Influence of soil structure of newly formed agricultural landscape of recultivated landfill of municipal solid waste on its humidity

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Abstract. The objective of the study is to justify the influence of different proportions of sewage sludge introduction into the soil of a newly formed agricultural landscape on a recultivated landfill site taken out of operation. To achieve this goal it is necessary to monitor the dynamics of humidity in the recultivated areas during the growing season of 2020 under actual weather conditions. The areas were recultivated applying various technologies and the irrigation mode was introduced on the Area No. 2. This area is characterized by three types of soil: test-ordinary chernozem; a mixture of chernozem and sewage sludge; pure sewage sludge. Area No. 1 is pure wastewater sludge. The studies on humidity dynamics show that the humidity is changeable in different periods of the growing season, but in the areas with wastewater sediments, the field humidity is higher than in the test area. Thus, it can be concluded that the introduction of sewage sludge influences the structure of the resulting soil, which favorably impacts its water-retaining capacity.

1. Introduction

In our region as well as in the entire Russian Federation there are lands withdrawn from agricultural crop rotation for various reasons. These areas are used to solve specific problems of the regions; however, their development causes land depletion or degradation, for example, the area of "solid municipal waste landfills are custom-built structures designed for waste disposal and processing." [1] There are 131.3 thousand hectares under waste landfills and deposits in Russia. [2] After filling the solid waste landfill it is closed and recultivation works are carried out. [1] When recultivating a landfill at the biological stage, it is environmentally and economically justified to use sewage sludge instead of a fertile soil layer. [3] The dynamics of soil humidity in the newly created agricultural landscape will depend on the structure of the soil used for recultivation and its ability to retain moisture. The soil structure will be significantly influenced by the introduced sewage sludge. [4]

Within the framework of the study, the objective was set to determine the influence of the sewage sludge norm in the soil of recultivated landfill of solid municipal waste on the dynamics of soil humidity on the newly formed agricultural landscape.
2. Materials and methods

To carry out the present research and achieve the goal, two sections of solid municipal waste landfill of the Barnaul city were taken and recultivated by creating a new agricultural landscape applying different methods. The areas are located in Barnaul, st. Kosmonavtov, 74a (figure 1) [5].

Recultivation was carried out using different types of soil, including ordinary chernozem and adding sewage sludge (solid fraction, consisting of organic and mineral substances introduced in the process of sewage purification via precipitation [6]) in different proportions. In the Area No. 1 - an anti-filtration layer of clay and pure sewage sludge were poured onto the pressed conditions of the landfill, where the planning and slope was made. Sewage sludge is a fertile soil that is suitable for crop production, which is backed by scientific evidence. [7] Seeds of perennial grasses were sown in 2018. In the Area No. 2 a watertight screen was also made on solid construction waste, pre-pressed and leveled; a fertile layer was poured in 3 options: test (ordinary chernozem), a mixture of sewage sludge and ordinary chernozem in equal proportions, and pure sewage sludge. In 2019 the seeds of perennial grasses were sown. [8] It is also worth noting that irrigation mode was in the Area No. 2 at the rate for perennial grasses (soil moistening to a depth of 0-30 cm at the rate of 230 m³/ha 5 times during the growing season [9]), and in the Area No. 1 irrigation was only in the form of precipitation.

Achievement of the goal is possible when performing the following task: to assess the change in moisture content during the entire growing season in the indicated areas during the period of 2020. The dynamics of field humidity was investigated applying the thermostat-weight method. [10,11]

3. Results and discussion
The growing season in 2020 was characterized by periods of drought and high humidity. (Figure 2) [12]
At the beginning of the growing season the temperature indicators exceeded the normal by 4 degrees on average; the actual rainfall was not enough to reach the normal level by more than 20%. By the middle of the growing season all climatic indicators returned to normal, and by the end of the growing season precipitation fell above normal by more than 50%, although the temperature indicators returned to normal, and the average temperature difference was 0.1 °C.

Let us focus on the indicators of field humidity in different areas during different periods of the growing season.

Field humidity in the Area No. 1 at the beginning of the growing season is higher due to its territorial location (a large layer of snow in winter up to 50 centimeters, which indicates good spring moisture). In the Area No. 2 the snow cover in winter reached 20 centimeters, and accordingly did not moist the soil enough.

Due to the sharp spring advent and air temperatures exceeding the norm, we can consider a high degree of moisture evaporation from the upper soil layers, which can be observed in figure 3.

However, in the lower soil layers, humidity is stable (Figure 4).
There are differences in the structural composition of the obtained soils, which characterizes the difference in humidity indicators in the areas.

Figures 3 and 4 show that ordinary chernozem retains moisture worst of all and is more exposed to evaporation and moisture infiltration.

The actual high temperatures and frequent lack of atmospheric precipitation affected plants growth; during periods of drought, even with an irrigation regime in the Area No. 2, stable wilting of perennial grasses was observed in both areas. The field humidity indicators increased in the period between July and September as the actual amount of the rainfall exceeded the norm, which is also evident from the field humidity indicators in Figures 3 and 4. Perennial grasses during this period regained their green color and even before the first snow their appearance did not change.

Now let us look at the humidity indicators for the soils options obtained:

In the Area No. 1 pure sewage sludge was dumped, but the layer did not exceed 30 centimeters. [13] As a result, we can observe that even with good snow retention in winter, the processes of evaporation and infiltration strongly affect the humidity indicators in this layer.

