"Assessing pesticide leaching at the regional scale: a case study for atrazine in the Dyle catchment/"

Leterme, Bertrand

ABSTRACT

The overall objective of this thesis is to better understand and assess pesticide leaching at the regional scale, using both the analysis of monitoring data and spatially distributed modelling. Atrazine contamination of the Brusselian aquifer (central Belgium) is poorly understood. Considerable uncertainty surrounds whether the pollution is agricultural or non-agricultural in origin. The spatial and temporal covariance of atrazine concentrations was studied by fitting semivariogram models to monitoring data. Correlation ranges were found to be 600 metres and 600-700 days. A non-parametric one-way ANOVA found a strong relationship between mean concentrations and land use, whilst other environmental variables were found to be less important. Higher levels of pollution were detected in areas dominated by urban land use suggesting that atrazine residues in groundwater resulted from non-agricultural applications. Modelling pesticide leaching at the regional scale (Dyle catchment) was used to assess groundwater vulnerability. Different approaches to process soil information were tested with both a linear (modified Attenuation Factor) and a non-linear (GeoPEARL) leaching model. The CI (calculate first, interpolate later) and IC (interpolate first, calculate later) approaches were identical for the linear model, but differences in the amount of leaching were found for the non-linear model. The CI approach would be expected to give better results than IC, but the CA (calculate alone) approach is probably the best method if no spatial output is required. Finally, a methodology was ...

CITE THIS VERSION

Leterme, Bertrand. Assessing pesticide leaching at the regional scale: a case study for atrazine in the Dyle catchment/. Prom. : Vanclooster, Marnik ; Rounsevell, Mark http://hdl.handle.net/2078.1/5345

DIAL is an institutional repository for the deposit and dissemination of scientific documents from UCLouvain members. Usage of this document for profit or commercial purposes is strictly prohibited. User agrees to respect copyright about this document, mainly text integrity and source mention. Full content of copyright policy is available at Copyright policy

Available at: http://hdl.handle.net/2078.1/5345
Assessing Pesticide Leaching at the Regional Scale:
A Case Study for Atrazine in the Dyle Catchment

Bertrand Leterme

Thèse présentée en vue de l’obtention
du grade de Docteur en Sciences

Université catholique de Louvain

Louvain-la-Neuve, Décembre 2006
Acknowledgments

This thesis was funded by the *Fonds Spécial de Recherche* (FSR - Université catholique de Louvain; October 2002 - September 2003) and by the *Fonds National de la Recherche Scientifique* (FNRS - Belgium; Research Fellow from October 2003). A part of this work was realised at the National Institute for Public Health and the Environment (RIVM - The Netherlands). I am grateful to Dr. A.M. Breure for his permission to work in the Laboratory for Ecological Risk Assessment. I also appreciate the delivering of data on groundwater quality by the *Direction générale des Ressources naturelles et de l’Environnement* (DGRNE) and the *Vlaamse Maatschappij voor Watervoorziening* (VMW).

My foremost thanks go to my thesis supervisors Mark Rounsevell and Marnik Vanclooster, who gave me the opportunity to work on this dissertation. First, I would like to thank Mark for his constant and friendly support, and for his numerous comments and corrections throughout the last four years. I would like to thank Marnik for his support and positive attitude, as well as for showing me the implications of my work. Furthermore, I thank him for introducing me into the ‘pesticide leaching community’ from the very first day of my thesis.

I would also like to thank Aaldrik Tiktak and Ton van der Linden for their important participation in the work presented here. Our collaboration was very fruitful and this was largely due to their profound knowledge of GeoPEARL as well as their kind offer to stay at the RIVM. They gave me new insights on the issues treated in this dissertation and though I am afraid that my Dutch has not improved, I learned a lot during my stay there. Mostly, I would like to thank Ton not only for the days we spent working together, but also for the numerous e-mails we exchanged to implement and
process the GeoPEARL Monte Carlo simulations.

Je tiens à remercier Patrick Bogaert, qui a fait preuve d’une constante disponibilité pour m’aider à comprendre et résoudre beaucoup de problèmes (géo)statistiques. Ses suggestions et commentaires toujours pertinents ont pris une valeur inestimable dans la réalisation de cette thèse.

Merci à Bas van Wesemael pour son apport précieux concernant le traitement des données pédologiques. Plus généralement, son aide toujours spontanée et son intérêt marqué pour les thèmes abordés dans ce travail furent très appréciés. Merci aussi à Dominique Peeters pour ses encouragements et son accord d’être membre du jury, malgré un sujet assez éloigné de son domaine de prédilection.

