GEO-REFERENCED REGIONAL EXPOSURE ASSESSMENT TOOL FOR EUROPEAN RIVERS (GREAT-ER): A CASE STUDY FOR THE RUPEL BASIN (B)

F. Verdonck*, G. Boeije*, D. Schowanek & P.A. Vanrolleghem***
* BIOMATH Department, University of Gent, Coupure Links 653, 9000 Gent, Belgium
** Procter & Gamble, Eurocor, Temselaan 100, 1853 Strombeek-Bever, Belgium

ABSTRACT

In the GREAT-ER project (Geography-referenced Regional Exposure Assessment Tool for European Rivers), an accurate aquatic exposure prediction tool for chemicals was developed and validated for use within environmental risk assessment schemes.
In this paper, the application of the GREAT-ER methodology to the Rupel basin in Belgium is presented. Spatial concentration patterns of the anionic surfactant Linear Alkylbenzene Sulphonate (LAS) were predicted for this basin. Different scenarios were simulated. LAS removal in waste water treatment plants is high (98-99.9%). However, since only 30-40 % of the wastewater in the Rupel basin is treated, predicted environmental concentrations (PECs) are high. For some subbasins, calculated PEC-values were positioned against biological and physico-chemical water quality measurements.
This case study showed the feasibility of implementing a new large catchment on a short term and indicated which efforts are required to apply GREAT-ER on a large, ultimately pan-European scale. It was found that it is possible to simplify the river network without considerable loss of accuracy. This allows to gain time and reduce effort.

INTRODUCTION

The goal of comprehensive risk assessment is to estimate the likelihood and the extent of adverse effects occurring to man, animals or ecological systems due to possible exposure(s) to substances. The assessment of whether a substance presents a risk to organisms in the environment is based on the comparison of a predicted environmental concentration (PEC) with a predicted no effect concentration (PNEC) to ecosystems (Feijtel et al., 1997).

As the current generic ‘unit world’ techniques to assess regional exposure do not account for spatial and temporal variability and do not offer realistic predictions of actual concentrations, they are merely applicable on a screening level. The objective of the GREAT-ER project (Geography-referenced Regional Exposure Assessment Tool for European Rivers) was to develop an accurate tool to predict chemical exposure in the aquatic environment (Feijtel et al., 1997).

In GREAT-ER, a new database, model and software system were worked out to calculate the distribution of PEC’s of 'down-the-drain' chemicals in European surface waters, on a river and catchment area scale. The system uses a Geographic Information System (GIS) for data storage and visualisation, combined with simple mathematical models for the prediction of chemical fate. At present, the system contains information for four catchments in Yorkshire (UK), one in Italy, and two in Germany. GREAT-ER 1.0 has been validated by comparing simulations with the results of an extensive monitoring campaign for the detergent ingredients Linear Alkylbenzene Sulphonate (LAS) and boron (Feijtel et al., 1997; Schowanek et al., in press).

The output of GREAT-ER 1.0 is three-fold (Schowanek et al., submitted):

1. a colour-coded GIS map with the distribution of a chemical's PEC in the river basin.
2. a profile of the chemical concentration as a function of the distance for a selected branch of the river.
3. aggregated PEC's (i.e. $PEC_{initial}$ and $PEC_{catchment}$) to integrate the results for an entire catchment (Boeije et al., in press).

In this paper, the application of the GREAT-ER methodology to the Rupel basin is presented. The Rupel is a tributary to the river Schelde (Figure 1). Compared to the other pilot study catchments, the Rupel catchment is significantly larger, with more than 1800 discharges and a catchment area of about 7000 km^2. Spatial concentration patterns of the anionic surfactant LAS were predicted for this basin.

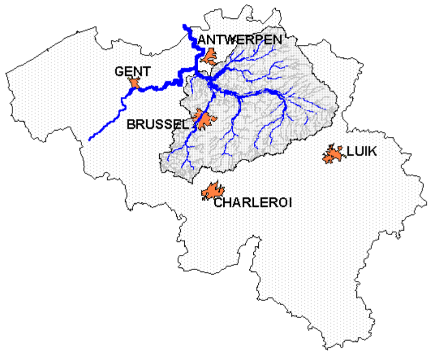

Figure 1. The Rupel basin in Belgium

METHODOLOGY

A large amount of input data is needed to run the GREAT-ER model. Information about treated and untreated waste water emissions, hydrological data and chemical market data are needed. These data were kindly provided by several organisations, i.e. AMINAL ('Administratie Milieu-, Natuur-, Land- en Waterbeheer', Brussels), AQUAFIN (Aartselaar), AWZ ('Administratie Waterwegen en Zeewezen', Brussels), MRW ('Ministère de la Région Wallonne', Namur), VMM ('Vlaamse MilieuMaatschappij', Aalst), and ECETOC (European Centre for Ecotoxicolgy and Toxicology of Chemicals, Brussels).

