Assessment of current state of conserved areas of mountain rocks in strip mining conditions

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Abstract. In the conditions of the development of today’s mining industries, many coal mining enterprises (even though the production volumes are currently increasing) are looking for the ways to conserve previously mined areas and monitor their ecological state. The extraction of fossils from the depths of the earth produces natural and manmade complexes that have a considerable impact on vast territories. The largest impact lies in turning the lands for general use into commercial mining areas and land allocations. Open cut mining leads to the emergence of quarries, stopes and embankments of different sizes, changes in relevant and absolute elevation marks compared to the initial surface, which is connected with the construction of quarry dumping complexes. Direct dumping methods contribute to the formation of the system of narrow crests that are combined with leveled plateau-like parts of a spoil pile. The slopes of spoil piles have high angles of gradient (14-40°) and are subject to sheet and gully erosions which form large alluvial cones. Technogenic sediments formed at their bottom reach the height of several meters and spread up to a few hundred meters from the dumps. During coal mining, the rocks are stored in external and internal dumps of coal strip mines without any preliminary sorting, which also leads to soil and water pollution with heavy metals.

1. Introduction
Environmental protection in coal mining enterprises is a priority task at all levels of mining operations, especially during temporary conservation. The most damaging impact on natural complexes is produced by open cut mining. In this connection, the Russian legislation obliges enterprises to implement the systems and programs of environmental observation and monitoring. One of such systems is the monitoring of conservation areas [1]. All environmental events require special attention and careful planning.

Work objective: assessment of the current state of the areas of temporary conservation in the framework of ecological monitoring and their impact on natural territories.

2. Methodical approach and research findings
Target of research: area of the temporary conservation of coal strip mines, including the research of natural environments which have been changed and/or lost their productivity in the result of a negative impact. The research was carried out in accordance with all-Union State Standards (GOST) methods and requirements of regulatory documents. Selection, storing and preparation of samples were held in accordance with the norms set by state standards.
Open cut mining is considered ecologically hazardous and harmful to the environment [2]. Its impact is complex and diverse. It is not limited to mining alone but includes gas and dust pollution, contamination of surface and subsurface waters, hydrobalance disturbance, technogenic soil disturbance, withdrawal of productive agricultural and forest lands, change of the qualitative composition and integrity of subsurface resources, multiple industrial waste, electromagnetic and sound pollution, activation of destructive natural physiogeographic processes (gully ing, flooding, aridization, etc.) [3]

The researchers of the V.B. Sochava Institute of Geography of the Siberian Branch of the Russian Academy of Sciences were assigned with the task of assessing the current state of conserved areas and creating an ecological monitoring program during their collaboration with the mining companies Tulunugol Ltd and Vostsibugol at the base of Azeiskii mines. As there was no program of ecological monitoring of conserved mining areas available at that moment, the creation of such program became a necessity. At the first stage of the scientific research, special attention was given to the initial analysis of the current state of conserved mining areas, examination of the sources of exposure, and monitoring of the soil thickness based on qualitative and quantitative indicators in the monitored areas.

The ecological monitoring program is based on the assessment of the state of the environment in conserved areas and its natural counterpart, i.e. an analogue area before the commencement of mining operations. The identity of the analogue area is expressed in the slope exposure, identical wind patterns, uniform geological environment, soil characteristics and vegetation layer. Besides that, the analogue territory must not be affected by any coal mining activity, yet at the same time, must be relatively close to the conserved area (figure 1).

