Environment Protection Engineering

Vol. 12 1986 No. 3

COMMUNICATION

ANDRZEJ BARTOSZEWICZ*, JANUSZ FIEDOROWICZ*, ZDZISŁAW PRZEWŁÓCKI*

AN ATTEMPT OF DETERMINING FILTRATION COEFFICIENT OF SOIL SUBJECT TO SILTING-UP BY LIQUID MANURE

1. INTRODUCTION

The phenomenon of filtration and silting-up may – according to the Darcy's law – be described by the equation

$$-A\,dh = k(t)\,i\,dt \tag{1}$$

where:

A – flow cross-section,
h – height of the column of liquid,
t – flow time,
i – hydraulic gradient,
$k(t)$ – filtration coefficient.

The coefficient $k(t)$ is the basic filtration parameter and depends not only on time but also on the factors promoting silting-up, i.e., amount of suspended matter in liquid manure, its viscosity, temperature, porosity and structure of soil, and so on. Thus, instead of $k(t)$ one may write $k(t, b_1, \ldots, b_p)$ where $b_1, \ldots, b_p$ are the parameters characterizing the silting-up process. Then eq. (1) will take the form

$$h(t) = b_0\, e^{-1/l \int k(t, b_1, \ldots, b_p) dt}$$

where b_0 is an integration constant.

In this paper we consider the following general form of the filtration coefficient

$$k(t, b_1, \ldots, b_p) = b_1 + b_2 e^{-b_3 t} + \ldots b_{p-1} e^{-b_p t} \tag{2}$$

from which it follows that for the time $t = 0$

$$k(0, b_1, \ldots, b_p) = b_1 + \ldots + b_{p-1},$$

and for $t \to \infty$

$$k(\infty, b_1, \ldots, b_p) = b_1 \quad \text{if} \quad b_3, b_5, \ldots, b_p > 0.$$

* Department of Civil Engineering, Academy of Agricultural Sciences and Technology, Wyzwolenia 30, 10-106 Olsztyn, Poland.

In our experiment we have measured the time t and the corresponding column height h. Results of measurements have been analysed by the least squares method, consisting in finding the values of $\hat{b}_0, \hat{b}_1, \ldots, \hat{b}_p$ for which the sum of squares of deviations

$$S(b_0, \ldots, b_p) = \sum_{j=1}^{n} [h_j - h(t_j)]^2$$

has minimum. The symbol h_j denotes the height measured at the time t_j, i.e.,

$$h_j = h(t) + e_j$$

where e_j are unobservable errors of measurement.

In the computer programme the Marquardt iteration method [4] has been applied.

2. METHODS OF INVESTIGATIONS

The investigations have been performed in a plexiglass column composed of two parts, upper and lower ones, of the respective lengths of 1 m and 50 cm, and inner diameter of 12 cm. Both the segments of the column were connected by means of screws. The column with perforated bottom was kept in vertical position with the help of a tripod and a guide. The lower part of the column had been filled with sand–gravel mix. The processes of filtration and silting-up were started after the upper part of the column has been filled with liquid manure. The level of the latter in the upper segment of pipes was measured for one month. The investigations were repeated, but the sand–gravel mix was covered with 5 cm thick layer of smoke-box dust taken from thermal-electric power station of the tyre factory OZOS. In the first case liquid manure was taken from the pig farm at Waplewo (liquid manure 1), in the second case being taken from the pig farm at Knopin (liquid manure 2). Their physicochemical parameters are given in tab. 1. The concentrations of the separate forms of nitrogen, i.e., total nitrogen, ammonia nitrogen, organic nitrogen, as well as total phosphorus were determined according to standard methods [1], [3].

Table 1

Physicochemical parameters of the used liquid manure

Sampling place	Density at 298 K g/cm³	Viscosity at 298 K P	Redox potential mV	rH	N_0	N_{NH_4}	N_{org}	P_c
					mg/dm³			
Waplewo (liquid manure 1)	1.0025	0.01305	560	16.2	1868	1524	344	371.8
Knopin (liquid manure 2)	0.9994	0.01070	522	16.5	688	538	150	64.0

3. RESULTS AND DISCUSSION

The time-varying heights of the liquide manure column are presented as points in fig. 1 (liquid manure 1) and in fig. 2 (liquid manure 2). In the same figures there are three curves denoted by the

