WROCLAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

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MODELLING OF PERCOLATION RATE OF STORMWATER FROM UNDERGROUND INFILTRATION SYSTEMS

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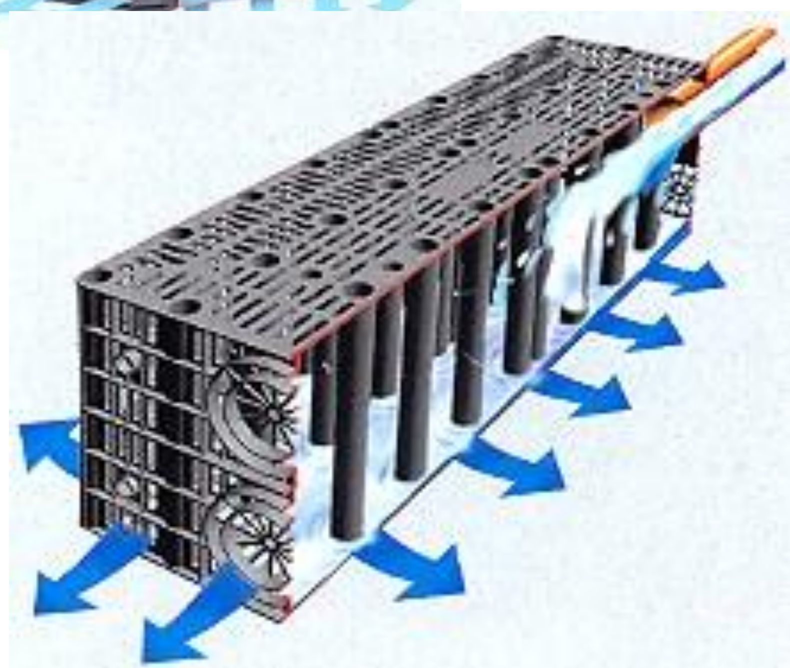
Subsurface stormwater storage tank systems with infiltration of water into the ground constitute the basic elements used in **Sustainable Urban Drainage Systems (SUDS).**

MECHANISMS OF OPERATION



Source: www.tehnoworld.ro

The first model of infiltration of water into the ground was developed by Green and Ampt in the year 1911 .

$$q(t)=\frac{dI(t)}{dt}=K_f\left(\frac{H_s+Z(t)-h_f}{Z(t)}\right)=\left(\frac{H_s-h_f}{Z(t)/K_f}\right)+K_f \qquad (1)$$

$I(t)$ accumulated water infiltration into the ground (cm)

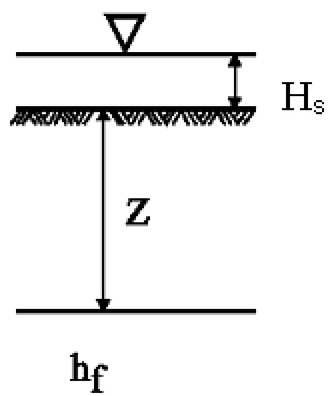
t time (min)

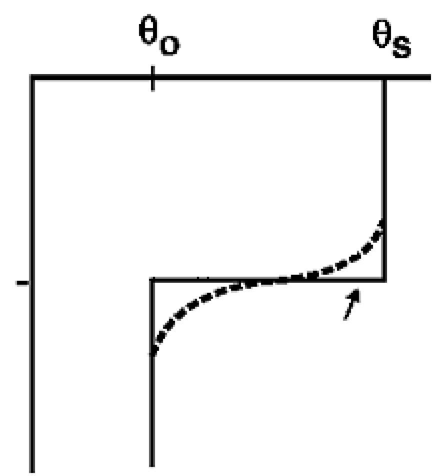
K_f wetting zone hydraulic conductivity (cm min-1),

H_s water level above ground surface (cm)

$Z(t)$ depth of wetting front (cm)

h_f negative pressure head at wetting front (cm)





Assuming that:

$Z(t)=Z_{const}$ (2)

and introducing a parameter R defined by the ratio:

$R=Z_{const}/K_f$. (3)

equation (1) will has the form:

$$q(t)=\frac{H_s-h_f}{R}+K_f \quad (4)$$

Where:

$Z(t)$ depth of wetting front (cm)

K_f wetting zone hydraulic conductivity (cm min^{-1}),

$q(t)$ infiltration rate at time t (cm min^{-1}),

h_f negative pressure head at wetting front (cm)

R substituted hydraulic resistance (min)

THE AIM OF THE ANALYSES

develop **simple models describing the changes in the infiltration rate in the phase of filling and emptying** of retention and infiltration reservoirs and **to test their usability in the evaluation of the progress of clogging**.

