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Impact of Pipeline Construction on Air Environment

I A Tomareva¹, E Yu Kozlovtseva², V A Perfilov¹

¹Department of Oil-and-Gas Constructions, Volgograd State Technical University, 28, Lenin avenue, Volgograd 400005, The Russian Federation

²Department of Life Safety in Construction and Urban Economy, Volgograd State Technical University, 28, Lenin avenue, Volgograd 400005, The Russian Federation

E-mail: elenakozlovtseva@gmail.com

Abstract. The research of the environmental imbalance causes in the construction of pipelines is provided in the article. On the basis of the generalized data, a block diagram of a comprehensive model for reduction of the negative impact on the environment from the pipeline construction is made. It allowed us to identify the parameters of the subgoals describing the characteristics of measures to ensure the environmental balance as well as the parameters related to risk factors. The analysis of hazards made it possible to determine their sources, the probability of occurrence of a negative effect and to create a tree of causes of atmospheric pollution due to the pipeline construction. The research pays a special attention to the impact from the particulate matter of inorganic and abrasive dust on the air while pipeline construction.

1. Introduction

Pipelines are a complex technogenic system. The increase in the ecological safety during the pipeline construction is an issue, which requires the systematization of calculation methods and creation of a data bank for the safety of pipelines. Recently, more and more attention has been paid to the environmental issues concerning the pipeline construction, thus in [1,2] researches different kinds of monitoring have been analyzed, and proposals on improvement of environmental monitoring for the majority of construction activities are made.

Environmental impacts of pipelines consist of two aspects: construction and operation, however, the construction period has a greater impact on the ecology of the affected area [3]. Unavoidably, the installation of a pipeline leads to ecological disturbance, since there are clearing of vegetation, excavation, soil compaction and others [4]. Moreover, due to the linear arrangement of the pipelines, various natural and climatic zones with various geological, hydrological conditions are affected by technogenic impact.

Thus, the research is aimed at improvement of the environmental safety of the pipeline construction using a complex approach to the optimization of the existing and developed solutions.

2. Material and experimental methods

The aim of the reduction of the negative impact from the pipeline construction on the environment is to minimize the causes of the environmental imbalance [5,6]. In this case, the analysis of the reasons for the negative impact, specification of the purpose of choice, adoption of the planning, organizational and technical decisions and the implementation of the decision with a socio-economic



assessment of the subsequent consequences are necessarily included in the "a building site - a person - an environment" system while making decisions.

Since the research is aimed at systematization and formalization of a large amount of information and calculations, the developed comprehensive model (the block diagram of which is presented in Figure 1) is the most acceptable mean for describing of the decision-making process with regard to the reduction of the negative impact from the pipeline construction on the environment.

Analysis of the construction processes and negative factors arising from the pipeline construction has allowed us to identify the main causes of the environmental imbalance: deterministic, temporary and stochastic anthropogenic impacts.

Realization of the main goal requires more detailed specification: the transition from the main goal to separate objective functions (subgoals); the decrease in the probability of serious mistakes in the decision-making; the proportionality determination between the objective functions and resources.

In order to support the specified objectives, we have identified the parameters of the subgoals for reduction of the negative impact from the pipeline construction on the environment, describing the characteristics of measures to ensure the environmental balance, as well as parameters related to the risk factors. It is allowed us to create a tree of goals.

The subgoals (quantitative parameters) describe: efficiency, as the main technological characteristic of any kind of measures undertaken to reduce the negative impact from the pipeline construction on the environment; reliability, as a basic functional parameter, which is capable to characterize the effectiveness of measures for any period of time; economic effect and the reduced costs as the basic indicators of profitability of the decisions made.

Reliability of measures undertaken to reduce the negative impact from the pipeline construction on the environment - P can be described by the adjusted formula [7,8]:

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{E_{\max} - E_f}{\sigma_E}} \exp\left(-\frac{u^2}{2}\right) du \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{E_f - E_{\min}}{\sigma_E}} \exp\left(-\frac{u^2}{2}\right) du \quad (1)$$

E_f is the effectiveness of measures undertaken to reduce the negative impact from the pipeline construction on the environment in the given range of values from E_{\min} to E_{\max} ; u is the degree of impact of machinery and equipment; σ_E is the root-mean-square deviation of the actual negative impact from the average value.