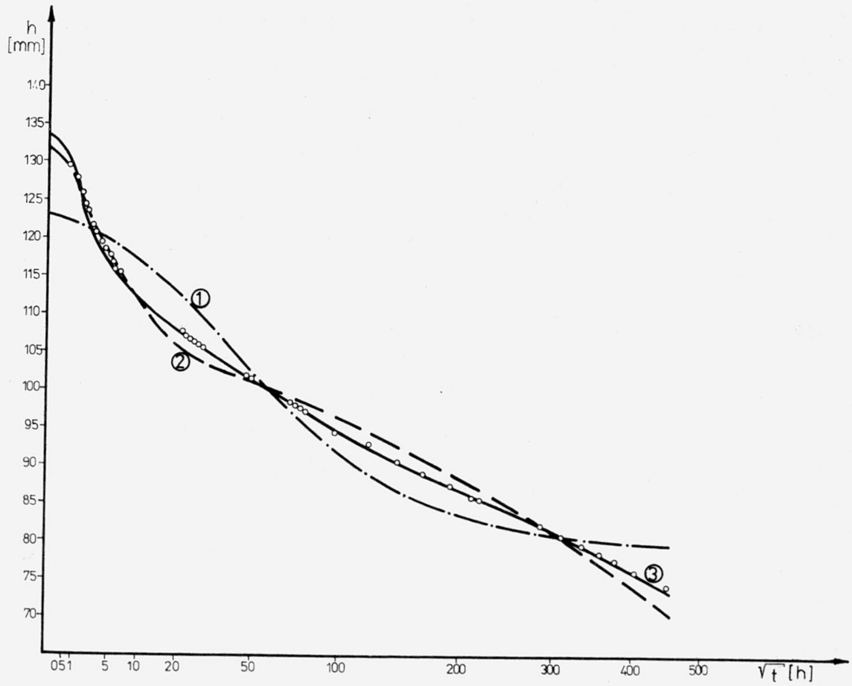

Fig. 1. Time-dependent changes of the height of liquid manure 1 in filtration column

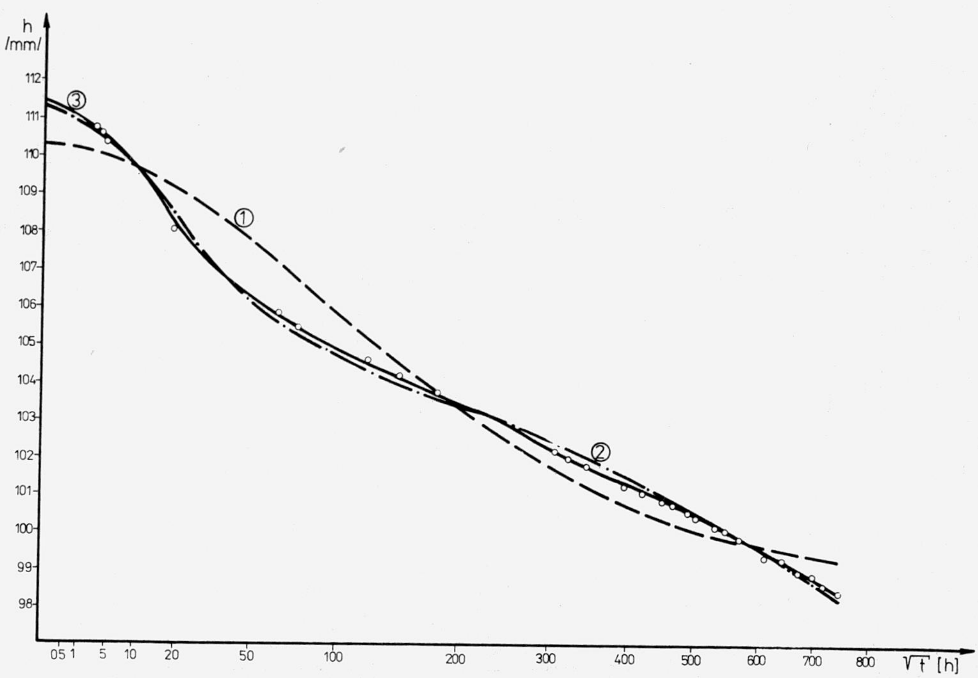

Fig. 2. Time-dependent changes of the height of liquid manure 2 in filtration column

numbers 1–3. They describe the relation $h = h(t)$ calculated according to the following three forms of the function $k(t)$:

$$k(t) = b_2 e^{-b_3 t} \text{ (curve 1)},$$

$$k(t) = b_1 + b_2 e^{-b_3 t} \text{ (curve 2)},$$

$$k(t) = b_1 + b_2 e^{-b_3 t} + b_4 e^{-b_5 t} \text{ (curve 3)}.$$

From the figures it follows that for the two kinds of liquid manure the curves 3 are closest to the points illustrating the results of laboratory investigations and do not show systematic deviations.