CHARACTERISTICS OF THE MODEL

the increase in water volume in the inf.modules

volume of water flowing into the inf.modules

amount of water infiltrating into the ground

$$F \cdot dH(t) = Q \cdot dt - F \cdot q(t) \cdot dt \qquad (5)$$

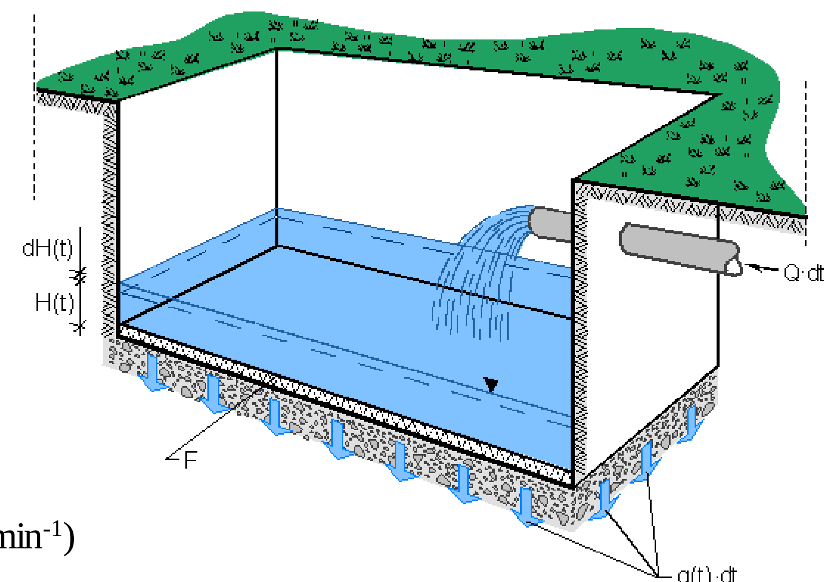
Assuming that:

$$q(t) = \frac{H(t)}{R} + K_f \qquad (6)$$

and introducing a parameter defined by the ratio:

$$Q_F = \frac{Q}{F} \qquad (7)$$

$$H(t) = Q_F\, R\left(1 - \exp\left(-\frac{t}{R}\right)\right) - K_f\, R\left(1 - \exp\left(-\frac{t}{R}\right)\right) \qquad (8)$$



where:

F bottom surface of infiltration facility (cm^2)

$H(t)$ water level in the infiltration module at time t (cm)

Q infiltration flow ($cm^3\ min^{-1}$),

$q(t)$ infiltration rate at time t ($cm\ min^{-1}$),

t time (min), K_f wetting zone hydraulic conductivity ($cm\ min^{-1}$)

R substituted hydraulic resistance (min), Q_F variable parameter used in model ($cm\ min^{-1}$), The function of change of the water surface level in the module in the emptying phase will be described by the following equation:

$$H(t) = H_0 \exp\left(-\frac{t}{R}\right) - K_f R\left(1 - \exp\left(-\frac{t}{R}\right)\right) \qquad (9)$$

During the infiltration of water containing suspension a significant decrease of the filtration coefficient of the top layer of soil is observed. In the case if the value of the product of the Kf ·R constants is close to 0, equations (8) and (9) will have the respective forms:

$$H(t) = Q_F R\left(1 - \exp\left(-\frac{t}{R}\right)\right) \qquad (10)$$

$$H(t) = H_0 \exp\left(-\frac{t}{R}\right) \qquad (11)$$

where:

$H(t)$ water level in the infiltration module at time t (cm)

H_0 water level in the infiltration module at the end of the filling phase (cm)

t time (min),

K_f wetting zone hydraulic conductivity (cm min^{-1})

