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SATURATED HYDRAULIC CONDUCTIVITY COEFFICIENT MEASUREMENTS OF BALKANINE™ AND TURFACE® SUBSTRATA THROUGH THE CONSTANT HEAD METHOD

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Abstract

In the paper hereby results obtained after conducting laboratory measurements of saturated hydraulic conductivity coefficient are presented. The utilized method follows the Constant Head approach. The tested soil samples are zeolite substratum Balkanine™ and clay substratum Turface®. These are artificial media mostly used in greenhouses for plant cultivation on-board space stations under microgravity conditions. The laboratory equipment is discussed and the results are put down for different substrata fractions.

Introduction

The main objective of studying the hydrodynamic properties of plant root artificial media is selecting an optimal fractional composition of the substrate in order to use it on-board a space greenhouse. By way of example, related experiments were carried out on-board Salyut-7 space station back in 1985, [1]. The goal was studying capillary raise of water within a substratum under microgravity conditions.

In the present study, the saturated hydraulic conductivity coefficient is examined regarding two artificial media extensively used in space experiments. A mineral substratum, based on natural zeolite from a Bulgarian deposit, has been developed since 1979, [2]. This substratum is enriched by nutritive substances further and is called Balkanine™. Another substratum used is Turface®, [3]. The results eventually give a correct idea

of time required for water to move through the media under saturated conditions.
There are two main laboratory methods of analysis that are based on Darcy's law: the constant head (steady state) and the falling head (unsteady state), Wit [4]. In the present article the former approach is solely used. The experiment is motivated by lack of data for the artificial media mentioned above.

Materials and Methods

The method of study makes use of the U-shaped interconnected vessels' property. It implies that the fluid level is preserved in both arms provided no external pressure is applied onto either of them. The scheme of the experimental set-up is shown in Fig. 1. The main elements are: 1) a cylindrical tube filled with substratum being tested, 2) a socket union fitting with a net with large clearance protecting the substrate from falling, 3) a funnel with an overflow weir, and 4) a drain tube mounted on top of the pipe. The excessive pressure was set by the funnel that went up every 10 cm, thus altering the system equilibrium. The exact water level in the funnel was guaranteed by a weir mounted inside. The filtrate was collected from the drain tube mounted on the main tube's upper end. For a given level of the funnel (head), time for collecting 1 liter of filtrate was measured. This time depends on the excessive pressure value (head), the substratum fraction, and the substratum degree of sealing (treading-in). The amount of water expended on the current measurement was being recovered through an external tank. Each substratum sample was poured and left undisturbed in the container. Prior to measurement, initial soaking in water within one day was performed in order to let the air bubbles out of the tube. What is more, due to the Balkanine dual porosity, the soaking procedure is mandatory so that the micro pores have enough time to get filled in with water.
The experimental goal is determining a relation between the flux

(1) $$J = \frac{Q}{At}, \quad cm^3.cm^{-2}.s^{-1}$$

and the hydraulic gradient

(2) $$i = \frac{\Delta H}{h}, \quad cm.cm^{-1}$$

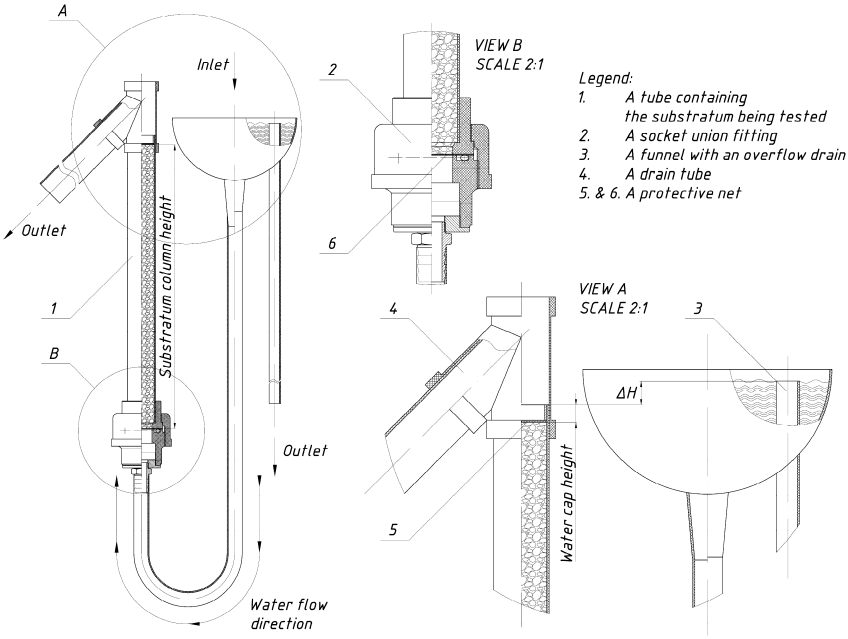

Fig. 1. The experimental stand layout ensuring constant head value ΔH

In formula (1) Q is the amount of water, mL, flowing through the cross section A, cm^2, per unit time t, s. In formula (2) ΔH represents sum of the substratum column, cm, and the top water column, cm H_2O, heights. In addition, h is the substratum column height, cm, alone. The saturated hydraulic conductivity coefficient Ks, cm/s, following Darcy, is a constant angular coefficient defining a linear relation between the variables J and i. Hence, expressed in terms of finite differences, this coefficient is computed within linear part of the chart according to the formula:

