Using a higher-tier coupled modelling approach to support the evaluation of groundwater monitoring studies on a sub-catchment scale

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Introduction

In the regulatory assessment of plant protection products in the European Union groundwater monitoring is recommended as a higher-tier option (EC 2014 [1]). The aim of our study was to support the evaluation of groundwater monitoring studies on a sub-catchment scale and address some of the regulatory concerns with regard to such studies. Questions on representativeness of sampling and well/screen position should be answered using a higher-tier modelling approach. The one-dimensional leaching model FOCUS-PEARL [2] was therefore coupled with the multi-dimensional scientific software OpenGeoSys [3] following the methodology in [4]. In a first step, measured concentrations of a non-relevant metabolite at the well were compared with simulated ones to demonstrate hydraulic connectivity and plausibility of the applied approach. After the first step was completed successfully, sensitivity analyses were performed to evaluate the influences of different configurations of well/screen position and screen length on measured concentrations.

Methods & Scenarios

For the comparison one site in Northern Germany with medium vulnerability was selected from a monitoring study which is represented by example study designs II & III in Gimsing et al. 2019 [5]. 7 applications on 3 fields (1.1, 1.2, 1.3), located up-gradient of the well, were considered for the simulations. A vertical transect along the dominant groundwater flow direction was selected to model the groundwater system (Fig.1).

❑ **Aquifer characteristics**

- aquifer thickness: 16 m; average groundwater level: 3.9 (mbgl); hydraulic conductivity: 6.00E-4 (m/s), filter screen at 9-14 (mbgl); groundwater recharge ≤150 (mm/a)

❑ **Soil characteristics**

- Topsoil: sandy loam, 70% Sand, 1.4% OC, Soil hydraulic parameters estimated based on HYPRES [6]
- Subsoil: well borehole log profile used to identify similar FOCUS groundwater scenarios [2] for the parameterization

❑ **Meteorological data**

- next German Weather Service station

In general, the simulation gives a good estimate of the course of the concentrations arriving at the well screen (Fig.2). The effect of treatments on 3 fields with different distances to the well could be simulated (Fig.2, Tab.1). Sensitivity analyses were performed in which metabolite concentrations at the screen were modelled for varying hypothetical configurations of the screen position (Tab.2).