R substituted hydraulic resistance (min),

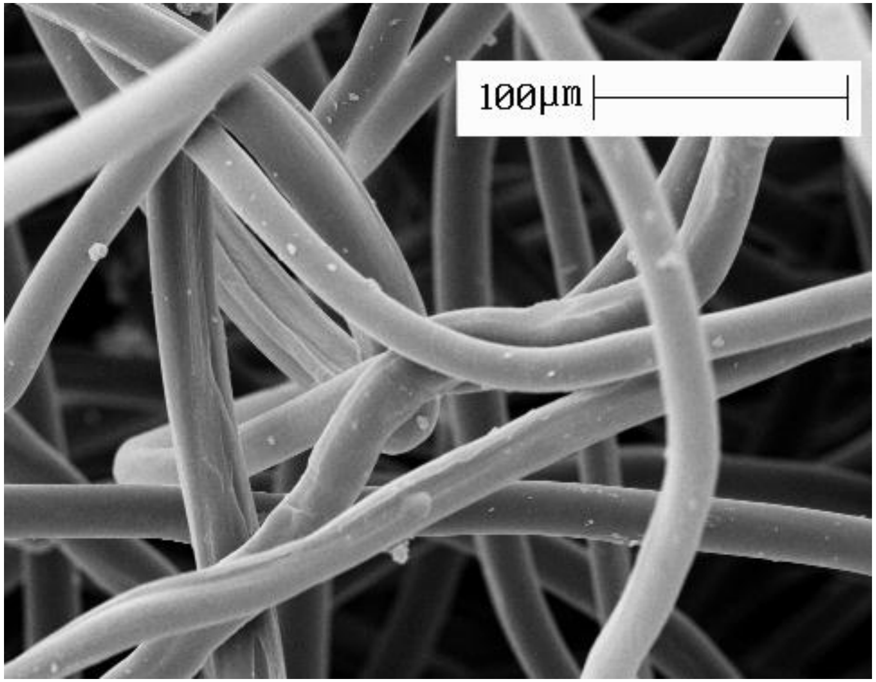
Q_F variable parameter used in model (cm min^{-1}),

EXPERIMENTAL SITE

The dimensions of the inf. modules are 500x1000x400 mm

commonly used in engineering practice !!!

GEOTEXTILE



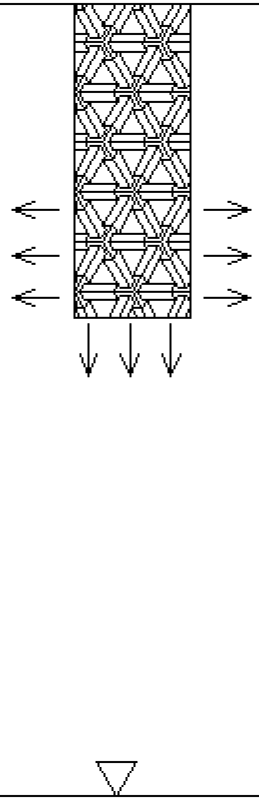
Scanning photos of geotextile magnified 1000 times

LITHOLOGICAL PROFILES OF THE SOIL

BOREHOLE No.1

SCALE	DEPTH OF SOIL	TYPES OF SOIL
0,20	0,20	humus
0,40 / 0,60 / 0,80	0,60	medium sand
1,00 / 1,20	0,50	sandy clay
1,40 / 1,60 / 1,80	0,40	medium sand
2,00 / 2,20 / 2,40	0,70	fine sand
2,60	0,20	sandy clay