The identified parameters of subgoals are almost equivalent, contradirectional and initially irreducible. The connection between them is disjunctive (the "or" principle). The comparison of options is made with regard to the smaller degree of realization of a particular goal that can be compensated by the best achievement of the other. The result can satisfy the requirements of the majority of parameters involved, i.e. this is a method of parallel optimization [9]. Optimization strategy of the objective function for reduction of the negative impact from the pipeline construction on the air environment involves a firm sequence of actions that allow in real time to make an objectively justified choice of organizational and technical solutions in the construction environment, if the necessary information is known in full.

In general, the reduction of the negative impact from the pipeline construction on the air environment can be achieved in accordance with:

- manufacturability (efficiency (E_f) - selection of machinery, equipment, materials with maximum E_f parameters, efficiency (η) - selection of machinery, equipment with maximum η parameters);
- ecological compatibility (technological reliability (R_{tech}) - selection of machinery, equipment, materials with maximum R_{tech} parameters, sanitary and hygienic reliability (R_{s-h}) - selection of machinery, equipment, materials with maximum R_{s-h} parameters);
- economy (reduced costs (P) - minimum costs for machines, equipment, materials, economic effect (E) - maximum economic effect).

3. Results and discussion

The analysis of hazards allows us to determine their sources, the sequence of actions, the probability of occurrence of the ecological imbalance, the magnitude of the consequences, and the ways to prevent them. The analysis of hazards made it possible to describe them in qualitative and quantitative manner. As a result, the planning of preventive measures is provided.

