Impact of earthworks on the atmosphere during the reconstruction and overhaul of trunk pipelines

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Abstract. The paper discusses adverse atmospheric impact of earthworks during reconstruction and overhaul of trunk lines. The review of the trunk line insulation replacement process under normal and complex conditions helped identify the number of excavating machines adversely affecting the environment when operated simultaneously. The point is made that the calculation of adverse impact should be performed in at least two stages to, first, estimate noxious emissions of operating machines and mechanisms; and, second, quantify the amount of fine-dispersed dust from cutting off the fertile soil layer, extracting the old pipeline, excavating the trench, leveling the trench bottom and other earthworks. It is further noted that the diversity of work techniques and the use of multi-criteria factors hinder the estimation of the adverse atmospheric impact of earthworks, as the engineering process does not consider the meteorological and other related conditions. Therefore, a “construction blockchain technology” (CBC technology) comprising GIS data is required. The CBC technology identifies the construction technologies, machines, equipment, mechanisms, resources etc., as well as software products to select the optimum work techniques, technology and organization, including scheduling. Overall, the integration of CBC and BIM technologies should underline environmental safety of construction works including, among others, earthworks.

1. Introduction

The scientific publications [1-6] justifiably stress the adverse environmental impact of earthworks as part of reconstruction and overhaul of extended linear facilities, which include, among others, trunk lines. In particular, the papers [1-3,5,6] explored the adverse atmospheric impact of operation of excavating machines during the construction of motor roads and railroads. The paper [1] emphasizes that when the GPS technology is used, excavating machines operate in a more precise way, thus reducing the scope of earthworks and, accordingly, the amount of atmospheric emissions caused by operating machines. As to using the GPS technology efficiently to strip a trunk line subject to overhaul or reconstruction, of special interest is the study provided in [7]. The great scope of earthworks (by various estimates, 35-50% of the total work cost) [6], cyclic nature of operation of excavating machines and fuel spills [8], complex road conditions [9-11], extensive capacity of construction machines [10-13] causing a dramatic increase in noise and vibration not only adversely impact the atmosphere, but also affect other layers of the geosphere, as well as the biotic components of the Earth, such as flora and fauna. A sustainable development of the construction sector and obtaining an environmentally friendly product requires devising a holistic approach to all lifecycle stages of a construction system [14-16].
Considering that the extensive scale of environmental impact of earthworks reaches its maximum [17] during trunk line construction, reconstruction and overhaul, further studies on the topic at hand will be conducted focusing on overhaul or reconstruction of the linear part of trunk lines.

2. Main text

2.1. Goal, tasks, research methods

Therefore, this study is aimed at identifying the effects of operation of machines and mechanisms when performing earthworks and stripping works as part of reconstruction and overhaul of trunk lines.

The purpose of the paper is to estimate noxious atmospheric emissions from operating machines and mechanisms during the performance of earthworks with the use of conventional methods.

Objectives:

1. Study of the conventional technologies of trunk line reconstruction and overhaul (by the example of gas pipelines) under normal and complex conditions based on the effective regulatory documents.
2. Random identification of machines and mechanisms required to perform earthworks with one conventional technology of trunk line reconstruction and overhaul under normal and complex conditions.

The principal research methods are analysis, synthesis and comparison featuring the conventional technologies for trunk line reconstruction and overhaul under normal and complex conditions.

2.2. Stages and recommendations for identifying adverse atmospheric impact of earthworks

The structuring of the construction processes during reconstruction and overhaul of trunk lines shows that earthworks (including stripping works) cause the maximum environmental damage [12]. Tables 1 and 2 below list the machines and mechanisms involved in the performance of works under normal and complex conditions based on the analysis of the following documents [18,19]. The work conditions differ in terms of their geography and climate characteristics, as well as the organization and process solutions. Thus, normal conditions include: plain terrain, absence of natural and manmade obstacles, normally good weather, absence of stony and rocky soils, availability of supplies, qualified workforce, necessary machines and mechanisms. Complex conditions can be identified as follows: deserts, swamps, adverse weather, permafrost, plateaus, landslides etc. It is also worth noting that in Russia, the most common complex conditions for trunk line reconstruction and overhaul, due to the geographic location, are swamps and underflooded areas (northern and swampy lands, areas with a high level of underground waters, and inundated areas) [18]. In this regard, the complex conditions in Table 1 are assumed as swamp areas of the first type.