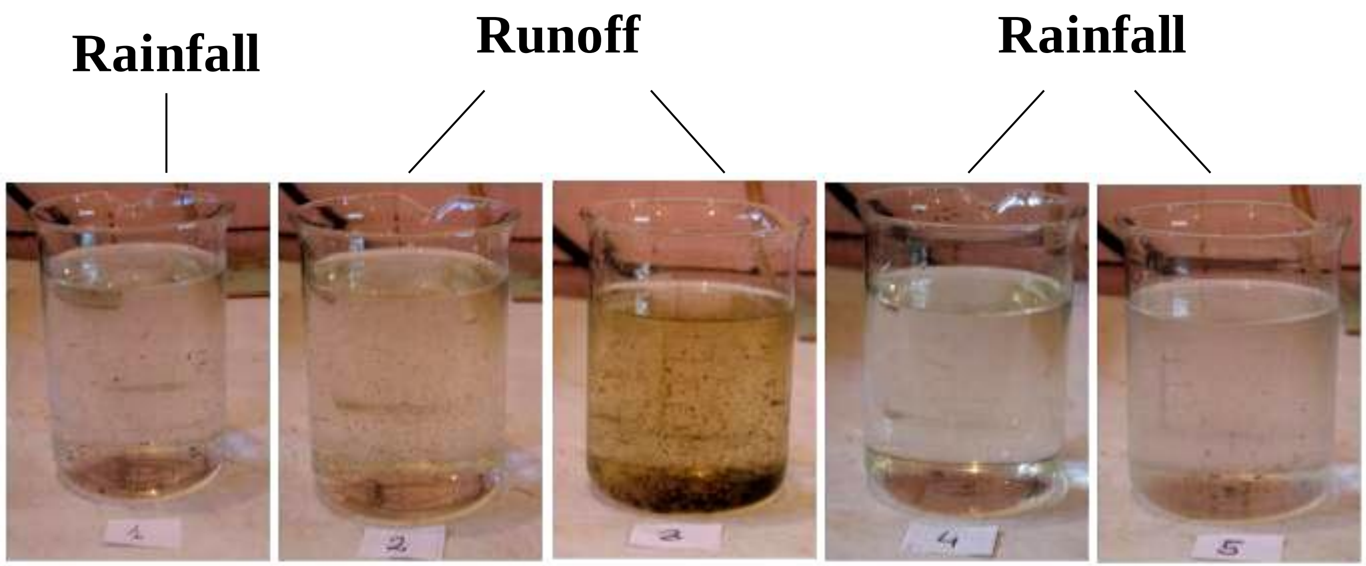
EXPERIMENTAL SETUP



BOREHOLE No.2

SCALE	DEPTH OF SOIL	TYPES OF SOIL
0,20	0,20	humus
0,40	0,20	fine sand
0,60 / 0,80	0,50	sandy clay
1,00 / 1,20	0,40	cohesive clay
1,40 / 1,60 / 1,80 / 2,00 / 2,20 / 2,40	1,10	sandy loam
2,60		

SAMPLES OF RAINFALL AND RUNOFF

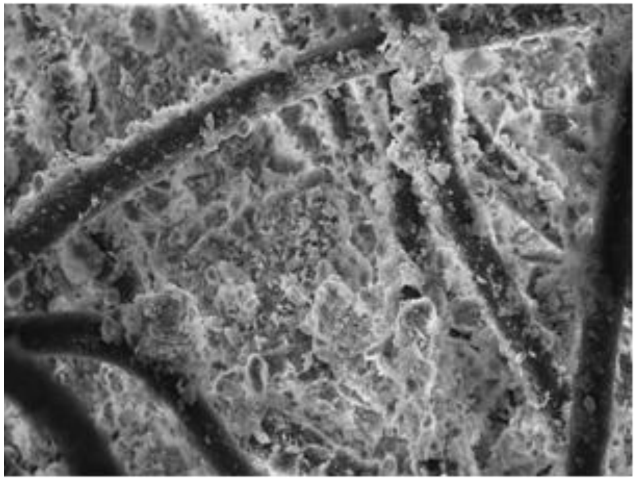
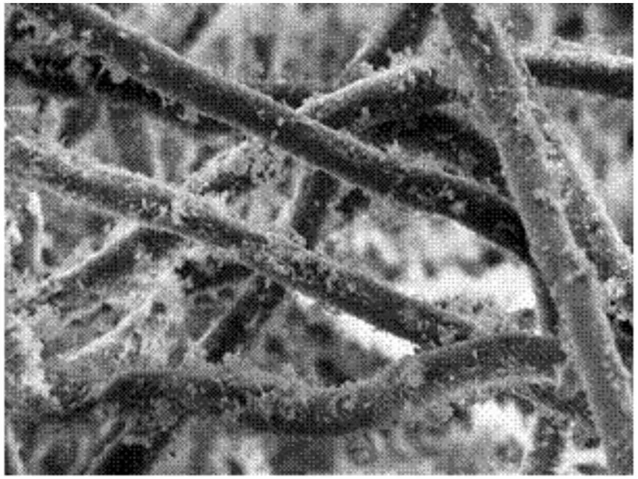


1-rainfall -11.06.2004, Strzelin, Jana Pawła II; 2-runoff - 11.06.2004, Strzelin Jana Pawła II; 3- runoff -9.06.2004 Wrocław, Dicksteina; 4- rainfall - 9.06.2004, Bielawa Oś. XXV-lecia; 5- rainfall 10.04.2004, Racibórz

kaolin clay suspension
(clogging agent)

