Specifics of soil forming and vegetation restoration of man-made landscapes of the south of the Far East of Russia

Oleg Viktorovich Polokhin[1], Lyudmila Nikolaevna Purtova[1], Victoria Andreevna Semal[1,2], Lidiya Alekseevna Sibirina[1], Serafima Vladimirovna Klyshevskaya[1]

[1]Institute of Biology and Soil Science FEB RAS, 100 years of Vladivostok ave., 159, Vladivostok, 690022, Russia
[2]Far Eastern Federal University, Octobers str., 27, Vladivostok, 690091, Russia

Abstract. Forming soils and vegetation of man-made landscapes of forest-steppe area and the area of taiga deciduous mountains of the Primorye Territory have been studied. As it has been found out in all areas soil forming evolution is being realized as succession of four main types of embryo soils replacing each other: initial – organ accumulative – cespitose – humus accumulative. This course of evolution is determined by specifics of biological processes development. It has been proved that development stages of forming vegetation and forming soils depend on their position in relief, granulometric and mineralogical characteristics of layers, bioclimatic conditions of native zone. Technology of nonselective spoil disposal during technogenic phase is the main reason of limitation of embryo soils development. The highest speed of pedogenic transformations and forest restoration may be observed on trans-accumulative and accumulative positions of man-made landscapes. Pedogenesis processes manifest themselves most actively only in upper biogenic layers. In alluvial positions biogeocenoses evolve slowly. Pioneer of overgrowing are ecologically plastic species capable to withstand severe conditions of technogenetic environment.

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Introduction

The main method of brown coal production in Far East of Russia is open-cut mining. It results in fundamental changes in all landscape up to its full destruction. Territories where capping is stored are also affected. It should be noticed that major part of land allocation for open-pit mine is taken for mine dump (more than 40%). Spoil disposal results in man-made landscapes that are ecoclines with specific set and level of soil-ecological functions. Self-overgrowing and self-restoration of soil layer goes in these areas. Significant number of works [1, 2] has been dedicated to study of soil layer and vegetation regeneration processes in reclamation. It has been found out that physical properties of rocks forming mine dump play significant role in soil forming and phytocenosis development in post-technogenetic stage [3]. It has been also proved that the processes of accumulation and transformation of organic matter are leading processes in initial stages of soil forming [4, 5]. There are just several works like this for Primorye Territory [6, 7]. Aim of the present work is determination of main limiting factors affecting restoration of soil and vegetation layer, determination of soil forming development patterns in man-made landscapes in different native and climate zones of Primorye Territory.

Method

Soils and vegetation forming on exposed mine damps of different age of stripping and country rock of brown-coal open mines “Pavlovski” and “Luchegorski” districts in Primorye Territory were objects of research. “Pavlovski” mine is situated in forest-steppe area in 20-30 km to the north from Ussuriisk city and “Luchegorski” mine in north-west part of Primorye Territory in taiga deciduous mountains zone. Coal is produced by the open method with non-selective mine dumping. Stripping mass including country rock is being filled into waste dump. Three positions were chosen in each waste dump: on the top – alluvial (Al), in the slope – trans-accumulative (Trans-ac), and at the foot – accumulative (Ac). Positions were defined by position in relief and vegetation type. Morphing assessment examination of vegetation and soil sampling were repeated 5 times according accepted methods. Gross compound of soil samples was defined by roentgen-fluorescent spectrometer Shimadzy EDX 800 (made in Japan) and organic matter content- on carbon and nitrogen elemental analyzer Flash 2000 (made in the USA). Determination of chemical characteristics of rocks forming mine dump was made by accepted methods [8]. Substantive genetic classification by V.M. Kurachev was applied [9].

Main body

Main dumps selected for research are similar in relief and slope exposition and may be considered as forming technogenic catenas [6,7]. Rocks forming mine dumps differ in granulometric, mineralogical and petrographic compounds. Heterogeneity of rocks all substances are spread in dump body irregularly in the form of numerous macro, meso and microfocuses [6].

Mine dumps of Luchegorski coal mine consists of chaotic mixture of siltstones, argillits and sandstone of different granularity, pebbles, olivinic basalts of pliocene age, overburdens represented by river-bed, flood-land and bog facies as well as coal-containing inclusions. These are heavy loamy, light and medium loamy stratums. Amount of cations absorbed is above average (22-31 mg.-eq/100 gr) due to heavy granulometric composition. Ca^{2+} and Mg^{2+} are the most frequent cations. Saturation level is heightened (H=89-83%). Stratum is not salted.

Stripping rocks of Pavlovski coal mine are represented by quaternary loams, alluvium sandy-pepples in sediments of Suifunskaya suite, argillits, siltstones, anisomerous sandstones and coal layers of Ust-Davydov suite. Base saturation level is 60-85%. Stratum is heavy loamy, light and medium loamy.

Although research objects are in different soil and climate zones they have similar development features. During evolution process soil covering have been developing from initial embryo soils (on the earliest stage) to the most matured – humus accumulative embryo soils. Biologic factor is the leading factor of soil forming.

