Briefing Note

The main directions of securing geocryological safety of economic activity in the Arctic region

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In this work, the attentions focused on the securing geocryological safety of the economic activity in the Arctic region. The security is a prerequisite for the development, prosperity and well-being of the arctic communities, to ensure sustainable economic activity in the region. This new article addresses the risks in the arctic, which may pose a threat to human life and health, the environment, economic objects, as well as ways to prevent these risks. We pay special attention to geocryological safety. The authors consider that the geocryological safety means protect ability from a complex of negative consequences, associated with the condition of permafrost rocks. Geocryological security should be evaluated and ensured along various algorithms for stages of construction and exploitation of engineering projects and aspects of nature management.

Introduction

The Russian Arctic is a region of special geostrategic and long-term interests for Russia, primarily from the point of view of the development and rational use of natural resources, ensuring global ecological balance and the preservation of economic infrastructure facilities.

The national security strategy of the Russian Federation, approved by the President of the Russian Federation on December 31, 2015, calls natural disasters, accidents and catastrophes, including those associated with global climate change, a deterioration in the technical condition of infrastructure, among the main threats to state and public security. Security is a prerequisite for the development, prosperity and well-being of Arctic communities, to ensure sustainable economic activity in the region. This new topic addresses the risks in the Arctic, which may pose a threat to human life and health, the environment, economic objects, as well as ways to prevent these risks. We pay special attention to geocryological safety.

The authors consider that geocryological safety means protection from a complex of negative consequences associated with the condition of permafrost rocks. Geocryological security should be evaluated and ensured along various algorithms for stages of construction and exploitation of

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engineering projects and aspects of nature management. The Chara-China railway route and the Arctic section of the Northern Railway are considered in our work.

Techniques and materials

Our investigations were carried out on two roads. The first one is the Pecets-Khanovey, situated beyond the Polar Circle (approximately 67.2° N, 63.5° E) in Bolshezemelsk Tundra, at the extreme north-east of the Komi Republic, in the Vorkuta district. The second one was built, but not operated: the Chara-China Road (Kolarsk district, Transbaikal Region).

In 2014-2018 a complex of field activities were carried out: drilling work, definition of thermo-physical properties of soils, definition of temperature regime of the surface, geophysical investigations (electrical survey), studying the temperature regime of permafrost rocks and the seasonal thawing layer, landscape microzoning of the locality, studying upheavals, thermokarst, definition of radiation balance, temperature regime of the stream, etc.

Our task was to study the sustainability of the railway in the Arctic (areas of cryolitozone development). This is the priority objective for designers and specialists in operation. There are many methodological recommendations, but our task is to check the effectiveness of administrative measures for deformed zones of roads.

The effectiveness of administrative measures in such difficult conditions cannot be considered without regarding the geocryological state of the environment, the engineering methods which were used for the railway construction, and the economic evaluation of the decisions taken or engineering protection.

Railway construction in the Arctic zone leads to heat transfer changes between the ground surface and the atmosphere. There are known factors affecting heat transfer. Among them: 1) removal of vegetation cover; 2) disturbance of the surface run off; 3) increasing snow cover; and 4) reflections of sun rays from the surface. All these factors directly influence permafrost grounds, which develop hazardous geocryological processes directly affecting the state of the railway stability (Isakov, 2016). Analyzing literature and research materials, we can assert that when the railway is in operation, the appearance of deformations is inevitable. Deformation zones are either technogenic or natural. The latter are of scientific interest to us, as they appear as a result of geocryological processes (Fig. 1 - 6).

Figure 1.
Pecets-Khanovey Road (archival photo).

In order to choose effective administrative measures for development and construction in the Arctic region, it is necessary to foresee the economic factors, or more precisely, economic effectivity. Economic efficiency is a value that manifests itself in costs (rubles, dollars) for the maintenance of transport facility. Attention to this property helps to avoid unforeseen costs for engineering protection or maintenance of the road in the working condition (Voytenko, 2017).

Figure 2. Disturbances in the zone of Chara-China Road due to the development of dangerous geocryological processes (photo by I. Chesnokova, 2016).

Figure 3. Disturbances in the zone of Chara-China Road due to the development of dangerous geocryological processes (photo by D. Sergeev, 2016).

Figure 4. Disturbances in the zone of Chara-China Road due to the development of dangerous geocryological processes (photo by I. Chesnokova, 2016).

Figure 5. Disturbances in the zone of Chara-China Road due to the development of dangerous geocryological processes (photo by I. Chesnokova, 2016).

Figure 6. Disturbances in the zone of Chara-China Road due to the development of dangerous geocryological processes (photo by D. Sergeev, 2016).

Results and discussion

As a result, terrains were specified which helped to reveal the regularities of space distribution of geocryological phenomena and processes. The landscape typification of the area provided the basis for preparing the original map-scheme of the locality, which allows us:

- to divide areas into conditionally disturbed or undisturbed;
- to demonstrate schematically the development of the area during changing geocryological conditions and to identify the leading factors associated with development of hazardous processes;
- to compare the data on changing geocryological conditions to present a concept on stage development of geocryological processes and phenomena; and
- to identify localities suitable for the organization of monitoring of geocryological processes.