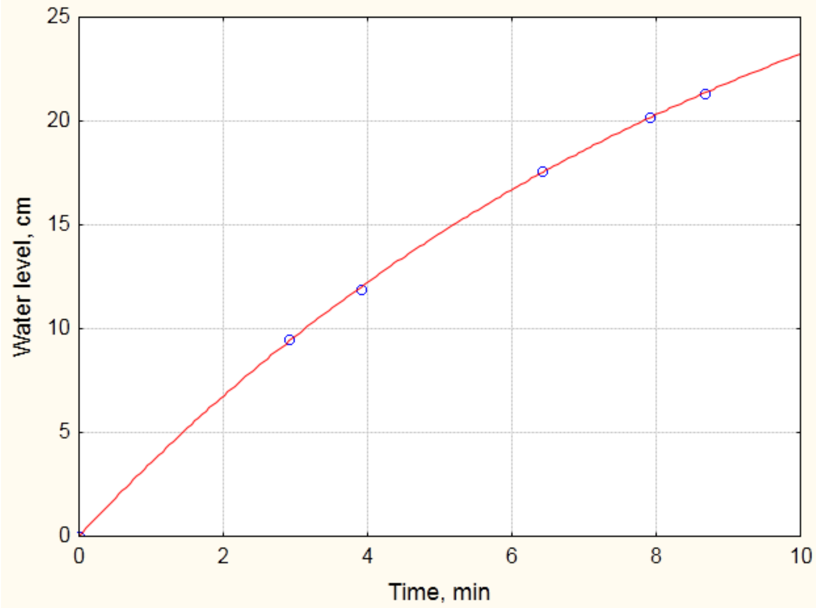
Results


The appearance of the module (site 2) after removal from the ground and the distribution of sediments on geotextile on the inside

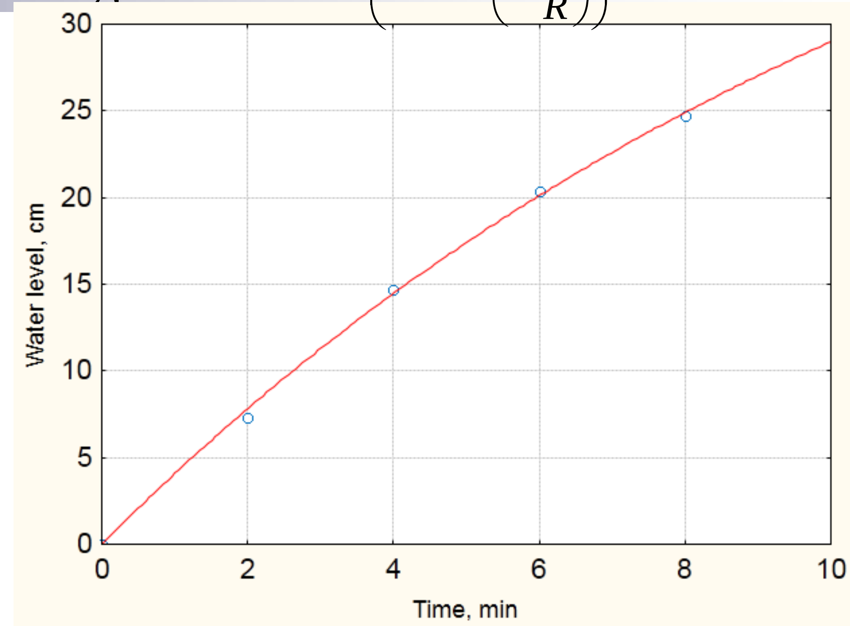



Scanning photos of kaolin clay sediment deposited in the geotextile on the bottom of the module (left image) and on the side walls of the site (right image) magnified 1000 times

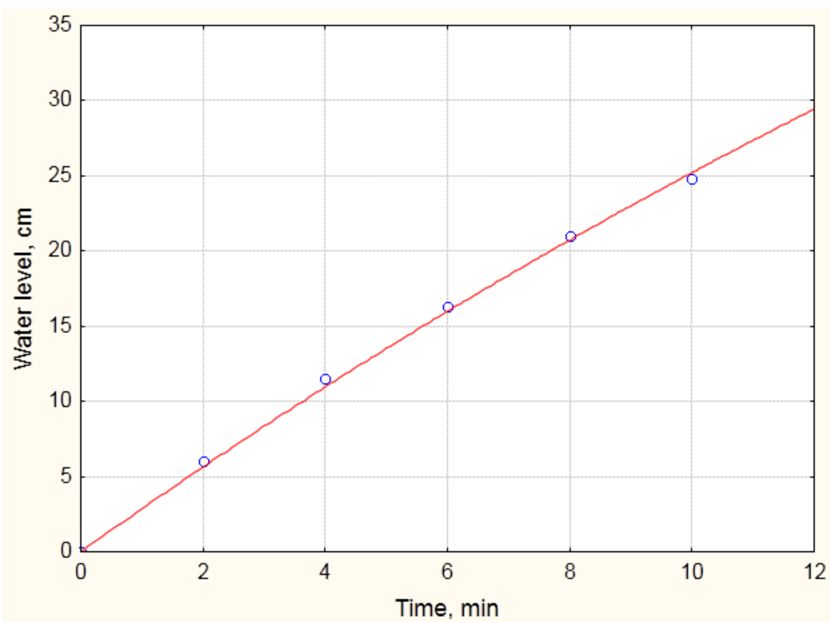
Changes in the water level during filling $H(t) = Q_F\,R\left(1-\exp\left(-\frac{t}{R}\right)\right)$



