Water-physical properties of artificial soils of layered composition, used in dumps recultivation of mining and oil industry

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Abstract. There is a need to carry out recultivation of technological dumps as the territory is filled with waste of the mining and oil industry. After planning of the territory, it is necessary to create a fertile layer providing a long-term growth of perennial grasses. Turf is created under their action; it prevents the blowing of waste from the blade. Water-physical indicators are considered to be the main indicators on which the development of plants depends - the main indicator is the lowest moisture capacity. The use of homogeneous granulometric composition of soils leads to rapid loss of water and death of herbaceous plants. Therefore, it is necessary to find ways to retain water in the root zone and prevent it from flowing deep into the blade. Studies were carried out at the State Agrarian University of Northern Trans-Urals by creating experimental sites based on dark gray forest soil. As the studied material, the authors took rubble (fraction 2-3 cm); sand and low-lying peat. The introduction of coarse layers (rubble) reliably ensures the rupture of the capillary network, thereby preventing the flow of water deep into the blade. The least moisture capacity of the overlying layers increases compared with a homogeneous soil, and water supplies increased almost 2 times. The most effective is the use of rubble in soils of medium and heavy-loamy granulometric composition; rubble will provide a reliable obstacle to the downward and upward movement of water and stabilize water reserves in the root layer. When using as a fertile layer of light loams and sandy loam, it is recommended to create layered soils consisting of 1-2 layers of peat or other water-retaining materials (hydrogels, hydrophilic polymers) with good moisture capacity.

1. Introduction.

Water is considered one of the main factors causing fertility of soils. Water properties are characterized by several indicators, these indicators should be taken into account without fail, when creating artificial soils. Otherwise, there is a violation of the moisture supply of plants growing on these soils and the cessation of the reproduction of fertility. The most important water-physical characteristics are considered to be the lowest capillary water capacity, water permeability and water-lifting capacity of soils. In natural soils with a homogeneous heavy-loamy granulometric composition, the problem of water-physical properties does not exist [1, 2, 3]. However, when creating artificial soils, the ratio of the volume of large voids and capillaries is broken, which significantly complicates the movement of water vertically. This is especially critical when you are creating a fertile layer of earth covering the technological dumps, consisting of rocks of different granulometric composition.

The fundamental basis of the water-retaining capacity of soils is a capillary-sorption mechanism based on a moisture binding solid phase and pore space. When you create a recultivation, soil-mix in the tailings can be formed using different modes of water permeability and water-holding capacity [4, 5]. In soils with a uniform granulometric composition, water is retained only due to sorption (capillary) forces. This is most important for the reclamation of dumps of mining and metallurgical industry, where the bulk of the material is represented by a large granulometric composition, reaching a size of more than 10 cm [6, 7].

Slurry dumps of the oil industry are represented by silt or dusty material, which initially has very low water permeability and, in some cases, is water resistant. Therefore, the reclamation of dumps requires a detailed analysis of the granulometric composition of rocks and determination of their water-physical properties [8, 9, 10].

To estimate water-holding capacity of soils in practice, we usually use the smallest capacity that characterizes the maximum amount of moisture that the porous solid is able to hold by capillary forces after gravity drainage of water. It should be noted that the method for determining the lowest moisture capacity was developed for soils that are homogeneous in granulometric composition, where the flow of water passed freely. In recultivation of dumps, we have to deal with heterogeneous layered soils, where capillary movement of water is disrupted, because of manifestation "Jamenovskaya chain". At the boundary of the layers, one often observes stagnation of water, leading to changes in the living conditions of microorganisms and plants. In addition, this water logging can cause sliding of bulk soil in the presence of slopes of more than 5 degrees [10, 11].

2. Objects and methods.

Laboratory experiments were carried out in 2012-2015 on the basis of the Federal State educational institution of State Agrarian University of the Northern Trans-Urals. The subject of research was artificially created experimental soils with alternating layers of mineral and organic materials of different particle size distribution. Alternation of layers and their thickness (cm) are shown in figure 1.

	Variants			
	1	2	3	4
Layers thickness, (cm)	The humus layer (10 cm)	The humus layer (10 cm)	The humus layer (10 cm)	The humus layer (10 cm)
	Peat (10 cm)	Peat (10 cm)	Rubble (10 cm)	Peat (10 cm)
	Sand (30 cm)	Sand (10 cm)	Sand (30 cm)	Sand (10 cm)
		Peat (10 cm)		Rubble (10 cm)
		Sand (10 cm)		Sand (10 cm)

Figure 1. The location and thickness of the layers of the various ingredients in the creation of an artificial layered soil-mix

Models of layered soils were created on the mineral base of medium-loamy granulometric composition of dark gray forest soil, the upper 50 cm of which were seized. The humus layer was used in the experiments. The area of each variant was one square meter. In the formed deepening, peat, sand and rubble with a fraction of 2-3 cm covered in layers. Markets were closed with plastic wrap and left for 10 days. At this time, the process of self-absorption and formation of the capillary network in the humus layer took place. After that, the process of determining the smallest ratio according to the method Kachinski began, which is described in detail in books on agrophysics [12]. The density of addition was determined by a volume-weight method; humidity – in each layer with a ten-centimeter

interval by a thermostatic-weight method. Sampling was carried out to a depth of 50 cm in four repetitions.

As a control, we used a section of dark gray forest soil with an undisturbed structure and uniform granulometric composition throughout the profile. Statistical processing was performed using Microsoft Excel software product.

