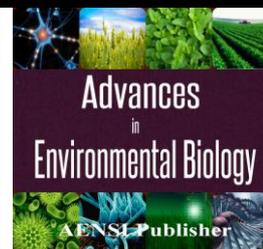




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Properties of Young Soils in Dumps of Diamond Mining in the Western Yakutia

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ABSTRACT

Researches have been conducted in the Western Yakutia in the territory of Mirninsky ore mining and processing enterprise which is a part of ALROSA air company (CJSC). The area of research is located in a subzone of the middle taiga, in the middle reach of Irelyakh river, the left-hand inflow of Small Botuobuya River (62°30' N, 114° E). From administrative perspective the objects of research are located in the Mirninsky area of the Republic of Sakha (Yakutia), in surroundings of Mirny city. Studying of the soil forming process at self-organized vegetation and reclamation according to various schemes has been conducted on uneven-age dumps of the overburden rocks consisted of marls, magnesian limes and limestones. These dumps represent accumulative forms of a neo terrain usually of a trapezoid form (single- or multilevel) with relatively leveled surface at their top. There were 2 basic groups of objects identified according to morphological features on the studied territories (the area of 2674 hectares, including horizontal – 1528 hectares, slope – 1136 hectares). The first group (A) is on dumps without reclamation (the area of 2590 hectares or 96% of the territory), the second group (B) is on reclaimed dumps (84 hectares or 3.2%). The second group is subdivided into 2 subgroups: the first of them (B1) is presented on slopes with incline of more than 35°, on horizontal surface in fragments, the second subgroup (B2) is presented on the horizontal surface and gentle slopes (to 35°), occupies tops and toes of dumps. 35 years later after dumping and simplified reclamation the soil-forming process was registered in a type of: a) forming of initial microbial community with high number of CFU, a low functional variety and no differentiation on a profile, b) increasing of ability of a substratum to support initial growth of test plants in vitro approximately for 30-40%. Because of weak processing of a dumps' mineral basis the classification of embryozems on standard physical and chemical criteria is complicated, their differentiation into classes is possible according to soil and microbiological criteria, into types according to comparative fertility of a substratum.

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INTRODUCTION

Effectiveness of restitution of disturbed ecosystems becomes now a global problem which determines stability of mankind existence [2]. At all variety of types of anthropogenous violations some soil and ecological knowledge is a basis for development of comprehensive programs of landscapes' restitution [10,18]. Thus structuring of this knowledge is impossible without reliable classification of young soils which are forming on disturbed territories. It should be noted that available classifications usually address practical questions of reclamation of disturbed lands and do not consider young soils on technogenic landscapes as developing systems [12,20,16]. A similar approach is presented in the last edition of classification of soils in Russia [5].

The other approach to classification of young soils recognizes that technogenically disrupted territories in a post-technogenic phase of their development should be considered as a peculiar natural landscape. Its anthropogeny should be considered as no more than starting specifics therefore when studying these landscapes it is necessary to use the same methods which are applied to studying of natural landscapes, it is necessary to approach to classification of embryozems from positions of classical genetic soil science. [14]. Informational content of such approach to classification of soils of technogenic landscapes was demonstrated in numerous studies on dumps of the coal industry in Western Siberia. [19]. Now development of the substantive genetic classification of young soils is on its initial stage. The data on its applicability for the soils which are forming on

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less favorable substrata is not sufficient. In particular, dumps after diamond mining can serve as an informative object in a zone of permafrost as an example of the most destructive impact on environment.

Work objective: to make an attempt to classify embryozems in dumps of the diamond-mining industry according to the profile and genetic classification of soils on technogenic landscapes. To compare informational content of various measure groups for achievement of the research objective.

MATERIALS AND METHODS

History and description of the research area: Industrial mining of diamonds in Yakutia has begun with "Mir" pipe operation in 1956. Now more than 99% of Russian diamonds which is 78% of world production are extracted in the territory of the Republic of Sakha (Yakutia). Open-pit mining with drilling and blasting and imperfect concentrating technologies caused radical destruction of initial ecosystems. Now dumps of dead pit rocks of pipes "Mir" and "Internatsionalnaya" occupy the territory with an area of 2674 hectares, 84 hectares or 3.2% of them are reclaimed. Feature of these dumps is in an adverse combination of the factors regulating process of young soils formation – high phytotoxicity of dump rocks and cryo-aridity of climate.