Some soil forming stages (initial embryo soils) that are singenetic to pioneer stages of phytocenosis development are characterized by almost total absence of pedegenetic stratum differentiation on genetic layers [10]. Soil profile is represented by several layers that are usually different in density. Organ genetic layer is absent. Organic carbon content in soils of one-year deposits is 0,1-0,2 % of soil weight.

Accumulative positions are the first to overgrow with pioneering vegetation. Development of phytocenosis on trans-accumulative positions in first 1-3 years is beyond those of lower accumulative positions.

Isolated specimen of weed vegetation and ruderal vegetation from neighboring territories start to grow on initial technogenetic ecotopes of Pavlovski coal mine. The base of pioneering vegetation is comprised of knotweed, hydnum, clover, wormwoods. Isolated ruderal and weed species may be observed: *Artemisia argyi* Levl. et Vaniot, *Sonchus arvensis* L., *Commelina communis* L., *Oenothera depressa* Greene. Initial embryo soils remains after three years on all elements of catena. *Equisetum pratense* L., *Picris davurica* Fisch., *Chenopodium album* L. begin appearing in phytocenosis. These species have high vitality, easily adapt to adverse conditions of vegetation, and quickly overgrow free territory.

Vegetation has different types from weed to buckwheat, pink sedge species, thistle, reeds. On leveled surfaces or slanting slopes pioneering stage lasts up to 3 years. On steep slopes it may last up to 8-10 years. In initial 10-years embryo soils in both zones low silt content differentiation is observed that may be caused by the processes of physical disintegration and chemical airing that result in some accumulation of silt fraction in upper layers of the profile. Profile has no differentiation in other indicators. Alluvium positions are characterized by the lowest rate of development. Initial embryo soils under initial vegetation groups may remain on them even after 30 years. It may be explained by extremely severe conditions for fixing and growing of plant (sharp edges of dumps, contrast temperatures, water and wind erosion, etc.).

Organ-accumulative embryo soils like initial are soils of the very first stages of evolution. Expressed biogenic characteristic that is genetic layer represented by ground litter [11,12, 13] is diagnostic indicator. Low development of pedogenesis processes is observed. On mine dumps of Luchegorski fuel and energy complex there are primitive plant aggregations of poic type: horse-tail, wormwood and horse-tail, horse-tail and sally-bloom. Herbs may be rarely observed. Profile formula is O(0-1sm) + C1(1-5sm) + C2(5-10sv) + C3(10-22sm) + C4(22-70sm). Duration of this period is 3 – 18 years. Limiting factors are heavy granulometric compound, mineralogical compound and steep slopes.

On mine dumps of Pavlovski mine this stage lasts 3-12 years. That means that in forest-steppe zone this period is shorter than in taiga-deciduous zone. Simple mixed plant aggregations are being formed here in transient and accumulative positions after 10 years. Trassak *Calamagrostis epigeios* (L.) Roth, *Trifolium pratense* L., *Artemisia umbrosa* (Bess.) Turcz. ex DC. dominate in these aggregations. On accumulative position there are clover-wormwood-reed-forb aggregations with 30-45-percent projective covering. Stratum reaction in surface level of embryo organ-accumulative soils is subacid. The lower profile is more is reaction. Exchange base sum and base saturation level are lower with depth.

Turfing embryo soils with complex vegetation aggregations are being formed on trans-accumulative and accumulative positions in forest-steppe zone after 10-12 years (on Luchegorski fuel and energy complex after 13-15 years). Gley processes are frequently observed on accumulative positions. Turfing embryo soils profile is expressly differentiated on biogenic (turfing layer) and lithogenic (profile formula is Ao(0-1sm) +Ад(1-3sm) +C1(3-17sm) + C2(17-45sm) + C3(45-100sm)). Profile has low differentiation in physical and chemical properties. Organic matter content is up to 0,25-1,24 % (in pit-run fines of turfing layer) with abrupt reduction lower the profile. Ruderal species in phytocenosis are replaced by more stable including bunchgrasses. *Calamagrostis epigeios*, *Poa pratensis* L., *Trifolium pratense*, *Hieracium umbellatum* L. dominate on this stage of development. Projective covering reaches 80-90%. Turfing embryo soils of technogenetic landscapes of Luchegorski fuel and energy complex are characterized by profile formula O(0-2sm) + Ad(2-7sm) + C1(7-13sm) + C2(13-25sm) + C3(25-75sm). Vegetation is of wormwood-herb-horse-tail-sally-bloom type. Projective covering is 90-100%.

