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Method Article

A modification of the constant-head permeameter to measure saturated hydraulic conductivity of highly permeable media

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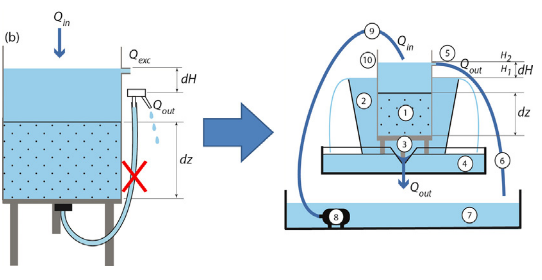
GRAPHICAL ABSTRACT



ABSTRACT

The saturated hydraulic conductivity (K_s) is a key characteristic of porous media, describing the rate of water flow through saturated porous media. It is an indispensable parameter in a broad range of simulation models that quantify saturated and/or unsaturated water flow.

The constant-head permeameter test is a common laboratory method to determine K_s on undisturbed soil samples collected from the field. In this paper we show that the application of this conventional method may result in a biased K_s in the case of highly permeable media, such as the top layer of *Sphagnum* peat and gravel. Tubes in the conventional permeameter, that collect water under the sample, introduce a hydraulic head-dependent resistance for highly permeable media and result in an underestimation of K_s.

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We present a simple and low-budget alternative of the constant-head permeameter test that overcomes the disadvantages of conventional permeameters. The new method was successfully tested on intact highly permeable peatmoss collected from a northern peatland.

- Conventional constant-head permeameters underestimate K_s of highly permeable media due to flow resistance in tubing systems
- We developed the low-resistance permeameter to overcome this disadvantage.
- Testing of the low-resistance permeameter demonstrated no systematic bias and successful application for highly permeable media.

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1 Method details

1.1 Conventional constant-head permeameter

The constant-head permeameter is a broadly used laboratory instrument to determine the saturated hydraulic conductivity (K_s) in laboratory conditions. The procedure is well-documented [1–3] and standardized (e.g. ISO/TS 17892-11 [4], ISO/FDIS 17312 [5], and NEN5789 [6]).

The hydraulic conductivity can be determined using Darcy's law (Eq. (1)) and measured data of the water flow rate (Q_{out}; L^3T^{-1}) through a sample, the sample cross section area (A; L^2) the difference in hydraulic head (dH; L) and the distance over which dH is applied (dz; L).

$$Q_{out} = -AK_s\frac{dH}{dz} \quad (1)$$

To that end, an undisturbed soil sample is placed in a PVC sample ring (Fig. 1). To establish a pressure head difference, another PVC ring is clamped watertight on top of the sample ring and filled with water (Q_{in}). Water is caused to flow through the sample and collected at the downflow end of the sample ring through a tubing system to an outlet. The rate of water flow Q_{out} can be adjusted by modifying the pressure head difference dH, which can be achieved by adjusting the height of the tube outlet. The hydraulic head difference is kept constant through time, by a continuous supply of water from above in combination with an overflow outlet (Q_{exc}). In a closed system the excess water can be collected and repumped on top of the water column. In the conventional constant-head permeameter tests it is assumed that K_s is independent on all other parameters, such as the hydraulic head difference, and that the sample is the only resistance to water flow. To obtain an accurate K_s estimate, the applicability of the constant-head permeameter is constrained to hydraulic head differences larger than 0.01 m (i.e. hydraulic gradients larger than 0.1 m m^{-1}). Smaller hydraulic head differences cannot be accurately estimated and introduce considerable error.

2 Application of the constant-head permeameter on highly permeable media: living *Sphagnum* peat

An example where adequate estimation of hydraulic conductivity plays a central role is in the hydrology of northern peatlands [8–10]. Northern peatlands fix large quantities of carbon and represent a key component of the global carbon cycle [11,12]. Carbon is stored through the process of photosynthesis, during which CO_2 is transferred into organic matter, which will be (partially) decomposed and accumulate as peat. Photosynthesis, hence CO_2 uptake, predominantly takes place by peatmosses, which represent the dominant vegetation in northern peatlands. During the last 10,000 years, northern peatlands acted as a net carbon sink. Besides light availability, wet surface conditions