Researches were conducted during 2007-2012. The area is located in a subzone of the middle taiga, in the middle reach of Irelyakh river (62°30' N, 114° E). "Internatsionalniy" pit dumps are located in 16 km to the southwest of Mirny city. Open-pit mining here was held in 1971-1981. The body of dumps consists of sedimentary carbonaceous rocks of the Cambrian. "Mir" pit dumps are located on the western part of Mirny city. Open-pit mining here was held in 1959-1999. The body of dumps consists of Mesozoic and Paleozoic aleurolite and sandstones with pro-layers of conglomerates with impurity of clays and loams with considerable concentration of pyrite. About 35 years ago the part of dumps was reclaimed by leveling surface and coating a layer of loam with a width up to 2.5 m.

The research area is located in a zone of continuous extension of permafrost with a depth up to 412 m. Average annual air temperature is – 9.7°C, absolute minimum temperature is – 58°C, absolute maximal temperature is +32.6°C. Average annual rate of a precipitation is 346 mm at evaporability of 283 mm, snow cover holds up for 240-270 days [6]. Dumps without reclamation are still remaining without vegetable cover, reclaimed dumps are occupied with rare mixed culture of a larch and a birch, the vegetation is on a pioneer reduction stage.

On soil geographical zoning the territory belongs to the West Vilyuisky cespitose and carbonaceous heavy clay loam area of the Yakut East Siberian taiga and bottomland province. Zonal type is cryogenic cespitose and carbonaceous soils.

Research methods:

Soil samples were selected on layers in 10 cm, from open test pits and sections. Individual samples were analyzed (n=10-15). Total Organic Carbon was determined according to Tyurin, Total Nitrogen – according to Kjeldahl, phytotoxicity of soils – by biotesting on radish sprouts. Tests were carried out at a temperature of 20°C and soil humidity of 20%. CFU (colony-forming units) number was calculated in the medium of the following structure (g/l): dry medium of MRS agar – 0.3, peptone – 0.6, glucose – 0.1, invertase activity – according to Galstyan (1978). The functional range of a microbial complex was determined by method of multisubstrate testing (CLPP) (Garland, Mills, 1991). 24 substrata were used; activity of their utilization was estimated in points. Reliability of distinctions was estimated by results of an analysis of variance on Statsoft Statistica 6 software package.

Results:

There were 2 basic groups of objects identified according to morphological features on the research territories (the area of 2674 hectares, including horizontal – 1528 hectares, slope – 1136 hectares). The first group (A) is on dumps without reclamation (the area of 2590 hectares or 96% of the territory), the second group (B) is on reclaimed dumps (84 hectares or 3.2%). The second group is subdivided into 2 subgroups: the first of them (B1) is presented on slopes with incline of more than 35°, on horizontal surface in fragments, the second subgroup (B2) is presented on the horizontal surface and gentle slopes (to 35°), occupies tops and toes of dumps.

Only the horizon D (0-6 cm) stands out in the morphological structure of A substrata group's profile the dump body begins below. The vegetation practically is absent, some specimen of ruderal plants occur. The strong rockiness is noted. Some accumulation of loamy fine soils is observed on the surface and in spaces between stones. Environment reaction is low and highly alkaline (pH 8.1-8.5). Accumulation of organic matter is not observed. The high carbonate concentration (to 41%) is caused by properties of spreading rocks. Dependence of properties on direction of slope and position according to catena is not observed.

Representatives of group B are found only on reclaimed sites. Young soils of B1 subgroup are developed under weed and ruderal vegetation with a plant cover to 20%. Their main morphological feature is a lack of

biogenic horizon. The layer of 0-200 cm is not differentiated on the studied parameters, granulometric composition is loamy (the proportion of physical clay is 6-36%), a substratum is not condensed ($1-1.1 \text{ g/cm}^3$). Environment reaction is neutral (pH 6.9-7.6). Concentration of Total Organic Carbon is 0.11-0.66%, of Total Nitrogen is 0.01-0.04%. Concentration of exchange bases, moving forms of phosphorus and potassium is low. Salts and carbonates are absent in the profile.