(3) $$K_s = \frac{\Delta J}{\Delta i}, \quad cm.s^{-1}$$

Results

Initial data: temperature 20 ºC, ambient pressure 101325 Pa, tube internal diameter 4.6 cm. A tap water was used for all experiments with temperature 10 ºC.

Substratum Balkanine, fraction 2 ÷ 3 mm, was studied first at different head values, i.e. 10, 20, 30, and 40 cm H_2O column. The slowest experiment lasted up to 7 min and took place at 10 cm head. The substratum column was 48.5 cm high. The water column above the substratum was 2 cm high. The results are shown in Table 1.

Table 1. Balkanine 2 ÷ 3 mm

Flow Rate, mL/sec		Flow Rate, mL/sec		Flow Rate, mL/sec		Flow Rate, mL/sec	
Head 10 cm	2,848	Head 20 cm	3,878	Head 30 cm	6,280	Head 40 cm	8,630
	2,569		3,789		6,205		8,609
	2,361		3,740		6,218		8,498
	2,192						
	2,085						
Mean	2,411	Mean	3,802	Mean	6,234	Mean	8,579
StdErr	0,122	StdErr	0,033	StdErr	0,019	StdErr	0,033

In accordance with formula (3), the saturated conductivity coefficient Ks = 0.6 cm/s.

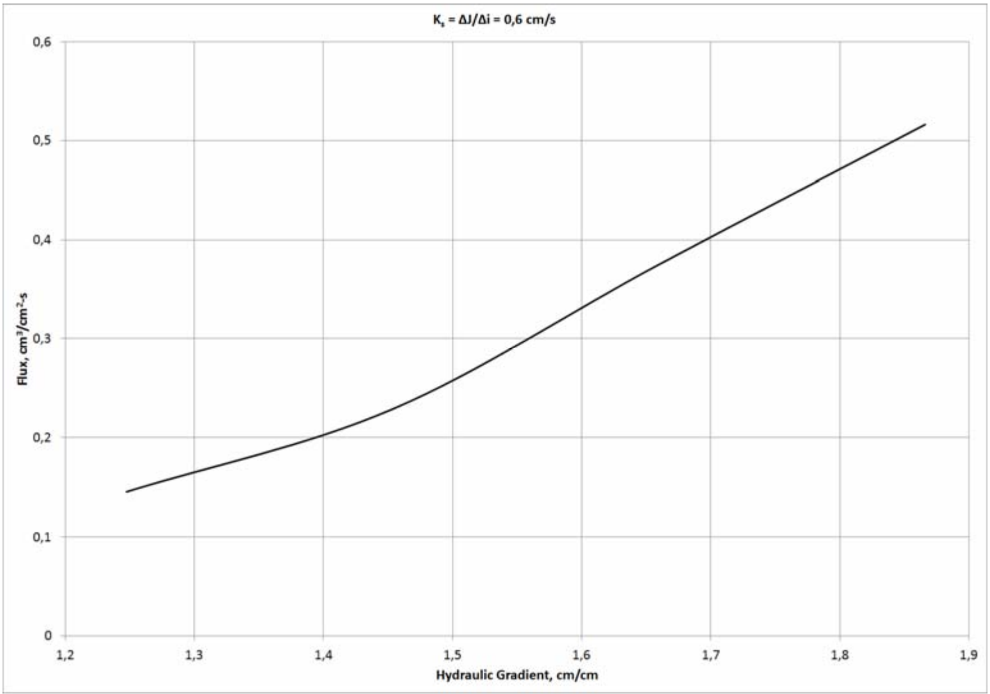

Fig. 2. Balkanine, fraction 2 ÷ 3 mm

The same experiment was carried out with substratum Balkanine, fraction 1.5 ÷ 2 mm. The substratum column was 48.6 cm high. The water column above the substratum was 2 cm high. The results are put down in Table 2.