![Figure 1. Arrangement of conserved site and natural counterpart.](image)

By the time of the commencement of the current research, the areas withdrawn for the conservation were in different environmental states and had a different time of stoppage of mining operations. In this regard and in accordance with the developed monitoring program, the research sites were located in both “moonscape” and vegetated areas. The vegetation in the latter area is diverse and represented in various successive species from the pioneer stage on crests and slopes of the dumps to the tallgrass aspen, birch tree and pine forest in the perimeter. Most of the vegetation species of the community are represented by grassland vegetation [4]. To obtain a more complete picture of the transformation of the territory and its pollution, we examined the soil in the conserved areas and that in the analogue area to make subsequent comparisons [5]. The research showed that the chemical qualities of man-made soils have common features, notably weak-acid and or neutral reaction of the environment (from 6.4 to 7.3) in the upper profile horizons, pH is often higher due to the biogenic base accumulation. At
the same time, the pH indicators of the dump crests in the conserved areas, with pioneer vegetation or without it, vary from 4.7 to 4.9, which is the consequence of a heavy mixing of all layers of the soil sample and bedding rocks. The technogenic soil is low in humus (0.2 – 0.8), nitrogen and phosphorus. Exchangeable cations include Ca$^{2+}$, Mg$^{2+}$, occasionally aluminum and hydrogen ion [6]. The sum of absorbed cations is not high. One of the main indicators of soil fertility is the composition of water extracts. Their analysis showed low content of water-soluble salts in the ground and technogenic soils. Their content is higher in technogenic soils due to the technogenic input. HCO$_3^-$, a Cl$^-$ and SO$_4^{2-}$ are the dominant anions, their content is much lower than in the natural soils [7]. Dominant cations are Ca$^{2+}$ and Mg$^{2+}$. The analogue territory located in the pine and shrub forest on the meadow wood podzolized soil has a clear distribution of pH in the section and varies from 4.4 to 6.0. The natural soil is characterized by a highly sufficient accumulation of humus. Its content conforms to the norms adopted for these particular soils, and has a good depthwise distribution and decreases with a depth from 13.5 cm in the sod soil horizon with the depth of 4 cm to 0.25% at a depth of 61 cm [8]. The soil is rich in nitrogen whose content also decreases as the depth increases. The analysis of water extracts showed that the content of water-soluble salts in the meadow wood podzolized soil is not very high. Their maximum concentration can be seen in the upper part of the section. As for the salt composition, HCO$_3^-$ is a dominant anion, and Ca$^{2+}$ is a dominant cation.

The main pollutants of the technogenic soils in the industrial areas are heavy metals. They penetrate the environment of the coal mining complex mostly through atmosphere. Dust pollution dominates in the area, because we did not detect a high concentration of polluting elements in the snow cover. The comparison of the concentrations of the total forms of Mn, Co, Pb, V in the natural and technogenic soils was carried out considering the maximum permissible concentrations (MPC) and established hygienic standards. The comparison of the concentrations of the total forms of Cr, Ni and Cu was carried out considering their approximate permissible concentrations (APC).

To increase the reliability and informativeness of the monitoring data in assessing and identifying the trends of the rehabilitation of natural environment, we took into account the regional background (RB): the content of an element in bedding rock, bottom sediments, surface waters, snow cover, soil, vegetation, fauna which have been identified in an experimental way and are available in scientific press [9]. Regional background helps to increase the accuracy of impact assessment of the objects of ecological monitoring on the components of natural environments. The comparison of the MPC values of heavy metals with the received indicators in the analogue territory showed that their content is within the norms of the permissible values. Copper and nickel have the highest indicators exceeding maximum permissible concentrations by a factor of five. However, they are much lower than the regional background which means that the natural area is not polluted.

One of the monitored zones located almost in the center of a coal strip mine and experiencing most of its impact was picked for a more detailed analysis of the technogenic soil of the conserved areas. Two small catenas with the inclusion of the highest point at the top of the dump and flattened surface at the bottom of the dump were set in the coal strip mine. The first one includes points B-1, B-2, and B-3, the second one – points B-4 and B-5. The five-year observations showed fluctuations in the content of metals in the upper layer of the technogenic soil. For example, maximum accumulation of copper and nickel was detected at the top of the dump in 2010 and 2011 respectively (figure 2).