Young soils of the B2 subgroup are found under grassy and wood vegetation. The grassy cover consists from the ruderal types with slight proportion of zonal cereals and beans with a plant cover from 60 to 100%. The soil profile is not differentiated, but not decomposed underlayer is accumulated on a surface which is a typodiagnostic feature. In a layer of 0-100 cm the mineral part of the profile is not differentiated. Granulometric composition of soils varies from friable sand to medium-textured loam (the proportion of physical clay is 3.5-39.3%), the substratum is condensed ($1.04-1.26 \text{ g/cm}^3$). Environment reaction is neutral. Concentration of Total Organic Carbon is 0.09-0.67%, of Total Nitrogen is 0.01-0.04%. In a layer of 0-10 cm some accumulation of Total Organic Carbon in comparison with initial rocks is revealed approximately for 0.25-0.52% at the top and toe of dumps. Concentration of exchange bases, moving forms of phosphorus and potassium is low. Salts are absent in the profile. The proportion of carbonates is slight.

Physical and chemical properties of the research objects:

Degree of transformation of the mineral part of substratum was estimated according to standard physical and chemical measures which apparently reflect the structure of rocks of initial and brought dumps, instead of results of the soil-forming process (fig. 1).

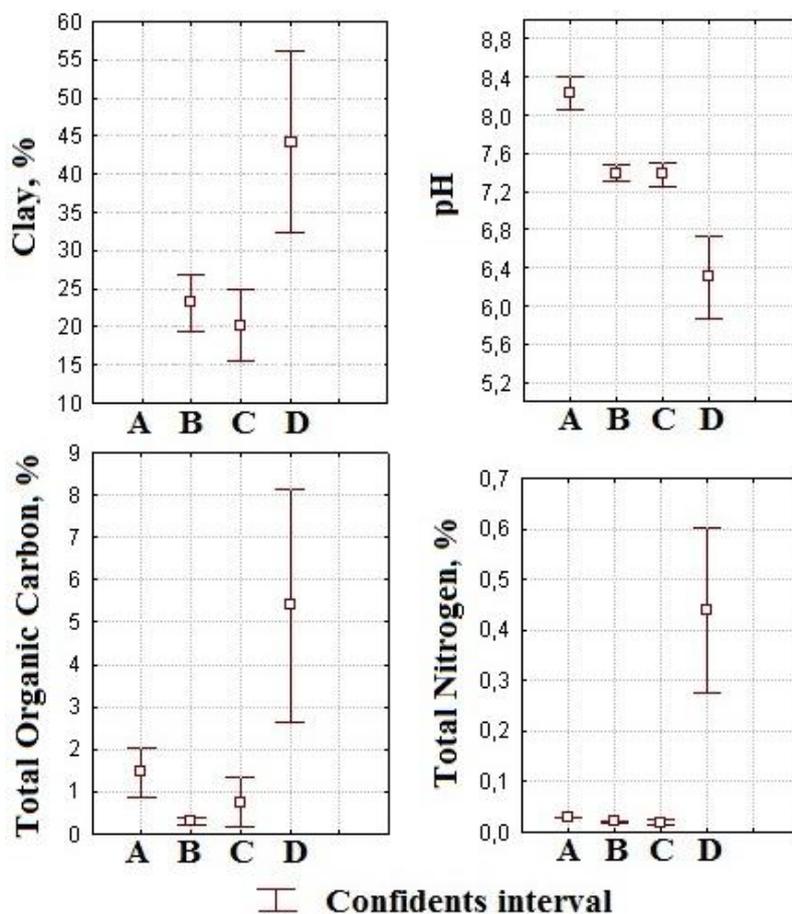


Fig. 1: Some physical and chemical measures of soils on the research objects.

- A – substratum A (dumps without reclamation);
- B – substratum B1 (reclaimed);
- C – substratum B2 (reclaimed);
- D – zonal soil.

Features of the soil-forming process are observed when studying number and activity of the cultivated part of microbial community of the objects. It should be noted that CFU number of a saprotrophic microbiota was calculated in the diluted medium as condition of such mediums are closer to natural habitats for their development. In this medium we calculated about 3 times more CFU, than in the medium with standard concentration. Microbial population of a layer of 0-40 cm in subgroups B1 and B2 was not inferior to measures of zonal soils (fig. 2). In substrata of group A CFU number did not exceed 1-2 thousand/g. It means that they can be considered almost sterile in comparison with the studied young soils. If the average level of CFU number in the layer of 0-40 cm, characterizing the zonal soil, is considered as 100%, it means that objects: A – B1 – B2 made a chain: 0.01 – 135 – 145%. Thus a microbiological profile specific to young soils was detected. Namely, CFU number increased with depth up to the sizes exceeding those of zonal soils to 3-6 times (fig. 3)

