Transformation of Ecofunctional Parameters of Soil Microbial Cenoses in Clearings for Power Transmission Lines in Central Siberia

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Abstract—Changes in soil microbial processes and phytocenotic parameters were studied in clearings made for power transmission lines in the subtaiga and southern taiga of Central Siberia. In these clearings, secondary meadow communities play the main environmental role. The substitution of meadow vegetation for forest vegetation, the increase in the phytomass by 40–120%, and the transformation of the hydrothermic regime in the clearings led to the intensification of the humus-accumulative process, growth of the humus content, reduction in acidity and oligotrophy of the upper horizons in the gray soils of the meadow communities, and more active microbial mineralization of organic matter. In the humus horizon of the soils under meadows, the microbial biomass (Cmicr) increased by 20–90%, and the intensity of basal respiration became higher by 60–90%. The values of the microbial metabolic quotient were also higher in these soils than in the soils under the native forests. In the 0- to 50-cm layer of the gray soils under the meadows, the total Cmicr reserves were 35–45% greater and amounted to 230–320 g/m²; the total microbial production of CO₂ was 1.5–2 times higher than that in the soil of the adjacent forest and reached 770–840 mg CO₂-C/m³ h. The predominance of mineralization processes in the soils under meadows in the clearings reflected changes in edaphic and trophic conditions of the soils and testified to an active inclusion of the herb fallow into the biological cycle.

Keywords: meadow communities, gray soils (Luvic Retic Someric Phaeozems), structure of ecological and trophic microbial groups, carbon of microbial biomass, basal respiration, microbial metabolic quotient
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INTRODUCTION

Construction and operation of linear engineering facilities (power transmission lines, PTLs) is a permanent technogenic factor that disturbs natural processes for a long period. Linear constructions greatly increase the fragmentation of forests and create intrazonal habitats, not typical for the surrounding area. From the 1960s, in Russia, forests were cut for power transmission lines in the area of 25 thousand ha. At present, only in Krasnoyarsk region, more than 4000 ha of land are under transmission towers, overhead power lines, and electric substations. At the present level of industrial development and construction of power stations, the number of the power transmission lines will inevitably increase [13].

Laying of power lines, clear cutting of forest with tree logging, poling, and wire tension are accompanied by the restructuring of forest biogeocenoses. The soil cover of the clearings for power lines is affected during the construction and for the whole period of the PTL operation, as the clearings are periodically cut to maintain them as open space.

The main factors affecting the biocenosis of the PTL clearing are nonspecific (civil and operating economic activities) and specific arising in the work of the transmission lines (electromagnetic field (EMF), acoustic noise, and air ionization) [19, 23, 32]. Available results on the influence of EMF on the biological activity of soils are contradictory. In the steppe zone of the central Volga River basin, in the soil of the spring wheat field made directly under transmission line PTL-110 kV, the total number of bacteria and actinomycetes significantly increased. There, the values of dehydrogenase and peroxidase activities were very high, and the invertase activity of the typical chernozem was reduced [26]. In the soil of the areas under wires of the PTL, the humus and phosphorus contents became higher with increasing the distance from the radiation source. On the contrary, the catalase activity of the soil in Izmailovsky forest-park decreased when approaching the PTL [34].

The model experiments [10] showed that EMF of 800 W suppressed the microflora in the soils of different genesis and with different properties [10]. The tolerance of different microorganisms to EMF depends on the soil type and the time of its influence. The most resistance to irradiation were bacteria of the Azoto bacter genus [12]. Soil enzymes compared to microorganisms are more resistant to EMF. The complex
assessments of affecting EMF on soils is expedient to conduct using the integral index for their biological state [11].

Plekhanov and Kartashev showed that the influence of EMF on the vegetation and soil fauna when operating PTL was insignificant and overlapped by the effect of natural and nonspecific factors [19, 23, 24]. Among the factors affecting the soil and plant covers and determining the anthropogenic transformation of territories under power transmission lines, the nonspecific factor related to their construction and operation is the leading one.

