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title: **Comparison of common and new methods to determine infiltration rates in Lake sediments**

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INTRODUCTION

For more than 100 years, rivers and lakes have been used as a source for bank filtration in Europe. Due to its proven efficiency in pathogens and persistent contaminants removal many developing countries such as Brazil, India and Egypt have also used this system for drinking water supply in the last few years. The amount of riverbank filtered water used for public supply is dependent on the stream bed permeability, in addition to other factors such as pumping rate, river elevation, water viscosity and stream bed thickness. Fischer *et al.* (2005) reported that the proportion and the volume of bank filtrate strongly depend on riverbed clogging. The deposition of fine grained sediments on the stream bed normally happens during low stream velocities. In addition, algal growth in higher temperatures can result in the deposition of organic matter on the bottom of the stream. This causes the increase of the streambed thickness, while consequently decreasing the bed permeability. During lower temperatures the water viscosity increases, thus reducing the water flow through the sediments. The increased flow velocity during floods causes cleaning of the river bed and re-suspension of the sediments, thus the thickness of the stream bed is assumed to decrease and bed permeability to increase.

Interest in analyzing infiltration rates has increased because of the necessity of water management at sites with high abstraction rates as well as sites with decreasing abstraction rates. At the same time, a variety of techniques and methods has been developed to examine and monitor infiltration. An improved understanding of the connection between surface and groundwater is viewed as an important prerequisite to effectively managing these resources (Sophocleos, 2002).

This study provides a comparison of new and common techniques to determine infiltration rates. Methods using Rn-222 (Macheleidt et al., 2006), fluorescent tracers such as melamine resin particles and air-dried FPOM from alder leaves (Gunkel et al., 2009), temperature and the use of monitoring wells and seepage meters (Rosenberry and LaBaugh, 2008) will be discussed and compared.

DESCRIPTION OF METHODS

Three of the most commonly used methods to calculate or directly measure groundwater flow will be described in the first section, with new methods described later. All of them are useful to determine infiltration rates under specific conditions.

Common methods for infiltration studies

Segment Approach Method

In this method, the shore-line of the superficial water is divided into segments (Figure 1). The number of segments depends on the number of observation wells. Hydraulic conductivity and the gradient between the well and the surface water are determined for each shore-line and consequent observation well. This method considers the area of a vertical plane (A), which consists of the length of the shore-line segment (m) multiplied by the thickness of the aquifer (b). The amount of water that passes through each the vertical plane is calculated by the Darcy's equation (Equation 1),

$$Q = KA\frac{h_1 - h_2}{L} \qquad (1)$$

where Q is the flow through the vertical plane (L^3/T), K is the horizontal hydraulic conductivity (L/T), A is the area of the vertical plane (L^2), h_1 and h_2 are the hydraulic head difference between the observation well (h_1) and the surface water (h_2) in (L), and L is the distance from the observation well to the shore-line (L). The net flow is calculated using the sum of flows to and from the surface water. The infiltration rates for each of the sections are obtained also using equation 1.

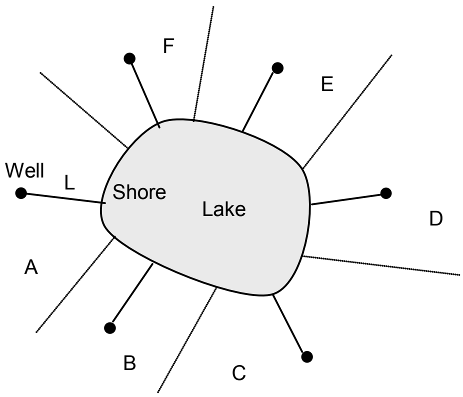

Figure 1. A segmented lake based on positioning of near-shore water-table wells. Adapted from Rosenberry et al., 2008.

Seepage Meter

This method is one of the most commonly used for measuring the infiltration rate directly in the sediment-water interface. It consists of the use of a cylinder attached to a plastic bag partially filled with a known amount of water. The cylinder is submerged in the water and placed in the sediment of the water body. The plastic bag is attached to the chamber and the change in volume is measured (Figure 2). The volumetric rate of flow through the part of the bed covered by the chamber is obtained. To calculate the infiltration rate, it is necessary to divide the volumetric flow rate by the area covered by the cylinder.