Humus accumulative embryo soils with developed low capacity humus layer are formed on mine dumps of Pavlovski coal mine after 20 years under closed phytocenosis. Humus layer existing in humus-accumulative embryo soils along with ground litter and turfing layer is common feature for all zones. Forming of this layer is followed by substrate aggregation, rock mass differentiation by chemical, physical and chemical and physical characteristics. Profile formula is O(0-3sm) + Ad(3-7sm) + A1(7-23sm) + BC(23-30sm) + C1(30-65sm) + C2(65-100sm). Differentiation is observed mainly in root-inhabited (0–20 sm) layer. Transient layers are difficult to define in morphologic examination. It may be explained on one hand by low development of processes and on the other hand by coaly particles existing in rocks forming mining dumps. Upper layers composition density 0,7–0,9g/sm^3 (0–10sm), growing with depth up to 1,4 g/sm^3. Actual acidity in upper layer is subacid lowering with depth. General organic carbon content along profile is lowering from 7 % in 3-5 sm layer to 1.1% on the depth 15 sm (see Table). General organic carbon distribution curve along profile is concave with abrupt lowering with depth (accumulative distribution type). Upper layers are depleted with sesquialteral oxides and enriched with oxides of biophilic elements (Table).

Vegetation forming on 20-years mine dump has the following overgrowing types: 1 – initial primitive aggregations, dv – composition density (horse-tail and hawkweed aggregations on upper parts (Al) of dumps with projective covering 10-20%), growth and development is slowed down, 2 – closed aggregations with significant amount of ruderal species in lower parts (Acc) clover-wormwood-reed-forb aggregations with projective covering 75-90% and on middle parts of dumpt (Trans-Acc) bluejoint-clover-wormwood-forb with projective covering 85-100%; 3 – introduction of woody and shrubby plants on south-west, south-east, east and west slopes on positions Trans-Acc and Acc. Humus-accumulative embryo soils under these type of vegetation on dumps have developed after 20 years on Trans-Acc and humus-accumulative gley embryo soils on Acc. Humus-accumulative embryo soils on Trans-Acc with bluejoint-clover-wormwood-forb aggregations (dominating species *Calamagrostis epigeios* and *Trifolium pratense*) and humus-accumulative glay embryo soils on Acc have developed after 20 years on dumps also under closed phytocenosis with significant amount of ruderal species clover-wormwood-reed-forb aggregations with projective covering 90-100%, with dominating species *Trifolium pratense* and *Phragmites japonicus* Steud.) But we should note that the stage of complex phytocenosis has conditional character because species composition of this phytocenosis is different from zonal. We didn't observe zonal type vegetation aggregations on technogenetic ecotopes.

Table. 20-year embryo soils of forest-steppe zone features in self-overgrowing

Depth, sm	dv, g/cm^3	pH	Humus, %	Gross content, % of tempered weigth								
				MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3
3-5	0.64	6.51	7.02	0.33	15.69	72.43	0.07	2.82	1.22	0.39	0.11	1.85
5-10	0.94	6.27	2.43	0.25	16.75	76.38	0.08	3.11	0.52	0.44	0.05	1.90
10-15	1.04	5.36	1.05	0.29	18.56	74.86	0.03	2.87	0.28	0.41	0.03	2.04
15-20	1.19	5.31	0.50	0.29	17.43	72.52	0.05	2.79	0.41	0.53	0.04	3.33
20-30	1.25	5.25	0.53	0.28	17.40	71.34	0.03	2.62	0.34	0.50	0.04	3.20

Rough humus accumulative embryo soils have formed in Luchegorski fuel and energy complex after 30 years. Profile formula is O(0-1sm) + Ad(1-3sm) + A1(3-6sm) + A1B(6-10sm) + BC(10-20sm) + C1(20-38sm) + C2(38-70sm). Substrate aggregation is observed, mass differentiation by chemical, physical and chemical and physical characteristics. Differentiation is observed mainly in root-inhabited (0-20 sm) layer. Vegetation is represented by forbs and herb. Woody species *Betula platyphylla* Sukacz. and *Populus tremula* L. are observed.

Conclusion

Research has shown tight relationship and interconnection of sin-genetic vegetational fluctuation of phytocenosises in forming technogenic ecosystems with phases of post-technogenetic soil forming, characterized by one major soil type. Surface relief, granulometric and mineralogical compound of rocks, biological and climate conditions of native zone, biogenetic factor are the main factors of soil covering evolution. Specific of young technogenetic soils is forming of neogenic organogenic or organ-accumulative layers of small capacity. The share of embryo soils of late stages of development in soil covering of forest-steppe zone is higher that if taiga zone. Long-term stage of organ-accumulative embryo soils is characteristic for taiga zone.

Ecologically plastic species are overgrowing pioneeres. Aggregations that reflect zonal vegetation type on studied mine dumps were not found.

Accumulative (shelf) parts of mine dumps and trans-accumulative as well as inter-edge hollows, north and east slopes, non steep slopes are the most favorable for phytocenosis development and soil forming. More favorable conditions for vegetation growth and development are there too.

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Corresponding Author:
Dr.Polokhin Oleg Viktorovich
Institute of Biology and Soil Science FEB RAS
100 years of Vladivostok ave., 159, Vladivostok, 690022, Russia

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