Ecological state of the soil cover of coal deposits in the Republic of Tyva

A D Sambuu¹, A M Mezhekey¹, A O Okculuk¹ and A K-Kh Dadar²

¹ Tuvan Institute for exploration of natural resources SB RAS, Internacionalnaja str., Kyzyl, Republic of Tyva, 667007, Russian Federation
² Tyvan State University, Lenina str., 36, Kyzyl, Republic of Tyva, 667000, Russian Federation

E-mail: sambuu.anna2012@yandex.ru

Abstract. The article deals with the ecological state of the soil cover of the currently actively developed coal deposits, which are located in the steppe zone of the Central Tuva Basin. Two of them – Kaa-Khem and Chadan – mining is carried out in an open way for more than 50 years, resulting in the formation of quarries and extensive waste rock dump fields. The third field – Mezhegey – has been producing by mine method since 2013. It was revealed that in the areas where open-pit mining is carried out, the maximum concentration of Zn, As, Ni in the eastern and south-eastern parts of the fields, soil contamination by Ni and As was also established. The presented materials can be used to manage the state of the environment and optimize the use of natural resources in the areas of activity of mining enterprises, which will help to reduce the anthropogenic impact on the ecosystems of the dry-steppe region.

1. Introduction
Mining on the territory of Tuva has not a long history. Coal bearing in Tuva is mainly associated with the Jurassic deposits of the Ulugh-Khem coal basin, confined to the flat and shallow foothills and the bottom of the vast Central Tuva basin. Coals are of industrial importance, they have been known since 1883, from 1951 to 1970. The main volume of coal production in Tuva was carried out at the deposit near the village. Ust'-Elegest. In total, from the beginning of the development of coal deposits until 1970, at least 1 million tons were produced. tons of coal, extraction from the subsurface occurred from underground mine workings. Therefore, the volume of extracted coal-free rocks was insignificant, their dumps occupied small areas, thus not causing significant damage to the natural environment.

With the launch of the Chadan coal mine in 1964 and the Kaa-Khem mine near Kyzyl in 1970, the impact of coal mining on the natural environment increased significantly. Quarry mining involves the opening and movement of huge volumes of rocks located above the planned extraction of raw materials. Overburden rocks are stored in dumps, which usually occupy large areas of natural areas near quarries.

2. Materials and methods
The object of the study is the soil cover within the License areas of the Kaa-Khem and Chadan coal deposits in the Republic of Tyva.
The research was conducted in the period 2018–2020. The methodology for carrying out the ecological state of the soil cover is determined by the documents regulating the conduct of similar works on the territory of the Russian Federation. The ecological state in the area of Tuva coal deposits was carried out by testing soil samples on monitoring sites that are located on various elements of the landscape. Methods for determining the physical and chemical properties of soils are generally accepted using the "Recommendations for assessing the ecological state of soils as a component of the environment", 2004, "Guidelines for assessing pollution of environmental objects with chemicals and control methods", 1995, in accordance with the regulation "On Land Monitoring in the Russian Federation "of 15.07.1992. Chemical analyses of soil samples were carried out in an accredited laboratory of the Federal State Administration of Agrochemical Service "Tuvan" (Cd, Pb, Ni, Zn, Cu, Hg, As, Co, Fe, Mn) was determined.

3. Results
The soils of the coal deposits of Tuva were formed under the conditions of a sharply continental climate (low precipitation, higher annual temperature amplitudes), richness of the underlying rocks, the predominance of flat hilly area, where steppe landscapes with xeromorphic steppe natural vegetation and sagebrush-cereal deposits dominate. The relief of the deposit area is low-mountain, poorly divided with absolute marks of 750–950 m, relative elevations from 10 to 70 m and steepness of slopes – 5–10°.

In the geological structure, the substrate of dumps represents Jurassic coal-bearing deposits of Paleozoic rocks with a thickness of 1500 m on older lower carboniferous formations. The Quaternary system is represented by eluvial-deluvial deposits of plate-like fragments of sandstones and siltstones. Deluvial deposits are widespread, and are represented by sandy loams (60–65%) and fragments of sandstones and siltstones with a thickness of 0.5–5 m. Sediments and rocks are non-toxic.

