Technology for Draining Heavy, Poorly Water-Permeable Soils with Two-Tier Drainage

O V Balun¹, N N Semchuk² and S N Gladkih²

¹Novgorod Research Institute of Agriculture, a branch of the St. Petersburg Federal Research Center of the Russian Academy of Sciences, ul. Parkovaya, 2, s. Borki, Novgorod region, Russian Federation
²Yaroslav-the-Wise Novgorod State University, 41, ul. B. St. Petersburgskaya, Veliky Novgorod, Russian Federation

E-mail: bov0001@mail.ru

Abstract. The described technology refers to the hydro-technical construction of drainage systems. The design purpose is to drain surface and groundwater from waterlogged heavy, poorly water-permeable farmland soils. The method includes making two-tier drainage with lower tier consisting of dehumidifiers, which are a drainage tube with a protective filter filled to a height of 10 cm with a sand and gravel mixture, and the upper tier made of non-cavity drains. The plan location of the upper tier drains is perpendicular to the lower tier drains. A column of sand and gravel mixture is arranged at the intersection of the upper and lower tiers. The technology allows reducing the volume of the filter drainage backfill by 1.5–2.0 times while maintaining a high drainage rate and reliable hydraulic connection of the arable horizon with the drainage pipe while reducing the material consumption of the proposed structure by reducing the volume of the drainage backfill made of sand and gravel mixture.

1. Introduction

The natural and climatic conditions of the Novgorod region often lead to water logging of soils and, as a result, to a decrease in effective fertility. This is especially evident on flat terrain soils heavy in granulometric composition. The main measure to optimize the water-air regime of such soils is drainage [1, 2, 3]. At the end of the last century, closed drainage was used to drain such lands [4]. The experience of using closed drainage on such soils has shown that it does not always cope with the timely removal of excess moisture [5, 6]. The main reason is the presence of a poorly permeable soil layer between the arable horizon and the drainage pipe [7]. To solve this problem, a fairly large number of technologies and designs of drainage systems have been proposed. In China, the use of a well-filtered drainage trench backfill led to an increase in drainage flow by 1.9 times [8]. Studies of various subsurface drainage structures during the agricultural lands drainage in the floodplain of the Moldavian river have shown the advantage of a structure with a filtering drainage backfill based on flax [9]. In Belarus, there is a two-tiered drainage system consisting of a ceramic or plastic drain, which is placed on the bottom of a trench and covered with a sand and gravel mixture at a certain height, it is crossed by molehills cut perpendicular to the material drainage.
Water from the arable horizon enters the molehill along the crack, which remains in the soil after the cutting of molehills, then gets into the backfill and drain [10]. G.S. Pototsky and V.L. Zhivitsa proposed the design of two-tier drainage and humidification system, consisting of two tiers drains: upper and lower. The distance between the drains of the lower tier is 20–40 m, of the upper one – 6–10 m. The tiers are connected with vertical outlets made of plastic fittings. The drains of the upper and lower tiers are made of pottery pipes with a diameter of 50 and 75 mm, respectively. The depth of the lower tier is 1.1–1.8 m; the upper one is 0.5–0.7 m [11]. A.I. Klimko proposed a technology for draining heavy, poorly water-permeable soils with two-tier drainage: the lower tier, consisting of closed collectors, located 30–40 m apart, and the upper tier – of non-cavity drains. The collectors are a drainage pipe with a protective filter placed at the bottom of the trench and filled up to the upper tier with a well-filtering material. A sand and gravel mixture can be used as a well-filtering material. The average depth of the enclosed collectors of the lower tier is 1 m, the upper tier – 0.7 m [12]. The presented designs have their drawbacks: fragility of mole drainage, lack of hydraulic connection of the arable horizon with the upper tier of drains, and a large volume of sand and gravel backfill.

2. Research objects and methods
The research object is the technology of draining heavy poorly permeable soils with two-tier drainage.

3. Results and discussion
An innovative technical solution is to cheapen the construction of two-tier drainage by reducing the volume of sand and gravel mixture while maintaining the hydraulic connection of the arable horizon with a drainage pipe embedded in the lower tier. To solve this problem, an innovative technology has been proposed for draining heavy, poorly water-permeable soils with two-tier drainage, its lower tier consists of dehumidifiers which are a drainage pipe with a protective filter filled to a height of 10 cm with a sand and gravel mixture, whereas the upper tier is made of non-cavity drains. The plan location of the drains (figure 1) of the upper tier (2) is perpendicular to the drains of the lower tier (1).

![Figure 1. Location of two-tier drainage in plan.](image)

In the vertical plane (figure 2 and figure 3), the lower tier is a drainage pipe with a filter (3), placed on the bottom of a trench, 1–1.1 m deep, filled with filter material along its entire length to a height of 10 cm (4). The upper tier is a non-cavity drain (5) with a depth of 0.5 m. The drains of the upper and lower tiers are connected with columns made of filtering material (6).
The problem solution is achieved by the fact that in the structure for draining heavy, poorly permeable soils with two-tier drainage, consisting of an upper tier of non-cavity drains and a lower tier, the lower tier consists of dehumidifiers with filtering material columns located at the linking with the upper tier, whereas the depth of the upper tier is 0.5 m.

In the proposed method for draining heavy, poorly permeable soils with two-tier drainage, the all-over 0.3 m high filtering backfill of the drainage tube of the lower tier is replaced with a backfill which is 0.1 m high and columns of the same material at the intersection with the upper tier placed at a distance of 5–6 m. The depth of the upper tier non-cavity drains is reduced by 0.2 m.

As a result, if the volume of backfill made according to traditional technology is 230–270 m³/ha, then the volume backfill made according to the innovative drainage technology is 135–160 m³/ha.

The given data show that innovative technology can reduce the backfill volume by 1.5–2.0 times.

The following specifications are retained:

– reliable hydraulic connection of the arable horizon with the drainage pipe is provided due to the linking of the upper tier with the lower one by means of columns made of sand and gravel mixture;
– the rate of excess moisture removal remains unchanged due to the invariability of the distances between the non-cavity drains of the upper tier, which in this case work as collectors. The proposed decrease in the depth of the upper tier will not affect the rate of water drainage from the arable horizon, since in poorly water-permeable soils it depends only on the distance between the collectors and does not depend on the depth of their placement.

Main technical and economic indicators:
- Depth of tubular drainage of the lower tier 1.0–1.2 m
- Depth of non-cavity drainage of the upper tier 0.4–0.5 m
- Intersection of the upper and lower tiers at an angle 90°
- Volumetric filter of tubular drains of the lower tier 10 cm
- Columns made of well-filtering material are placed in 5–6 m
- Distance between drains of the lower tier 20–30 m
- Distance between drains of the upper tier 5–6 m

4. Conclusion
The innovative technology allows reducing the volume of the filtering drainage backfill by 1.5–2.0 times while maintaining a high drainage rate and reliable hydraulic connection of the arable horizon with the drainage pipe and reducing the material consumption of the proposed structure by reducing the volume of the drainage filling made of the sand and gravel mixture.

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