Formation of Agrophysical Properties in the Affected Soils of Recultivated Areas

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Abstract – The work studied the process of forming agrophysical properties of sod-podzolic soil on reclaimed territories after opencast mines. It is established that in case of withdrawal, reclaimed land from agricultural use, the 30-year period after the remediation is insufficient to restore agrophysical parameters and condition of disturbed soil due to natural factors of soil formation. The residual effects of its physical degradation manifested in changing the parameters of structural state, density, porosity, and as a result, the quantitative characteristics of water-physical constants and forms of moisture content of the ground.

Key words – recultivated soils, soil structure, soil porosity, soil density, soil moisture, soil moisture content.

I. Problem

Mining adversely affects the efficiency and environmental condition of land, involved in mining developments. Holding open cast mining withdraws from agricultural use large areas of productive land, destroying the earth relief, producing large overburden dumps. Therefore, one of the most effective measures to renovate the natural state of the soil cover is reclamation of lands and bringing them to a state most suitable for agricultural production. However, carrying out reclamation associated primarily with fundamental violation of evolutionary indicators of balanced physical structure of the soil, of which the dominant place tales structure of the soil. This index serves as the main criterion for the physical structure of the soil and determine the full range of natural, water-physical and agrochemical soil characteristics and modes.

Despite the scientific and practical relevance of the subject, the accumulation of experimental data on the formation of agrophysical soil characteristics under conditions of techno genesis is insufficient. In particular, for reclaimed areas there are not explored recovery time characteristics of the physical structure parameters and physical constants of water and soil disturbed by natural soil conditions. Therefore, the purpose is to establish laws in the process of restoration of natural and water-physical properties of sod-podzolic soil on reclaimed areas after mining development.

II. Materials and research methods

The results of study of soil agrophysical properties were conducted on sod-podzolic sandy soils of Zhytomyr region, located in the territorial limits of Irshansk mining plant for extraction and processing of ilmenite ore. Reclaimed in the mid 80-ies industrial plot of over 80 ha has not been in agricultural use, which created the preconditions for the study of recovery of agrophysical characteristics of soil reclaimed areas by natural factors.

Research of consequences of the change of agrophysical remediation of soil parameters were based on a comparative analogy and carried out by comparing the changes of physical indicators of disturbed ground with specified control.

The reliability of the results was provided by selection of the required number of individual soil samples, making it possible to reliably estimate the measurement parameters. To this end, on not reclaimed area in three places we laid heel-in of soil with disclosure of humus and eluvial horizons. A similar heel-in, as a control, was laid at a distance of 50 meters from the boundary of the study area. For laboratory determination of parameters of agrophysical properties of the soil, in these heel-ins in 8-time repetition using cylinder capacity of 109 cm^3 and height of 5 cm we selected undisturbed samples (monoliths) of soil horizons of 0-5; 5-10; 10-15 and 15-20 cm.

To determine the structural state of the soil, we selected additional soil samples from identified horizons, which defined macroagregate state using dry and wet sieving according to Savinov, water strength structure in stagnant water determined by the method of Andrianova.

For laboratory determination of parameters of water and physical constants in selected undisturbed samples (monolith), we determined: the total moisture (TM) by fill of monolith with capillary water after its saturation; the smallest (field) moisture (SM) according to the modified method of S. I. Dolgov; Humidity of capillary connection gap (HCCG) according to accelerated method of V. B. Mackiewicz; sustainable wilting humidity indicator (SWH) – by the method of S.I. Dolgov according to soil moisture on border0 of wetting. Soil moisture was determined by gravimetrically thermostat method with thermal regime of drying 105 ° C.

III. Results and discussion

The results of our research found that injuries of the soil at remediation works had significant impact on the index of macrostructure in 0-20 cm soil layer (Fig. 1).