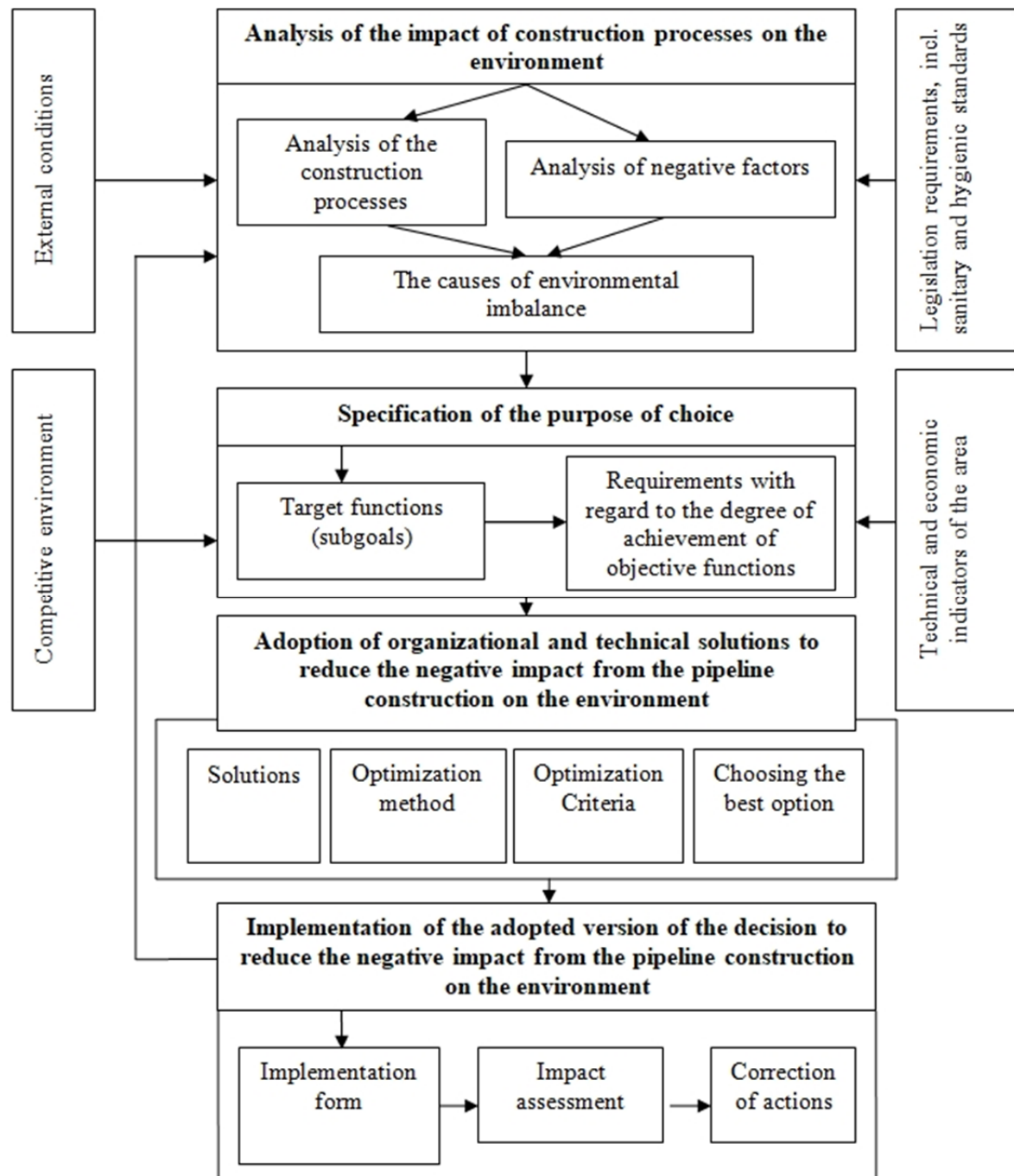


Figure 1. Block diagram of the comprehensive model of the reduction of the negative impact from the pipeline construction on the environment.

Qualitative methods of analysis include: a preliminary hazard analysis; an analysis of hazards using the tree of causes; an analysis of hazards with the using the tree of consequences [7, 10-13].

The technogenic impact of the pipeline construction is complex due to the negative changes in the air, soil and water. One of the possible negative impacts on the environment is air pollution.

Construction works is accompanied by a large amount of dust and toxic matters, such as carbon monoxide, hydrocarbons, nitrogen oxides, chromium, manganese, zinc, silicon, fluoride compounds, solid particulate matter, etc. [14-16]. Getting with inhaled air into the human's organism, they can lead to various diseases. There is an evidence of interconnection between PM_{2.5} concentrations in the room and decrease in the pulmonary function; the risk of inflammation of respiratory in asthmatic children is increasing [17,18]. In the studies of Delfino, Liu, Allen, et al. [19-21], the interconnection is observed between PM_{2.5} concentration in room and changes in cardiovascular systems in the elderly people. The hygienic standards GN 2.1.6.2604-10 [22] have been enacted in Russia. Since June 21, 2010 the maximum permissible concentration (MPC) of pollutants in the atmospheric air of populated areas (mg/m³) has been established with respect to the particulate matter with the size of less than 10 μm (PM₁₀) and particles with the size of less than 2.5 μm (PM_{2.5}).

The dusty air of the working area and temporary auxiliary facilities of the construction site is mobile, therefore a significant part of small particles (less than 10 microns) almost never precipitates and poses a great danger to a human health.

Analysis of possible causes of air pollution while the pipeline construction has showed that they include: deterministic, temporary and stochastic anthropogenic impacts.

The logical formula has the form:

$$N = \sum_{i=1}^3 D_i + \sum_{i=1}^3 T_i + \sum_{i=1}^3 S_i \quad (2)$$

While creating the tree of causes of atmospheric pollution, we consider: x_1 - as soil erosion; x_2 - as a change in the microclimate, in the landscape; x_3 - as the tectonic changes (increase in seismicity); x_4 - as welding (aerosol particles); x_5 - as an operation of the construction equipment; x_6 - as a disturbance of soil and vegetation; x_7 - as oil pollution; x_8 - as the thermal, mechanical, chemical pollution; x_9 - as the emergency emissions.

As a result, the logical formula is:

$$N = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 \quad (3)$$

where x_i is considered for the both items: 1 - air pollution appeared; 0 - no air pollution.

The tree of causes shows that the critical components are all components, because the appearance of one of them is enough to cause pollution of the air environment.