The tables feature the following work technologies: insulation replacement with pipe wall restoration by lifting and placing the pipeline on rollers on the trench shoulder; insulation replacement by lifting under both normal and complex working conditions.

For normal work conditions (Table 2), the following work technologies were assumed: insulation replacement with pipe wall restoration by lifting and placing the pipeline on rollers inside the trench; insulation replacement inside the trench without pipeline relocation.

The analysis and comparison of the data provided in Tables 1 and 2 show that the number of machines involved remains the same for all work conditions and across the work technologies discussed. However such machines and mechanisms, even when used for handling the same size pipeline subject to reconstruction (or overhaul), differ by their characteristics and, what is important, even by the rated motor power. As such, the amount of noxious atmospheric emissions, with the same number of operating excavating machines, depends on their running hours and the type and power of motors. Consequently, the first stage of estimating the atmospheric impact of earthworks should provide for selecting the trunk line reconstruction and overhaul technology for the specific work conditions; determining
the necessary number and type of machines and mechanisms, their running hours, motor type and power, as well as the lifespan of excavating machines and mechanisms.

**Table 1.** Excavating machines required for insulation replacement during trunk line reconstruction and overhaul under normal and complex working conditions.

| Work conditions | Recommended machines and mechanisms |
|-----------------|-------------------------------------|
|                 | Type of machines and mechanisms     | Quantity (each) | Pipeline size, mm |
| **Insulation replacement with pipe wall restoration by lifting and placing the pipeline on rollers on the trench shoulder** |
| Normal          | Bulldozer                          | 2              | 530-1420         |
| Complex         | Bucket excavator (rotary type)     | 2(1)           | 530-1420         |
|                 | Bulldozer                          | 2              | 530-1420         |
|                 | Bucket excavator (swamp type)      | 2              | 530-1420         |
| **Insulation replacement by lifting and placing the pipeline on rollers on the trench shoulder** |
| Normal          | Bulldozer                          | 2              | 530-1420         |
| Complex         | Bucket excavator (rotary type)     | 2(1)           | 530-1420         |
|                 | Bulldozer                          | 2              | 530-1420         |
|                 | Bucket excavator (swamp type)      | 2              | 530-1420         |
| **Insulation replacement by pipeline lifting** |
| Normal          | Bulldozer                          | 2              | 720-1020         |
| Complex         | Bucket excavator (rotary type)     | 2(1)           | 720-1020         |
|                 | Bulldozer                          | 2              | 720-1020         |
|                 | Bucket excavator (swamp type)      | 2              | 720-1020         |

Other relevant factors to determine the atmospheric impact of earthworks are the amount of soil removed when cutting off the fertile soil layer, stripping (extracting) the pipeline, trench excavating, soil dumping, trench bottom leveling, removal of excessive soil, backfilling of the trench etc. Currently, there is a variety of recommendations and methodological guidelines for determining the amount of fine-dispersed dust emitted into the atmosphere in the performance of the above-described works, in view of the type and category of soil, category of roads used for soil transportation and other indicators. Therefore, the second stage for estimating the atmospheric impact of earthworks is about calculating the scope of the above works and determining the amount of emitted dust based on the available recommendations and methodological guidelines.

Considering that the trunk line reconstruction and overhaul technologies themselves are different and the necessary machines and mechanisms differ in terms of their technical characteristics, it appears impossible to determine all potential adverse atmospheric effects of earthworks without employing computer technologies. The use of the BIM technology during the engineering phase is set to facilitate dramatically the identification of adverse impacts affecting the atmosphere during the performance of earthworks (briefly summarized in this paper – with two stages of calculation). However, the amount of dust emitted into the atmosphere also depends on specific meteorological conditions, which cannot always be factored in advance, i.e. during the engineering phase of trunk line reconstruction and overhaul. Even if the historical data are available, the true picture for this stage will remain abstract. Hence, it is the operation stage, where the recalculation of the amount of noxious atmospheric emissions is required.