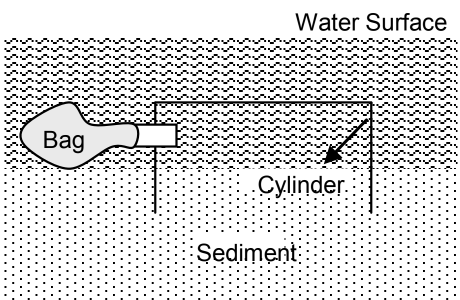

Figure 2. A typical seepage meter to estimate infiltration rate. Adapted from Rosenberry et al., 2008.

Temperature

The continuous exchange of water between the surface and groundwater provides an opportunity to use heat as a natural tracer to estimate infiltration rates indirectly. The use of heat as a tracer relies on the measurement of temperature gradients. Water and sediment temperature can be measured either directly by using a probe driven into the ground or indirectly by measuring water temperature at different depths in an observation well. In both cases it is necessary to use a probe connected to a data logger that can be programmed to read the parameter at least daily. More exact measurements will read the parameter every hour.

Many models of heat and groundwater transport have been developed. One of them was developed for cases where pore water velocities are sufficiently high and heat transport by conduction is negligible when compared to heat transport by advection. For this case, pore water velocity, v (m/s) is calculated by equation 2:

$$v = v_T \frac{1}{\theta} \frac{Cs}{Cw} \tag{2}$$

Where v_T is the vertical velocity of the temperature peak down into the streambed sediments (m/s), θ is the percent volumetric water content, C_S is the volumetric heat capacity of water, and C_W is the bulk sediment (both in $J/(m^3\ K)$).

In order to estimate infiltration rates, a computer modelling program from the U.S. Geological Survey called VS2DH has been used, where streambed temperature profiles are defined as input. This two-dimensional simulation code is based on inverse modelling to match simulated temperatures against measured temperatures to estimate heat and water fluxes into or out of the streambed.

Infiltration Chambers

In situ infiltration rates can also be determined by using special plexiglass chambers. The plexiglass is pressed into the sediment and connected (without pressure) to a plastic bag, which is previously filled with a known amount of water. After a period of 24 hours, the plastic bag is retrieved and reweighed. The infiltration rate can be determined by equation 3,

$$IR = \frac{Q}{A} \rightarrow where \rightarrow Q = \frac{V_i - V_f}{t} \tag{3}$$

where IR is the infiltration rate (m/h), Q is the flow (m^3/h), A is the cross sectional area of the infiltration chamber (m^2), V_i is the initial volume of the bag (m^3), V_f is the final volume of the bag (m^3) and t is the exposition time (h).

New Methods for infiltration studies

Fluorescence labelled tracers

The fluorescent labelling method is normally used as a tool for the investigation of particle transport in sediment interstices but can also be utilised as a method of infiltration rate analysis (Gunkel et al. 2009). In this procedure, melanine resin particles (which are produced by a private company) are labelled with 7-amino-4-methylcoumarin (AMC). The fluorescing MF-AMC particles have a blue colour (λex 360 nm / λem 429 nm), a density of 1.5 g cm^{-3} and a hydrophilic surface charged positively by amino groups. The particles are delivered in aqueous medium and are used for studies in microfine particle transport.

In addition, fluorescein-5-isothiocyanate (FITC) fluorescent labelling (λex 560 nm / λem 529 nm) (produced from a private company as well) is also a method that allows the study of vertical particle transfer in sediments. The application of this fluorescent can be utilised in natural organic substrates from the sampling site or for analysis of the biological decomposition of particulate organic material. In both fluorescent methods the recovering rate of the tracer is analysed at different depths in order to investigate the infiltration rate.

The restriction of this method is the need of sophisticated materials such as fluorescent tracers and microscopes equipped with UV lamps. The use of incorrect filters can cause errors in detecting the colour of the fluorescent particles in the sediment. Particle agglomeration can also be a problem when the samples are not ultrasonicated. Furthermore, the ingestion of FITC-labelled particles by invertebrates can occur, and severe clogging can hinder the vertical transport of the fine resin particles.