In the analysis, the system under consideration has been divided into separate subsystems. The tree of causes consists of 9 "or" subsystems. When calculating the probability of the events connected by the "or" logical system, the de Morgan formula [7] is used:

$$P = 1 - \prod_{i=1}^n (1 - P_i) \quad (4)$$

For equally possible N :

$$P[E_i] = P, \quad i = 1 \div 9 \quad (5)$$

P is the probability for n -connected events. Then we have:

$$N = 1 - \prod_{i=1}^9 (1 - P[E_i]) \quad (6)$$

$P[E_i]$ is the probability of the event occurrence.

$$N = 1 - \prod_{i=1}^9 (1 - P) = 1 - (1 - P)^9 \quad (7)$$

Using a series expansion, we obtain:

$$N = 1 - e^{-9P} \quad (8)$$

Since we have identified three blocks of equivalent and equilibria causes, we take the probability of an event - $P = 0,33$. Then:

$$N = 1 - e^{-2,97} \quad (9)$$

The research was conducted at the construction of the underwater crossing facility across the Desna River (the Russian Federation).

As sources of emissions of particulate matter, inorganic dust and abrasive dust (white corundum, monocorundum) that affect the air pollution in the pipeline construction area, the following objects have been selected:

- work of construction equipment at the construction sites;
- excavation;
- welding of metal structures;
- mechanical restoration of metal structures.

During excavation, intensive dusting takes place. Inorganic dust is released with a SiO_2 in the amount of 20-70%. The calculation was carried out in accordance with "Methodological Tool for Calculating Emissions from Unorganized Sources of Building Materials" [23]. Many chemical compounds are released in the air during welding of metals. The calculation of gross emissions of pollutants during welding of metals was made in the calculation program "Welding" (version 2.1) in accordance with the methodology [24]. The norm of MPC is fulfilled without exceptions.

The mechanical processing of metals is accompanied by a large release of dust particles. The calculation of pollutant emissions during mechanical processing of metals was made in accordance with the methodology [25,26]. The results of the calculations are presented in Table 1.

Table 1. The pollutants emissions during the different types of work.

Work type	Name of substance	Emission, g / s	Ejection, t / year	MPC/SRLI standard
Excavation work	Dust inorganic (SiO_2 20-70%)	0.02667	0.1174	Yes
	Iron oxide	0.0134615	0.000291	Yes
Welding of metals	Manganese and its compounds	0.0011585	0.000025	Yes
	Nitrogen (IV) Oxide (Nitrogen Dioxide)	0.0047222	0.000102	Yes
	Carbon Oxide	0.0418704	0.000904	Yes
	Fluoride gases	0.0023611	0.000051	Yes
	Fluorides poorly soluble	0.0041556	0.000090	Yes
	Dust inorganic (SiO_2 20-70%)	0.0017630	0.000038	Yes
Mechanical processing of metals	Dust abrasive (Corundum white, Monocorundum)	0.2480000	0.062496	No
	Suspended substances	0.7680000	0.193536	Yes

According to [27], the SRLI (safe reference level of impact) standard for "Dust abrasive" is not fulfilled.

Thus, the mechanical processing of metals is accompanied by the release of the fine dust fraction, which has a negative impact on the human health and environment. The fractional concentration of the dust should be taken into account in the territorial assessment of air pollution in further research and in the development of environmental measures.

4. Conclusions

On the basis of the results of the researches on the negative impact from the pipeline construction on the air environment, the following measures, which minimize the occurrence of an ecological imbalance, are proposed:

1. Since the majority of the processes, during which the pollutants are released into the atmosphere, do not occur simultaneously and are dispersed in the territory of the construction site, it is necessary to install a fence with a height of 2.5-3 meters. It will reduce the negative impact on the surrounding territory, and exclude the access of unauthorized persons. The fence, functioning as a screen, reduces the spread of pollutants, especially dust, during the excavation and mechanical processing of metals.
2. The construction machinery and equipment should be selected in accordance with minimum specific emissions of harmful substances (carbon monoxide, hydrocarbons, nitrogen oxides, etc.) into the atmosphere.
3. The welding by physical methods should be under control.
4. The machines and pipelines should be tested with regard to strength and tightness after installation by hydraulic method.
5. The excavation by the open method should be replaced by the horizontal directional drilling, if it is possible.

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