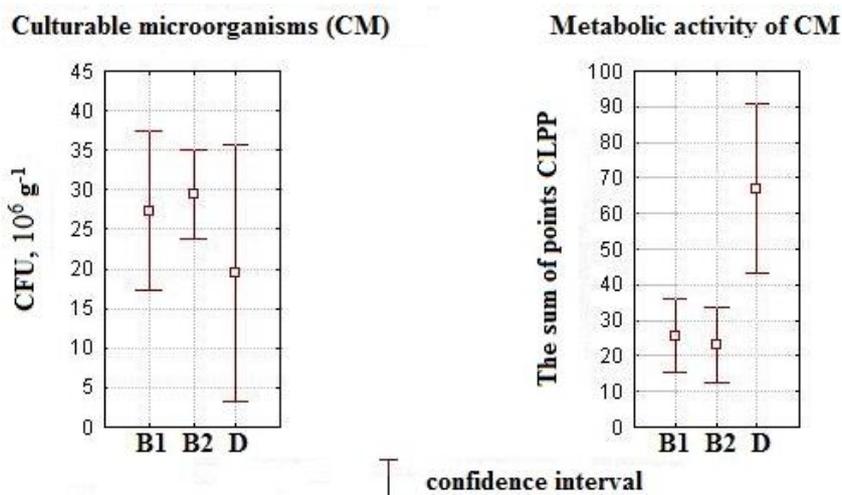


Fig. 2: Some microbiological measures of the research objects.

The following feature of the microbial population of the studied objects was that the microbial complex of embryozems was presented by cells with rather low speed of growth (in embryozems about 60% of total number of colonies grew in 48-72 hours after inoculation, in the zonal soil growth was relatively uniform within 72 hours). Thus, the following features of the microbial complex of embryozems distinguishing them from zonal soils were established: higher CFU number, increasing of CFU number with depth and lower speed of growth in the agar medium.

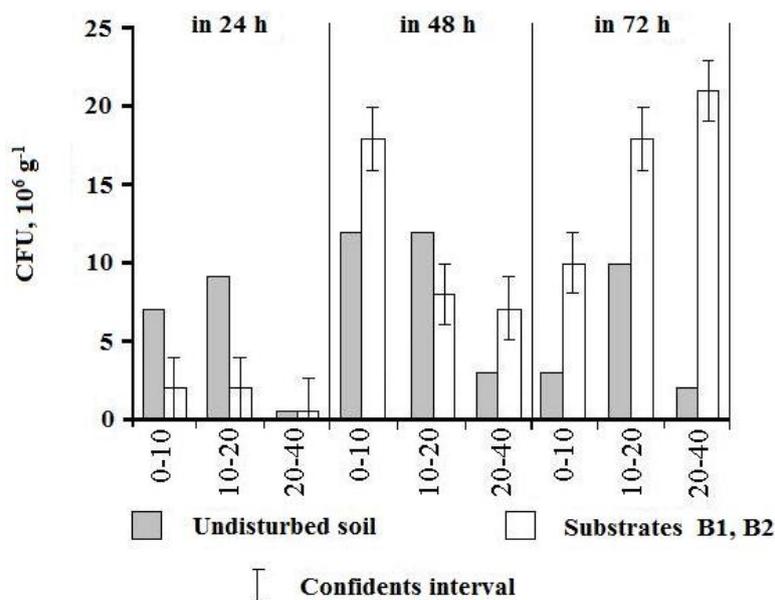


Fig. 3: Differentiation of microbial community of the zonal soils according to growth rate in a medium.

The common metabolic activity of microbial community was estimated on the score of multisubstrate testing of 24 substrata used in the experiment (fig. 1). The common activity of the cultivated part of a microbiota of B1 and B2 subgroups was almost similar to each other and was significantly inferior to measures of zonal soils. In the chain: the zonal soil – group A – B1 – B2 constituted 100 – 0 – 5-30%. The functional variety of embryozems community (B), according to Shannon criterion, was below measures of the zonal soil to 2.5 times. The analysis of activity of separate substrata consumption demonstrated that in young soils, unlike zonal, microbial community practically did not decompose cellulose.

