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# Features of the Distribution of Manganese in Soils of the Prichulym Taiga in Tomsk Region During Forest Logging

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**Abstract.** In the course of the summer expedition, soil samples were taken from the upper, the most 'active' for migration and pollution by chemical elements, horizon in the taiga zone of Zyranskiy district, Tomsk region. Soils were sampled in two plots: in a typical taiga forest and in the area after selective logging carried out six years ago. The selected soil samples were analyzed for the presence and total content of manganese. As a result of statistical data processing, the average value of the content of this element was obtained. Changes in the species composition of vegetation in the logged area could affect the redistribution of the considered chemical element in the soil. For a complete picture of the deposition and the reasons for possible migration of manganese in the upper layer of the soil horizon, the acid-base conditions and the organic component (humus) were additionally determined in the soil samples. The global indicators of the world's soils – clarke values – were used as standards to compare with the average values of the manganese content in soil. The obtained average values of manganese in the upper horizon of soils in the studied areas were compared with respect to the data on the content of manganese in soils of the taiga forest zone of Eurasia. The southeast of Tomsk region is included in this zone. Based on the ecological and geochemical analysis, the reasons for the change in the content of manganese and the degree of its dangerous impact have been revealed. This characteristic made it possible to interpret the data obtained on the manganese content in the soil of the study areas, as well as to assess the state of the environment after anthropogenic transformation and other possible factors.

## 1. Introduction

The distribution of manganese in the soil layer is very heterogeneous; it can accumulate in different soil horizons. However, this element usually accumulates in the upper soil layer due to fixation with organic matter, being its component [1]. The quantitative content of manganese in soils depends on the respond of the environment, redox potential, biological characteristics (species composition of vegetation), moisture conditions, etc. [2]. Large-scale deforestation significantly changes not only the appearance of the territory devastating taiga open spaces. The systematic logging of woody vegetation causes a change (violation) in the hydrological regime (in some cases, there is a tendency to waterlogging) [3] and in the temperature regime of the area. During compaction and waterlogging, soils are poorly drained and therefore, they typically contain an excess amount of manganese [4]. In this regard, the mobility of this element decreases. These processes contribute to accumulation of manganese in the upper soil horizon [5].



Analysis of the samples shows that in the study areas of the Zyryansk forestry, which have undergone anthropogenic transformation, the content of manganese changed. Manganese is included in the category of chemicals of the third hazard class. Therefore, quantitative content of manganese in the study area should be determined and its hazardous impact on the natural environment should be assessed.

The aim of the study is to determine the content of manganese in soils and to assess the degree of its harmful effect during deforestation in the Prichulym taiga, Tomsk region.

## 2. Study area

Tomsk Region, part of the Siberian Federal District, is located within 56–61° N and 75–89° W. The region extends 600 km north to south and 780 km west to east. The total area of Tomsk region is 314,4 thousand km<sup>2</sup>. The distance along the Ob River between the extreme points of Tomsk region from north to south is 1065 km [6]. The study areas of the Prichulym taiga geographically belong to Zyryanskiy district located in the southeastern part of Tomsk region (Fig. 1).



**Figure 1.** Administrative division of Tomsk region. Legends: ▨ Siberian Federal District on the map of Russia; → indicator of the location of Tomsk region as part of the Siberian Federal District; ● Zyryanskiy district.

## 3. Materials and methods

The object of the study is gray forest soils sampled in two plots: in a typical taiga forest with 'background' soils (plot 1) and in the area after logging (undergone anthropogenic transformation) (plot 2) carried out in 2012. Soil samples were taken in August 2018. Sampling was performed in accordance with the requirements of GOST 17.4.3.01-83. The samples were taken from the upper soil horizon 0-20 cm deep. The collected material was analyzed at the collective use center Analytical Center for Geochemistry of Natural Systems (CUC ACGNS), Tomsk State University. It was used by inductively coupled plasma mass spectrometry (ICP-MS), which allows the determination of a wide range of chemical elements at a microlevel. The soils were analyzed for the content of manganese, its gross trace element composition. This analysis was carried out by the engineers of CUC ACGNS

using an Agilent 7500cx instrument, Agilent Technologies. Laboratory studies of soils were performed in May 2019. Statistical processing of the obtained data was performed using Statistica 6.0 software and MS Excel 2010. Global indices of the world's soils were used as standards for comparison with the mean values of the concentrations of the studied microelement. The average values provided by other scientists defined as acceptable Clarke values for manganese were also used. As mentioned above, the acid-base medium and the organic component are critical for accumulation and fixation of some chemical elements in the upper soil layer. The acid-base conditions (pH) were determined, and the average value of the total humus content in the soil was calculated. Determination was fulfilled in accordance with GOST 26213-91 in the laboratory of the Institute of Biology, Ecology, Soil Science, Agriculture and Forestry, Tomsk State University.

