Assurance of environmental safety of conventional overhaul and reconstruction technologies for trunk pipelines

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Abstract. In the paper, the author presents the analysis of certain overhaul methods for the linear part of oil and gas trunk pipelines involving the replacement of thermal insulation, which is aimed at assessing the environmental safety thereof. In particular, the following methods were reviewed: lifting and laying the pipeline on rollers on the trench shoulder or inside the trench, pipeline repair without changing its spatial layout, lifting and suspending the pipeline by pipe layers. Thereby, the paper specifically focuses on the overhaul technology providing for pipe wall restoration. In order to determine the adverse impact of operating machines and mechanisms on the atmosphere, the repair and construction works were structured to determine the number of machines and mechanisms required for each operating procedure based on the existing process flow diagrams. The amount of noxious atmospheric emissions was computed so as to factor in the motor power of machines and mechanisms. It was found that the time intervals, associated with the simultaneous performance of earthworks, lifting, cleaning, remedial welding, insulating and pipe laying works pose the greatest threats to the environment. The novelty of the paper consists in suggesting a methodology, offering new organizational solutions for overhaul and reconstruction of trunk pipelines in support of the environmental balance of the natural-industrial system.

1. Introduction

Adverse impacts of construction, reconstruction and overhaul of trunk pipelines are the subject matter of many scientific research publications [1-13]. The authors of publications find the environmental situation disastrous, because the performance of construction, installation and overhaul operations affect nearly all geospheric shells of the Earth. And as experience shows, emergency situations on trunk pipelines increase proportionally to the extension of their length [14,15]. Despite the existence and inflow of innovative technologies, the use of conventional technologies for reconstruction and overhaul of trunk pipelines remains extremely relevant [16,17]. According to the regulatory document currently effective in Russia [18], the current practice of reconstruction and overhaul of the linear part of trunk pipelines features the following types of overhaul technology: overhaul with the replacement of pipes; overhaul with the replacement of insulation coating and restoration of the bearing capacity of pipe wall; overhaul with the replacement of insulation coating. The above technologies can utilize a variety of practical methods. Thus, by the number of repair and construction operations, the pipe replacement technology differs drastically from the succeeding technologies and proves the most dangerous for the natural and man-made environmental system. This, in particular, stems from the fact
that the performance of operations requires the greatest number of machines and mechanisms. The overhaul technology only involving the replacement of insulation coating, on the contrary, differs from the preceding technologies by the smallest number of operating procedures and the minimum use of technical resources. Each of the above types of overhaul technology can be implemented in a number of ways. This paper will review the pipeline overhaul technology involving the replacement of insulation coating and pipe wall restoration in order to identify the adverse impacts of operating machines and mechanisms to the environment, in particular, to the atmosphere.

There is a specific set of works and processes characteristic of all conventional technologies and methods for reconstruction and overhaul of trunk pipelines: earthworks (stripping), lifting and cleaning, remedial welding (solely for partial pipe replacement and pipe wall restoration), insulating and pipe laying works. Therefore, these works will be highlighted in the paper.

2. Mein text

2.1. Goal, tasks, research methods
The goal of this research is to develop a methodology for computing atmospheric emissions of hazardous substances discharged by machines and mechanisms during reconstruction and overhaul of trunk pipelines using conventional technologies, including the replacement of insulation coating and partial restoration of pipe wall. For this, the following tasks were solved: the conventional technologies of reconstruction and overhaul of trunk pipelines were analyzed from the environmental perspective, and the primary ways to reduce noxious atmospheric emissions were identified for the operation of machines and mechanisms during reconstruction and overhaul of trunk pipelines.

As such, the key methods used for this research were the analysis and comparison of the existing methods and methodologies exploring the topic in question.

2.2. Basics of the suggested methodology for computing noxious atmospheric emissions of operating machines and mechanisms during reconstruction and overhaul of trunk pipelines
The basic principle of the methodology suggested by the author consists in computing the total amount of emission of hazardous substances with reference to a specific time and a specific location. The computation algorithm includes the following steps: preliminary structuring of the main process flows (earthworks, lifting and cleaning, remedial welding, insulating and laying works) and identifying the operating procedures as part of the process flows; itemizing the process flows by work areas, subject to the linear pattern of pipelines; determining the overall period of work for each work area as part of each process flow; determining the overall work period using the matrix method; building a sequence diagram of the work process; identifying a vulnerable environmental zone of the general work flow; computing the total amount of hazardous substances for this specific zone and locating the zone with the maximum emission of hazardous substances. Then the computed parameters of expected emissions are compared to the maximum allowable concentrations. If computed emissions are greater than the allowable limits, the overall work flow shall be subject to time-based optimization to preserve the environmental balance.