In the Area No. 2 in option (test) - ordinary loamy chernozem has the lowest water retention. (Figure 5).

![Figure 5. Indicators of field humidity on different types of soils](image)

Compared to mix and sludge options in pure form, during periods of drought on chernozem the plants burned out, which required additional perennial grasses sowing, even with watering.

In the option of chernozem and sewage sludge mixture in presence of irrigation, favorable conditions have developed for perennial grasses growth and development due to the stable field humidity. Water retention in this case is characterized by the structural composition of the obtained soil; the presence of evaporation and infiltration processes does not affect the field humidity indicators.

In the Area No. 2 in pure sewage sludge option humidity indicators are high due to the structural composition of this soil; evaporation and infiltration processes are present, but they do not particularly affect the field moisture content of this option, and even moisture transpiration by plants does not reduce the field humidity indicators.

Humidity in sewage sludge is due to the presence of capillarity and high moisture capacity of resulting soil structure; with the decrease in the average daily temperature, the field humidity rises due to the hygroscopic moisture increase in the soil.

4. Conclusions

Within the framework of this study humidity indicators during the growing season of 2020 were considered in the recultivated areas of the solid municipal waste landfill of the Barnaul city, where new agricultural landscapes were formed.

The dynamics of field soil humidity in different areas and in different options of the obtained soil were considered. The dependence of field humidity on meteorological conditions was determined.
In options with sewage sludge one can mention the presence of capillary moisture in the soil obtained, which has a favorable impact on the conditions, created for perennial grasses. The presence of infiltration and evaporation processes does not critically affect the field humidity. The introduced mode has a favorable effect on the plants water-air regime.

In the chernozem option the processes of infiltration, evaporation and transpiration have a detrimental effect on the presence of moisture, which leads to excessive soil drying out and perennial grasses burnout, even in the presence of irrigation. It is necessary to carry out recultivation measures to create more favorable conditions for plants.

The most optimal and favorable option turns out to be the option of ordinary chernozem and sewage sludge mixture; a change in the structural composition caused capillarity in ordinary chernozem and an increase in moisture capacity, which contributes to favorable conditions for the plants growth and development.

It can be argued that the introduction of sewage sludge causes change in the structural composition of the soil and an increase in moisture capacity, as well as the field moisture content of the soil, but the introduction of an irrigation mode has a beneficial effect on the growth of plants and the soil water-air regime in general.

References
[1] SP 320.132580.2017 “Landfills for solid municipal waste. Design, operation and remediation” (approved by the Order of the Ministry of Construction and Housing and Communal Services of the Russian Federation of November 17, 2017 N 1555 / pr and entered into force on May 18, 2018.)
[2] State report “On the state and environmental protection of the Russian Federation in 2019” 2020 (Moscow, Lomonosov Moscow State University) p 1000
[3] Bugai Y, Minenko A and Khorunzhin M 2019 State and problems of exporting the products of the agro-industrial complex in the Altai region. IOP Conference series: earth and environmental science. International conference on sustainable development of cross-border regions 2019 (SDCBR 2019 Barnaul, 19–20 April 2019. Institute of Physics Publishing) pp 012105
[4] Sudnitsyn I I, Egorov Y V, Bobkov A V and Kirichenko A V 2014 Influence of soil structure on their hydrophysical properties Bulletin of the Moscow University. ser. 1. Soil science 1 14-9
[5] Google Planet Earth 11 October 2020 (edited on 10 June 2021) Website of Public company “Google Planet Earth” Retrieved from: https://earth-google.ru/planeta-zemlya-sputnika.php
[6] GOST R 17.4.3.07-2001: “Nature protection. Soils. Requirements for the properties of sewage sludge when used as fertilizers” (adopted and put into effect by the Resolution of the State Standard of Russia of January 23, 2001 N 30-st) International Code of Conduct for the Sustainable Use and Management of Fertilizers” 23-29 June 2019 FAO Commission on genetic resources for food and agriculture assessments (Rome) p 576
[7] Cheprunova Yu V, Tingaev A V, Vorob'eva R P, Sheptalov V B and Davydov A S 2019 Influence of sewage sludge on the yield of oat hay during biological recultivation of solid municipal waste landfill Bulletin of the Altai State Agrarian University 12 50-56
[8] Liskonov A A 2003 Formation of highly productive agrocenoses of perennial grasses under irrigation in the dry-steppe zone of the Volga region and their phytomeliorative role (Penza: State Agricultural Academy)
[9] Makarychev S V and Mazirov M A 1996 Soil thermophysics: Methods and properties (Suzdal: Russian Academy of Agricultural Sciences, Vladim. Research Institute of rural economy) p 231
[10] GOST 28268-89 “Soil. Methods for determining humidity, maximum hygroscopic humidity and humidity of sustainable wilting of plants” (approved and put into effect by the Resolution of
the State Committee of the USSR on standards of 27.09.89 N 2924)

[12] Reference and information portal "Weather and climate" Website of Public company “Weather and climate” Retrieved from: http://www.pogodaiklimat.ru/monitor.php?id=29838

[13] Argunov N D, Vatueva O B, Veselov V M, Salomatina N A and Pilgun V A 2013 Some properties and features of sewage sludge *Agrochemical Bulletin* 4 39-43