Table 2. Balkanine 1.5 ÷ 2 mm

Flow Rate, mL/sec		Flow Rate, mL/sec		Flow Rate, mL/sec	
Head 20 cm	1,828	Head 30 cm	2,389	Head 40 cm	4,133
	1,759		2,288		3,647
	1,685		2,311		3,386
					3,259
Mean	1,758	Mean	2,329	Mean	3,606
StdErr	0,034	StdErr	0,0250	StdErr	0,167

The experiment was initiated at 40 cm head in order to let the substratum particles redistribute within the volume thus having the substratum subsided. Head of 10 cm H_2O column hasn't been considered here because the water flow is too slow. In this case, the saturated conductivity coefficient Ks = 0.27 cm/s.

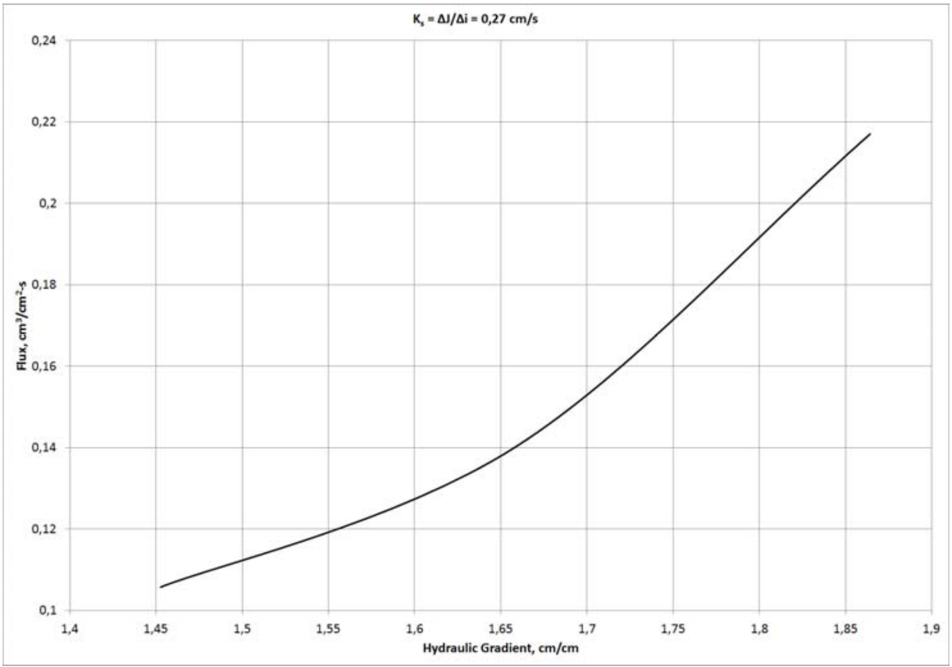

Fig. 3. Balkanine, fraction 1.5 ÷ 2 mm

Next experiment involved substratum Balkanine, fraction 1 ÷ 1.5 mm. The substratum column was 48.9 cm high. The water column above the substratum was 2 cm high. The results are reported in Table 3.

Table 3. Balkanine 1 ÷ 1.5 mm

Flow Rate, mL/sec		Flow Rate, mL/sec		Flow Rate, mL/sec	
Head 20 cm	0,987	Head 30 cm	1,511	Head 40 cm	2,742
	0,989		1,454		2,491
	0,993		1,418		2,314
					2,163
Mean	0,990	Mean	1,461	Mean	2,428
StdErr	0,001	StdErr	0,022	StdErr	0,108

The saturated conductivity coefficient Ks = 0.21 cm/s.