The soil cover of coal deposits is characterized by a small variety, which is due to a complex of climatic, geomorphological, edaphic, and hydrological factors. The main background of the soil cover is formed by chestnut soils – low-power on sloping slopes, medium-thick – in saddles and on flat places. Varieties of sandy loam of mechanical composition predominate, gravelly variants are widely distributed. Significant areas are occupied by eluvial sands. Most of them are covered with grassy vegetation, under which sandy chestnut soils with a fairly developed humus horizon are formed. In some places, the sands are strongly fluttering, forming small-bumpy and ridge-bumpy areas, almost devoid of vegetation.

When studying the soils of the coal deposits of Tuva, the "Classification and diagnostics of the soils of Russia" was adopted as a basis, according to which the soils of the studied territory belong to the dry-steppe zone of dark chestnut and chestnut soils. According to the soil-geographical zoning of B. F. Petrov and K. A. Ufimtseva, the soils of the study area belong to the Altai-Sayan mountain soil province. According to the scheme of soil zoning of the Tuva ASSR, the soils of the Tuva Basin belong to the South Altai-Tuva-Khangai basin-mountain province of the steppe zone. According to the totality of landscape features, the province is also divided into a number of natural districts, within which soil-geographical areas are allocated. Thus, the research area is included in the Kyzyl dry-steppe region of the Central Tuva basin steppe and dry-steppe district.

The results of chemical analysis of soils for the content of heavy metals in the area of the Kaa-Khem and Chadan coal deposits show that the content of trace elements in the studied area varies widely, due to the complex structure of the soil cover, a large variety of mountain and soil-forming rocks, and their initial lithochemical contrast (table 1). Analytical studies of the content of elements in the soils of Tuva coal deposits indicate the presence of Cd, Pb, Hg, Co, Cu, Mn, Zn, Fe in quantities below their maximum permissible concentrations (MPC and APC for sandy loam and sandy soils), i.e. in the studied area these elements characterize the natural (background) state of the soil cover. The average values of gross concentrations of elements are close to the established average values for Tuva soils. A slight excess was found for cadmium,
while in light loamy soils the concentration decreases gradually down the profile. In sandy soils, some accumulation of cadmium was observed at the boundary of the carbonate horizon.

### Table 1. Gross concentrations of trace elements in soils in the area of the Kaa-Khem (K-KH) and Chadan (ChD) deposits (mg/kg).

