

3.11 Tools for quantification of duration and effect of sources of pesticides to the groundwater resource case study, Denmark

Title of Case Study	Industrial PhD project: Tools for quantification of duration and effect of sources of pesticides to the groundwater resource
Location (region, Country)	Marbaek, Northern Zealand, Denmark
Other information	The abstraction wells are affected by the fungicide/biocide metabolite DMS. The monitoring wells are located at an upgradient site which is believed to be the source of contamination. The land use of this site was formerly storage and rental of agricultural machinery and cultivation of strawberries.

Description of Case Study (background information on the region)

This case study is one of two in an industrial PhD project conducted by the Environmental Institute at Technical University of Denmark and the consultancy company Ramboll. The regional authority The Capital Region of Denmark and the water utilities Novafos and HOFOR are partners in the project, and GEUS supervises on the use of groundwater dating tracers for assessment of the history and fate of the investigated contaminants. The focus is on the metabolite DMS, which derives from the fungicides/biocides tolylfluanid and dichlofluanid.

The limestone aquifer is the main source of drinking water in this region. All six wells in the well field are affected by DMS, four more severely (frequently >0.1 µg/L). The abstraction wells are open in the limestone, from about 14 m bgs. One well is 22 m deep (192.613), the other is 33 m deep (192.614). They are sampled at depth specific levels by separation pumping at the main inflow zones at respectively 14 and 19 m bgs (192.613) and 15 and 20 m bgs (192.614).

The believed origin of the pesticide contamination is situated 1.4 km upgradient of the abstraction wells. The two monitoring wells are screened in the meltwater sand aquifer at respectively 12-14 m bgs (192.2217) and 17-24 m bgs (192.2171). The highest DMS concentrations measured are 9,5 µg/L (192.2217) and 5,9 µg/L (192.2171). A range of other pesticides are found in substantial concentrations, most notably benazolin at 48 µg/L.

The source is currently thought to be a combination of a DMS point source from the agricultural machinery rental and a more diffuse effect of DMS from the cultivation of strawberries. Investigation of the source site and the catchment area of the well field is in progress.

The samples were collected in collaboration with GEUS, The Geological Survey of Denmark and Greenland. The dating tracers $^3\text{H}/^3\text{He}$ will be analysed at the Helis lab. at University of Bremen, Germany, while SF_6 is analysed at Spurenstofflabor in Wachenheim, Germany. The tracer and age distribution will be simulated by a lumped parameter model (TracerLPM) developed by the USGS (Jurgens et al., 2012) and particle tracking.

Description of problem (why is this location chosen for a Case Study)

The abstraction wells are contaminated with the pesticide metabolite DMS in levels exceeding the national drinking water criterion as well as the groundwater criterion specified by the Danish EPA. This site is chosen because the pesticide levels are high, the site is quite well-studied and the geology is believed to be relevant to other sites nationally.



Methods used in the Case Study (analytical and isotope techniques, modelling)

The case study includes the application of the groundwater age indicators SF_6 and $^3\text{H}/^3\text{He}$, the lumped parameter modelling tool “TracerLPM” (<https://www.usgs.gov/software/tracerlpm>) and particle tracking by numerical modelling. $^3\text{H}/^3\text{He}$ is analysed by the Helis lab. at University of Bremen <https://www.noblegas.uni-bremen.de/eng/>. SF_6 is analysed by the Spurenstofflabor in Wachenheim (no web site).

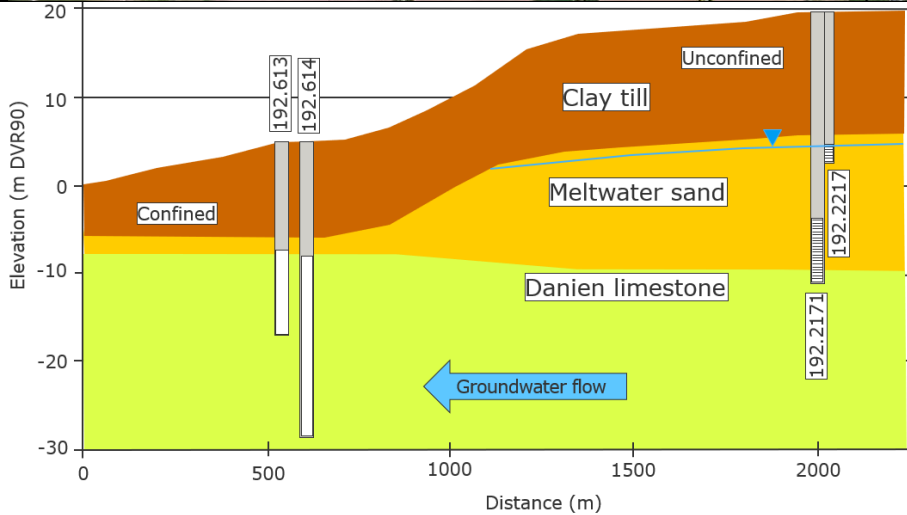
Results from this Case Study

The results from the laboratories will be received ultimo 2020 and primo 2021.

