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To cite this article: T Dedenko and S Navalikhin 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **226** 012024

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Ecological aspect of the industrial soils' penetration resistance in wood recultivation of Kursk Magnetic Anomaly

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Abstract. The dynamic of industrial substrates penetration resistance changing on the recultivated field with the growing stock over a period of 42 years is shown. Forest growth conditions of industrial soils became closer to the bioecological requirements of wood and bushy species. For industrial soils formed by applying a meliorative layer 15...20 cm the soil penetration resistance falls more intensively. The control check research conducted in 2016 on embryogeny soil of chalk and marly solid showed the increase of penetration resistance in 2 times at the top layer 0... 5 cm, at 10 cm depth - 1.6 times, at 20 cm depth - 1.4 times, at 30 cm depth - 1.3 times. The same pattern is for industrial soils with applying of chalk and marly of meliorative layer of sand, clay loam or humous soil with the yield of 40...50 cm. For industrial soils formed by applying a meliorative layer 5...10 and 15...20 cm the penetration resistance of the top edaphotopic layer was changed considerably over a period of 42 years. The most essential differences were in an industrial soil made by a sand layer 5...10, 15...20 cm, where the penetration resistance of the topsoil raised in 2.5 and 5.6 times.

1. Introduction

It is important to develop the complex of technologies of recultivating industrially disturbed soils as the amount of mineral resources mining is developing nowadays. In the sedimentary cover of the iron-ore open-pit mine of Kursk Magnetic Anomaly (KMA) there are 60-80% of sand and chalk of all the other overburdens. Chalk and marly solids have a lot of peculiarities which are determined by the amount of calcium carbonate and the formation of low yield soil body [1-3].

The artificial formation of industrial substrates (embryogeny and industrial soils) is one of the ways of improving edaphic characteristics of chalk and chalk and marly heaps and rising their forest growth potential for their forest recultivation [4, 5].

Filling layers of industrial soils are not genetically bonded with each other unlike natural soils, but they have specific soil ecological functions. Like natural soils the upper layer of industrial soil is enriched by organic matter which contains the soil horizon of the donor soil. This leads to change of physical characteristics of geological materials, the intensity of their elation, redox processes and the speed of biological cycle [6, 7].



The soil penetration resistance is an important measure of forest recultivation which characterizes physical and mechanical features of soil [8-10]. This measure is a limiting index for growth and development of plant root system in edaphotopes of industrial origin. The high level of soil penetration resistance in any layer decreases moisture movement through the soil body and limits the growth of root system. In other words, it has a negative influence on soil and plants [11, 12].

Goal of research - determination and studying the dynamics of penetration resistance embryogeny and industrial soils formed on chalk and marly heaps over a period of 42 years.

2. Methods and materials

2.1. Object describing and sample selection

The target of research is the chalk and marly heap of Schigrovskiy phosphoritic mine in Kursk region formed in 1974. Phosphorite was got by the opened method in 1953-1971. The technology did not provide the maintaining of a fertile layer. Disturbed soils looked like ranges of cone-shaped heaps and trenches made of chalk, marl and their technological mixtures. The height of heaps and trenches was between 3 and 10 m [4].

The main point of the experiment was to model different forest growth conditions by the application of more fertile and steady to deflation different meliorative layers to the heap surface (sandy deposits, clay loam or humous soil layer), yield (5-50 cm) with further mechanical processing (tilling, disking, cultivation) and further forest planting.

To measure the penetration resistance of embryogeny and industrial soils which were formed on chalk and marly found in 2016 - 108 measurements were conducted.

2.2. Data preparation and proceeding

The penetration resistance of the topsoil was measured in the field with the help of soil penetration resistance measuring instrument with the tip by Revyakin–plain wheel with the 10 mm diameter. The depth of the measurements – topsoil and subsurface layers, in certain cases, till the soil-forming material, - chalk and marly. The direction of tip diving is vertical.

The result of measurements was cross-sectional (1-D - one-dimensional) soil penetration resistance diagram with continuous distribution of soil penetration resistance through the depth. The source data were taken from the graph paper and then they were converted to kgs according to the predetermined calibration. 1 mm corresponds to the soil penetration resistance on 1 kg/cm². Statistical data processing was made on ECM of the type IBM using such programs as Excel, Statistica with identification of average values, roughness and truth of the trial.