The conventional technologies for reconstruction and overhaul of trunk lines in any case require the use of high-duty excavating machines and mechanisms. This is why new studies will be required to develop new work technologies or improve the existing ones to exclude at least part of the necessary earthworks machinery. For example, the paper [20] describes an innovative extraction technology for
trunk line reconstruction and overhaul by way of complete pipeline replacement, which helps minimize the number of necessary machines and mechanisms. The new technology can be classified as energy saving, as its use allows avoiding adverse effects produced by the natural and manmade environment itself on the trunk line during its lifecycle [21].

Table 2. Excavating machines required for insulation replacement during trunk line reconstruction and overhaul under normal working conditions.

| Recommended machines and mechanisms                                      | Type of machines and mechanisms | Quantity (each) | Pipeline size, mm |
|---------------------------------------------------------------------------|--------------------------------|----------------|------------------|
| **Insulation replacement with pipe wall restoration by lifting and placing the pipeline on rollers inside the trench** | Bulldozer                      | 2              | 530-1420         |
|                                                                            | Bucket excavator (rotary type)  | 2(1)           |                  |
|                                                                            | Burrowing machine               |                |                  |
|                                                                            | Soil compacting machine         | 1              |                  |
| **Insulation replacement by lifting and placing the pipeline on rollers inside the trench** | Bulldozer                      | 2              | 530-1420         |
|                                                                            | Bucket excavator (rotary type)  | 2(1)           |                  |
|                                                                            | Burrowing machine               | 1              |                  |
|                                                                            | Soil compacting machine         | 1              |                  |
| **Insulation replacement with pipe wall restoration inside the trench without pipeline relocation** | Bulldozer                      | 1              |                  |
|                                                                            | Layer-excavation machine        | 1              |                  |
|                                                                            | Rotary excavator                | 1              | 720-1420         |
|                                                                            | Burrowing machine               | 1              |                  |
|                                                                            | Soil compacting machine         | 1              |                  |
| **Insulation replacement inside the trench without pipeline relocation**  | Bulldozer                      | 1              |                  |
|                                                                            | Layer-excavation machine        | 1              |                  |
|                                                                            | Rotary excavator                | 1              | 720-1420         |
|                                                                            | Burrowing machine               | 1              |                  |
|                                                                            | Soil compacting machine         | 1              |                  |

3. Conclusions

Summing up, it is appropriate to underline that to identify adverse effects of earthworks, it is insufficient to make certain calculations simply to estimate the amount of noxious atmospheric emissions. This issue requires a holistic approach, where the integration of the blockchain and BIM technologies should be the basis of the key environmental protection efforts as part of construction works including in particular earthworks. The “construction blockchain technology” (CBC technology) (the expression is invented by the authors) should include not only data gathering for construction technologies, necessary machines, equipment and mechanisms, material resources etc., but also various software products to select the optimum machinery and technology, as well as work organization patterns, including work scheduling. During the immediate performance of construction and repair/construction works, information should be made available regarding the climatic and meteorological conditions for prompt optimization of the work process in order to exclude the adverse impact produced by reconstruction and overhaul of trunk lines, and in particular earthworks, on the natural and manmade environment. This means that the GIS technology (or GIS enabled data) shall form part of the new CBC technology.
The theoretic relevance of this paper stems from the fact that it can be used as the basis for developing the overall CBC methodology and its integration with the BIM technology.

References

[1] Capony A, Lorino T, Muresan B, Baudru Y, Dauvergne M, Dunand M, Colin D and Jullien A 2012 Assessing the productivity and the environmental impacts of earthwork machines: a case study for GPS-instrumented excavator Proc. Social and Behavioral Sciences Transport Research Arena 48 256

[2] Tunay M 2006 The assessment of environmentally sensitive forest road construction in Calabrian pine forest areas of Turkey Journal of Environmental Biology 27(1.3) 529

[3] Gavin K, Oslakovic IS, Vajdic M, Puz G and Sporcic V 2012 Smart Maintenance and Analysis of Railway Transport Infrastructure (Smart Rail) Road and Rail Infrastructure II ed S Lakusic (Dubrovnik: CROATIA) pp 429–35