#### **4. Results and discussion**

The content and distribution of manganese in soils is characterized by great diversity, which is its main distinctive feature. Differences in the manganese content in regional soils are due to unequal climatic conditions, a variety of vegetation, soil formation conditions, and the granulometric and mineralogical composition of the parent rocks [4]. The study was conducted in the forest fund of Zyryanskiy district leased for logging.

##### *4.1 Characteristics of the landscape zone of the study area*

According to geobotanical zoning, the territory of Prichulym region belongs to the Eurasian coniferous-forest (taiga) region of the European-Siberian subregion of dark coniferous forests. The southern subzone of the taiga, covering the basins of the Chulym and other rivers, features a more diverse vegetation cover. It is characterized by the presence of dark coniferous and mixed forests with a predominance of fir. At present, in this part of the Pozdona, a larger area is covered by secondary derivative birch and birch-aspen stands rather than dark coniferous forests [7]. By the order of Rosleskhos *On approval of the List of forest growing zones of the Russian Federation and the List of forest regions of the Russian Federation* dated 09.03.2011, No. 61 [8], the territory of Zyryanskiy district is assigned to the West Siberian southern taiga plain region in the taiga forest zone, featuring zonal forest cover, flora and fauna of landscapes of the southern taiga zone of Tomsk region.

##### *4.2 Features of the relief and soil and vegetation cover*

Geomorphologically, the area is confined to the third above-floodplain terrace of the Chulym River. The terrace is mainly composed of fine-grained yellow-gray and gray sands with interlayers of loam, sandy loam, clay, silt; there are interlayers and lenses of buried peat bogs. Sands are yellow-gray, gray, fine-grained, silty, feldspar-quartz, weakly micaceous. The most common are gray forest and podzolic soils [9]. There are soddy-podzolic soils that are formed under mixed coniferous-deciduous and pine forests, as well as under secondary birch-aspen forests. Light gray and gray forest soils are predominant in the structure of the soil cover of the study areas. In the study area, forest woody vegetation is represented by wide distribution of secondary birch-aspen plantations with a rare interspersing of pine. The botanical characteristics of the species composition of stands in both plots are similar. In both plots, the forest formula is 4B6Oc + C. Hence, it follows that pine stands are less common in the study area than birch-aspen stands.

##### *4.3 Results of the study of soils in the Prichulym taiga for manganese content*

In the study areas of the taiga zone in Zyryanskiy district, the minimum content of total manganese was 679,5 mg/kg for soil samples taken in the plot with soils covered by typical taiga vegetation assumed as the background. The maximum value of the total manganese content up to 1060,9 mg/kg (Table 1) was observed in the plot after logging of woody vegetation. The average manganese content in soils is characterized by Clarke values of 850 mg/kg [10] and 1000 mg/kg [11]. In contrast to the northern part of the Vasyugan plain, where the manganese content in the soil ranges from 1300 to 1700 mg/kg, in the Eurasian coniferous-forest (taiga) region of the European-Siberian subregion, the