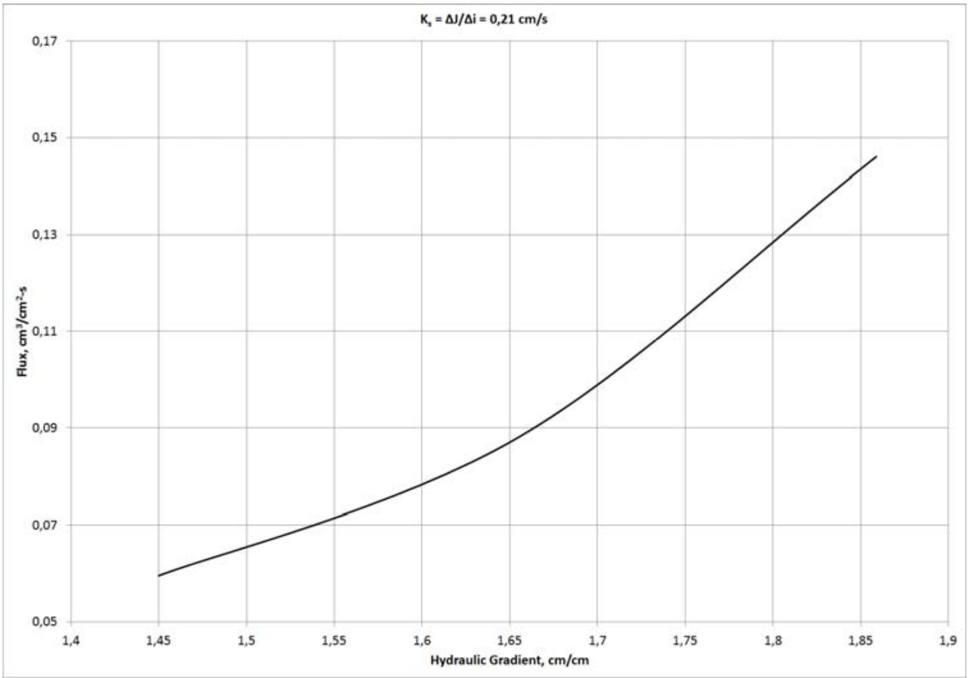

Fig. 4. Balkanine, fraction 1 ÷ 1.5 mm

Results concerning substratum Turface, fraction 1 ÷ 2 mm follow in Table 4. The substratum column was 48.8 cm high. The water column above the substratum was 2 cm high.

Table 4. Turface, fraction 1 ÷ 2 mm

Flow Rate, mL/sec		Flow Rate, mL/sec		Flow Rate, mL/sec	
Head 20 cm	1,110	Head 30 cm	1,696	Head 40 cm	2,480
	1,060		1,647		2,422
			1,577		2,290
Mean	1,085	Mean	1,640	Mean	2,398
StdErr	0,014	StdErr	0,028	StdErr	0,040

In this case, the saturated conductivity coefficient Ks = 0.19 cm/s.

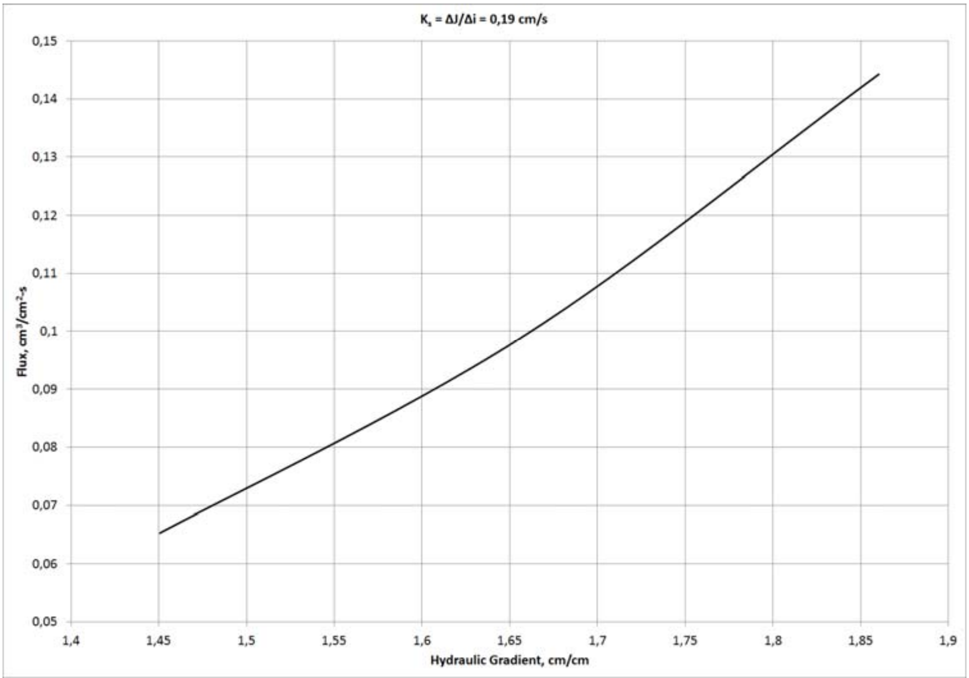

Fig. 5. Turface, fraction 1 ÷ 2 mm

Conclusion

The proposed experiment has claims on following. The apparatus is simple and affordable enough so that one could carry out measurements with a large variety of soils. Moreover, little has been known so far about the proposed coefficient values of the substrata studied. Hopefully, this article retrieves the missing data.

Fig. 6. An overview of the tube containing tested substratum

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ИЗМЕРВАНЕ НА КОЕФИЦИЕНТА НА НАСИТЕНА ХИДРАВЛИЧНА ПРОВОДИМОСТ ЗА СУБСТРАТИ БАЛКАНИН И ТУРФЕЙС ПО МЕТОДА НА ПОСТОЯННИЯ ВОДЕН НАПОР

К. Методиев

Резюме

В настоящата работа са представени резултатите от измервания на коефициента на наситена хидравлична проводимост в лабораторни условия. Използван е методът на постоянния воден напор. Изпитваните почвени образци са зеолитен субстрат Балканин и глинен субстрат Турфейс. Това са изкуствени среди, използвани предимно в оранжерии за отглеждане на растения в условията на микрогравитация. Разгледано е лабораторното оборудване. Резултатите са получени за различни фракции на субстратите.