Table 2

Values of standard deviation and coefficient of determination for the particular forms of the filtration coefficient

Form of filtration coefficient	$k(t) = b_2 e^{-b_3 t}$	$k(t) = b_1 + b_2 e^{-b_3 t}$	$k(t) = b_1 + b_2 e^{-b_3 t}$	$k(t) = b_1 + b_2 e^{-b_3 t} + b_4 e^{-b_5 t} + b_6 e^{-b_7 t}$
Standard deviation $\hat{\sigma}$				
liquid manure 1	3.998	1.809	0.5044	—
liquid manure 2	0.688	0.2269	0.1241	0.1299
Coefficient of determination 100 R^2				
liquid manure 1	95.22	98.97	99.92	—
liquid manure 2	97.32	99.71	99.92	0.092

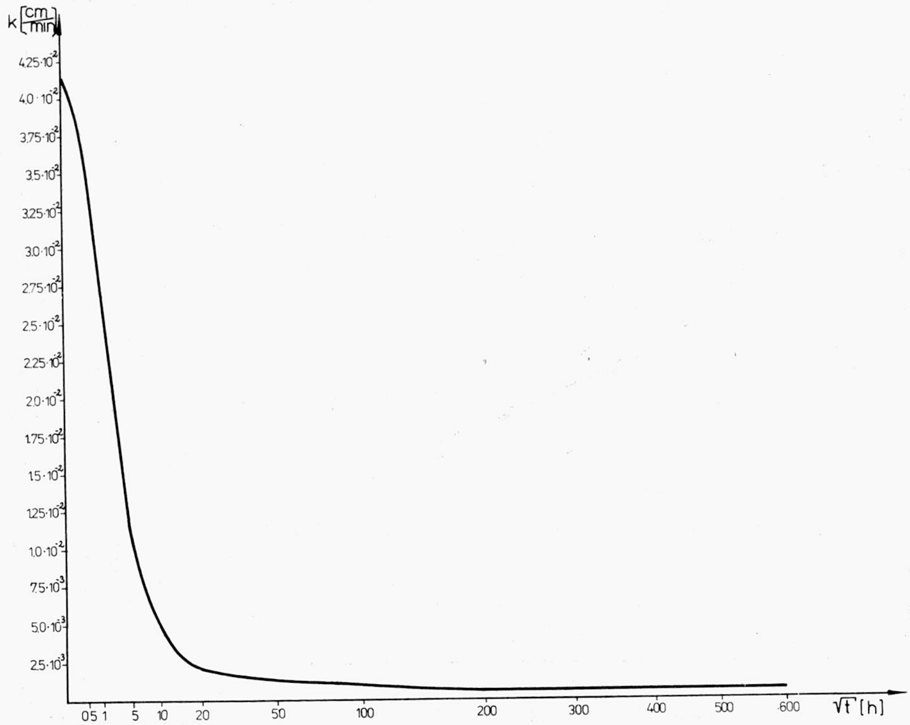

Fig. 3. Time-dependent changes of the value of soil filtration coefficient for the flow of liquid manure 1