Results

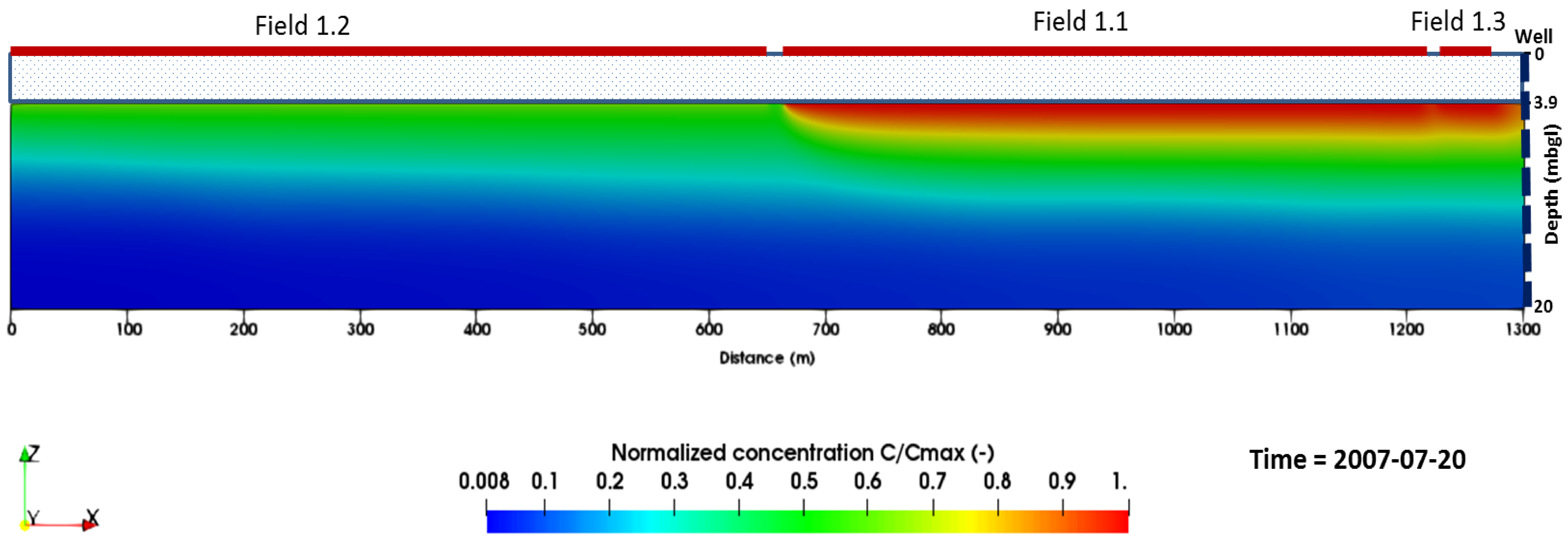

Figure 1: Illustration of model domain and distribution of normalized non-relevant metabolite concentration
(direction of groundwater flow ==> from the left to the right)

