XXXVIII IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **494**

topic: **1**
Groundwater quality sustainability

1.4
Groundwater quality and agriculture

title: **Risk of pesticide pollution to groundwater — a case study to identify threatens to groundwater**

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keywords: pesticides, leaching, groundwater, modelling

In the project "Groundwater and Dependent Ecosystems: New Scientific and Technological Basis for Assessing Climate Change and Land-use Impacts on Groundwater (GENESIS)" coordinated by Bioforsk, the objective is to integrate new methods, concepts and tools for the revision of the Ground Water Directive and better management of groundwater resources. By case studies in different climatic regions various land use pressures are studied.

Recent research indicates that a major part of diffuse pesticide pollution originates from minor areas, "hot spots". Both micro topographical conditions and soil properties will influence where these "hot spots" are situated. In areas with cold winters below zero, large water quantities can be collected in terrain depressions during periods with frost in the soil, followed by rapid infiltration and transport of large water amounts down to groundwater in spring (Kværner et al., 2005). In Norway the most important groundwater resources are located in alluvial deposits along the rivers. Such areas are used for intensive cereal and potato production, and groundwater investigations demonstrate that diffuse pesticide pollution from agriculture is a major threat to these aquifers (Eklo et al., 2002). The case study in Norway is Grue located along the Glomma River in Hedmark County, north-east of Oslo. The area is situated above a deep basin filled with marine deposits beneath a top layer of fluvial sediments. The deposits consist mainly of sand with a top layer of flood plain sediments of silt and sand. The thickness of the unsaturated zone varied between 1.8 and 5.9 m. The mean groundwater recharge is estimated to be 300 mm $year^{-1}$. The velocity of the groundwater flow has been < 40 cm day^{-1} at a hydraulic gradient of 0.2%. The main crops in the area are potatoes and cereals.

To identify threatens to groundwater pollution MACRO_GV (Lindahl, 2005) has been used simulating the movement of pesticides used in potatoes and cereals. The simulation set-up and output from the tool is similar to the FOCUS (2000) groundwater scenarios. Output consists of simulated average yearly leaching concentrations (20-year simulation) at one meter depth, and the long-term average concentration. Relevant soil parameters needed for the MACRO-GV simulations were extracted from the Norwegian Soil Data Base for 13 soil types in the Grue area. The results from the simulations with herbicides used in spring cereals are given in table 1–3. The applied dose of the pesticide represents the highest legal dose (NAD). The risk classes are based on the combination of simulated concentration and hydrological classes of the soil type.

Table 1. Soil types and selected properties.

	ATm4	AFs5	FOs5	TLt5	KMk5	KGl5	KLr5	TKi5	THg5
WRB-unit	Haplic Arenosol	Endogleyic Arenosol	Gleyic Fluvisol	Umbric Fluvic Cambisol	Endostagnic Fluvic	Fluvic Cambisol	Endostagnic Fluvic	Fluvic Stagnosol	Fluvic Stagnosol
Org. C (%)	1-2	2-3	3-5	>5	2-3	1-2	2-3	2-3	2-3
Influence of water	None	Gr.w. >50cm	Ground w.	Surface w.	Surf.w. >50cm	None	Surf.w. >50cm	Surface w.	Surface w.
Hydrological class	A	B	B	B	B	A	B	B	B

Table 2. Risk of herbicide leaching to groundwater from different soil types according to table 1.

		Soil types									
Trade name	**Active ingredient**	**ATm4**	**AFs5**	**FOs5**	**TLt5**	**KMk5**	**KGl5**	**KLr5**	**TKi5**	**THg5**	**Dosage (NAD)**
Actril 3-D	Ioxynil	1	1	1	1	1	1	1	1	1	3 l/ha
	Dichlorprop - P	4	4	4	4	4	4	4	4	4	
	MCPA	1	1	1	3	2	1	1	1	1	
Ally 50 ST	Metsulfuron - methyl	4	3	3	3	3	4	3	3	3	0.012 kg/ha
Ally Class 50 WG	Metsulfuron - methyl	4	3	3	3	3	4	3	3	3	0.05 kg/ha
	Carfentrazone - ethyl	4	3	3	3	3	4	3	4	3	
Ariane S	Fluroxypyr 1-methylheptylester	4	3	3	3	3	4	3	4	3	2.5 l/ha
	Clopyralid	4	4	4	4	4	4	4	4	4	
	MCPA	1	1	2	3	3	1	1	1	1	
Roundup ECO	Glyphosate	1	1	1	1	1	1	1	1	1	4 l/ha
Express	Tribenuron - methyl	4	3	3	3	3	4	3	3	3	1 tabl./0.5 ha
Harmony Plus 50 T	Thifensulfuron - methyl	1	1	1	1	1	1	1	1	1	0.015 kg/ha
	Tribenuron - methyl	4	3	2	2	3	4	3	3	2	
Hussar	Mefenpyr - diethyl										0.2 kg/ha
	Iodosulfuron - methyl	3	2	2	2	2	3	2	2	1	
MCPA 750	MCPA	4	1	3	4	4	4	1	4	3	4 l/ha
Optica Mekoprop - P	Mecoprop - P	4	2	3	3	3	4	3	3	2	3 l/ha
Primus	Florasulam	1	1	1	1	1	1	1	1	1	0.1 l/ha
Puma Extra	Fenoxaprop - P - ethyl	1	1	1	1	1	1	1	1	1	1.2 l/ha
	Mefenpyr - diethyl										
Starane	Fluroxypyr 1-methylheptylester	4	4	4	4	4	4	4	4	4	2 l/ha

Table 3. Risk classes based on hydrology and pesticide concentrations.

	Concentrations (µg/L) simulated with MACRO_GV				
Hydrological class	< 0.001	0.001 - 0.01	0.01 - 0.1	0.1 - 1	> 1
A	1	2	3	4	4
B	1	1	2	3	4
C	1	1	1	1	1

1 = no risk
2 = low risk
3 = moderate risk
4 = high risk

Hydrological classes. A: Well-drained soils (natural drainage) with no drains or no gley features within 100 cm depth. B: Moderately well drained soils with gley features within 100 cm depth and poorly drained soils with gley features directly below the topsoil, or soils that have drains. Hydrological class C: Poorly drained soils formed on massive clays or shallow soils on hard rocks.

ACKNOWLEDGEMENTS

The project is financed by EU's 7th Framework program and Norwegian Research Council.

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International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0