The research of Zakharchenko [15, 16] for 20 years after the construction of a PTL in the southern part of the West-Siberian Plain (Kemerovo oblast) showed that a wide range of species from different ecological groups characterized the plant communities there. This reflected the high differentiation of environmental conditions in the clearing, which presented an unstable and unbalanced technogenically transformed ecosystem. Significant mechanical disturbance of the soil cover in the clearings made for PTL was observed near and under the transmission towers, as well as on maintenance roads. In clearings, the humus-accumulative soil horizon was partly compacted and destroyed, and many trucks of machines used for constructing the power lines were found. The morphological and physicochemical properties of the anthropogenically transformed soils begin to change immediately after the termination of acting the non-specific factor (economic operating activities) [19, 24]. When passing from the forest to the clearing, the thickness of the humus-accumulative horizon increased for 15 years due to roots of developing forest–meadow plants in successions. The formation of anthropogenically transformed soils under PTL proceeds according to the (humus-accumulative soddy) type with the of humus and increase in the absorption capacity of soil and sum of exchangeable bases [15].

The transformation of phytocenoses, of hydrothermal and trophic soil conditions, when the forest vegetation is replaced by the meadow one, is reflected in the soil microbial community, which being a polyfunctional body, serves as an indicator of soil processes since it is highly sensitive to the changes in the environment [2, 17, 35].

Wide clearings for PTL, whose effect is higher than that of the marginal forest one, create unique possibilities to study the response of biocenosis to the removal of tree layer, as well as the rates of soil formation, adaptation of the forest cover and formation of the meadow cover, and changes in the microbial complex as an indicator of the soil biological activity.

The purpose of this research is to study the transformation of ecological and functional parameters of the microbial cenoses in the soils of native forests (pine and fir formations) after the appearance of meadow vegetation in clearings of power transmission lines.

**OBJECTS AND METHODS**

The geobotanic and soil investigations were carried out in a clearing with two parallel power transmission lines PTL—500 kV of 150–160 m wide arranged at the distance of 30 m from the forest. They were made in 1969 in an area of the southern dark coniferous taiga and pine subtaiga in the upper reaches of the Kacha River (Emel’yanovsky district, Krasnoyarsk region). According to the physical—geographical zoning [6], the region studied belongs to the zone of taiga and open woodlands, characteristic of the northern edge of the Altai–Sayan mountain ranges and representing the low mountains of the Eastern Sayan with small-leaved, light coniferous and dark coniferous forests. According to the vegetation zoning [30], the southern part of Krasnoyarsk region belongs to the Chulyms subtaiga in the western offshoots of the Eastern Sayan. This area is dominated by mixed forests composed of light coniferous (pine and larch) and small-leaved species (birch, aspen). To the northwest, in the stands, dark coniferous species (fir and Pinus sibirica) appear [30]. In the subtaiga, forb pine and birch stands predominate; the southern taiga is dominated by short-grass–green moss and derivative short-grass aspen forests.

The climate of the region is severely continental. The average annual precipitation is 470 mm; in some years, it varies from 320 to 630 mm. The total precipitation is 330 to 350 mm in the warm period, 110 to 120 mm in the cold one. The growing period lasts 144 days [1].

The studies were carried out in two PTL sections, where transects were arranged. The first transect crossed a derivative aspen–birch forest with fir in the second layer presenting the tallgrass forest type (T-aspen) of the dark coniferous southern taiga. The other transect was made through a tall–grass–reed grass forest (T-pine) of the light coniferous subtaiga. On each transect, the following areas differing in environmental conditions were chosen; (i) a reference forest stand, through which the clearing passed; (ii) under the power transmission lines in the central part between the towers, where the influence of electric field was the highest [32]; (iii) and in the central part of the clearing between the power transmission lines, where the effect of EMF was minimum (Table 1).

A geobotanical description of the ecotopes was made by the traditional method [25]. The number of species was determined on a model plot of 0.25 ha.

In the middle of the growing period, soil pits were made, their morphology was described [14], and soil samples were taken by genetic horizons (organic O, humus-accumulative AY, and mineral horizons: EL (AEL), BEL, and BT) to the depth of 50 cm in three replicates [22] The thickness of the horizons varied in different areas (Fig. 1). During sampling, the following measurements were made: soil moisture (using the thermal gravimetric method), temperature of soil layers (by a portable “Checktemp” thermome-