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Forecast of change in filtration properties of soils in aeration zone during land irrigation

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Abstract

The article discusses the main problems of predicting changes in the geological environment under anthropogenic impact: in terms of, changes in the filtration properties of soils in the aeration zone. The value of soil water permeability serves as the basis for calculating the loss of water from the projected canals, irrigation areas, setting the norms and timing of irrigation, calculating and placing the collector-drainage network. The geo-filtration characteristics of the loess soils of the aeration zone were determined by experimental filling into pits, according to field observations on existing drains and by soil locking in experimental pits and laboratory studies. Based on these data, the predicted values of the filtration coefficient of rocks of various genesis and ages were calculated and recommended for calculations.

Keywords: drainage, assessing the rate of settlement of structures, water permeability of loess soils, filtration coefficient, subsidence deformation, filtration rates, water consumption, filtration properties, subsidence thickness, weir

Introduction

During irrigation of the plain areas of the Kashkadarya and Surkhandarya depressions, where loess and loess-like rocks are widely developed, significant changes in the moisture regime of the rocks of the aeration zone occur; intensive filtration of water under irrigation canals and irrigated fields, leading to filtration leaching of rocks; selective nature and increased intensity of manifestation of unfavourable engineering-geological processes associated with both abundant moisture of rocks and the activity of surface waters.

In majority of the irrigated zone of the aforementioned depressions, groundwater is widespread in Quaternary sediments, their main direction of movement is from east to west and southwest. The nature of the movement is due to the heterogeneity of the filtration properties of the rocks, the variability of the conditions of feeding and unloading over the area, etc. The groundwater depth varies from 1-3 to 5-7 m.

Materials and Methods

The experience of the development of loess territories showed that where the construction of buildings and structures, irrigation systems and the development of irrigated territories took place in the absence of the designers and builders of information about possible changes in the filtration properties of soils, the destruction and losses caused by the underestimation of these phenomena were significantly greater than where the predicted changes in these properties were foreseen [1].

The basis for calculating the inflow of water to construction pits, canals, underground workings, collector-drainage systems, to assess water losses for filtration of irrigated areas, to solve the issue of methods of their drainage, to assess the rate of settlement of structures are the values of the filtration coefficient and their possible changes in the development process ... Filtration coefficients can also serve as a basis for making regional forecasts of changes in hydrogeological and engineering-geological conditions of the territory under the influence of irrigation and reclamation construction [2]. Changes in the water permeability of loess on the massives of newly cultivated lands are very poorly covered in the engineering-geological and hydrogeological literature, and the relevance of their study is beyond doubt.

As noted above, within the Kashkadarya and Surkhandarya depressions on all massifs of newly developed lands, loess and loess-like soils have a very wide and sometimes predominant distribution. These are typical loess of the Karshi and Sherabad, Tivet, Lyalmikar and other steppes. The named territories with a total area of more than 1.0 million hectares, composed of these rocks, are almost everywhere characterized by difficult water flow conditions and require drainage measures during irrigation and construction.

Infiltration losses of irrigation water are almost completely spent on watering the rocks of the aeration zone with a thickness of up to 30 m. In loess soils, in contrast to non-sessile sandy loamy-loamy rocks, significant changes in water permeability occur [3]. Considering that loess and loess-like rocks occur in the aeration zone, i.e. in the zone of the most active influence of irrigation structures, underestimation of changes in their permeability can cause serious miscalculations in the design of buildings and structures. For example, according to our data, in the northern part of the Karshi and central massifs of the Sherabadkoy steppes, loess-like soils to the locks showed a filtration coefficient on average of 0.42-0.94 m/day; this value with a margin of 20-30% was recommended for drainage calculations. The filtration coefficients of the same soils after flooding, determined from field observations on existing collectors and drains, turned out to be 1.2-3.5 times less in Karshi (G.A. Mavlyanov, K.P. Pulatov, Yu.I. Irgashev, 1974) [4], 1.5-4.0 times - in Lyalmikar (K.P. Pulatov, Yu.I. Irgashev, A. Tukhtaev, 1994) [5] and 1.3-3.8 times - Sherabad steppes (N.N. Khodzhibaev, B.Ya.Neyman, 1982) [3].