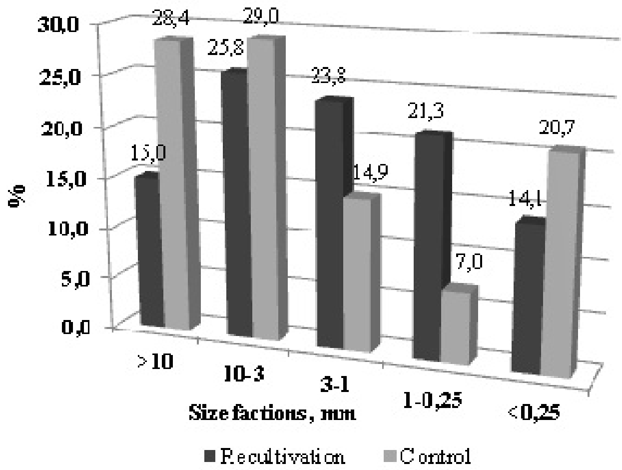

Fig. 1. Macroagregate composition of 0-20 cm soil layer (for dry sieving)

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Most vulnerable to mechanical soil abuse proved to be structural units larger than 10 mm, the contents of which decreased from 28.4% (control) to 15.0%. This trend can be traced for structural units ranging in size from 3 to 10-mm.

Due to the relative decline of participation in a ground of largest components of macrostructure, the relative percentage of small factions rose from 14.9 to 23.8% (1.3 mm) and from 7.1 to 21.3% (size fractions 1-0,25 mm). Structural units smaller than 0.25 mm, forming the microstructure decreased from 20.7% (in control) to 14.1%.

According to the established in agronomic literature conclusion, the optimum size of the structural units included macrostructure size from 0.25 to 10 mm and coarse microstructure with the size of the structural units of 0.25 to 0.01 mm. The most valuable are recognized structural components ranging in size from 3.0 to 0.25 mm.

Considering it, the evaluation was conducted on the existing soil structure, the results of which are shown in Fig. 2. In the analysis we highlighted the optimal size of macro aggregates from 0.25 to 10 mm and the sum of fractions <0.25 and> 10 mm.

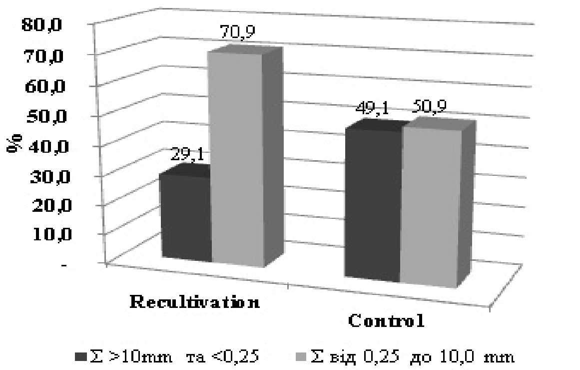

Fig. 2. Distribution of ground macrostructure according to its agronomic value

As we can see from the above histograms, reclamation significantly damaged the natural relationship between these structural elements. These changes were accompanied by the general increase in the proportion of structural units ranging in size from 0.25 to 10.0 mm in the background of percentage fractions smaller than 0.25 and more than 10 mm.

Quite important is the question of ascertaining the nature of the formation water resistance patterns on disturbed soils. To this end, we conducted wet sieving soil samples, the results of which are shown in Fig. 3.

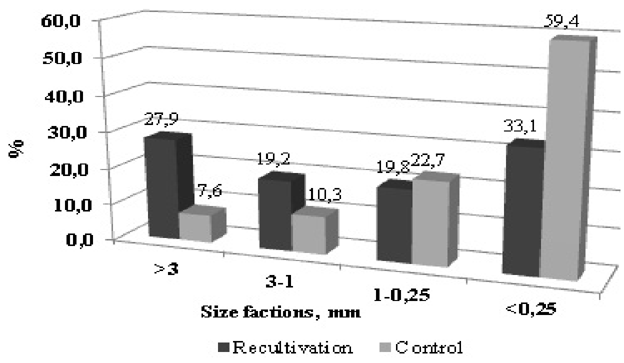

Fig. 3. Macroagregate composition of 0-20 cm soil layer on the results of wet sieving (%)

The presented data shows that after a long stay of structural units with size> 3 and 3-1 mm in water, from 19.2 to 27.9% of their amount retained its structure and suffered no destruction, meanwhile in the control sample this figure was less than 7, 6-10,3%. In analyzing the structural units of smaller size (1-0, 25 mm and <0.25 mm) we established the opposite trend.

