Ecological and geochemical features of the landscapes of the Baikal State Natural Biosphere Reserve

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Abstract. The aim of the study is a comprehensive assessment of the state of natural-territorial complexes of the Baikal State Natural Biosphere Reserve, including an ecological and geochemical assessment of soils, analysis of plant communities, determination of the ecological and biogeochemical features of the vegetation of the area. The distribution of mobile forms of heavy metals in the soils of the Baikal Biosphere Reserve has been studied. The coefficient of total soil pollution has been calculated. The maximum allowable concentrations exceedances for Cr, Mn, Cu and Pb were registered. Analysis of the microelement composition of the crust of *Pinus sibirica* showed the accumulation of Cd and Ni in relation to the Dobrovolsky clarke in all the studied areas of the reserve. Based on the studies carried out, it can be recommended to monitor the ecological state of natural territorial complexes on a regular basis on the territory of the Baikal State Biosphere Reserve.

1. Introduction
Lake Baikal, the largest freshwater body of water on the planet, and its coastal area are part of the UNESCO World Natural Heritage Sites. The territory of the Baikal Biosphere Reserve is located within the boundaries of its central ecological international protection zone. With a unique ecological system, a large number of endemic animals and plants, this region is able to withstand a certain anthropogenic load. Currently, there is a lot of scientific interest in this field. However, despite the special status for this territory, the sources of negative anthropogenic impact have not decreased. One of the main potential sources of pollution is the Irkutsk-Cheremkhovsky industrial complex. Additionally, there is a direct recreational impact on the buffer zone of the reserve.

The aim of the study is a comprehensive assessment of the condition of the natural-territorial complexes of the Baikal State Natural Biosphere Reserve, including the ecological and geochemical assessment of soils, analysis of plant communities, determination of the ecological and biogeochemical characteristics of the vegetation of the territory.

2. Models and Methods
The field research took place in August 2019 in the Republic of Buryatia, on the territory of the Baikalsky Nature Reserve and in the city of Baikalsk (Irkutsk Region). For the ecological and geochemical characteristics of the soils, four geocological profiles were laid, in different terrain areas with different soil types, so that the migration of heavy metal (HM) fluxes in the landscape can be traced. Six soil sections with a depth of 47 to 150 cm were laid. To identify biogeochemical indicators of the technogenic transformation of heavy metal fluxes, 29 soil samples were taken.
Determination of mobile forms of heavy metals was carried out at the Resource Centre of St. Petersburg State University by atomic emission spectroscopy using an acetate-ammonium buffer (pH 4.8).  

Profile 1 was laid 3.3 km east of the recreation centre of the Baikalsky nature reserve. In the middle and lower parts of the terrace of the Vydrina River, two soil profiles were laid: the soils are represented by sod-podzolized brown soils on loamy alluvial deposits in the lower part of the slope and typical burozem (brown earth) on loamy eluvial-deluvial deposits in the middle part of the slope.

Profile 2 was laid 3.3 km to the east of the Baikal Nature Reserve’ Office, next to the trail “Into the jungle of Khamar-Daban”. The profile runs along the lower part of the northern macroslope of the Khamar-Daban ridge in the valley of the Osnovka river. The profile contains one soil profile, represented by typical mountain burozem on colluvial deposits.

Profile 3 was laid 800 meters from the Office of the Baikal Nature Reserve. Three soil transects were laid on the profile: at the top of a gently sloping plain, on the slope of the river terrace, and also in the middle of the slope of the river terrace on the ledge.

Analysis of the state and dynamics of vegetation was carried out on the territory of the buffer zone of the reserve, in three areas with different levels of anthropogenic impact. At each site, several reference sites were identified, referring to various landscapes. All sites were located on the northern macroslope of the Khamar-Daban ridge in the dark coniferous mountain taiga. On each site 20x25 m, a detailed description of the phytocenosis was carried out, the characteristics of the soils, the characteristics of the anthropogenic impact on the site and the level of disturbance of the landscapes were given.

