Assessment of Environmental Changes of Valley of the Undytkan River in Impact Zone of the Elginsky Coal Complex and the Railway Track “Ulak-Elga” with Use of Ground and Remote Methods

D D Pinigin¹, N A Nikolaeva¹, D D Nogovitsyn¹

¹V.P. Larionov Institute of Physical and Technical Problems of the North SB RAS, Department of problems of energetics, Oktyabrskaya str., 1, Yakutsk, 677980, Russia

E-mail: pinigind@mail.ru

Abstract. Environmental monitoring studies are of primary importance to assess the characteristics of anthropogenic changes in the environment on the territory of the Elginsky coking coal deposit, which is one of the largest resource potential of the Republic of Sakha (Yakutia). Due to the inaccessibility and territorial remoteness of the field, remote research methods are a valuable tool for environmental monitoring. The article shows the experience of using the satellite image analysis method for assessing anthropogenic impact and spatial detection of changes in the components of the natural environment in conjunction with field study. On the territory of the Elginsky deposit there is a complex of production, infrastructure and linear structures: coal mine, processing plant, hydraulic structures, shift camp, power transmission lines, roads and railways, as well as a railroad bridge under construction. Technical structures interact with the components of the natural environment and modify them, forming geotechnical (geotechnical) systems. Two geotechnical systems were considered in the article: (a) ‘Elginsky coal mining complex - natural environment’ and (b) ‘River – Bridge’ on the Undytkan River, formed as a result of interaction of the valley of the Undytkan River and a complex of linear road structures of railway track “Ulak – Elga”. And the analysis of high-resolution satellite images, as well as data from expeditionary ground-based studies, made it possible to establish that the formation and functioning of the transport geotechnical system led to a change in a number of components of the natural environment — mesorelief, hydrological parameters of surface waters, inhibition of vegetation cover, and changes in soils associated with increased water level, as well as with icing processes.

1. Introduction

Currently, the vitality and energy security of the Republic of Sakha (Yakutia) and Russia remain in its fuel and minerals resources and mining. However, development of inaccessible natural resources in extreme climatic conditions inevitably leads to negative changes in the environment and its components. In these circumstances, such advance research work, as the study of the peculiarities of transformation of ecosystems by industrial development, is urgently needed [1].

The Elginsky deposit of high quality coking coal, which is located in South Yakutia, has crucial importance for the economy of the country. Its development has been carried out since 2011 in open pit with reserves, reaching more than 2.0 billion tons [2].
Intensive development of the Elginsky coal deposit open pit and the creation of Elginsky coal complex has consequences in the form of a serious natural ecosystem’s changes which lead to vital need to find ways to resolve the emerging problems.

To evaluate the characteristics of man-caused environmental changes in the area of the Elginsky deposit is necessary to conduct complex environmental monitoring, the main purpose of which should be the study of the spatial and temporal patterns of the dynamics of the natural environment during industrial development.

In the conditions of territorial remoteness to and from industrial centers and low availability of the deposit, remote research methods possessing the technical ability to obtain operational information and environmental mapping are a valuable environmental monitoring tool. Among them, there is a method for the analysis of high resolution satellite images, which is one of the accessible and effective methods of remote research [3, 4].

The aim of the work is to assess changes in the components of the natural environment of the geotechnical system on the river Undytkan in the impact zone of the Elginsky coal complex (Figure 1) by remote sensing and field studies.

2. Material and research methods
The main method of landscapes disturbance assessment is satellite images analysis method, in which satellite images of “Bing Maps” (2010) and “Yandex.Maps” (2016) web services and true color images from satellitecraft Sentinel-2 are used. Satellite imagery service the Bing Maps were loaded in the QGIS application, and Sentinel-2 images are obtained via Internet service Copernicus the Open the Access Hub in JPEG2000 format.

The study was conducted in by combining scientific research with a method of landscape analysis – a concept to geotechnical systems. This allows to explore the technical object and the environment as the related subsystem of single geotechnical system and to provide complexity and completeness of
the received information [5]. Analyses of relationships and structures of the system gives a possibility to predict anthropogenic transformation of natural components and to provide environmental protection technology to mitigate impact on the environment [6].

Available satellite images of various spectra and resolutions of the territory of the coal complex were used as a basic material, as well as data from field studies.

3. Research results and discussion

Two natural and technical (geotechnical) systems have been identified on the territory of the Elginsky coal complex - the regional mining ‘Elginsky coal complex - natural environment’ and the local transport ‘River - Bridge’ formed by structures of the railway track “Ulak- Elga”. One of the conditions for the functioning of the geotechnical system is the interaction of all subsystems by means of numerous internal and external relations between them, which ensures the integrity and unity of the whole system [5].

**Mining geotechnical system.** A regional mining geotechnical system – ‘Elginsky coal mining complex - natural environment’ had been formed on the studied area as a result of the interaction of technical and natural components. The system has three blocks: technical, natural and management [7]:
- the technical block consists of subsystems - a complex of production and auxiliary facilities interconnected by local technological connections and performing the functions of coal mining, coal preparation and transportation. These are mining, processing, dumping, hydraulic engineering, transport and residential complexes;
- the natural block is represented by a combination of types of landscapes of altitudinal zonation: mountain-desert, mountain-tundra, subalpine, mountain-sparse and mountain taiga. Intrazonal types of landscapes are widespread as well.
- the control block is represented by the management and maintenance personnel of the coal complex.