Studies have shown that 30-year period of reclaimed land stay in undisturbed condition is insufficient for a full recovery performance of its physical structure: the density of content and total porosity specified in the Table 1. As seen from the above data, density of content for arable (0-20 cm) soil stabilized during the period at 1.14 g / cm^3 and remained significantly lower than the rate in the control region (1.24 g / cm^3). The largest average value are in the control - 1.27 g / cm^3 and the reclaimed area - 1.16 g / cm^3 at a depth of 10-20 cm layer of soil.

TABLE 1

SOIL DENSITY OF CONTENT (G/CM^3)
AND TOTAL POROSITY (%) OF SOIL

Soil layer, cm	Control		Recultivation	
	g / cm^3	%	g / cm^3	%
Values for each layer				
0-5	1.21	54.1	1.2	60.4
5-10	1.21	53.9	1.14	58.1
10-15	1.26	50.9	1.16	57.4
15-20	1.28	51.2	1.16	56.2
Average values				
0-10	1.21	54.0	1.12	59.2
10-20	1.27	51.6	1.16	56.8
0-20	1.24	52.8	1.14	58.0

Total porosity consists of pores, which are very different in shapes and sizes. Obviously, the size of the pores in the first place will depend on water, air, thermal and biological properties of soil. The results of our research found that performance capillary porosity, unlike non-capillary is more stable and slightly changed in the depth of arable soil for both areas (Fig. 4).

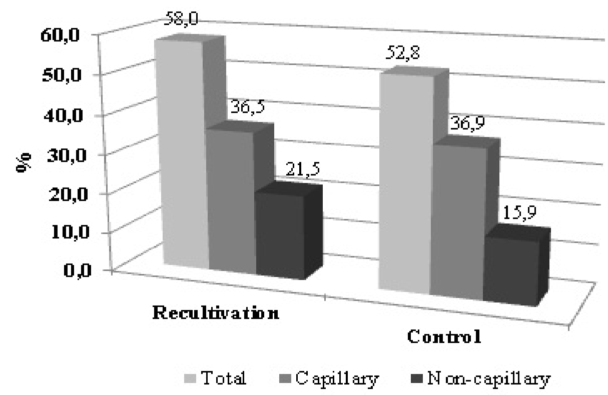

Fig. 4. Values of porosity of 0-20 cm soil layer

Index of capillary porosity on the reclaimed area was 36.5% and in fact did not differ from control values (36.9%). Non-capillary porosity varied significantly with depth. Its higher performance characteristic were found in the upper layers of soil, and noticeably reduced with the depth. Indicators of non-capillary arable soil porosity unlike capillary, as shown in Fig. 4, exceeded control values in 1.4 times and made 21.5%.

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Changes in the physical structure of the soil under the influence of remediation affected the nature of the fluid formation and physical constants (Table 2). Soil moisture, which corresponds to TM for topsoil increased by 5.3% to 45.6%. Decisive role in shaping productive moisture content play SM and HCCG, characterizing respectively upper and lower limit of optimal moistening the soil for plants. As seen from the above data, soil moisture, which corresponds to SM and HCCG, on the reclamation area was significantly lower and amounted to 29.3 and 18.2%, while in the control area it was at level 32 and 23%. However, sustainable wilting humidity on impaired territory was less dynamic and actually meet the benchmarks.

TABLE 2

SOIL MOISTURE FOR WATER-RELAVANT PHYSICAL CONSTANTS, % IN THE DRY SOIL

Depth, cm	Reclaimed area				Control			
	TM	SM	HCCG	SWH	TM	SM	HCCG	SWH
0-10	46.5	29.5	18.4	11.4	42.9	31.8	22.6	11.7
10-20	44.6	29.1	17.9	10.8	37.6	32.1	23.3	11.1
0-20	45.6	29.3	18.2	11.1	40.3	32.0	23.0	11.4

The full moisture capacity is determined by the total porosity of soil. It describes the state of wetting of the soil, when all the pores filled with water, and thus serves as a criterion of its water accumulation capacity. Studies have shown that because of the remediation, ability of the water accumulation of soil increased and total potential moisture content for 0-20 cm layer increased from 99.9 mm (control) to 104 mm (Table 3). However, the main role in the moisture of plants play the moisture content, which is within the least moisture capacity and capillary moisture communication gap because it is most readily available and held in the ground for a long time. It is formed after free outflow of gravitational moisture and soil for a long time held exclusively by capillary forces. As seen from the results of research, the volume of moisture content as a result of remediation decreased from 79.4 mm to 66.8 mm (TM) and from 57.0 mm to 41.5 mm (HCCG). A similar trend is observed in regard of change in moisture content that meets its borders of availability for plants (SWH).