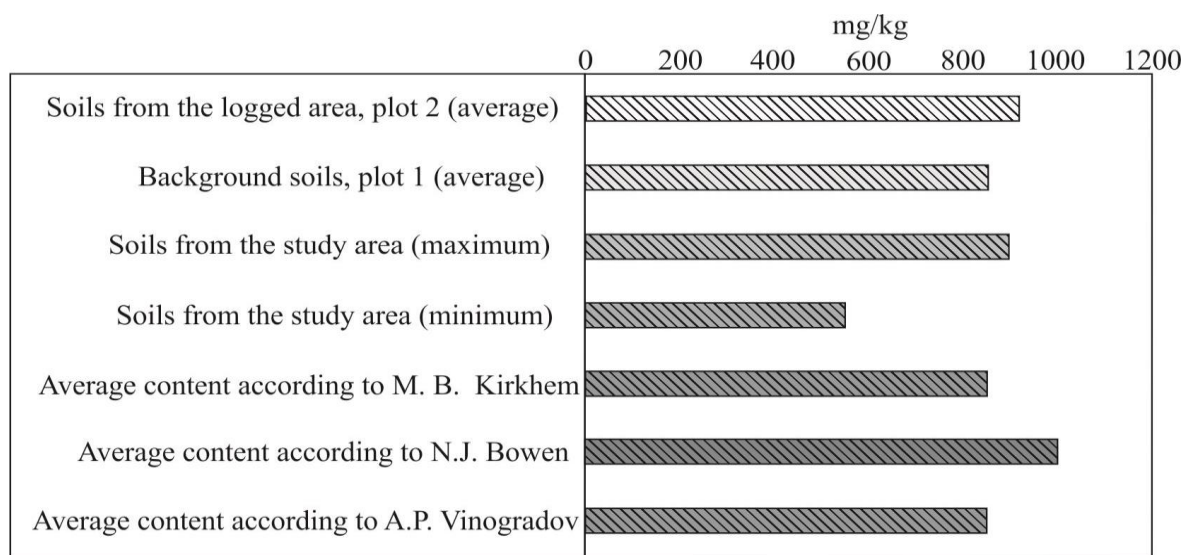
content of this element in the study area in the southern taiga plain is close to the average of 550–900 mg/kg [12]. To assess the risk manganese can pose to the soil cover, the average manganese content in plot 1 and plot 2 was compared with the standards taken as the average permissible content of the element proposed by different researchers. The obtained data showed that the manganese content in the studied soil samples according to A.P. Vinogradov [10], M.B. Kirkham [13] and with respect to the world's soils [11] is characterized by permissible limits in terms of their clarke values. In comparison with the soils referred to the study area, the average value of the manganese content corresponds to the permissible limits (Tabl. 1).

**Table 1.** Comparison of the total manganese content in the soils of Zyryanskiy region with the permissible limits determined by different authors (g/t).

Element	Clarke according to A.P. Vinogradov [10]	Soils of the world according to N.J. Bowen [11]	Soils referred to the study area [12]	The average content of elements in soils according to M.B. Kirkhem [13]	Forest soils, Plot 1	Soils from the logged area, Plot 2
Mn	850	850	1000	550–900	$\frac{899,3 \pm 30}{679,5-921,3}$	$\frac{905,9 \pm 30}{809,7-1060,9}$

Note: in fractions above the line – average content ( $\pm$ error); under the line – fluctuation limits (minimum and maximum values).

Comparison of indicators of the total manganese content in the study areas with the maximum permissible values determined by the above authors is presented in Figure 2.



**Figure 2.** Comparison of the content of total manganese in the study plots with the maximum permissible values proposed by different authors.

The acid-alkaline environment and the organic component play a key role in deposition of some chemical elements in the upper soil layer. For a complete picture, the total content of humus and soil pH was determined (Tabl. 2).

**Table 2.** The content of total humus and pH in soils of Zyryanskiy district.

Soil	pH	humus %
Plot 1 (forest soils)	5.46	3.96
Plot 2 (soils from the logged area)	5.78	5.58

Thus, the data in Table 2 show that the soil acidity in plot 2 remained practically unchanged (changed minimally). The increase in the manganese content in the plot after logging could be caused by soil compaction and decreased mobility of the element. An insignificant increase in the total humus could be due to the formed leaf litter, decomposed root systems of felled trees, and overgrowth of the area with tall grasses. Over a six-year period, woody vegetation has partially taken the original form of a secondary birch-aspen forest, with predominance of young aspen growth.

## 5. Conclusion

The topic under study is of high relevance since it provides assessment of the ecological picture of the state of forests undergone anthropogenic transformation. The result of the study showed that the content of manganese in soils of the Prichulym taiga in Tomsk region does not pose any environmental hazard. Various types of soils in Zyryanskiy district require additional data on geochemical characteristics of the soil cover in the adjacent areas. These data should be used for comparison when monitoring soil pollution in neighboring areas. Such measures should be taken to preserve a favorable ecological situation in the forests of the forest fund in the regions [14]. Currently, the authors are analyzing soil samples for the content of heavy metals and other toxic chemical elements collected in the study area.

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