Thus, the forecast of changes in the water permeability of loess soils under the influence of watering is one of the important aspects of the characteristics of the hydrogeological, engineering-geological and reclamation conditions of the newly developed land massifs.

The basis for predicting regional changes in the filtration properties of soils is based on the following research materials (from 1964 to 2010): I) experimental filtration, carried out in Uzbekistan on the massifs of newly developed lands of the Karshi, Golodnaya and Sherabad steppes; 2) full-scale permeability of rocks on collectors and drains of Sherabad, Golodnaya and Karshi steppes; 3) full-scale during the soil locks of experimental pits in the Karshi steppe and the left bank of the river. Chirchik.

Medium-Upper Quaternary proluvial loess and loess-like rocks, with a thickness of 7-10 to 30-50 m, common on the massifs under consideration, practically do not differ from each other in grain size, mineralogical and chemical composition. However, as is known, in natural occurrence they have high total porosity (42-50%, sometimes up to 52%), water permeability, wettability, macroporosity and vertical separation, lamination is usually absent or poorly expressed. This difference determines their increased water permeability and filtration anisotropy [3]. As is known, the water permeability of loess soils is higher in the vertical direction (2-5 times) than in the horizontal one; in non-forest layered soils, on the contrary, the vertical filtration is several times lower than the horizontal one. When the loess rock is soaked, the skeletal bonds are destroyed and the bulk density of the skeleton increases, i.e. seal. We took this indicator as the main characteristic that determines the water permeability of the loess.

Results and Discussions

Results of determining the filtration coefficients of rocks by filling water into the pits. Within the Kashkadarya and Surkhandarya depressions, we carried out more than 600 determinations of the filtration coefficient by the method of filling water into pits, in the process of large and medium-scale engineering-geological and hydrogeological surveys, at depths from 0.3 to 15 m, according to N.S. Nesterov and N. I. Bindeman. Almost all experiments were accompanied by the determination of density, porosity, moisture content and micro-aggregate composition in an undisturbed constitution [6]. The filtration coefficient usually varied in loess soils from 0.06 to 1.94 m/day, and in fine, fine and medium-grained sands from 3.10 to 11.6 m/day (Table 1). Smaller and larger values were obtained rarely: smaller - at a high density, not typical of loess-like soils, and larger - at depths usually up to 3.0 m, where large macropores and burrowing burrows are common. For each type of section, the weighted average of the filtration coefficients of the entire power of the aeration zone is calculated separately according to the following formula:

$$K_{w.a.} = \frac{K_1 h_1 + K_2 h_2 + \cdots + K_n h_n}{h_1 + h_2 + \cdots + h_n},$$

where K1, K2 ... Kn - filtration coefficients (m/day) of the calculated homogeneous layer by petrographic type or a variety of soils;

h_1, h_2… h_n is the thickness of the calculated layer, m.

As a result of such calculations, data are generalized on the filtration properties of various genetic, age and petrographic types of soils (Table 1), on the basis of which areas with different weighted average values of filtration coefficients in the following gradations (m/day): 0.1; 0.1-0.3; 0.3-0.5; 0.5-1.0; 1.0-2.0; 2.0-3.0; 3.0-5.0; 5.0-7.0; 7.0-10.0, etc. [7].

The most common values of the filtration coefficient, depending on the mineralogical composition, structure, texture, moisture content, salinity, density, subsidence of loess, vary in the range of 0.42-0.94 m/day). On the regional level, there is a slight increase (1.5-2 times) in the value of the soil filtration coefficient in the direction from gentle slopes and bottom parts of large valleys to watersheds. As our studies have shown, with an increase in the thickness of the aeration zone of loess strata (where they reach 30-50 m and more), the role of lighter (usually less dense lithological varieties of loess rocks), as well as buried soils, increases. Filtration coefficients of buried soils decrease by 1.4-2.5, up to 5 times due to an increase in the content of clay fraction and their density [8].

In general, the loess strata of the region are characterized by an increase down the section of the total density and a decrease in the filtration coefficient from 0.42-0.94 to 0.1-0.2 m/day. Also, the filtration heterogeneity of loess rocks is observed in the vertical and horizontal directions, the value of the filtration coefficient of which in the latter is lower by 1.2-5, up to 8 times.