Radon-222

Radon-222 (^{222}Rn) is an inert natural gas found in different concentrations in groundwater and superficial water. It is the natural decomposition product of the radioactive ^{226}Ra, which also exists in the soil. In groundwater it is in equilibrium with ^{226}Ra, but in surface water its high volatility prevents its presence. As a consequence, it can be used as a natural tracer to estimate infiltration rates indirectly, based on its equilibrium concentration and retention time. For the application of this method, the homogeneity of ^{222}Rn emanation in the soil is assumed.

The restriction of this method is in the local sedimentary stratification, which can influence the equilibrium concentration of ^{222}Rn. In addition, the volume of gas in the saturated upper zone of the aquifer can influence the concentration of ^{222}Rn and its measurements.

CONCLUSION

Table 1 shows some positive and negative aspects for the methods described before. The selection of the method to estimate infiltration rates depends on availability of material, field site conditions, streambed grain distribution, etc. In general, all field measurements must be conducted at many locations in the river/lake bed to obtain reliable data for infiltration rates.

Table 1. Brief comparison between common and new methods.

Method		Positive Aspects	Negative Aspects
Common Methods	Seepage Meter	It is a direct measurement of infiltration rates; Possibility of having a good idea of the real distribution of the flux; Well suited for calm and shallow water settings (Rosenberry and LaBaugh, 2008).	Badly suited for surface water with strong hydraulic movement; Very soft and rocky sediments might are not adequate; Dense vegetation interferes in the measures (Rosenberry and LaBaugh, 2008).
	Segment Approach Method	It is possible to quantify flow between groundwater and surface water; Interesting for homogeneous aquifers; It is possible to have a general idea of the aquifer characteristics (Rosenberry and LaBaugh, 2008).	No information about infiltration rates at a specific area. Large numbers of monitoring wells needed.
	Temperature	Heat is a natural tracer free from issues of contamination associated with the use of chemical tracers; Well suited for investigations of stream/groundwater exchanges; Temperature data are immediately available as opposed to most chemical tracers (Rosenberry and LaBaugh, 2008).	Very low hydraulic gradients and/or extensive clay-textured streambeds can affect the temperature measurements (Rosenberry and LaBaugh, 2008).
	Infiltration Chambers	Infiltration rates can be measured *in situ* and it is relatively fast to obtain the measured results; It is relatively easy to handle; Low costs for building.	Badly suited for surface water with strong hydraulic movement; Rocky sediments might are not adequate; Dense vegetation might interferes in the measures.
New methods	Radon-222	It is a natural gas found in different concentration in groundwater and superficial water; Possibility of having a good idea of infiltration rates regimes (Macheleidt et al., 2006).	High volatility of Rn-222 when in contact with atmosphere; Demands specific sampling; Expensive Rn analyser needed; Sedimentary stratification can influence the concentration of Rn-222 (Macheleidt et al., 2006).
	Fluorescent Labelled Tracers	It is a possibility of measuring infiltration rates by labelling natural organic substances from the sampling site (Gunkel et al., 2009).	High costs for fluorescent particles; Severe clogging can limit the resin passage through the sediment; Ingestion of tracers by invertebrates; Particle agglomeration (Gunkel et al., 2009).

REFERENCES

Fischer T., Day K., Grischek T., 2005: *Sustainability of riverbank filtration in Dresden, Germany. Recharge systems for protecting and enhancing groundwater resources.* In: Proceedings of 5th International Symposium on Management of Aquifer Recharge. UNESCO Publishing, Paris, pp. 23-28.

Gunkel G., Beulker C., Hoffmann A., Kosmol, J., 2009: *Fine particulate organic matter (FPOM) transport and processing in littoral interstices – use of fluorescent markers. Limnologica*. 39(3): pp. 185-199.

Macheleidt W., Grischek T., Nestler W., 2006: *New approaches for estimating streambed infiltration rates.* In: Hubbs, S. (ed.) Riverbank Filtration Hydrology. NATO Science Series IV. Earth and Environmental Sciences Vol. 60, Springer, Dordrecht, pp. 73-91.

Rosenberry D.O., and LaBaugh. J. W., 2008: *Field techniques for estimating water fluxes between surface water and ground water.* U.S Geological Survey Techniques and Methods 4-D2, 128 p.

Sophocleous M., 2002: *Interactions between groundwater and surface water—The state of the science:* Hydrogeology Journal, v. 10, pp. 52–67.

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