3. Results and discussions

One of the main goals of forest recultivation on the mine technical stage is the optimization of surface edaphotopic soil horizon to bioecological requirements of wood and bushy species; in other words, decreasing of penetration resistance of soil horizon to 6...12 kg/cm².

The penetration resistance of industrial soils changes by the time (Table 1). The process is influenced by humidity of edaphotopic layer, change of grain soil texture caused by physical and biological erosion during the process of soil formation, consolidation processes and natural settlement of geological materials [13].

When applying meliorative layer about 5...10 cm on chalk and marly solid the penetration resistance of industrial soil decreases roughly. It balances through the profile of topsoil from 7...10 kg/cm² to 15...22 kg/cm² at the depth of 25 cm [4]. The biggest decrease is present when applying a sand layer, then humous soil and clay loam. It is connected with the grain soil texture: light meliorative sand layer decreases penetration resistance more than clay loam.

Rising of meliorative layer yield to 15...20 cm decreases penetration resistance of formed industrial soil. When applying a meliorative layer of 15...20 cm of sand and humous soil the

penetration resistance was 4 - 10 kg/cm². The penetration resistance of technical mixture with clay loam is higher - 13...15 kg/cm². When burying chalk and marly soil are under the meliorative layer to 50 cm, the penetration resistance of embryogeny soil will be determined by the kind and characteristics of meliorative layer. Humous, sand and quaternary clay loam will have the lowest penetration resistance.

Table 1. The dynamic of changing of industrial soils' root layer penetration resistance over a period of 42 years.

Depth, cm	Year of research	Chalk and marly solid with a sand layer, cm				Industrial soil Chalk and marly solid with a quaternary clay loam layer, cm				Chalk and marly solid with humus soil layer, cm			
		5...10		15...20		5...10		15...20		5...10		15...20	
		%by		%by		%by		%by		%by		%by	
		kg/cm ²	1974	kg/cm ²	1974	kg/cm ²	1974	kg/cm ²	1974	kg/cm ²	1974	kg/cm ²	1974
0-5	1974	7.0		5.0		10.0		12.1		10.2		4.9	
	2016	25.5	364	21.0	420	33.0	330	31.5	240	24.5	240	22.5	459
5-10	1974	8.0		6.5		11.0		13.5		10.2		5.0	
	2016	37.5	468	31.0	476	37.5	341	38.9	285	33.0	323	35.0	700
10-15	1974	10.0		6.7		14.8		14.0		13.0		5.1	
	2016	38.0	380	35.5	529	40.0	270	39.0	278	36.0	276	37.0	725
15-20	1974	11.0		6.8		18.2		14.8		15.0		6.0	
	2016	39.0	354	37.0	544	40.0	219	40.0	270	38.0	253	38.5	641
20-25	1974	13.0		6.9		20.4		15.0		16.0		7.0	
	2016	40.0	307	39.0	565	40.0	196	39.0	260	39.0	243	40.0	571
25-30	1974	15.0		7.0		22.3		15.0		19.0		10.0	
	2016	40.0	266	40.0	571	40.0	179	40.0	266	39.0	205	40.0	400
Average in the topsoil	1974	10.6		6.4		16.1		14.2		13.9		6.3	
	2016	36.6	345	33.9	529	38.4	238	38.0	267	34.9	251	35.5	563

The hardness of chalk and marly is exposed to acute fluctuations depending on humidity. Chalk and marly in technical mixtures loses one of the main negative characteristics – hardening to very high index when drying. The character of root system development changes in technical mixtures. According to Andruschenko P. F. (1979), the root system of 2 years old bastard Robinia pseudo acacia unlike the control variant (chalk and marly soil) does not isolate at the volume of the planting trench, but have a tendency to intensive development. Developing in the layer of industrial mixture, anchor roots go deep and penetrate to chalk and marly solid.