Results of determining the filtration coefficient according to field observations on operating drains. This work was carried out by Sredazgiprovodkhlopkom [9-11] and PA "Uzbekhydrogeology" [4,5], respectively in Golodnaya, Karshi and Sherabad steppes, where groundwater rose to the surface and horizontal drainage built in advance began to work.

Within the Golodnaya Steppe B.Ya. Neiman and E.V. Mavlyanov (1988) in the Pakhtakor region; in the Karshi steppe by Y. Irgashev and others (1983, 1998) in the regional centres of Guzar, Beshkent, Yangi-Nishan, Kasan; Sherabad steppe K.Pulatov, Yu.Irgashev, Yu.P. Isomatov, R.Eshboyev (1991-2012) in the regional centres of Leninuli, Uchkyzyl; In the Kumkurgan district of the Surkhandarya region, Yu. Irgashev et al. (1986-2005) laid 34 in the first case, 46 in the second, 42 in the third, and 12 hydrogeological diameters in the fourth through open collectors and drains, which, in comparison with closed drains, have significantly lower filtration resistance.

Table 1. Arithmetic mean values of the filtration coefficient of soils of different genesis and age

(according to the data of experimental filling of water into pits and pumping out m^3/day)

Lithological composition	*Genesis and age of soils*									*Aquifer filtration coefficient (according to pumping data)*
	v Q_4 ad	ed Q_4 ad	a Q_4 ad	pa Q_3 sk	ap Q_3 sk	p Q_2 kr	dp Q_2 kr	ed Q	v Q	
Fine and fine-grained sand	1,17-1,90	-	-	-	1,33-4,22	-	-	-	-	10,76-16,40
Mixed-grained sand	-	-	-	-	3,55-6,0	-	-	-	3,0-10,6	11,97-18,50
Sand with the inclusion of gravel	-	3,0	5,0	-	-	-	-	-	-	-
Light sandy loam	-	0,04-0,56	-	-	0,2-2,1	0,48-1,57	1,12-1,56	-	-	0,39
Medium sandy loam	-	-	-	-	-	0,13-1,38	-	0,04-1,94	-	0,63-2,51
Light loam	-	0,06-1,48	0,15-0,45	0,46-0,49	0,41-0,48	0,40-0,62	-	-	-	1,47-1,84
Medium loam		0,08-0,94	0,06-0,16	-	0,30-0,34	0,04-0,05	-	-	-	-
Heavy loam	-	0,004-0,330	-	-	0,039-0,320	-	-	-	-	-

Each hydrogeological cross-section includes two portable weirs for measuring drainage flow and alignment from 4-8 observation wells [3].

Lithologically, the territory of the considered areas of the Golodnaya Steppe is represented mainly by light and medium loams, which at a depth of 12-15 m had a loess appearance before irrigation. The installed thickness of loams in object 6 reaches 80 m, and object 2 is 40-50 m, below there is a layer of different-grained sands 5-10 m thick and underlain by clays, siltstones, sandstones of the Upper Neogene.

After watering the soils, the values of the filtration coefficient changed significantly: in object 6, the loams, mainly medium and light, began to have K = 0.15-0.5 m/day; in object 3, predominantly light loams and sandy loams - 0.2-0.85 m/day, in the Pakhtakor area, interbedded light, medium and heavy loams with interlayers of sandy loams - 0.06-0.5 m/day; in object 2, the average loam is 0.3-0.5 m/day [9].

For the entire territory of the Golodnaya Steppe, according to observations by N.N. Khodzhibaev, B.Ya. Neiman and E.V. Mavlyanov on operating drains, the following values of the filtration coefficient were obtained: loam 0.06-0.3 m/day, sandy loam 0, 3-0.6 m/day, alternating loams and sandy loams with lenses of sands 0.5-0.9 m/day, Karshi steppe [2,5,6] - loams of light, medium, heavy 0.1-0.2 m/day; light and heavy sandy loam - 0.2-0.3 m/day, interbedded loam, sandy loam and sand - 0.3-0.5 m/day, Sherabad steppe -

0.2-0.3 m/day, in object 4 - sandy loam 0.2-0.4 m/day. Areas with a filtration coefficient of 0.1 m/day or less are unfavourable for the use of horizontal drainage, and areas with a filtration coefficient of more than 0.5 m/day are favourable.