| Plots     | Cd  | Pb  | Ni  | Zn  | Cu  | Hg  | As  | Mn  | Co | Fe  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|----|-----|
| K-KH 2-3  | 0.38| 19.30| 23.4| 39.4| 25.0| 0.032| 3.41| 255 | 14.1| 20 974 |
| ChD 3-3   | 0.43| 12.80| 26.7| 36.7| 13.0| 0.031| 3.32| 335 | 10.0| 20 616 |
| ChD 4-5   | 0.42| 12.70| 25.1| 40.2| 19.0| 0.031| 3.00| 316 | 11.6| 20 328 |
| K-KH 4-6  | 0.25| 6.65 | 26.2| 42.8| 9.2 | 0.034| 3.11| 328 | 5.07| 24 702 |
| CD 5-2    | 0.21| 9.25 | 25.2| 40.6| 11.2| 0.036| 3.00| 323 | 6.50| 13 884 |
| K-KH 6-2  | 0.20| 12.80| 23.4| 38.9| 17.0| 0.030| 3.72| 373 | 11.2| 21 031 |
| CD 6-3    | 0.15| 10.20| 22.0| 40.6| 12.3| 0.032| 3.67| 252 | 9.20| 13 347 |
| CD 6-5    | 0.18| 12.10| 21.9| 38.0| 19.0| 0.032| 3.54| 331 | 11.5| 14 040 |
| CD 7-2    | 0.19| 9.86 | 29.1| 39.4| 11.8| 0.032| 3.86| 372 | 11.5| 14 031 |
| CD 7-4    | 0.16| 8.80 | 26.3| 42.5| 10.3| 0.030| 3.92| 241 | 7.30| 136 233 |
| K-KH 8-5  | 0.29| 9.33 | 32.3| 46.4| 11.1| 0.031| 4.67| 246 | 7.10| 15 743 |
| K-KH 9-2  | 0.26| 11.20| 39.2| 47.9| 25.3| 0.028| 3.33| 279 | 8.00| 15 674 |
| K-KH 11-3 | 0.48| 19.20| 26.6| 39.6| 24.6| 0.036| 2.00| 196 | 15.0| 21 791 |
| K-KH 11-5 | 0.36| 17.80| 29.8| 37.0| 22.5| 0.034| 3.85| 370 | 15.7| 16 923 |
| **Max**   | 0.43| 19.30| 39.2| 47.9| 25.3| 0.036| 4.67| 373 | 15.7| 136233 |
| **Min**   | 0.15| 6.65 | 21.9| 36.7| 9.2 | 0.028| 2.00| 196 | 5.07| 13347 |
| **Mid**   | 0.29| 1.97 | 30.6| 42.3| 17.3| 0.032| 3.33| 285 | 10.38| 74790 |
| **MPC**1  | 0.5 | 32   | 85  | 100 | 55  | 2.1  | 2   | 1500 | x   | 27533 |
| The Dutch list2 | 0.8 | 85  | 35  | 140 | 36  | 0.3  | 29  | x   | 20  | x   |
| APK для sandy loam and sandy soils3 | 0.5 | 32  | 20  | 55  | 33  | x   | 2   | x   | x   | x   |
| APK for acidic loamy soils3 (ph>5.5) | 1   | 65  | 40  | 110 | 66  | x   | 5   | x   | x   | x   |
| APK for neutral loamy soils3 (ph>5.5) | 2   | 130 | 80  | 220 | 132 | x   | 10  | x   | x   | x   |
| The average content in the soils of Tuva4 | x   | 16  | x   | 51.7| 20.5| 0.08 | x   | 560 | 9.7 | x   |
| The average content in the soils of Russia4 | x   | 40  | 24  | 35  | x   | x   | 3.6 | 475 | 12-28| x   |
| Clark in the Soils of the World5 | 0.5 | 10  | 40  | 50  | 20  | 0.12 | 5-7.8| 850 | 8   | x   |
| Clark in the Earth's crust5 | 0.16 | 13-16| 58  | 83  | 47  | 0.08 | 1.7  | 1000| 18  | x   |

Note that: 1 – FN 2.1.7.2041-06. Maximum permissible concentrations (MPC) of chemicals in soil; 2 – [http://www.contaminatedjand.co.uk/std-guid/dutch-l.htm](http://www.contaminatedjand.co.uk/std-guid/dutch-l.htm); 3 – FN 2.1.7.2511-09. Approximate permissible concentrations (APC) of chemicals in soil; 4 – Puzanov, Malgin, 1990; 5 – Alekseev, 1987; Bolshakov, 2002; Vinogradov, 1975; Vodyanitsky, 2008; x – no data available.
Exceeding the MPC for As may be due to regional characteristics of the background content of this element. Soil contamination of the Kaa-Khem and Chadan coal deposits by Ni and As is clearly observed (figures 1–4).

4. Conclusion
The results obtained in the course of the study give reason to believe that the soil cover of Tuva adjacent to the coal deposits, as well as the territories located in the zone of indirect influence, are affected by different degrees of severity. Performing the functions of geochemical barriers and having the ability to extract heavy metals from landscape cycles, soils are one of the main indicators of the well-being of the territory. At the same time, these functions and abilities are preserved only up to a
certain level of concentration of incoming toxic elements, after which the soil ceases to function
normally. The conducted research, of course, is not enough to clarify the environmental situation on
the territory of coal deposits. Special attention should be paid to the soils formed on the surface of
dumps, since they are the basis for recultivation of disturbed areas and their involvement in the
landscape.

Further exploitation of coal deposits, expansion of quarry areas will lead to an increase in the area
of impact of enterprises on the surrounding landscapes, and therefore it is necessary to organize
constant monitoring of soil and vegetation cover.

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