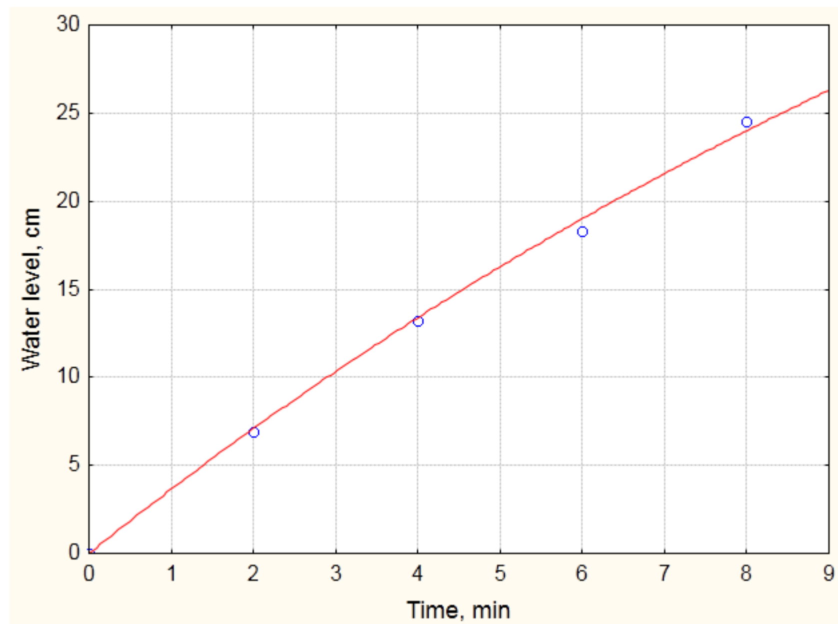
15.09.03 (R^2=0,999)



10.12.03 (R^2=0,995)

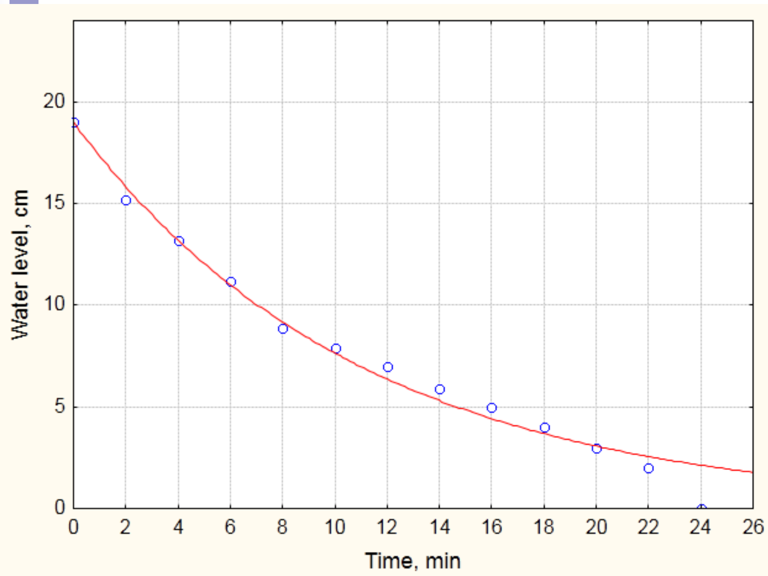


11.07.03 (R^2=0,998)