The results of determining the filtration coefficient according to field observations of soil closure in experimental pits. In 1965-1984 employees of PO "Uzbekhydrogeology" under the leadership of G.A. Mavlyanov, K.P. Pulatov, Y. Irgashev and others 15 km east of the city of Karshi, and in 1988 [5]. Isomatov) on the left bank of the Chirchik river, experimental locks were carried out in the middle Quaternary loess of the Karnab complex with a subsidence thickness of 18-30 m. Long-term observations were made of the process of locking, water consumption, soaking and subsidence of soils along with a series of surface and depth benchmarks. Before starting the experiments, after their completion and the completion of subsidence deformations, pits were dug out and in them, after 0.5-1.0 m, the soil moisture and filtration coefficient were determined by pouring water [10].

Along with the Karshi site (the area of the lock is 44 m2), the soils are mostly medium loam, the duration of the lock is 94 days, about 4.0 thousand m3 of water was supplied, the calculated drawdown according to laboratory determinations is 65.3 cm, in fact, 78.4 cm was obtained. The value of the filtration coefficient of the subsiding strata with a thickness of 18.0 m before the start of the lock was 1.71 m/day, after 14 days - 1.14, after 19 days - 1.01, after 42 days - 0.86 and after 94 days (upon completion of subsidence) - 0.29 m/day (Table 2).

Table 2. Dependence of the rate of subsidence on the water flow rate in the pit and its filtration rate

Measurement period, day	*The magnitude of the drawdown, cm*	*Water consumption, m3/day*	*Filtration coefficient, m/day*	*Filtration coefficient, m/day*		
				at depth, m	to the lock	after the lock
On the 3rd day after the start of the lock	20	103	1,67	3	1,71	1,67
After 14	44	68	0,98	6	1,14	1,04
After 19	60	56	0,81	9	1,01	0,80
After 42	72	27	0,41	12	0,86	0,36
After 94 (end of experience)	78,4	10	0,18	18	0,29	0,18

At the Yangibazar site (left bank of the Chirchik River), the subsidence stratum is represented by heavy loams, with interlayers of buried soils (0.1-0.3 m thick). According to laboratory measurements, the value of the maximum subsidence at the site is 1.16 m, and according to the full-scale - 1.38 m. The filtration coefficient, on average, in the thickness of 30 m before the lock was 0.94 m/day, after 15 days - 0, 71, after 30-0.54, after 50 days - 0.32 and after 90 days (at the end of the drawdown) - 0.24 m/day.

Comparing the results of determining the filtration coefficient of loess soils by the three indicated methods, we can conclude that the magnitude of the filtration coefficient of soils of the same composition before the lock and after the occurrence of subsidence turned out to be similar, the average deviation in differences is not more than 20%, rarely up to 30%, and the value of the filtration coefficient of soils after the manifestation of the drawdown decreased on average 2-3, sometimes 5-8 times. Moreover, there is a close relationship between the flow rate of water in the pit, the rate of its filtration in the rock and compaction, i.e. with an increase in the total value of the subsidence, a decrease in the filtration rate and water consumption for infiltration from the pit is observed. This means that the most active change in the filtration coefficient, towards a decrease, occurs in the aeration zone, therefore, first of all, a forecast is made of the filtration properties of soils for the entire thickness of the aeration zone [11].

Based on these data, the following predicted values of the soil filtration coefficient were calculated and recommended for calculations: silty clays - 0.05-0.01, heavy, medium, light loams - 0.1-0.2, heavy and light sandy loams - 0.2 -0.3, silty, fine and medium-grained sands - 0.3-0.5 m/day (Table 3).