The volume of a root system was 4 times more on industrial soil than on chalk and marly soil in 2 years already. It was bigger on technical mixtures than on humous soil. It is caused by the decreasing of topsoil penetration resistance to the preferable value and improving of water regimes of industrial soils. It denotes the high efficiency of increasing of forest growth potential opportunities of chalk and marly solids on industrial landscapes as a result of formation of industrial soils.

The research conducted in 2016 on embryogeny and industrial soils formed on heaps of Schigrovskiy phosphoritic mine on bastard acacia and drooping birch showed that on embryogeny soil of chalk and

marly solid the penetration resistance was increased by 2 times at the top layer 0... 5 cm, at 10 cm depth - 1.6 times, at 20 cm depth - 1.4 times, at 30 cm depth - 1.3 times. There is a pattern of decreasing the penetration resistance growth on the edaphotopic layer at the depth. The absolute measure is from 37.0 kg/cm² on surface to 40.0 kg/cm² at 30 cm depth. There is the same pattern for industrial soils with applying of chalk and marly of meliorative layer of sand, clay loam or humous soil with the yield of 40...50 cm.

The maximum penetration resistance to 1974 is in the layer of industrial soil at 5...10 cm depth with the further penetration resistance decreasing on surface and at the depth (Table 2).

Table2. The dynamic of changing of embryogeny soils' root layer penetration resistance over a period of 42 years.

Depth, cm	Year of research	Embryogeny soil							
		Chalk and marly solid		Chalk and marly solid with an applicated meliorative layer					
		kg/cm ²	% by 1974	Sand		Quaternary clay loam layer		Humous soil	
				kg/cm ² by 1974	%	kg/cm ²	% by 1974	kg/cm ²	% by 1974
0-5	1974	17.8		4.8		12.0		5.0	
	2016	37.0	207	23.5	489	27.5	229	21.4	428
5-10	1974	22.8		5.0		15.0		5.1	
	2016	38.5	168	32.0	640	37.5	250	33.4	655
10-15	1974	27.6		9.0		16.0		6.0	
	2016	38.5	139	37.5	416	38.0	237	36.0	600
15-20	1974	29.0		13.2		17.0		8.0	
	2016	39.5	136	38.0	287	39.5	232	38.0	475
20-25	1974	29.7		13.5		17.3		10.0	
	2016	39.5	133	39.0	288	39.5	228	40.0	400
25-30	1975	29.7		14.0		17.5		11.5	
	2016	40	134	39.0	278	40.0	228	40.0	347
Average in the topsoil	1974	26.1		9.9		15.8	234	7.6	
	2016	38.8	148	34.8	351	37.0		34.8	457

The biggest values of penetration resistance increasing to 1974 are for industrial soils presented by sandy deposits with the medium penetration resistance increased by 4.5 times; with applying of humous soil - 3.5 times, and quaternary clay loam - 2.3 times. The medium value for all the variants at the research time in 2016 was 35 - 38 kg/cm².

For industrial soils formed by applying a meliorative layer 5...10 and 15...20 cm the penetration resistance of the top edaphotopic layer was changed considerably. There is a distinct pattern of increasing industrial soil penetration resistance when the yield of applied meliorative layer on chalk and marly soil at the formation period. The peculiarities of granulometric texture of sand, clay loam and humous layer of soil also influence on it.

The most essential differences took place in an industrial soil made by a sand layer 5...10, 15...20 cm, where the penetration resistance of the topsoil raised in 2.5 and 5.6 times.

The same indicators were got with the help of applying a humous soil layer: the penetration resistance of the topsoil raised in 3.4 and 5.2 times; the formation of the industrial soil with a clay loam were 2.3 and 2.6 times.

4. Conclusions

An artificial formation of industrial soils is an effective way of raising the potential opportunities of forest growing conditions of geological materials with a high level of soil penetration resistance.

Forest growth conditions of industrial soils improve, getting nearer in the way of soil penetration resistance to the bioecological requirements of wood and bushy species. For industrial soils formed by applying a meliorative layer 15...20 cm the soil penetration resistance falls more intensively. As times go by the process of natural consolidation of the industrial soil influence the growth and condition of the forest plantations as the roots of the wood species get in the chalk and marly subsoil. The top layer of the edaphotopic horizon of the industrial soil performs a mulching function preventing the top layer from an excessive siccation.

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