An analysis of the functional structural relationships between the subsystems of the technical and natural blocks made it possible to establish qualitative indicators of the direction, character, intensity of the impact of the technical block’s subsystems on natural components, as well as indicators of pollution and the intensity of natural complexes’ components transformation.

**Transport geotechnical system.** A local geotechnical system ‘River - Bridge’ was formed on the territory of the coal mining complex on valley of the river Undytkan as a result of the interaction of the river and the complex of linear road structures. The technical subsystem includes roads and railways, a railroad bridge, an artificial embankment, and a dam. The natural subsystem is represented by the riverbed of the Undytkan river and surrounding landscapes.

The railroad bridge crosses the river Undytkan at a point with a mark of 810 m above sea level, and on 296.1 km of its construction in 17.0 km from the mouth of the river. The total length of the Undytkan is 50 km, the catchment area of the river before the crossing is 227 km².

According to the project documentation, the water consumption at 1% supply according to the empirical reduction formula is 543 m³/sec.

An auxiliary hydraulic structure was constructed across the natural river bed in 2011-2012, as, in result of which an embankment of coarse material with height of 2.5 m was formed. A culvert on one of the left branches of the river ensures the passage of river waters (Figure 2).
Figure 2. Construction of the railroad bridge across the river Undytkan on an artificial embankment (August 2012).

At present, the construction of the bridge is not completed; the embankment is not leveled to the level of the natural bed of the river valley (Figure 3). An automobile bridge is in operation downstream 0.57 km from the railway crossing, through which finished products are delivered to the railway terminal for further transportation to the station Ulak; currently year-round transportation of the products of enrichment is made from the concentrating plant “Elginsky” by the dump trucks.

Figure 3. The railway track “Ulak-Elga” crossing the river Undytkan (August 2019).

Natural perennial aufeis on the Undytkan is adjoined to the railroad bridge from the south, the volume of the aufeis, according to the project documentation, is $12 \times 10^6$ m$^3$, the supply value is 93
litres per second. By analyzing the results of satellite images the length of the aufeis in 2011 was 2.5 km, the width of the longitudinal profile of the stream valley in place of maximum was 0.5 km (Figure 4).

![Aufeis on the river Undytkan before the construction of the bridge on the satellite image of Landsat-5 satellite craft (May 27, 2011).](image1)

Figure 4. Aufeis on the river Undytkan before the construction of the bridge on the satellite image of Landsat-5 satellite craft (May 27, 2011).

Analysis and evaluation of the results of the use of satellite images of high resolution allowed to fix the change in runoff of the Undytkan on topographical plan of scale 1: 25 000 as a result of its backwater by the construction of the embankment. It is also determined that there was an increase of the aufeis area in the direction of the left side of the valley, i.e. its increment by artificial icing on an area of 1.3 hectares. At the same time, the passage of aufeis waters below the embankment along the old riverbed is recorded.

Aufeis circuit area (May 6, 2019) is shown in figure 5, and sections of raising water level above the automobile ($S = 1.43$ m), and railroad bridges ($S = 2.01$ ha), decrypted on the satellite image Sentinel-2 (June 10, 2016).

![Assessment of environmental changes in the area of bridge crossings over the river Undytkan.](image2)

Figure 5. Assessment of environmental changes in the area of bridge crossings over the river Undytkan.
High resolution satellite images (“Yandex.Maps” web mapping service) analysis allowed to identify land cover change due to apparently lower levels downstream the river, flooded larch forests on the left bank of the river and waterlogging of aufeis meadow upstream the crossing as well.

Field study of both bridge crossings in 2019 identified vegetation oppression near railroad bridge upstream the Undytakan river, presumably associated with water increasing level and aufeis formation process. Signs of aufeis formation processes, classified in [8], there were: "drunken trees", peeling the bark of trees, shrubs drying mass on the section of aufeis meadow adjacent to the railroad bridge, bleached and sanded tree trunks, whose height was 2-3 m (Figure 6).

![Figure 6. Signs of vegetation oppression upstream from the crossing of the railway track “Ulak- Elga” across the river Undytkan.](image)

Thus, high resolution satellite images analysis reveal that the formation and functioning of the local transport geotechnical system ‘River – bridge’ led to the violation of components of the natural block - change of runoff and water levels upstream and downstream the Undytkan River, vegetable cover and, as a consequence, the state of soil cover.

4. Conclusion
It was found that geotechnical (geotechnical) systems of various orders were formed as a result of the interaction of geotechnical components in the territory of the Elginsky coal complex: the regional mining ‘Elginsky coal complex - natural environment’ and the local transport ‘River – Bridge’ to the Undytkan River.

Estimate of quantitative and qualitative indicators of the direction, nature, and intensity of the impact of the technical block subsystems on the environmental components has been carried out due to determination of their structure and the analysis of functional relationships between the subsystems of the technical and natural blocks.

It is shown that as a result of the construction of linear road structures on the river Undytkan formed a local geotechnical system ‘River - Bridge’ was formed. Using remote sensing techniques, analyzing high-resolution satellite images, as well as expeditionary research data made it possible to establish that the formation and functioning of the transport geotechnical system led to a change in a number of components of the natural environment — mesorelief, hydrological and hydrochemical parameters of surface waters, inhibition of vegetation cover, and soil changes, associated with an increase in water levels, as well as with icing processes.
5. References
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