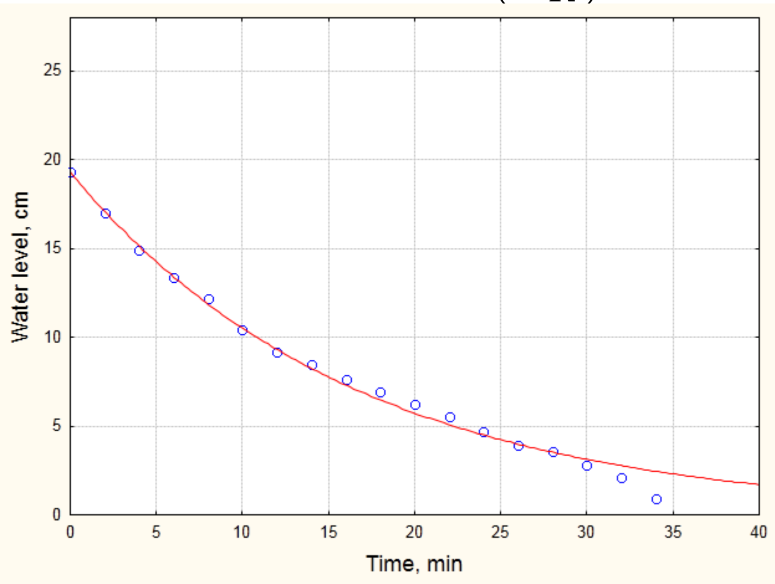


18.08.03 (R^2=0,989)

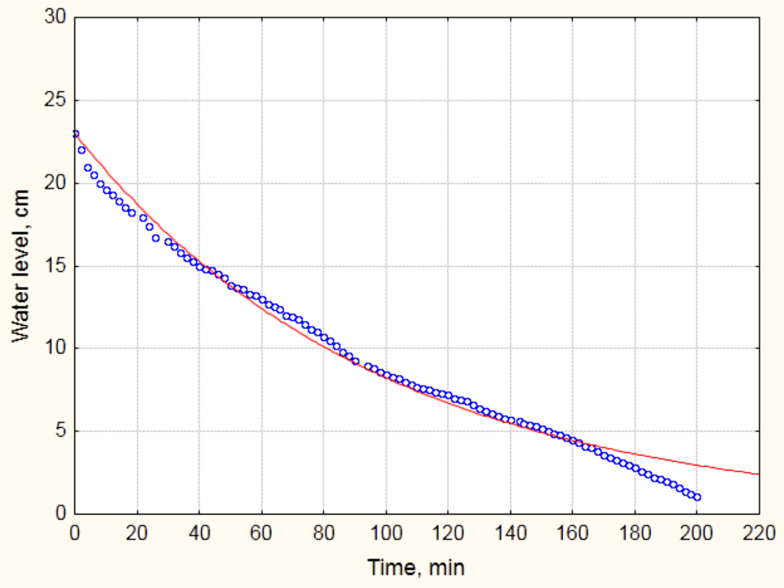
Changes in the water level during infiltration $H(t) = H_0 \exp\left(-\frac{t}{R}\right)$



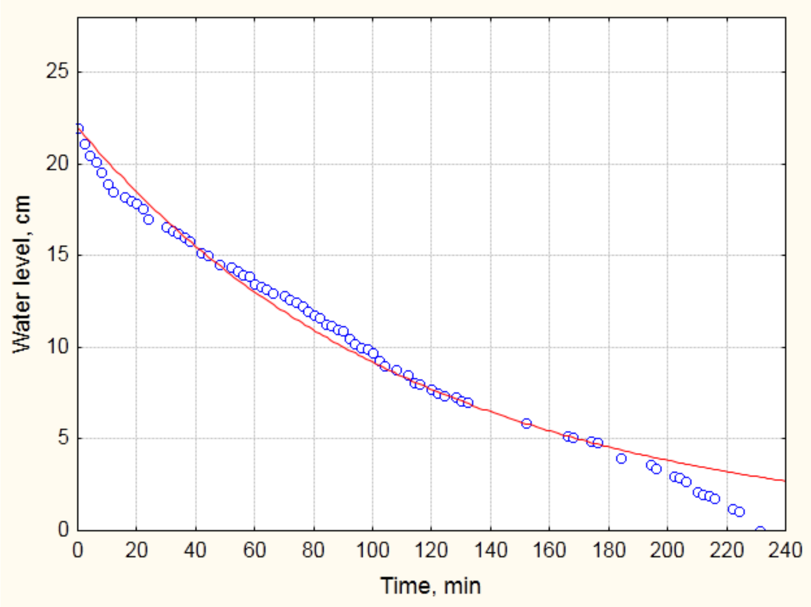
30.07.03(R^2 = 0,964)



11.08.03 (R^2 = 0,985)