[4] Yao T J and Liu L X 2014 The Stack Soil Management for Construction Site Advanced Materials Research Modern Technologies in Materials, Mechanics and Intelligent Systems 1049 487

[5] Jensen J S, Sloth M, Linneberg P, Paulsson B and Elfgren L 2014 MAINLINE - Maintenance, Renewal and Improvement of Rail Transport Infrastructure to Reduce Economic and Environmental Impacts Bridge Maintenance, Safety Management and Life Extension 1056

[6] Parente M, Correia A G and Cortez P 2016 A novel integrated optimization system for earthwork tasks Transportation Research Proc. Transport Research Arena (TRA 2016) (Warsaw: POLAND) 14 3601

[7] Akhmedov A M 2017 The Improvement of Preparative Processes During the Earthworks on the Linear Main Pipeline Portion Don's Engineering Bulletin 1

[8] Guerin T 2014 Root Causes of Fluid Spills From Earthmoving Plant and Equipment: Implications for Reducing Environmental and Safety Impacts Journal Engineering Failure Analysis 45 128

[9] Yao T J and Liu L X 2014 The Stack Soil Management for Construction Site Advanced Materials Research Modern Technologies in Materials, Mechanics and Intelligent Systems 1049 487

[10] Abramyan S G and Oganesyan O V 2019 Materials and Technologies Ensuring Environmental Safety of Reconstruction and Overhaul of Trunk Pipelines IOP Conf. Series: Earth and Environmental Science International Science and Technology Conf. "Earth science" 272

[11] Parsakhoo A, Hosseini S A, Lotfalian M and Jalilvand H 2009 Soil loss and displacement by heavy equipment in forest road subgrading projects Int. Journal of Sediment Research 24 (I.2) 227

[12] Abramyan S G 2018 Assurance of environmental safety of conventional overhaul and reconstruction technologies for trunk pipelines Int. Conf. on Constr., Architecture and Technosphere Safety (ICCATS 2018) (Chelyabinsk: IOP Publishing Ltd) 451(1) 7

[13] Lee S C, Hong J Y and Jeon J Y 2015 Effects of acoustic characteristics of combined construction noise on annoyance Building and Environment 92 657

[14] Li W and Wang X 2016 Innovations on Management of Sustainable Construction in a Large Earthwork Project: an Australian Case Research Integrating Data Science, Construction and Sustainability (ICSDSEC) (Arizona State Univ, USA) 145 677

[15] Park J Y and Kim B S 2019 Life-cycle Assessment-based Environmental Impact Estimation Model for Earthwork-type Road Projects in the Design Phase KSCE Journal of Civil Engineering 23 (I.2) 481

[16] Abramyan S G 2016 Environmental Compliance During Construction 2nd Int. Conf. on Industrial Engineering (ICIE) (Sevastopol, Russia) 150 2146
[17] Abdrakhmanov N KH, Azmetov Kh A, Pavlova A D, Zakirova Z A and Basyrova A R 2017 Modern Methods and Means of Ensuring Safe Exploitation of Oil Trunk Pipelines *NEFTEGAZ Territory* 6 192

[18] Aleksandrov A S 2006 Selection of an Optimal Strategy for Operation of Machinery Packages during Pipeline Overhaul *Oil, Gas and Business* 12 82

[19] STO Gazprom 2-2.3-231-2008 2008 Rules for Repair of Linear Segments of the Gas Transmission Pipelines of Gazprom JSC (Moscow) p 97

[20] Akhmedov A M and Abramyan S G 2019 Method for Pipeline Section Retrieval for Overhaul with Complete *Int. science and technology conference "EarthScience"* (FarEastCon 2019) (Vladivostok: IOP Publishing Ltd) 459(1) 8

[21] Abramyan S G 2019 Determining influence of natural and man-made factors on safe performance of trunk pipelines *Int. Conf. on Constr., Architecture and Technosphere Safety* (ICCATS 2019) (Chelyabinsk: IOP Publishing Ltd) 687 6