For the analysis of the biogeochemical features of the vegetation of the territory, a species of woody vegetation, widely represented in the region, was chosen – the cedar pine *Pinus sibirica*. Pine bark sampling was carried out at each reference site. Samples were taken from 8-10 trees of the same age at a height of 1.2 m from the entire circumference of the trunk after preliminary cleaning of the surface from lichens.

Throughout the history of the existence of the Baikal Biosphere Reserve (51 years), many studies have been carried out on its territory in various scientific fields. A lot of works are devoted to plant communities and flora of the region [1-5].

The flora of the reserve is typical for the mountains of Southern Siberia and includes more than 840 species of higher vascular plants. The overwhelming majority of species belong to the boreal ecological-geographical group. Most of the territory of the reserve, more than 60%, is occupied by the forest belt. For the study area, the indigenous dominant forests are cedar and cedar-pine. No published data on the microelement composition of the reserve’s plants were found.

As for the research of soils, the main research in this area is represented by the works of O D Ermakova, Ts Kh Tsybzhitov, V I Ubogunova, O A Proydakova, N B Sanina. Research by O D Ermakova reveal the main features of the formation and distribution of burozems over the territory of the reserve [6-8]. Ts Kh Tsybzhitov and V I Ubogunova indicate the diversity of the soils of the reserve, their structure and morphological features [9]. N B Sanina and O A Proydakova in their work [10] conclude that in terms of the content of the main microelements, the brown mountain-forest and alluvial-soddy soils of the Baikal Biosphere Reserve are similar to the soils of the eastern and western framing of Lake Baikal.

3. Results and Discussion

As a result of the study, the concentrations of mobile forms of heavy metals were measured in the following range: Fe – 18-1,900 mg/kg, Cr – 0.3-40.8 mg/kg, Cu – 0.23-98 mg/kg, Co – 0.4-1.7 mg/kg, Cd – 0.04-0.1 mg/kg, Ni – 0.02-1.32 mg/kg, Pb – 0.02-9.43 mg/kg, Zn – 0.1-9.8 mg/kg, Mn – 1.6-276.5 mg/kg. The exceedance of maximum allowable concentrations for some microelements were registered: in 13 samples – 6 mg/kg for Cr, in 5 samples – 60 mg/kg for Mn, in 1 sample – 3 mg/kg for Cu, in 1 sample – 6 mg/kg for Pb. Presumably, they are associated with sources of local pollution (roads, power lines, anthropogenic activities on the territory of the reserve, railways, boilers of private houses, etc.).

The index of total soil contamination $Zc$ on the studied territories does not exceed 16, which corresponds to the permissible category of soil contamination according to the assessment scale of soil
contamination hazard. To indicate the impact of a possible negative impact of industrial enterprises in the city of Baikalsk or the Irkutsk-Cheremkhovsky industrial complex, additional research is required.

Analysis of plant communities in the forest belt of the Khamar-Daban ridge showed that the most common in this area are cedar forests with different proportions of fir. At the same time, the dominance of fir-cedar blueberry, fir-cedar reed and fir-cedar dwarf shrub-green moss communities was noted [11]. For all communities, there is a different degree of regeneration of tree species after anthropogenic disturbances. The best restoration of native vegetation occurs in fir-cedar shrub-green moss communities. However, on some plots, a change of dominants in the forest stand with an increase in the proportion of fir is noted. A clear link between changes in the composition of plant communities and the existing anthropogenic impact has not been found.

Analysis of the microelement composition of the bark of *Pinus sibirica* showed the accumulation of Cd and Ni in relation to the Dobrovolsky clarke in all the studied areas of the reserve. At the same time, the performed studies of the microelement composition of the soils of the territory do not allow us to consider them as the source of these elements entering the plants. Presumably, the source of both Cd and Ni is the atmospheric transport of pollutants from the Irkutsk-Cheremkhovsky industrial complex, but this requires additional research.

4. Conclusion
Based on the studies carried out, it can be recommended to monitor the ecological state of natural-territorial complexes of the Baikal State Biosphere Reserve on a regular basis.

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