Studying the Moisture Capacity of Artificial Soils Containing Industrial Byproducts

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Abstract. Artificial soils based on sand and clay contain multiple byproducts such as defecation precipitate and byproduct of wet magnetic separation (WMS). The organic portion is the sediment from the sludge lagoons of the pig farm. We have studied the moisture retention capacity of artificial soils. The moisture capacity is mainly contributed to by clay (28 mg/g), defecation precipitate (20 mg/g), and the sludge-lagoon sediments (30 mg/g).

Specific surface area of artificial soils lies within a range of 50 to m²/g, which is close to ordinary chernozem soils. The obtained artificial-soil compositions can be used for land reclamation as an alternative substrate of natural soil.

1. Introduction

Mining and unsustainable use of the resources stored in the pedosphere have resulted in the depletion or even irreversible loss of fertile soil layers. The destroyed structure coupled with altered compositions and properties cause some types of the soil biocenosis to die, which in its turn results in the degradation of soils [1-2]. Reclamation can bring soil back to its original state, or at least close to it [3-4].

There are multiple approaches to soil remediation [5-6]. One of them consists in creating artificial soil [7-9]. Artificial soil is a complex system where each individual component is important [10-11]. There exist numerous ways to create artificial soil [12-14]. It mostly contains components used in the biotesting of soils, such as sand, white clay, sphagnum peat, and calcium carbonate [15-16].

2. Statement of Problem

In this research, artificial soil was mainly made of mineral components such as sand and clay, to which we added calcium-containing substances, i.e. chalk and defecation precipitate. Beside these components, we used byproducts of wet magnetic separation (WMS) as an inert structuring additive. The sludge-lagoon sediments from pig farms were used as the organic component (see Table 1). Sediments accounted for 15% of the total mass. As such sediments had a humidity of 80%, using them enabled us to use less water for the humidification of artificial soils. Chernozem from Belgorod Oblast was used as a control sample.
Table 1. Soil composition.

| Components                  | Control sample | Sample #1 | Sample #2 |
|-----------------------------|----------------|-----------|-----------|
| Sand                        | 20             | 20        |           |
| Clay                        | 35             | 20        |           |
| Defecation precipitate      | 10             | 10        |           |
| WMS byproducts              | 20             | 20        |           |
| Soil                        | 100            |           | 15        |
| Sludge-lagoon sediments     | 15             | 15        |           |

3. Results and Discussion

The obtained samples of artificial soil were studied for moisture absorption and retention qualities. To that end, we analyzed the absorption of water vapor by separate components as well as by the artificial soil as a whole.

Moisture absorption kinetics was studied by the weight method at various equilibrium pressures of the dessicator-generated vapor. The results are shown in Figures 1 to 3.

Figure. 1. Moisture absorption kinetics in the control sample at various desiccator humidity values.

The control sample was found to absorb up to 18 mg of moisture per gram of soil.
Sample #2 featured higher moisture absorption rates than its counterpart #1, perhaps due to higher porosity and aeration. We believe this was because Sample #2 contained 15% of the control soil.

Dry sludge-lagoon sediments absorb more water than natural soils (up to 30 mg/kg). When such sediment is dried, it becomes dispersed, which increases its porosity and therefore results in greater moisture absorption [17-19].

Defecation precipitate can retain up to 25 mg of moisture; similar patterns are observed when testing the moisture absorption capacity of clay (up to 28 mg/g).

Sand and WMS by-products have low moisture content when used as artificial-soil components. This means that clay, defecation precipitate, and sludge-lagoon sediments contribute more to the moisture absorption capacity of the soil. In this respect, sand and WMS by-products are “ballast” components, since their moisture retention capacity is 2.5 to 3 mg, which is 10 times less than clay or defecation precipitate.

We used the preliminary values to plot the adsorption isotherm.
Figure 4. Water vapor adsorption isotherms. **Legend:** control, 2, 1.

The observed moisture absorption were used to determine the specific surface area. According to the calculations, the specific surface area was consistent with the values characteristic of natural soils (see Table 2).

**Table 2. Specific surface area of artificial-soil samples**

| Indicator                  | Unit     | Control | 1   | 2   |
|----------------------------|----------|---------|-----|-----|
| Adsorption, a•10^{-3}      | g/g      | 11.5    | 7.4 | 10.9|
| Specific surface area, S   | m^2/g    | 70.2    | 49.4| 72.8|

These data indicated that the specific surface area was close to that of the ordinary chernozem of the Central Chernozem Region [20]. Therefore, moisture retention capacity is at max in clay, defecation precipitate, and sludge-lagoon sediments, meaning that adding them to artificial soils help retain not only moisture but also other nutrients.

For now, we can speak of substituting valuable components with various kinds of waste, including biological treatment waste that is generated in large amounts when treating the wastewaters of pig farms. Such waste can well be used in land reclamation.

**4. Conclusions**

Artificial soil created using industrial by-products was able to accumulate moisture no less efficiently than the control sample.

Moisture reserves in artificial soils rose from 4-6 to 14-18%, which was close to the control sample. That was mainly due to clay, defecation precipitate, and sludge-lagoon sediments.

The specific surface area of the obtained artificial-soil samples was close to that of ordinary chernozem.

These results prove feasible, solving a number of environmental problems by using such soil compounds as substitutes for natural soils when creating recreational areas or reclaiming man-destroyed areas, as well as when needing to dispose of large amounts of industrial by-products that cannot be reasonably recycled otherwise.
5. References

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Acknowledgments
The article was prepared as part of the development program of the supporting university on the basis of the BSTU named after V.G. Shukhov