According to our data, in substrata of A group enzymatic activity practically was not detected, level of a measure in group B was significantly inferior than in zonal soils (7 ± 1 mg of glucose g^{-1} 18 hour $^{-1}$ versus 20 ± 2). Profile differentiation according to this measure is not detected.

The substratum A did not support growth of the test plants by results of biotesting. According to this criterion embryozems of B group can be differentiated authentically into subgroups. So, average biomass of a garden radish sprout in a laboratory experiment in B2 substratum was 30% higher, than in B1. Therefore, selection of subgroups in B group on the studied territory has an objective basis (tab. 1).

Table 1: Comparative fertility of soils (n=50).

Substrate	Biomass of the test plants, mg	
	0-10 cm	10-20cm
A (untreated dumps)	$5 \pm 5^*$	3 ± 2
B1 (reclaimed dumps)	25 ± 4	23 ± 3
B2 (reclaimed dumps)	31 ± 4	35 ± 4

*confidence interval

Discussion:

Therefore, extremely low speed of soil formation in dumps of rocks after diamond mining in the Western Yakutia was indicated that is related to cryo-aridity of climate and toxicity of initial rocks. So, if the average speed of accumulation of Total Organic Carbon on nontoxic sandy dumps can constitute about 0.535% per year [1], dumps of brown coal mining – to 0.384% per year [15] dumps of the mining industry – from 0.014 to 0.339% per year [4,13], on our object these estimated values did not exceed 0.01% per year.

Nevertheless, if to consider our objects as consistent stages of initial soil formation, the chain keeps within the scheme of the profile and genetic classification of soils on technogenic landscapes. Morphologically the group A can be allocated to a class of lithogenically undeveloped type of eluviozems initial, group B – to a class of biogenically undeveloped type of eluviozems initial with division into types of embryozems initial (B1) and organoaccumulative (B2). However according to standard physical and chemical criteria the division of classes was impossible that is obviously related to weak processing of the mineral basis of dumps. This procedure was possible according to microbiological measures which are recognized indicators of initial soil formation [11,17,7,21]. A number of the characteristic features of young soils inherent for microbial community were peculiar to the studied objects. Namely, a) higher CFU number in comparison with the zonal soil that is quite explainable from the point of view of the provision on a microbial pool of soils: toughening of conditions of habitat is accompanied by increase of a total number of cells in microbial community [22] other features are related to the same situation: b) increasing of a measure with depth (the feature noted earlier by Klevenskaya, [11] on dumps of the coal-mining industry of Kuzbass) c) increasing of the proportion of cells with low speed of growth in the agar medium. The assessment of the functional range of community by means of multisubstrate testing showed that this pool is rather less active in comparison with the zonal soil and practically is not able to utilize cellulose. Thus, the microbial population of young soils on the studied dumps consisted of the based forms not capable to the fissile utilization of vegetable polymers, exceeding indicators of the zonal soil by quantity.

Formation of enzymatic activity is the major stage and a feature of the soil-forming process [3]. The choice of invertase activity as criterion was caused by the fact that the main source of this enzyme is roots of the highest plants. That is, in our opinion, invertase activity of young soils can serve as a resultant measure of interaction of three components of young soils: an initial substratum, roots of plants and microorganisms. Low invertase activity and lack of profile differentiation according to this measure shows that the process of formation of the specific organo-mineral fraction promoting fixing and preservation of activity of ferment proteins, secreted by roots of plants and microorganisms is still slowed down on our objects.

In general, soil and microbiological measures of embryozems initial were almost similar to measures of embryozems organoaccumulative. That is according to these criteria differentiation of objects into types was impossible.

It should be noted that the data given above in some degree are indirect evidences of the soil-forming process. The main result of the soil-forming process is rock processing to the state providing development of the highest plants. As appears from the results of biotesting, the division of young soil types is possible according to relative fertility of substrata.

Conclusion:

35 years later after dumping and simplified reclamation the soil-forming process was registered in a type of: a) forming of initial microbial community with high number of CFU, a low functional variety and no differentiation on a profile, b) increasing of ability of a substratum to support initial growth of test plants in vitro approximately for 30-40%. Because of weak processing of a dumps' mineral basis the classification of embryozems on standard physical and chemical criteria is complicated, their differentiation into classes is possible according to soil and microbiological criteria, into types according to comparative fertility of a substratum.

This work has been conducted on technogenic landscapes located in a subzone of the middle taiga. Further it is planned to expand geography of researches.

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