of microclimate changes and damage to green plantations. It is also advisable to improve the public participation in the process, as in most cases it has very formal and short-time proceeding.

2. Conduct periodic assessment of technogenic and environmental risks caused by objective and subjective factors of the activity of the natural gas transportation infrastructure.

3. Strengthen the requirements for the control over the condition of natural gas transportation infrastructure and ensure the implementation of the plan for obligatory periodic technical diagnostics of gas station equipment.

4. Develop the plan of environmental targets achievement. The plan should include the following: substitution of hazardous reagents with less harmful substances over the set period; reduction of technological losses of natural gas; reduction of emissions from heating installations; improve the waste management practices.

5. Introduce mandatory monitoring system within the

area of the gas transportation system impact, including continuous measurement of atmospheric air pollution with hydrocarbons and condition of green plantations as an indicator of environment pollution;

6. Present the information about the environmental performance of the enterprise at mass media to promote participation of local population in environment safety provision and prevent misunderstandings about the impacts on the environment

7. Improve ecological management system by the conduction of risk and opportunities assessment according to the provisions of ISO 14001:2015.

8. Develop and introduce the Environmental Passport for the facilities of the gas transportation infrastructure.

CONCLUSIONS. In the course of the research the most important impacts of the natural gas transportation pipelines on the environment have been considered. The analysis of the available EIA materials has showed the lack of attention to the issues of microclimate transformations due to emissions and thermal influence of the facility and damage to phytocenosis at the area of influence, including violation of living activity and morphological parameters.

The evaluation of the environmental aspects of the pipelines exploitation has revealed the most significant ones to be air pollution, damage to flora, fauna, soils degradation, injuries and traumas of personnel and equipment failure in case of accidents.

The criteria analysis has defined that the most serious types of accidents are those involving depressurization of the major pipeline linear part; depressurization of the compressor station and gas distribution networks; and depressurization of storage vessels with odorant, methanol. The last is connected with the highest significance of potential consequences, due to toxicity of stored materials.

The probability of accidents has been assessed and the results state that it is possible type of emergency situation and that attributes the corresponding equipment to the field of strict control and increased intensity of inspection and maintenance.

In order to for the efficient EMS at the pipeline facility according to the requirements of ISO 14001:2015, the risk assessment outcomes must be incorporated into the strategic plan of the enterprise development and provided with specific environmental targets, namely the formation of special monitoring system for the control of the environment state and identification of pre-accident conditions, as well as implementation of complex actions on soils protection and prevention of phytocenosis degradation.

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ОЦЕНКА РИСКОВ ДЛЯ ОКРУЖАЮЩЕЙ СРЕДЫ В СВЯЗИ С ДЕЯТЕЛЬНОСТЬЮ ГАЙСИНСКОГО ЛВУМГ

М. М. Радомская, А. И. Йовенко, И. В. Горобцов
Национальный авиационный университет
просп. Космонавта Комарова, 1, Киев, 05380, Украина, E-mail: m.m.radomskaya@gmail.com

В статье рассмотрено влияние на окружающую среду инфраструктуры и линейной части магистральных трубопроводов на примере Гайсинского ЛПУМГ. На основе требований международного стандарта ISO 14001 и специальной методики, разработанной ОАО "Укртрансгаз", проанализированы основные экологические аспекты деятельности газотранспортного предприятия, а также оценены основные последствия штатного и аварийного функционирования технологического оборудования предприятия для окружающей среды. Критический анализ имеющихся документов по оценке воздействия на окружающую среду участков магистральных трубопроводов и их вспомогательного оборудования обнаружил недостаточное внимание к потенциальным негативным изменениям в состоянии фитоценозов и микроклиматических параметров в зоне действия данных промышленных объектов. Определены основные типы аварийных ситуаций на данном объекте и оценена значимость соответствующего экологического и экономического ущерба. Проведена оценка вероятности возникновения аварий и разработаны рекомендации для снижения интенсивности проявления факторов рисков.

Ключевые слова: транспорт газа, экологические аспекты, оценка рисков, влияния на окружающую среду.