The charts of the concentrations of these elements in catenas are identical, although the level of content in the adjacent points is considerably lower. At the same time, there is a sharp increase in the concentration of copper at the bottom of the dump in point B-5, where the concentration of the element takes place with a following sharp decline. Chrome and cobalt have a high migration capacity, as evidenced by their high content in the lower part of the dump. Taking into account the migration capacity of the combinations of these elements and content fluctuations in the soil, it can be concluded that the pollution occurs through dust emissions of the enterprise itself during overburden removal. The main impact is produced by removed soils and rocks, or more precisely, their chemical composition. At the same time, the charts indicating their content in the technogenic soil show sharp increases and declines, which are aided by the soil compositions. It is mostly large coarse-grained
material with low content of fine earth, predominantly in the upper part of a coal strip mine mixed with a high quantity of coal waste.

The dust precipitating on the tops of the dumps is actively washed off by rain and snow waters which contributes to radial and lateral migration of the elements and their combinations. Despite the precise distribution of the elements along the catenary section, their content exceeds MPC 10. This pollution level in conserved areas is considered critical, thus the areas need to be detoxicated, even if they are brought back into production. The content of toxic elements in the analogue area is twice as low as in the conserved areas. The comparison of the content of pollutants with regional background was carried out to identify the technogenic load and pollution level of the dumps. The analysis showed that their concentration in the monitored area is lower than the average values in the region. Excess peaks do occur, but they are quite rare and show a sharp decline in the next observation period.

Besides the elements mentioned above, there has also been identified an elevated content of manganese in the upper part of the soil section covered with vegetation communities. This characteristic highlights the capacity of technogenically disturbed geosystems to return to their natural state, because Mn is a biophile element which is actively absorbed from soil by vegetation. Mn is re-emitted to soil during vegetation die-off and accumulated in the upper horizon [10].

3. Conclusion
Ecological monitoring in the conserved areas of mining activities allows to assess the current state of technogenic soil and its capacity for self-regeneration. The conducted research showed that technogenic soils have a good accumulation and migration capacity. The assessment of the ecological state of the conserved areas based on monitoring activities which follow the criteria of MPC alone leads to erroneous conclusions. The implementation of regional background criteria in the program of ecological monitoring increases the accuracy of determining the pollution level of the natural environments of conserved areas by more than 50 %.

Figure 2. Heavy metal contents in soils of techno-sealed plots (rooms are located on the x axis points selection with an indication of the year)
References

[1] Ashihmina T Y 2008 Ecological Monitoring (Moscow: Nauka Press) p 416
[2] Kharyonovsky A A, Litvinov A R, Danilova M Y and Mahmud T 2016 Evaluation of the environmental impact of open and underground coal mining methods J. Vestnik of the Scientific Center for the Safety of Work in the Coal Industry 4 113-8
[3] Litvinov A R and Kharyonovsky A A 2012 State of the environment in the coal industry Coal 1039(10) 74-8
[4] Dubynina S S 2017 Temporal and spatial changes of above-ground mass in the dump ecosystems after mining operations Achievements in Today’s Natural Science 9 57–62
[5] Motuzova G V and Bezuglova O S 2007 Ecological Monitoring of Soils (Moscow: MSU Press) p 237
[6] Vorobyeva I B and Vlasova N B 2012 Geochemical assessment of lands disturbed by strip mining of brown-coal strip mines in eastern Siberia Journal of Orenbourg State Agrarian University 38(6) 10-3
[7] Vorobyeva I B and Vlasova N B 2013 Research of technogenically altered seasonally-frozen soils of Southern Taiga International Journal of Applied and Fundamental Research 8(1) 34-7
[8] Kuzmin V A 1988 Soils of the Baikal and Northern Transbaikal (Novosibirsk: NSU Press) p 175
[9] Grebenshchikova V I, Lustenberg E E, Kitaev N A and Lomonosov I S 2008 Geochemistry of the Environment of Baikal Region (Baikal geocological polygon) (Novosibirsk: NSU Press) p 234
[10] Perelman A I and Kasimov N S 1999 Geochemistry of the Landscape (Moscow: MSU Press) p 768