

# Using basic hydrophysical characteristics of soils in calculating capacity of water-retaining fertile layer in recultivation of dumps of mining and oil industry

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**Abstract.** Large volumes of solid waste consisting of empty rocks, slags and slurries characterize active development of the mining, metallurgical and oil-producing industries. To accommodate them, a large area in the immediate vicinity of the production is required. Filled to capacity dumps require immediate reclamation to prevent erosion or swelling of solid waste. Lack of protection against external influences (wind and rain) will inevitably lead to deterioration of the ecological situation in the regions where mining or processing of minerals is concentrated. The reclamation includes the stage of formation of a fertile layer on the surface of the dumps, providing favorable development of perennial grassy vegetation. The fertile layer should have a good water-retaining capacity, preventing the penetration of water deep into solid waste and wash out harmful substances. Each climatic zone requires a layer of vegetable soil of a certain thickness and particle size distribution. To define these indicators, a software product was developed that allows one to simulate water-physical properties of bulk soil with the main hydrophysical characteristic. The program can calculate the composition of soil with the necessary parameters of granulometric composition. It is mathematically and experimentally established that for conditions of a forest-steppe zone of Western Siberia, formation of the soil layer consisting of the fertile earth not less than 32 cm thick is required; sand or crushed stone – 10-20 cm and the shielding layer of clay is no more than 30 cm thick. The creation of such soil will reliably retain atmospheric precipitation, and the shielding layer will prevent the rise of water and harmful substances to the surface.

## 1. Introduction.

The development of the mining and oil industry is accompanied by a reduction in natural ecosystems and a large increase in the area of disturbed lands [1, 2]. Resistance to anthropogenic factors and restoration capacity of such systems are reduced [3]. One of the main measures to protect the lithosphere is recovery areas. Recultivation is considered as a complex problem of productivity restoration and reconstruction of landscapes disturbed by industry generally.

Traditionally, recultivation is carried out by either technical methods or biological methods [3]. The technical stage includes planning, formation of slopes, removal, transportation and application of soils on the reclaimed land. At the biological stage, a complex of agrotechnical and meliorative measures



aimed at improving the agrophysical, agrochemical, biochemical and other properties of the soil is carried out [4].

When creating a fertile reclamation soil layer, it is necessary to take into account the optimal water retention capacity, porosity and volumetric weight, the absence of swimming and cracking of the soil mixture [5, 6]. It should also be noted that the planted or sown plants will be under the influence of local conditions of soil formation [7, 8]. Therefore, additional components of a soil mixture should be selected in accordance with the calculated indicators of granulometric composition, water-physical and physical-mechanical properties.

The most common way to improve the soil is "earthing". In this method, humus soil layers or soils of different capacities are applied to the surface of dumps, on which perennial grasses can grow [9]. Different views are expressed as to what the layer should be. Some consider that this layer should be 0.5–1.0 m, according to others' opinion - it should reach two meters. Such thickness layer of fertile soil will provide secure shelter dumps from external factors, but the cost in monetary terms will be extremely impressive. There will also be another problem related to the exploration of large amounts of land in the immediate vicinity of the reclaimed dumps. In addition, this amount of fertile soil will not be easy to find. Experiments show that when evidence-based approach that takes into account water-physical properties of soils and their nutrient status, enough artificial layers are thicker than 35-40 cm, but with such a small layer, costs for agriculture will be significant. Sometimes agriculture is not enough. To ensure that toxic substances do not enter the root zone, it is necessary to artificially disrupt the movement of water in the vertical direction. This is achieved by shielding the soil with rocks that are very different granulometric composition.

The purpose of our research was to develop a model of bulk soils with given water-physical and physical-mechanical parameters on the basic hydrophysical characteristics of soils. This method can be used in reclamation of dumps of process mining, metallurgical and oil industry in different climatic zones.

## 2. Materials and methods.

The main object of the study was leached chernozem. Basic physical properties (granulometric composition, density, porosity) that had been identified in the work were used to create the algorithm of the computer model and calculation method for determining the total water retention curve. The advantage of this method is the use of information available for mathematical modeling [10, 11]. It is based on the concept developed by Voronin, according to which the moisture pressure on the water retention curve corresponds to each soil-hydrological constant. The moisture pressure is determined by one of the equations:

- porosity  $\varepsilon \Rightarrow P=0$ ;
- yield strength  $W_{ys} \Rightarrow pF=2,17$ ;
- least moisture capacity  $W_{lmc} \Rightarrow pF=2,17 + W_{lmc}$ ;
- maximum molecular hygroscopic capacity  $W_{mmhc} \Rightarrow pF=2,17 + 3 \cdot W_{mmhc}$ ;
- maximum hygroscopicity of the soil  $W_{mh} \Rightarrow pF=4,45$ .