J’aimerais également remercier l’ensemble de mes collègues et du personnel des unités de Géographie et de Génie Rural. Impossible de les citer tous après huit ans passés ici, mais je tiens particulièrement à remercier—pour leur aide experte ou tout simplement pour leur soutien—Nico, Didrik, Juan, Claude, Antoine, David, Olivier, Anne-Christelle, Elisabeth, Laurent, Esther, Marijn, Mathieu, Sébastien, Isabelle, Pierre, Caroline.

## Contents

1 Introduction 1  
1.1 General introduction 1  
1.2 Problem statement 3  
1.3 Research objectives 5  
1.4 Outline of the thesis 7  

2 Groundwater Vulnerability and Pesticide Leaching Modelling: A Literature Review 9  
2.1 Groundwater vulnerability 9  
  2.1.1 Definition 9  
  2.1.2 Factors affecting groundwater vulnerability to contamination by pesticides 12  
  2.1.3 Vulnerability assessment methods 16  
2.2 Process-based models of pesticide leaching 20  
  2.2.1 Modelling approaches 20  
  2.2.2 Processes governing the environmental fate of pesticides 21  
  2.2.3 Validation of pesticide leaching models 26  
  2.2.4 Uncertainty in pesticide leaching modelling 27  
    2.2.4.1 Sources of uncertainty 27  
    2.2.4.2 Methods for propagating uncertainty 31  
2.3 Pesticide leaching models at the catchment/regional scale 34  
  2.3.1 Problems of scale 34  
  2.3.2 Spatial variability of pesticide and soil properties 38  
  2.3.3 Second-order Monte Carlo analysis 42  
2.4 Conclusions from the literature cited 43
3 Dyle Catchment: Description of the Study Area 45

4 Discriminating between Point and Non-Point Sources of Atrazine Contamination of a Sandy Aquifer 51
   4.1 Outline .................................................. 51
   4.2 Introduction ............................................ 52
   4.3 Data and methods ....................................... 54
     4.3.1 Atrazine monitoring data ......................... 54
     4.3.2 Data censoring ..................................... 54
     4.3.3 Spatio-temporal semivariograms ................. 57
     4.3.4 Influence of censored data on the semivariogram range 58
     4.3.5 Cumulative density function and histogram analysis . 59
     4.3.6 Analysis of variance ............................ 60
   4.4 Results and discussion ................................ 63
     4.4.1 Spatial and temporal semivariograms ............ 63
     4.4.2 Influence of censored data on the semivariogram range 64
     4.4.3 Cumulative density function and histogram analysis . 68
     4.4.4 Analysis of variance ............................ 72
   4.5 Conclusions ............................................ 79

5 The Consequences of Interpolating or Calculating First: A Simple Case Study 81
   5.1 Introduction ............................................ 81
   5.2 Validation data set .................................... 82
   5.3 Models and methods ................................... 83
   5.4 Results ................................................ 89
     5.4.1 CA approach .................................... 89
     5.4.2 CI approach .................................... 91
     5.4.3 IC approach .................................... 96
   5.5 Discussion and conclusions ............................ 104
6 The Consequences of Interpolating or Calculating First on the Simulation of Pesticide Leaching at the Regional Scale 107

6.1 Outline .................................................. 108
6.2 Introduction ........................................... 108
6.3 Material and methods ................................. 111
   6.3.1 Soil properties .................................. 111
   6.3.2 Pesticide leaching index based on the linearised Attenuation Factor ......................... 113
   6.3.3 Pesticide leaching simulated with GeoPEARL ......................................................... 116
   6.3.4 Calculate alone, and calculate or interpolate first: CA, CI and IC approaches ................. 117
   6.3.5 Comparison of the results .......................... 119
6.4 Results .................................................. 121
   6.4.1 Maps comparison of CI vs. IC ...................... 121
   6.4.2 CDFs comparison .................................. 129
6.5 Discussion and conclusions ........................... 131

7 Including Spatial Variability in Monte Carlo Simulations of Pesticide Leaching 135

7.1 Outline .................................................. 135
7.2 Introduction ........................................... 136
7.3 Material and methods ................................. 139
   7.3.1 GeoPEARL: model description and parameterisation ............................................. 139
   7.3.2 Uncertainty analysis ............................... 143
   7.3.3 Reproducibility and the effect of truncation ......................................................... 147
7.4 Results and discussion ................................ 148
   7.4.1 Deterministic simulation ........................... 148
   7.4.2 Stochastic simulation ............................. 148
   7.4.3 Reproducibility and truncation .................... 151
   7.4.4 Field samples vs. databases ....................... 153