Impact - how this Case Study contributes to the overall project aims

The case study investigates the groundwater age and travel time distributions of two long-screened abstraction wells in Northern Zealand, Denmark, by new tracer techniques and hence it contributes to the objectives of WP6 task 6.4 on groundwater age and travel time distributions of long-screened wells, as well as related studies in HOVER WP5 and 7 on travel times for nitrate and pesticides and the vulnerability of aquifers towards pollution from the surface, respectively.

The cited references and access information are listed at the end of the following information template.

Name of pilot area / aquifers / type: Marbæk – glacial deposits and limestone, confined and unconfined aquifer systems		Country: Denmark Region: The Capital Region of Denmark (Northern Zealand)	
Study level	Transboundary : ☐ Regional: ☐ Local: ☐ Single well(s): X		
Type of observations <i>(choose one of the options, create separate template if needed for each type if each type need specific information)</i>	X Short screened observation wells (not pumped) X Long screened observation wells (not pumped) X Pumped wells, long screens in one aquifer ☐ Pumped wells, long screens over multiple aquifers ☐ Springs ☐ Other (eg. research wells; indicate type and information on pumping):		
Approximate location of pilot:			
Geological cross section / conceptual model of the pilot area:	 Conceptual model of geology with sampled wells and regional groundwater flow.		

Name of Shape- / Geopackage file defining the area:  IOL_Marbaek_200aar.shp		Projection to be used: UTM32N (ETRS89)		
Hydrological parameters:	Mean annual precipitation (mm or range in mm)	Mean annual groundwater recharge (mm or range in mm)	Mean annual groundwater recharge temperature (°C)	Thickness of unsaturated zone (range in m)
	750	240	10	0-1
Pumped wells only		Typical pump discharge of sampled individual well (m ³ /day): 100 – 200 m ³	Typical pump discharge of complete well field (m ³ /day): 450 m ³	
List of aquifers and aquitards in pilot area		No. of confined or semiconfined aquifers in pilot area: 2	No. of unconfined aquifers in pilot area: 1	
Aquifer no. (aqf): 3 Aquitard no. (aqt): 1 Aquiclude no. (aqc): 0	Aquifer/aquitard type and/or name	Lithology (Resource WP6 terminology)	Depth range (m)	GW age range (yr)
Aqt-1:	Glacial clay till	Sandy, contains ochre and limestone	0-10	
Porosity type	Porous: ☐	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: X
Aqf-1:	Glacial meltwater sand overlain by clay till	Fine to medium sand, some gravel	10-24	< 5 – 100 ?
Porosity type	Porous: X	Fissured: ☐	Karst: ☐	Fissured and porous / dual porosity: ☐
Aqf-2:	Danien limestone	Limestone	24 - ?	25 - ?
Porosity type	Porous: ☐	Fissured: X	Karst: (X)	Fissured and porous / dual porosity: (X)
Applied tracer age indicators (³ H, ³ H/ ³ He, ⁸⁵ Kr, ³⁹ Ar, ¹⁴ C, ³⁶ Cl, ⁸¹ Kr, ⁴ He, CFCs, SF ₆ , etc.)		Aquifer-1 ³ H/ ³ He, SF ₆		
Applied recharge temperature indicators (¹⁸ O, D, noble gases)		Aquifer-2 ³ H/ ³ He, SF ₆		
Number of sites (wells/springs) with age indicators		Aquifer-1 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		
		Aquifer-2 1-5: X 5-10: ☐ 10-25: ☐ >25: ☐		



GW age range (GAR) GAR-1: Modern (< 60 yr) GAR-2: Old (> 60 yr and <10 kyr) GAR-3: Paleowaters (> 10 kyr)		Aquifer-1 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X GAR-2: 1-10%: X 10-25%: ☐ 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐			
		Aquifer-2 GAR-1: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: X GAR-2: 1-10%: ☐ 10-25%: X 25-50%: ☐ >50%: ☐ GAR-3: 1-10%: ☐ 10-25%: ☐ 25-50%: ☐ >50%: ☐			
		Groundwater age ranges (GAR) estimated by: Tracer based estimates ☐ Flow and age model simulations ☐ Combination of model and tracer estimates X Expert judgement: ☐			
Objective of age dating studies:					
Basic research or General groundwater management X	Assessment of pollutant history X		Assessment of the efficiency of remediation and mitigation measures		Indication of vulnerability of aquifers and water supply wells
Water Usage <i>(not relevant for observation wells)</i>	Water supply X		Irrigation	Industry	Other
Geoenergy related activities <i>(not relevant for observation wells)</i>	Shallow Geo-T	Deep Geo-T	Hydrocarbons		Nuclear waste disp.
Mining activities <i>(not relevant for observation wells)</i>	Construction materials		Minerals / metals	Coal	Other
References: OPEN Access reports and papers: (PDF versions made available in EGDI repository making them downloadable via maps and keyword / free text searches): Jurgens, B. C.; Bohlke, J. K.; Eberts, S. M. TracerLPM (Version 1): An Excel Workbook for Interpreting Groundwater Age Distributions from Environmental Tracer Data. U.S. Geological Survey Techniques and Methods Report, 4-F3, 60; 2012.			References: Reports and papers with restricted access:		
Remarks / other relevant information: Groundwater age dating results are yet to be received.					