Consequently, the problem of restoring the GHC is reduced to the calculation of soil-hydrological constants (SHC) from the data of soil granulometric composition. On the extensive experimental material, it is established that the values of SHC are related to the density  $\rho$ , the porosity  $\varepsilon$  of the soil and the content of fractions of the granulometric composition  $\omega$ , regression equations:

$$\begin{aligned}\varepsilon &= 0,805 - 0,183\omega_1 + 0,285\omega_2 + 0,057\omega_5 - 0,266\rho \\ W_{ys} &= 0,082 + 1,163\omega_2 - 0,287\omega_3 - 0,107\omega_6 + 0,312\varepsilon \\ W_{lmc} &= 0,15 + 0,085\omega_1 + 0,514\omega_2 + 0,142\omega_4 - 0,145\omega_6 \\ W_{mmhc} &= 0,053 + 0,941\omega_2 - 0,139\omega_3 - 0,031\omega_6 + 0,165\varepsilon \\ W_{mh} &= -0,009 + 0,198\omega_1 - 0,059\omega_2 + 0,04\omega_4 + 0,078\omega_5\end{aligned}$$

where  $\omega_1, \omega_2 \dots \omega_6$  – fractions of soil granulometric composition from silt to coarse sand according to the classification of N.A. Kachinski [12].

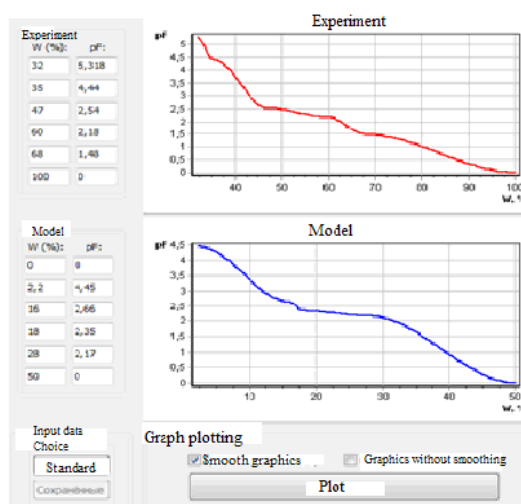
In the presented calculation equations, the organic carbon content is not taken into account and the soil profile is not differentiated by depth. But this disadvantage is compensated by taking into account the values of density and porosity of the soil, largely dependent on the genetic characteristics of soil horizons.

### 3. Results and discussion.

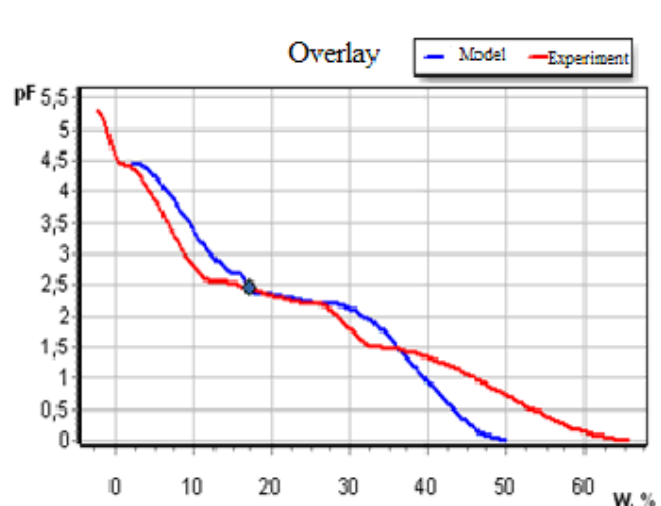
of the calculation model of soil and determination of its parameters are possible on the basis of comparison of laboratory test results and their virtual computer analogues. When creating our program, we do not set ourselves the task to find such substances which could be used to create artificial soil, which may contain a variety of components of different particle size distribution. We have tried to master the process of creating the soil known granulometric composition of particles of different mechanical strength, which have different ability to retain moisture forming different layers. Work in the laboratory has shown that such simulation is possible, if you know the hydrophysical characteristics of different soils, the basis of which can be created using our proposed method. It should be noted that the software was created without taking into account soil mineralization and its thermal properties [13, 14, 15].

In our work, we tried to create an algorithm and a simplified model of calculations and construction of the basic hydrophysical characteristics of soils, which would clearly allow observing and simulating the flow of the studied processes [16, 17].

