Determining influence of natural and man-made factors on safe performance of trunk pipelines

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Abstract. The paper discusses the relevance of ensuring environmentally safe pipeline operation by identifying natural and industrial hazards and the potential impact. An operating trunk pipeline running west to east across a specific territory (constituent entity) was given as an example to show areas likely exposed to the most dangerous destructions. These are natural and man-made pipeline crossovers and intersections designated by the authors as ecologically fragile areas (EFAs). For a natural/industrial impact identification methodology, relevant hazards were identified and classified by the exposure degree for each gas pipeline EFA. Given geodynamic changes, the data collected were to be updated after each change. The article outlines the new methodology also suitable for territorial cartographic zoning subject to hazard factors. An area to be affected by degradation processes of an accident is determined by using the radii of thermal impact and scatter of pipe fragments. Such data help compute flora and fauna damage and, for the best scenario, damage prevented. The key points of this survey may be used to developing computer programs to compute an aggregate hazardous impact on an operating pipeline and simulate emergency scenarios. The practical utility consists in assuring proper EFAs monitoring for timely prevention of accidents.

1. Introduction
The environmental safety of construction, reconstruction and overhaul of trunk pipelines is mainly discussed [1-19] from the standpoint of the environmental impact of their construction processes. In particular, it is noted [1] that an adverse environmental impact of oil pipelines is so intense that its assessment should start with the front-end and design engineering stages of the facility lifecycle with a view to identifying the key risks. Failures and large-scale accidents caused by pipe metal corrosion are damaging not only for the environment, but for economy and infrastructure as well [3,4], especially severe being subsea pipeline ruptures [4,7,8,20] affecting the balance of a water ecosystem. In this connection, of special interest is the paper [21] describing possible environmental imbalance scenarios for tundra in case of an accident. Obviously, the specific characteristics of trunk pipeline systems (large extent, various and complex geographic conditions, use of a great number of powerful machines and mechanisms etc.) [5] produce an extremely adverse impact on the environment. On the other hand, the natural/industrial system (NIS) itself has a negative influence on the safe operation of trunk pipelines. For instance, scientific publications [22-26] consider the influence of power transmission lines on underground steel pipelines. Both their parallel and intersecting installation poses a danger of pipeline corrosion caused by electromagnetic and electrostatic fields and conductive effects. Safe
operation of trunk pipelines is also affected by other natural and man-made intersections and crossovers: railways and motor roads, water courses, various product lines etc., creating ecologically fragile areas (EFAs), which are considered high-risk zones (HRZ [27,28]). Statistically, accidents occurring immediately at crossovers and intersections lead to the most extensive damage, thus, making especially relevant timely identification of factors affecting the safe operation of trunk pipelines at these particular points.

2. Mein text

2.1. Goal, tasks, research methods
The purpose of this paper is to develop and summarize the methodology for identifying factors affecting the safe operation of pipeline sections at various natural and man-made crossovers and intersections. The key points of the methodology can be used as the basis for hazard based zoning of territories accommodating pipeline sections. To avoid abstracting in achieving this goal, a specific 1,220mm gas pipeline was selected within a certain territory and all ecologically fragile areas were identified in relation thereto. The gas pipeline in question was found to have fifteen EFAs. The information for each EFA identified for the gas pipeline section was collected using the modern geoinformation system technologies (and thematic geographic maps of the area). The task consisted in assessing the aggressiveness of soils; identifying transitions of soil strata; determining the presence of underground and ground waters and their possible influence on the gas pipeline (GP); assessing the probability of electromagnetic and electrostatic impacts on the GP, soil erosion, sinkhole, landslide and seismic effects, GP vibration and a multitude of other factors, which might be destructive as applied to a pipeline system. They will hereinafter be described as factors reducing the safety of pipeline operation or negative impact factors (NIFs). In this case, a limited number of NIFs were considered in developing the methodology and classified by the degree of impact (hazard).

Although this methodology fundamentally differs from the existing ones, the key methods of the survey were the analysis and comparison of the existing methods and methodologies. It was found that the score system used for assessing the environmental influence on various facilities is fairly widespread; therefore, the degree of NIS's impact on the trunk pipeline as part of this survey was assessed on the basis of a specially developed scoring scale.

2.2. Focus of methodology and algorithm of work
The methodology suggested is focused on the key factors affecting the safe operation of trunk pipelines; determining the maximum number of factors causing pipeline rupture; identifying territories exposed to degradation processes in case of an accident.