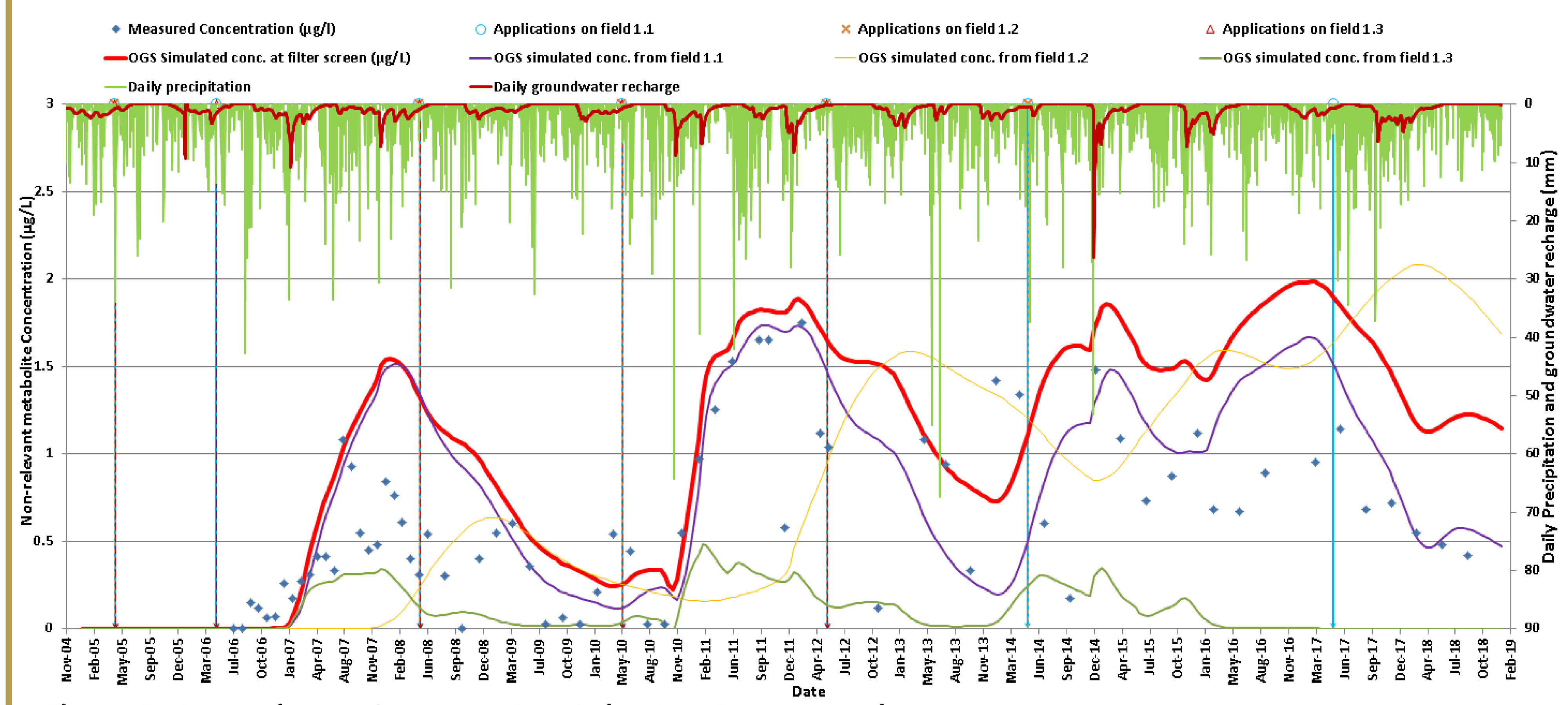

Figure 2: Comparisons of measured and simulated concentrations
"OGS simulated conc. at filter screen": effect of all applications simulated simultaneously at the well screen
"OGS simulated conc. from field 1.1/1.2/1.3": applications from three different fields simulated individually

Table 1: Simulated concentrations for all fields modelled simultaneously and for each field modelled individually

Year of peak concentration evaluated	Simulated concentrations (µg/L)			
	All fields	Field 1.1	Field 1.2	Field 1.3
2015	1.9	1.5	0.9	0.3
2017	2.0	1.7	1.5	0.0

Table 2: Results of sensitivity analyses: The effect of different configurations of the screen position and length

Screen configurations	Year of peak concentration evaluated	Simulated peak concentration of current configuration in % (mean) of hypothetical configuration
Distance to field edge current: 25 m hypothetical: 5 m	2007, 2011, 2015	**99**
Position of screen top current: 9 mbgl hypothetical: 4 mbgl	2007, 2011, 2015	**69**
Screen length current: 5 m hypothetical: 2 m	2007, 2011, 2015	**92**

Summary & Conclusions

- ❖ Measured concentrations can be reproduced by the modelling approach. Some measured peak concentrations seem to be slightly overpredicted.
- ❖ For the current well-field-distance the model predicts on average around 99% of the highest peak concentrations that can potentially occur in the well. Moving the well closer to the field edge (from 25 to only 5m distance) or reducing the screen length (from 5 to 2 m) would have only negligible or small effects on the measured concentrations. Shifting the current vertical screen position (9 mbgl) to the top of the saturated zone (4 mbgl) can result in a higher peak concentrations because the treated fields are close to the monitoring well.
- ❖ Applications on the third field (1.2) starting at 600m distance had an effect due to the relatively large aquifer thickness and deep position of filter screen. A full documentation of the application history on relevant upgradient fields is crucial for a modelling study to make reliable predictions.
- ❖ The sensitivity analysis showed that soil and hydrogeological properties, the arrangement of the treated fields and the screen position have different effects on the simulated concentrations.

References

[1] European Commission (2014): Assessing Potential for Movement of Active Substances and their Metabolites to Ground Water in the EU. Report of the FOCUS Ground Water Work Group, EC Document Reference Sanco/13144/2010, version 3, 613 pp.
[2] FOCUS (2000) "FOCUS groundwater scenarios in the EU review of active substances" Report of the FOCUS Groundwater Scenarios Workgroup, EC Document Reference Sanco/321/2000 rev. 2, 202 pp.
[3] Kolditz, O. et al. (2012): OpenGeoSys: an open-source initiative for numerical simulation of thermo-hydro-mechanical/chemical (THM/C) processes in porous media, Environ. Earth Sci.
[4] He, W., Miles, B., Staudenmaier, H. (2017): A generic modeling exercise to identifying factors influencing the representativity of measured pesticide concentrations at groundwater monitoring wells, International Conference on Pesticide Behaviour in Soils, Water and Air, University of York, UK.
[5] Gimsing, A.L., Agert, J., Baran, N. et al. (2019): Conducting groundwater monitoring studies in Europe for pesticide active substances and their metabolites in the context of Regulation (EC) 1107/2009. J Consum Prot Food Saf 14 (Suppl 1): 1. p. 69-71.
[6] Wösten J.H.M., Lilly A, Nemes A, Le Bas C (1998): Using existing soil data to derive hydraulic parameters for simulation models in environmental studies and in land use planning. Report 156, DLO-Staring Centre, Wageningen, NL, 104 p.