Damaged areas on the track were analyzed to assess the damage (Fig. 7). It is known that during the repair (when the structure on the way back to the design framework restored roadbed and drainage structures), the cost of 1 meter (km) road is N rubles. Therefore, with the data presented in the Fig. 7, we can estimate the value of damage (in rubles). And it can be done for different conditions - simple, medium and complex.

The authors conducted an analysis of the economic damage to the main geomorphological areas across which passes the Chara-China track. Results are given in table 1 below.

Table 1. Values of the economic damage from dangerous geocryologic processes in the Chara-China track (taking into account the geomorphologic location of zones)

Relief type	Significance of economic damage (rubles. n prices of 2009)		
	Min.	Medium	Max.
Chara River Valley	3,230,800	5,264,400	6,736,630
Piedmont tails	16,390,400	26,707,200	34,176,060
Sortan moraine	5,299,300	8,634,900	11,049,710
Highland area	4,363,550	7,110,150	9,099,560
Intermontane zone	24,239,950	39,595,350	50,668,480

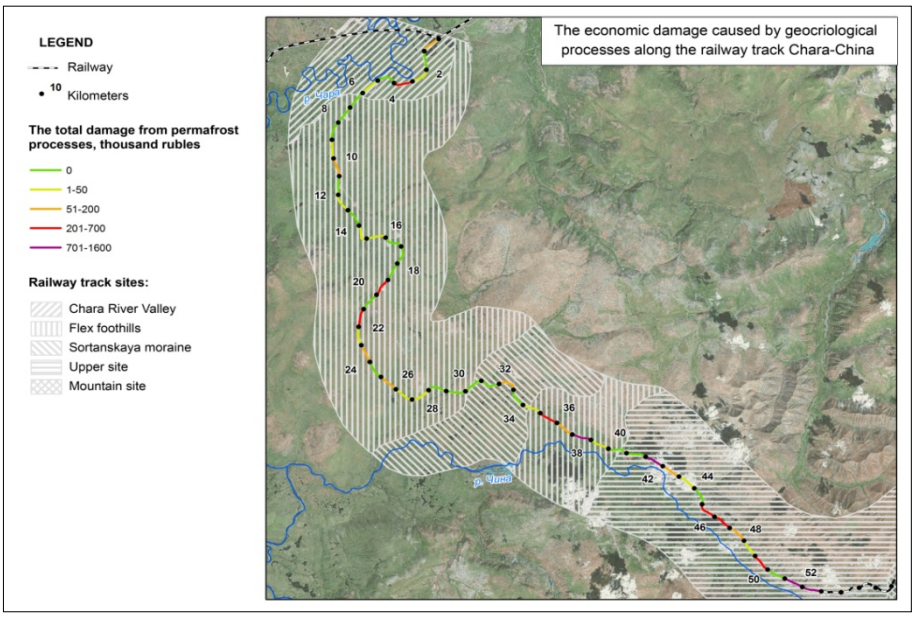

Figure 7. The economic damage caused by geocryological processes along the railway track Chara-China.

Conclusions

The concept of "Stable development in the Arctic zone" is considered in this article as an economic planning term, supporting linear objectives (in our case, roads) in working condition. These are complicated problems, and there are still no sufficient materials to secure stable development of linear objects in the cryolite zone (Sergeev, 2014; 2016). As an indicator of sustainable development, the authors consider the ratio of planned cost to the value of maximum possible cost. On the other hand, the ratio of the cost for construction repairs to the cost of the engineering protection can be used as a criterion for making decisions.

Based on identified localities and the character of deformations of the railway embankment, the map-scheme was drawn up for the linear zoning of the route.

Thus, some indicators, among them, were used to evaluate the sustainable development: unclarified geocryological hazards; costs of protection measures; unclear development of geocryological processes; losses due to changes in the surrounding landscape; and uncertain localities and the depth of occurrence of high ice rocks.

One of the ways to ensure sustainable development is optimization of the engineering protection of Arctic objects. Such work is an interdisciplinary challenge, which aims to unite geological specialists in geocryology and engineering (designers and specialists in operation) and specialists in economics.

Acknowledgments

This work was fulfilled as part of basic research funded by the Ministry of Science of Higher Education of the Russian Federation № AAAA-A19-119021190077-6 and № AAAA-A19-119040990079-3.

References

Isakov, V. A. (2016). Influence of cryogenic processes on the stability of roads and Railways: autoref. dis. on competition of a scientific degree. scientist. tap dance. kand. geographic locations. Sciences (25.00.31) / Moscow state University.- Moscow, 24.

Sergeev, D. O. & Chesnokovaa I. V. (2014). Problems of assessing the sustainable development of the territory in the cryolitozone. *Geoecology. Engineering Geology, Hydrogeology, Geocryology*, *2*, 127-130

Sergeev, D.O.; Chesnokova, I.V.; Morozova, A.V. & Voytenko, A.S. (2016). Cartographic analysis of the damage, associated with geocryological processes // XI ICOP. 20-24.06., Potsdam, Germany. Book of Abstracts. Edited by Frank Günter and Anne Morgenstern, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, International Permafrost Association. P.398.

Voytenko A. S., Grishakina E. A., Isaev V. S., Koshurnikov A.V., Pogorelov A. A., Podchasov O. V., Sergeev D. O. (2017). The Importance of changes in geocryological conditions for the operation of infrastructure and environmental protection (by the example of the site of detailed studies in the lower reaches of the Vorkuta river) // *Arctic: ecology and Economics, 2(*26). - p. 53-61.