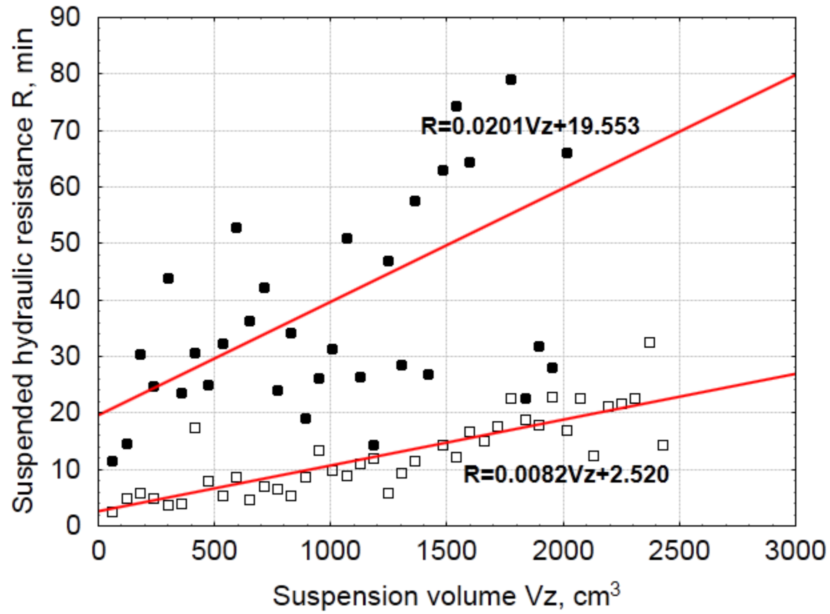
09.07.03 (R^2 = 0,978)



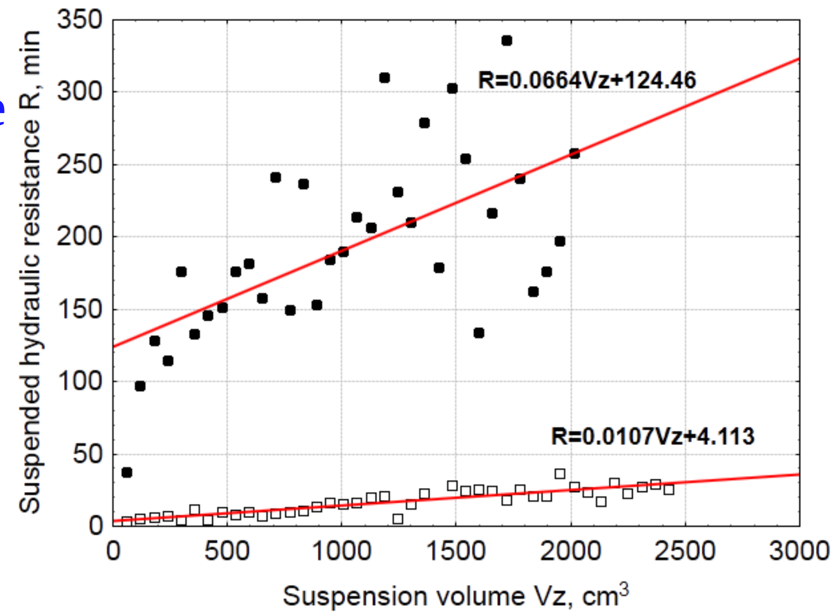
14.07.03 (R^2 = 0,971)

Hydraulic resistance of soil (R) on experimental site no.1 (white points) and experimental site no. 2 (black points)

- **in the filling phase**



- **in the infiltration phase**



CONCLUSIONS

1. **Complex models of soil clogging have a limited practical value for the purposes of designing of stormwater infiltration facilities**. This results from a large variability of the conditions in which the infiltration process takes place and from the complexity of the formal description of the models.

2. For engineering purposes, **simple models of changes in the infiltration rate in the phase of filling and emptying of infiltration modules can be applied**. The practical value of the developed models for the designing of stormwater infiltration systems translates mainly in the practical possibility to evaluate the degree of clogging and the need to take declogging actions.

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3. **Substitute hydraulic resistance R of the soil in the phase of filling** of infiltration modules **is significantly lower than that in the emptying phase**. **The difference between these values increased along with the increase in the volume of suspension introduced with infiltrating water**, which can be explained by a gradual clogging of the geotextile and of the superficial layer of soil.

4. **The degree and rate of clogging of the ground** in the course of long-term exploitation of stormwater storage and infiltration facilities **can be determined** basing on the measured values with use of **substitute hydraulic resistance *R*** in the emptying phase.