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title: **Evaluation of nitrate residue norm by estimation of process factors for groundwater, Flanders, Belgium**

author(s): **Okke Batelaan**
(1) Department of Hydrology and Hydraulic Engineering, Vrije Universiteit, Brussel,
(2) Department of Earth and Environmental Sciences, K.U. Leuven, Belgium,
batelaan@vub.ac.be

Koen Van Overtveld
Department of Earth and Environmental Sciences, K.U. Leuven, Belgium,
Koen.VanOvertveld@ees.kuleuven.be

Luk Peeters
Department of Earth and Environmental Sciences, K.U. Leuven, Belgium,
luk.peeters@ees.kuleuven.be

Jan Diels
Department of Earth and Environmental Sciences, K.U. Leuven, Belgium,
jan.diels@ees.kuleuven.be

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This contribution discusses a methodology for the estimation of a process factor for phreatic groundwater for the evaluation and differentiation of the current nitrate residue norm in Flanders, Belgium. The goal is to differentiate this norm for different crops, soil textures and hydrogeological homogeneous zones (HHZ). The process factor is an empirical factor, which summarizes all changes to the nitrate concentration between the moment when the nitrate residue leaves at 90 cm depth the soil profile in autumn and the measured nitrate concentration in phreatic groundwater. Since 2004 phreatic groundwater quality is systematically followed up by the Flemish Environmental Agency (VMM) (Eppinger, 2005) by way of analysis of samples from 2107 piezometers.

In the methodology eight HHZ's are selected, which are contrasting in soil texture, cover all agricultural regions and have different vulnerability with respect to exceeding the nitrate limits in shallow phreatic groundwater. A map of the groundwater table has to be obtained for the selected HHZ's. Groundwater table observations however, are scarce and irregularly distributed in space and time. Geostatistical interpolation methodologies like kriging correctly represent the spatial structure of the data and are exact predictors at the locations of observation. However it often fails to capture the patterns in groundwater table map, which result from hydrogeological flow systems. In this study, the Bayesian Data Fusion (BDF) framework (Bogaert, Fasbender, 2007) is used to combine a kriging interpolation with the results of a simplified groundwater flow model. The BDF is applied to Flanders to create a groundwater table map with a spatial resolution of 25 by 25 m^2. To evaluate the performance of the proposed methodology; a leave-one-out cross validation procedure is applied. It is shown that the BDF methodology produces a groundwater table map, which is exact in the observation locations and represents well the groundwater flow system. It is shown that the methodology outperforms both the kriging interpolation and the groundwater model in predictive capabilities.

Once a groundwater table map has been created, the flow line through a given point x,y in the study area is derived using a simple backward particle tracking algorithm. The flow line is defined as the path following the highest gradient over the simulated phreatic surface, starting at the given position x, y and ending at the water divide. Furthermore we can now calculate the location of infiltration for any piezometer at a certain depth in the phreatic aquifer (Cook and Böhlke, 1999). The uncertainty on the exact location of the infiltration point is further calculated by taking into account the spatial variability of the transmissivity. Deriving the standard deviation of the infiltration point in both the longitudinal and lateral direction along the flow line and solving the equation for the bivariate distribution $g(x,y, \rho_{xy})$, we delineate an elliptic area with a certain statistical probability around the calculated infiltration point, in which the real infiltration point is located.

The integral form of the Darcy-Buckingham equation is used to estimate the effective field capacity of the unsaturated zone. Using pedotransfer functions, yearly estimated groundwater recharge from WetSpass (Batelaan, De Smedt, 2007) and the estimated groundwater level unsaturated flow times are estimated. By means of an analytical solute transport model (Toride et al., 1993), the mean nitrate concentration in the percolated water is calculated. With the methodology the process factor can now be estimated for all piezometers as the ratio of weighted over the elliptical area average nitrate concentration in the percolation water at 90 cm depth and the nitrate concentrate in the uppermost oxidized filter. This is further used to link and evaluate the nitrate concentration with the land use in the infiltration area.

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