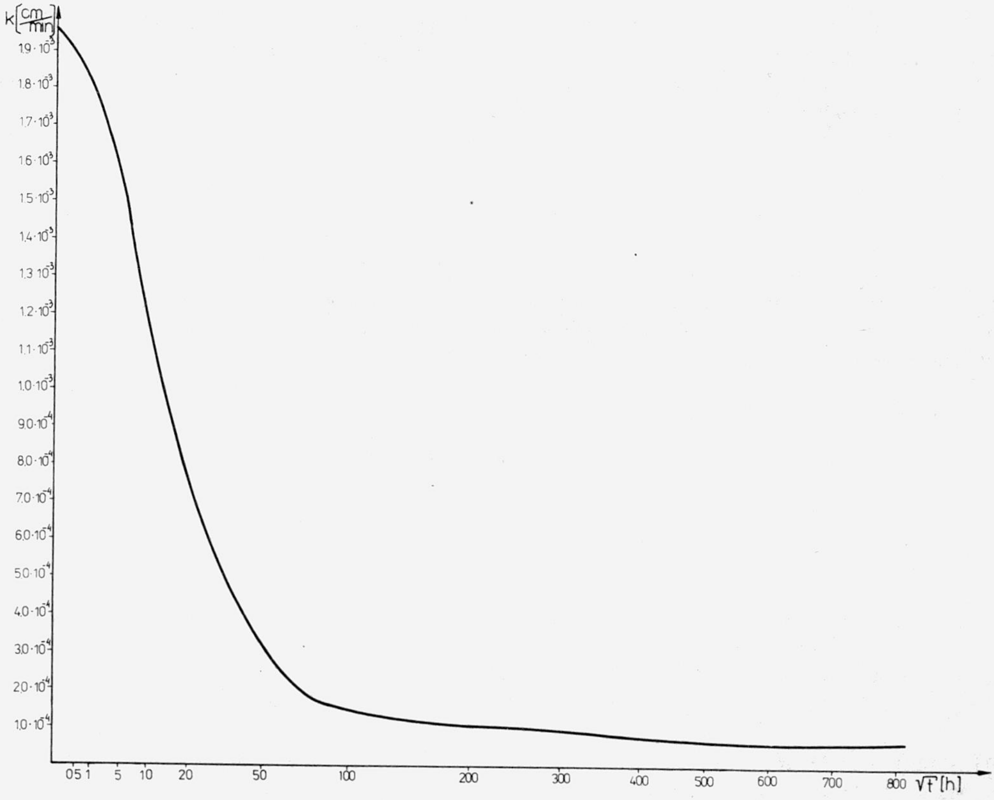

Fig. 4. Time-dependent changes of the value of soil filtration coefficient for the flow of liquid manure 2

The values of standard deviation and coefficient of determination 100 R^2 for the particular functions $k(t)$ are presented in tab. 2. For both the kinds of liquid manure the highest values of the multiple correlation coefficient (99.92 in both cases) were obtained for the function 3. Further evolution of the function $k(t)$ does not increase significantly the value of the coefficient 100 R^2. The changes in the value of the filtration coefficient of soil subject to the action of liquid manure are presented in figs. 3 and 4, the calculations being performed according to the equation

$$k(t) = b_1 + b_2 e^{-b_3 t} + b_4 e^{-b_5 t}. \tag{3}$$

From fig. 3 it follows that a rapid decrease of the soil filtration coefficient takes place during the first 20 hours. Later on these changes are rather small and the value of the filtration coefficient approaches b_1.

The curve shown in fig. 4, illustrating the changes in the filtration coefficient of soils treated with the liquid manure 2, follows a similar course. Rapid drop in the value of this coefficient can be observed during the first 100 hours, thereupon the changes are rather small and the coefficient approaches a certain value of b_1. For $t = \infty$ both the initial and final values of the coefficient of filtration can be calculated from equation (3)

$$\text{for } t = 0 \qquad k(0) = b_1 + b_2 + b_4,$$

$$\text{for } t = \infty \qquad k(\infty) = b_1.$$

The initial values for the soil treated with the liquid manure 1 of the filtration coefficient $k(0)$ and for the soil covered with a 5 cm layer of ash and treated with the liquid manure 2 are 4.147×10^{-2} and 1.97×10^{-3} cm/min, respectively. Final permeability $k(\infty) = 5.121 \times 10^{-4}$ cm/min for the liquid manure 1 and $k(\infty) = 5.970 \times 10^{-5}$ cm/min for the liquid manure 2.

4. CONCLUSIONS

The performed investigations have confirmed a complex character of the liquid manure flow through the soil medium. This flow, due to silting-up activity, results in self-sealing of the soil which, however, is not complete. The filtration coefficient of soil treated with liquid manure reaches the value different from zero, even for relatively long time periods.

It has been stated that the curve describing the relation $k(t)$ best fits the results of laboratory tests when the following equation is applied

$$k(t) = b_1 + b_2 e^{-b_3 t} + b_4 e^{-b_5 t}.$$

REFERENCES

[1] HERMANOWICZ W., DOŻAŃSKA W., DOJLIDO J., *Fizyczno-chemiczne badania wody i ścieków*, Arkady, Warszawa 1975.

[2] KOLLIS W., *Gruntoznawstwo Techniczne*, Arkady, Warszawa 1975.

[3] LITYŃSKI T., JURKOWSKA M., GORLACH E., *Analiza chemiczno-rolnicza*, PWN, Warszawa–Kraków 1972.

[4] MARQUARDT D. W., *An algorithm for least squares estimation of nonlinear parameters*, J. Soc. Appl. Math., 2 (1963).