The computing algorithm includes the following items: as stated above, gathering information on the factors affecting the safe operation of the trunk pipeline for each EFA (hereinafter impact factors); gathering information on the flora and fauna adjacent to the EFA (this information is needed to determine the extent of damage as a result of an accident); assessing the degree of hazard for each NIF (the scale for an approximate assessment of certain NIF is provided in table 1); estimating the total number of NIFs for each EFA; estimating the aggregate hazard for each EFA; ranking the ecologically fragile areas by the degree of hazard; cartographic zoning of the territory by the degree of hazard; estimating the extent of territories exposed to degradation processes in case of an accident; computing possible damage to flora and fauna.

The table was prepared based in particular on the survey data [29].

Previously, certain points of this methodology were used by the author to assess the environmental situation as part of the reconstruction and overhaul of extensive linear facilities [28], and develop the concept of a GIS technology for environmental monitoring of linear overhaul and construction object flows [30]; however, a new interpretation of certain points gives ground for the well-reasoned adaptation of the same points to determining the influence of the existing natural/industrial factors on the safe operation of trunk pipeline systems.
Table 1. Classification of certain NIFs affecting an operating trunk pipeline by the degree of impact.

| NIF description                      | Impact parameter                      | Impact score |
|--------------------------------------|---------------------------------------|--------------|
| Underground waters by the mineralization (in grams per liter) | Less than 1                           | 0            |
|                                      | 1-5                                   | 1            |
|                                      | 5-10                                  | 2            |
| Ground waters by the design groundwater level against the pipeline | Below the lower pipe line             | 0            |
|                                      | Above the upper pipe line             | 1            |
|                                      | Across the pipe                       | 2            |
| Aggressiveness of soils              | Limestone, calcareous marl, sandy marl, sand, silt, silty marl | 0            |
| by the type (kind) of soils           | Silty sand                            | 1            |
|                                      | Clay, clayey marl, peat, boggy soils | 2            |
| Aggressiveness of soils              | Less than 10                          | 0            |
| by the content of alkali soils, %     | 10-25                                 | 1            |
|                                      | 25-50                                 | 2            |
| Landslides                           | Absent                                | 0            |
|                                      | Hazard boundary                       | 1            |
|                                      | Active                                | 2            |
| Sinkhole effects                     | Absent                                | 0            |
|                                      | Existent but inactive                 | 1            |
|                                      | Active                                | 2            |
| Seismicity                           | Absent                                | 0            |
|                                      | Up to 2 degrees                       | 1            |
|                                      | More than 2 degrees                   | 2            |
| Vibration                            | Absent                                | 0            |
|                                      | Insignificant                         | 1            |
|                                      | Significant                           | 2            |
| Wind erosion by the average number of days with dust storms per year | 1.3 - 3                               | 0            |
|                                      | 6.5 - 10                              | 1            |
|                                      | More than 10                           | 2            |

The extent of territories exposed to degradation processes in case of an accident at intersections and crossovers of a gas pipeline was determined based on the average statistical data regarding the radius of scatter of pipe fragments and thermal impact. The data were produced as a result of the statistics analysis for the largest accidents on 1,220mm gas pipelines. It was established that an average radius of scatter of pipe fragments was 139 meters (vs. the maximum radius of 371 meters), the radius of thermal impact was 250 meters (vs. the maximum radius of 420 meters). The data obtained allowed determining not only the area affected in case of an accident, but also the degree of geodynamic changes in the territories of interest. These are namely the data that are used for determining possible damage to flora and fauna and, in the most favorable scenario, damage prevented.

3. Conclusions
Trunk pipelines, forming part of the natural/industrial system at various stages of the pipeline service life, not only adversely impact the environment, but are also affected by various negative impacts, eventually leading to a reduction of the pipeline service life and the occurrence of major accidents. Because the methodology for determining the influence of the natural/industrial system on the GP safe operation was applied to a specific pipeline section, this survey was focused on a very limited number of the negative impact factors identified. In fact, ecologically fragile areas may contain two-three times more of such factors, and in case of their combined impact, accidents may be purely catastrophic. The novelty of this survey consists in suggesting a new, comprehensive and synergetic approach to assuring the environmental safety of GP operation, because trunk pipelines, being part of
the natural/industrial system both influence the system and are influenced by it, since any GP accident disturbs the environmental balance of the natural/industrial system.

The use of the key points of this methodology may be the basis for developing computer programs to compute the aggregate hazardous impact of the natural/industrial system on an operating GP and simulate various options of the GP response. Given ongoing geodynamic changes, the relevant information is required to be gathered on a regular basis.

The practical utility of the paper consists in providing an opportunity for proper monitoring of ecologically fragile areas (natural and man-made crossovers and intersections) to timely prevent emergencies during trunk pipeline operation, because the environmental safety of important life-supporting objects is one of the main principles of national security, both on a local and global scale.

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