Note should be taken that the dangerous zone of the overall work flow is understood by the author as a period of time when the maximum number of machines and mechanisms operate simultaneously as part of all the above process flows. Previously, some aspects of this methodology were partially explored in other publications [17,19]. A specific feature of this methodology is the factoring-in of motor power of operating machines and mechanisms and their length of service, i.e. normal wear and tear of machinery, when determining the total amount of emission of hazardous substances. This approach allows specifying computed noxious emissions and building a computational program in the future to conveniently quantify atmospheric emissions. To date, a program has been developed that determines the overall duration of the reconstruction and overhaul flow for any linear facility having state registration [20]. The program also offers the function of automatic building of a sequence
diagram to simulate the performance of works and delineate a dangerous operational zone as part of the overall work flow.

3. Practical use of new methodology

The suggested methodology was substantiated by some calculations prepared as part of engineering a linear flow for the overhaul of a 14km gas transmission pipeline.

It is known that each method of reconstruction and overhaul of the linear part of trunk pipelines, depending on the operating conditions (normal conditions, swampy areas, sand dunes, rock soils etc.) requires an adequate fleet of machinery. The number and capacity of pipe laying cranes provided for lifting, cleaning, insulating and laying works depends on the pipe diameter. By way of example, table 1 shows the required numbers of machines and mechanisms to be provided for the overhaul and reconstruction of a 1,420mm gas transmission pipeline with pipe wall restoration where the works are to be performed under the normal conditions. The data is based on the analysis results [21,22].

| Work (flow) description                      | Required machinery          | Quantity |
|---------------------------------------------|-----------------------------|----------|
| Earthworks (stripping)                      | Bulldozer                  | 1        |
|                                             | Excavator                   | 2        |
| Lifting and cleaning works                  | Crawler                     | 1        |
|                                             | Pipe laying crane           | 7        |
|                                             | Pre-work scraper            | 1        |
| Remedial welding works                       | Gas cutting machine         | 1        |
|                                             | Mobile welding unit         | 1        |
|                                             | Mobile power plant          | 1        |
| Insulating and laying works                 | Pipe laying crane           | 7        |
|                                             | Finishing scraper           | 1        |
|                                             | Priming machine             | 1        |
|                                             | Coating machine             | 1        |

The developed computer program helped to determine the overall duration of work as well as the zone dangerous for the natural environmental balance, which is estimated at 9 days.

Although, for illustration purposes, figure 1 only shows the calculated values for daily emissions of hazardous substances, with simultaneous operation of 1 bulldozer, 2 excavators, 14 pipe laying cranes, taking into account their motor power and minimum wear and tear, the justification for the suggested methodology included all computed emissions of hazardous substances during simultaneous operation of the machines and mechanisms listed in table 1.

Figure 1. Average daily emissions of hazardous substances during simultaneous operation of a bulldozer, excavators and pipe laying cranes, in kg.
It is worth noting that the research included the computation of emissions of other hazardous substances, such as non-methane volatile organic carbons, as well as the mass concentration of suspended particles, sulfur dioxide and other pollutants. When comparing the values to the maximum allowable emissions, a conclusion was made that the impact of operating machines and mechanisms on the atmosphere does not exceed the allowable limits.

4. Conclusions
Although the suggested methodology only partially identifies the effects of reconstruction and overhaul (i.e. operation of machines and mechanisms) on the environmental situation, it still can serve as the bedrock for developing the technology and flowchart of overhaul and reconstruction of trunk pipelines from the environmental perspective.

The identification of a dangerous zone as part of the overall linear work flow using the suggested methodology allows performing other necessary environmentally-conscious computations, specifically for a chosen time period. This for example includes noise, vibration, electromagnetic effects, dust effects on the atmosphere during earthworks; changes in the volume of soil air necessary for breathing of tree roots and plants, changes in the volume of gravity and bound water in the soil etc.

The use of the suggested methodology in developing the method statements for overhaul and reconstruction of trunk pipelines based on conventional technologies helps to proactively adopt nature conservation solutions, because the use of geoinformation technologies allows predetermining the location where the dangerous zone of the overall linear flow will occur.

The comprehensive assessment of the environmental situation associated with the overhaul and reconstruction of trunk pipelines based on conventional technologies requires a step-by-step computation of emissions of hazardous substances. The first step is the assessment of not only adverse impacts of operating machines and mechanisms, but also the technological specifics of works and processes. The second step is the analysis of the entire scope of works to be performed, starting from preparatory works and ending by pre-commissioning testing. The third step is the identification of negative effects of conventional pipeline repair and reconstruction technologies on all the geospheric shells of the Earth.

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