Table 3. Predicted values of the filtration coefficient of rocks of various genesis and age in connection with irrigation (Karshi steppe)

Number of characteristic rock strata	Geological index	Lithological composition	The thickness of the layer, m	Filtration coefficient, m/day		The predicted value of the filtration coefficient after development, m/day
				for a given lithological type breeds	mean	
1	2	3	4	5	6	7
1	p Q_2	Light loam, compacted	3,0	0,15-0,25	02,18	0,1-0,2
2	a Q_4	Heavy sandy loam, compacted	2,7	0,16-0,20	0,16	0,1-0,2
3	a Q_4	Heavy loam, compacted	2,0	0,216-0,31	0,25	0,1-0,2
4	a Q_4	Plaster of loam and sandy loam	4,0	0,06-0,45	0,25	0,1-0,2
5	p Q_2	Light sandy loam, loess-like	5,0	0,26-0,49	0,36	0,1-0,2
6	p Q_3	Sandy loam, heavy, loess-like	5,0	0,24-0,37	0,32	0,1-0,2
7	p Q_2	Light compacted sandy loam	5,0	0,18-0,49	0,30	0,2-0,3
8	a Q_4	Highly saline loam	5,0	0,20-0,50	0,45	0,2-0,3
9	p Q_2	Light sandy loam, loess-like	5,0	0,74-0,95	0,94	0,2-0,3
10	p Q_2	Sandy loam, heavy, loess-like	5,0	0,60-0,82	0,74	0,2-0,3
11	a Q_4	Heavy loam, loess-like	3,5	0,61-0,69	0,64	0,2-0,3
12	a Q_4	Highly saline loam	5,0	0,55-0,71	0,62	0,2-0,3
13	p Q_2	Light sandy loam, loess-like	5,0	1,01-1,94	1,74	0,3-0,5
14	p Q_2	Light sandy loam, with prosl. sand	5,0	1,20-1,88	1,60	0,3-0,5
15	a Q_4	Light loam, lumpy	6,0	1,10-1,50	1,40	0,3-0,5
16	a Q_4	Mixed-grained sand	1,0	1,60-2,0	1,96	0,3-0,5

17	ap Q_3	Medium loam, compacted	3,0	1,00-1,30	1,21	0,3-0,5
18	pa Q_3	Mixed-grained sand with inclusions of gravel	4,0	2,20-6,24	3,10	–
19	pa Q_3	Light loam, sandy	3,0	0,39-2,20	1,40	0,8-1,4
20	v Q	Fine and fine-grained sand	4,5	3,10-9,86	4,55	–
21	v Q	Mixed-grained sand	7,0	4,30-11,60	6,20	–

The basis for the prediction of regional changes in the filtration properties of soils is a map of the filtration properties of the rocks of the aeration zone, compiled on the main of the results of complex engineering-geological large-scale and medium-scale mapping of the irrigated and promising for irrigation territory of the Karshi steppe. Field and laboratory experiments to determine the filtration properties of various genetic, age and petrographic types of rocks in the aeration zone were set in such a way that some of the experiments were located in the zone of ancient irrigated lands, the other in the zone of prospective irrigation [12-15]. In addition, several experiments are timed to test landfills, where the subsidence properties of loess soils were predicted by the method of pits locking.

Conclusions

1. In collapsible loess soils, a high filtration coefficient is noted in the area near the areas of demolition, as the distance from it, ie. from mountains to plains, depending on changes in the dispersion of rocks, their filtration properties deteriorate.

2. Vertical (in the aeration zone) and horizontal (in the saturation zone) changes in the filtration coefficient of the same rock are different. It mainly depends on the size and direction of the pores, salt and particle size distributions, the presence of buried soils and pore-clogging.

3. After the complete development and watering of the studied area represented by loess and loess-like soils, subsidence compaction will occur, due to which the filtration coefficient will sharply (2-3 times) decrease in the aeration zone. Analyzes show that with an increase in the content of the mineral montmorillonite in the soil, an increase in the filtration coefficient is observed. In the presence of montmorillonite in an amount of less than 2%, the average value of the filtration coefficient is 0.34 m/day, with 2-3% - 0.57, with its content exceeding 8%, the filtration coefficient is on average 1.04 m/day.

4. Filtration properties in some areas of the region, composed of non-forest rocks (sand, gravel, pebbles, etc.) as a result of irrigation does not change significantly..

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