TABLE 3

POTENTIAL MOISTURE CONTENT FOR APPROPRIATE WATER AND SOIL PHYSICAL CONSTANTS, MM

Depth, cm	TM	SM	HCCG	SWH
Reclaimed area				
0-10	52.1	33.0	20.6	12.8
10-20	51.7	33.8	20.8	12.5
0-20	104.0	66.8	41.5	25.3
Control area				
0-10	51.9	38.5	27.3	14.2
10-20	47.8	40.8	29.6	14.1
0-20	99.9	79.4	57.0	28.3

The practical interest has the question of the formation of soil moisture reserves, taking into account the extent of its availability for use by plants. Accordingly, we identified the following categories of soil moisture, the humidity in the range from TM to SM - the most available to plants, but does not play a decisive role in their moisture due to it short stay in the root layer of soil; from SM to HCCG - accessible (optimal) for plants moist; from HCCG to SWH - difficult to accept for plants, but plays a role in their moisture; lower SWH is practically unavailable to plants. [3] The results of our researches have established that the transformation of the physical structure of the soil, its porosity influenced by long period ongoing remediation the mobility of soil moisture and its availability for plants (Table 4).

As seen from the above data, the reclaimed area has a small (7.1 mm) increase in potential reserves of available moisture due, in our view, to increase of the volume of non-capillary pore space in the soil. This assumption is confirmed by the significant growth of excess moisture in the soil, which is formed in the range of TM-SM. The volume growth of such moisture content was the highest and amounted to 0-20 cm soil layer 16.7 mm. At the same time due to destruction of soil pore size of capillary volumes of moisture forms decreased from 28.7 mm (control) to 16.2 mm.

TABLE 4

THE DISTRIBUTION OF POTENTIAL MOISTURE CONTENT OF 0–20 CM SOIL LAYER BY CATEGORIES OF THEIR AVAILABILITY FOR PLANTS

Category of availability	Reclamatio n		Control		"+", "-" To the control. mm
	mm	%	mm	%	
Total reserves	104.0	100	99.9	100	4.1
Unavailable	25.3	24.4	28.3	27.7	-3.0
Available, total	78.7	75.6	71.6	72.3	7.1
including: inaccessible	16.2	20.6	28.7	40.1	-12.5
excess	37.2	47.3	20.5	28.6	16.7
and optimal	25.3	32.1	22.4	31.3	2.9

Among the categories of soil moisture in relation to its availability, the greatest practical interest represents moisture content category, limited to the upper (TM) and lower (HCCG) ranges outside the optimal wetting of the soil. By this measure reclaimed area proved to be close to the control. As seen from the above data, the volume of moisture content were at 22,4-25,3 mm respectively and made 31.3 and 32.1% of the total available water in the soil.

Conclusions

Reclamation of mining areas involved for a long period of development significantly alters evolutionary equilibrium of agrophysical properties of sod-podzolic soil. 30-year period is not sufficient to restore the physical structure of the soil. The consequences are manifested in ongoing remediation decrease of soil density content, which during the period stabilized at 1.14 g / cm^3, which is substantially lower than the rate in the control region of 1.24 g / cm^3.

There were changes of the total porosity of soil on reclaimed areas. The porosity of the soil throughout the depth of arable soils significantly exceeds the reference values for arable soil, which totaled 58.0%, which is 5.2% above the reference level. It was established that the performance of capillary porosity, unlike non-capillary is more stable and slightly changed in the depth of arable soil for both areas.

Reclaimed area preserves quantitative soil properties regarding moisture content to the extent of their availability to plants. Against the general trend to the growth of total available potential moisture content and their forms (7.1 mm) in the arable soil layer increases the volume of unproductive (excess) water (up to 16.7 mm) and decreases the number of severely accessed (12.5 mm) forms. Volumes of most productive ground moisture content that are classified as "optimal" stabilized at 25 mm, which practically corresponds to parameters obtained in the control region.

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