The developed program is intended for calculation of granulometric composition of soil from soil-hydrological constants. The program performs the construction of experimental and model graphs on the input points (Fig. 1), holds the combination of these graphs in a user-specified point and finds the error of moisture content  $W$  (%) and pressure  $pF$  to this point.



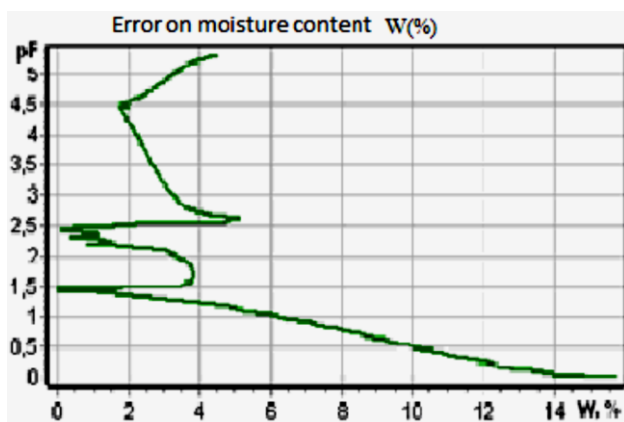
**Figure 1.** Graphs of the main hydrophysical characteristics of experimental and model experiments



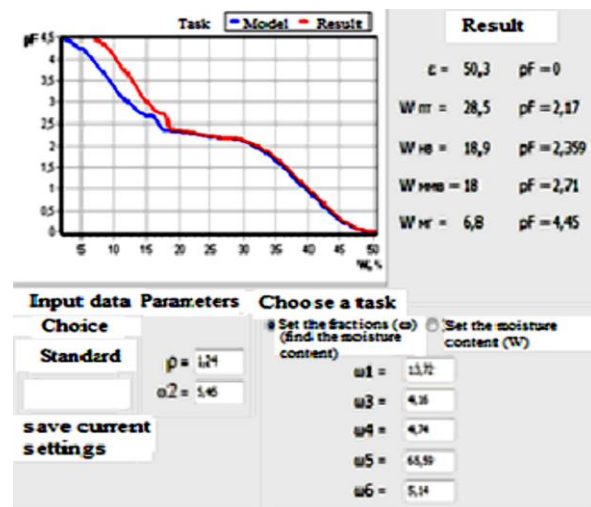
**Figure 2.** Combination of graphs of the function of the water retention curve obtained with the help of the software

After the graphs are plotted, they are combined at the point specified by the user (Fig.2), and there is a humidity error  $W$  (%) (Fig. 3) and the pressure  $pF$  for the specified point. Also, the developed program solves the problem of finding the values of humidity for given fractions of soil granulometric composition (from silt to coarse sand) (Fig. 4) and return it with the aim of finding the values of fractions at specified humidities (Fig.5). On each window of the program it is possible to save the current settings. This allows you to go back to the original calculations, a comparison and choose the best properties

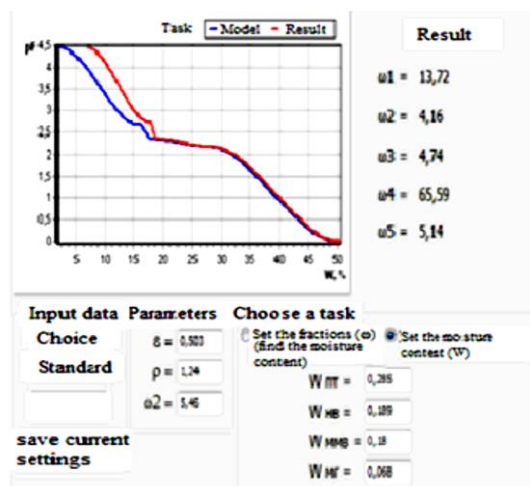
necessary for the design. The program allows one to reduce the complexity and increase the visibility



**Figure 3.** The error in the calculation of moisture for graphs function curve water-holding capacity obtained using software complex of the calculations.



**Figure 4.** Determination of humidity values



**Figure 5.** Determination of the fractions of granulometric composition of soil-mix

On the study site from 16% inclusive and up to 18%, we can talk about the state of physical ripeness of the soil, and, therefore, its readiness for processing. Stickiness begins to appear at 18% humidity, which will have a negative impact on the processing conditions. With 28% humidity, there is a manifestation of plasticity, and with 50% humidity the soil becomes a state of fluidity. The obtained values of soil-hydrological constants can be used to calculate the active soil layer.

$$H = \frac{M}{\rho_b \cdot (W_{\text{ппв}} - W_{0,7\text{ппв}})}$$

$$H = \frac{0,1}{2,62 \cdot 0,12} = 0,32 \text{ m}$$

where H is the active layer of the soil, m; M – The monthly rainfall, m<sup>3</sup>/ha;  $\rho_b$  is the density of the active layer of the soil, t/m<sup>3</sup>; Wmfwc - optimal moisture content of the active soil layer, almost equal to or slightly less than maximum field water capacity (MFWC); W<sub>0,7mfwc</sub> – humidity of the active layer before watering.