3. Results and discussion.

As our studies showed, the humidity corresponding to the lowest moisture capacity, 5 days after saturation of virgin dark gray forest soil with water on average per layer, was 20% by weight. The calculated data show a higher value of 25%. This feature is because in gray forest soils, there are eluvial-illuvial processes that form layers with different granulometric composition [13, 14]. In dark gray forest soil, these changes are minimal, but they affect the movement of water and water-retaining capacity of the upper horizons. The obvious rupture of the capillary network and disruption of water movement is characteristic of artificial soils, consisting of different granulometric composition layers. This is especially pronounced in three and four variants, where there is a layer of rubble. The lowest moisture capacity of the humus layer on the fifth day after filling the site was 27.3 and 34.5%, respectively. The calculated values differed from the actual values by no more than 1-3%. Regression analysis showed that the humidity corresponding to the lowest moisture intensity in layered soils depends on the thickness of the humus layer, the capillary network of which is broken by the introduction of a gravelly layer. Therefore, it can be expressed by a power function of type $W\%=40.521*H^{-0.1081}$, where H – is the thickness of the humus layer expressed in centimeters. A good confidence interval and a high approximation coefficient indicates that the value of the lowest moisture capacity in layered soils can be determined by the basic hydrophysical characteristic by mathematical modeling. This ability is of essential practical importance as there is an opportunity to make calculations of thickness of a fertile layer, which will be able to hold water effectively, preventing manifestation of the process of washing out of harmful substances from technological dumps of the mining, metallurgical or oil and gas industry [15, 16]. In addition, the results of mathematical modeling can be the basis for the design of the drainage system.

After the experiment, it was found that the introduction of coarse-dispersed materials into the layered soil grunt allows retaining water in the upper fertile layer in a significantly greater amount than when creating soils, homogeneous in granulometric composition. Humus layer thickness of 10 cm is able to hold almost 2 times more water in the presence of a layer of rubble. Adding a layer of low-lying peat will increase this figure by 30-50% compared to the values of virgin dark gray soil. This can solve the problem of water retention in the root zone over a permanently dried up coarse dump in the mining industry. Not only peat, but also hydrophilic strongly swelling hydrogels or polymers, which are currently widely used in industry, can be recommended to increase the moisture capacity to maximum values.

Use of crushed stone of small fractions interferes not only with movement of water deep into technological dumps, but also is a serious obstacle for water rise from underlying breeds. The problem of a capillary rise of water from the depth to the fertile layer on the coarse-grained or coarse-grained dumps does not exist, because there are large pores everywhere. However, this problem is extremely acute for oil sludge deposits, especially in the Far North. As earlier studies shown, granulometric composition of such waste consists mainly of small silty fractions [17]. Therefore, over time, the dumps are permeated with a well-developed capillary network. The proximity of groundwater due to the presence of permafrost provides a constant flow of moisture, and with it - water-soluble salts. This leads to the rapid death of perennial grasses sown during reclamation. In this case, it is necessary to use rubble or other coarse material to isolate the fertile layer from the sludge waste, which will solve the problem of secondary salinity of the fertile layer.

For the calculated data, the moisture capacity of layered soil does not give full information about its real amount, according to which it is possible to draw conclusions on the moisture availability of plants. As our studies have shown, the maximum water reserves accumulate during the alternation of

layers: humus layer – peat – sand – peat – sand (option 2) and option 4, where the alternation of layers is as follows: humus layer – peat – sand – rubble – sand. Water reserves in a half-meter layer are 130 and 150 mm, respectively. And it should be noted that it is due to the presence of a layer of gravel, water reserves increase by 15% compared to the second option. This fact indicates that the use of water absorbers (peat) even in several layers is less effective than large-fraction material for the formation of sufficient water reserves in the root zone of plants. Therefore, when designing recultivation activities, it is better to use one layer of crushed stone or similar material instead of several layers of peat or other biopolymer. The use of peat layers is possible only if the humus layer consists of a light-loamy granulometric composition, since their natural moisture content is very low. The introduction of 1-2 layers of low-lying peat into the artificial soil grunt will ensure the accumulation of water resources and create favorable conditions for the growth of plants.

From a practical viewpoint, the laws and technological methods of increasing the water capacity will only work if certain organizational aspects are observed [18]. During recultivation of dumps, it is necessary to achieve careful alignment of layers and the territory. In case of non-compliance with this rule, moisture can flow into the lowering or into the gravelly material, thereby worsening the water availability of plants and increasing the likelihood of contamination of the territories adjacent to the dumps of harmful substances washed with water. It is necessary to provide watering at the stage of biological reclamation, when herbaceous plants do not have time to form a well-developed turf, in dry periods [19]. This will make it possible to compensate for water losses because of physical evaporation.

Conclusion.
Water capacity of soil and artificial soils is formed as a result of water movement under the influence of gravitational forces. Filling each layer to the values of the lowest moisture capacity, the water gradually falls deep. Uniform particle size distribution throughout the profile is necessary for a constant rate of water movement. To reduce the depth of water penetration in soils and the formation of high moisture reserves in the root zone, it is possible to use the creation of layered soils. The introduction of coarse layers (rubble) reliably ensures the rupture of the capillary network, thereby preventing the flow of water deep into the blade. The least moisture capacity of the overlying layers increases compared with a homogeneous soil, and water supplies increase almost 2 times. In soils of medium and heavy loamy granulometric composition, the most effective will be the use of gravel, which will provide a reliable obstacle to the downward and upward movement of water and stabilize water reserves in the root layer. It is recommended to use 1-2 layers of peat or other water-retaining materials (hydrogels, hydrophilic polymers), which have good moisture capacity when used as a fertile layer of light loams and sandy loam. The data obtained during the experiment show the possibility of using mathematical models based on the basic hydrochemical characteristics to calculate the thickness of the fertile layer of layered soils of different granulometric composition. The use of rubble separating the root zone in the slurry dumps prevents from the penetration of salts and their negative impact on vegetation.

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