When calculating the thickness of bulk artificial soil, which will serve as a water-retaining layer, it is necessary to clarify the following indicators.

- possibilities of water consumption of vegetation used for reclamation of technological dumps;
- the lower permissible limit of moisture content in the soil, ensuring the viability of plants;
- the maximum amount of moisture that can hold the bulk soil crunch, excluding the penetration of precipitation in the technological waste dumps;
- the nature of the distribution of precipitation throughout the year and during the growing season of this plant species in the area;

- equilibrium density and granulometric composition of individual components of artificial soils.

According to our calculations, taking into account the hydrothermal conditions of the forest-steppe zone of the West Siberian plain, the thickness of the bulk soil should be at least 0.32 meters. As a material, it is necessary to use the ground of heavy granulometric composition [18]. The resulting thickness is well suited for the rapid development of perennial grasses and the formation of turf. To protect the root layer from the penetration of toxic elements, the underlying layer is poured with a capacity of not less than the height of the capillary rise of water. This layer can be formed from sands or other materials excluding the formation of the capillary network. For this purpose, it is possible to use small fractions of crushed stone, or nontoxic wastes of the mining industry. The thickness of this layer should be 10 to 30 cm. To enhance the effect of water resistance, it is possible to use a shielding layer thicker than 20 cm of clay. After the mechanical stage of recultivation, artificial soil mix should have a thickness of about one meter, where the fertile layer is not more than 30 cm. In its composition and location of layers, the soil mixture is similar to the profile of chernozem, which is optimal for the growth of perennial grasses and has high minimum moisture content [19].

## Conclusion

In the process of reclamation, there is the formation of soils and the creation of their fertility. At the same time, a fast and effective method of fertility restoration is application of a humus soil layer on the surface of the blade rocks. It is advisable to remove this layer before mass production of soil. In the future, the fertile layer can be used on recultivated lands. In addition to the formation of a fertile layer, using previously removed at the moment, it is possible to design bulk soils. The task is implemented if the working layer is set to the required granulometric composition using pedo-transfer functions. In addition, the main hydrophysical characteristic makes it possible to calculate the thickness of the root layer.

## References.

- [1] Iglovicov A 2016 *Procedia Engineering* **165** 800-805
- [2] Skipin L Petuhova V and Romanenko E 2017 *Procedia Engineering* **189** 593-597
- [3] Petuhova V Skipin L Gaevaya E and Skipin D 2017 *IOP Conference Series* **87** 042012
- [4] Motorin A Bukin A and Iglovicov A 2017 *IOP Conference Series* **90** 012053
- [5] Gaevaya E Skipin L Zaharova E Bogaychuk Y and Tarasova S 2017 *IOP Conference Series* **87** 042004
- [6] Motorin A Bukin A 2017 *MATEC Web Conf* **107** 02030
- [7] Eremin D 2016 *Eurasian soil science* **5** 538-545
- [8] Degefie D Fleischer E Klemm O Soromotin A Soromotina O Tolstikov A and Abramov N 2014 *Stoch Env Res Risk A* **28** 2161-2173
- [9] Eremin D and Eremina D 2016 *MATEC Web Conf* **106** 01044
- [10] Chelovechkova A 2015 *Agrarian Bulletin of the Urals* **1** 12-16
- [11] Rawls W Gish T Brakensiek D 1991 *Advances in Soil Science* **16** 213-234
- [12] Shein E Goncharov V 2006 *Agrofizika (Agrophysics)* (Rostov-on-Don Feniks)
- [13] Komissarova I 2008 *Agrarian Bulletin of the Urals* **4** 72-74
- [14] Kuhling I Redozubov D Broll G and Trautz D 2017 *Soil & Tillage Research* **170** 43-52.
- [15] Krivonos L Komissarova I 2009 *Agrarian Bulletin of the Urals* **1** 38-39
- [16] Chelovechkova A 2016 *Eastern European scientific journal* **6** 100-105
- [17] Edivaldo L Adalberto A 2017 *Geomorphology* **286** 27-33
- [18] Eremin D and Eremina D *Procedia Engineering* **165** 788-793
- [19] Chelovechkova A 2014 *Agrarian Bulletin of the Urals* **3** 13-18