Flows, flow velocities and depths are needed as hydrological input data. To this end, an empirical hydrological model was developed. Since the study area is very large and complex, it was not possible to apply a deterministic model which needs a lot of input parameters. The applicability of a power function relating flow to the sum of the lengths of all upstream rivers was demonstrated (Verdonck, 1999). A correlation coefficient of 0.94 was found.
A limited validation exercise was made. It appeared that the ratio of the modelled to measured flow varied from 1 to 3 (Verdonck, 1999). Because GREAT-ER's aim is to predict chemical concentrations with a accuracy factor 3 to 5 (ECETOC, 1999), the accuracy of this hydrological model was considered acceptable.

RESULTS & DISCUSSION

LAS removal in waste water treatment plants (WWTP's) is in the range of 98-99.9% (Schowanek et al., submitted). However, since only 30-40 % of the wastewater in the Rupel basin is currently treated, predicted environmental concentrations are rather high. An example of a concentration profile is shown in Figure 2 for the 'Kleine Nete' river.

Two scenarios were simulated: the current situation and a hypothetical situation without any WWTP's. The effect of the WWTP's at Dessel and Herentals is clearly shown. The untreated discharge at Geel causes an increase of the LAS-concentration in the river. The decreasing parts of the concentration profile are due to dilution, confluences with other rivers and biodegradation.

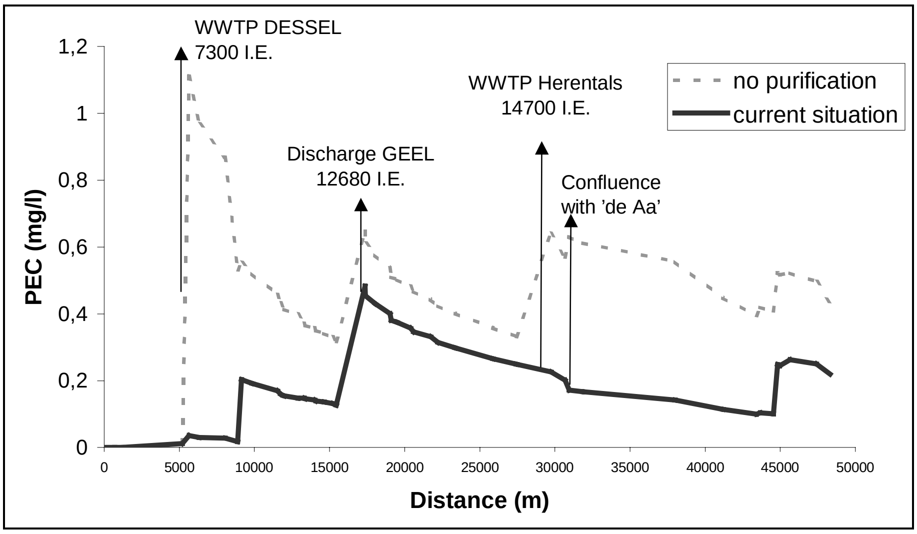

Figure 2: Concentration profile of LAS in the 'Kleine Nete'

Different 'what if'-scenarios could be simulated (Verdonck, 1999):

- What if all discharges are treated and what if none are?
- What if a trickling filter is replaced by an activated sludge system?
- How does building a new WWTP at a specific location affect the PEC in the rivers?
- How do in-stream-removal and in-sewer-removal affect the PEC in the rivers?

Results show that WWTP's induce a significant though local improvement on LAS-concentrations in the rivers. An activated sludge system has a better influence on the PEC compared to a trickling filter. LAS-concentrations are rather high in the Zenne basin and the downstream part of the Dijle basin, intermediate in the Demer basin and relatively low in the Nete basin and the upstream part of the Dijle basin.

The need to select many or few rivers in a river network (i.e. the level of geographical detail) was investigated. It was found that it is possible to simplify the river network without considerable loss of accuracy. Figure 3 shows 4 possible levels of geographical detail (selection only of stretches with flow rate *Q* larger than a certain value) and their effect on an aggregated concentration of the Zuunbeek basin, a subbasin of the Rupelbasin.

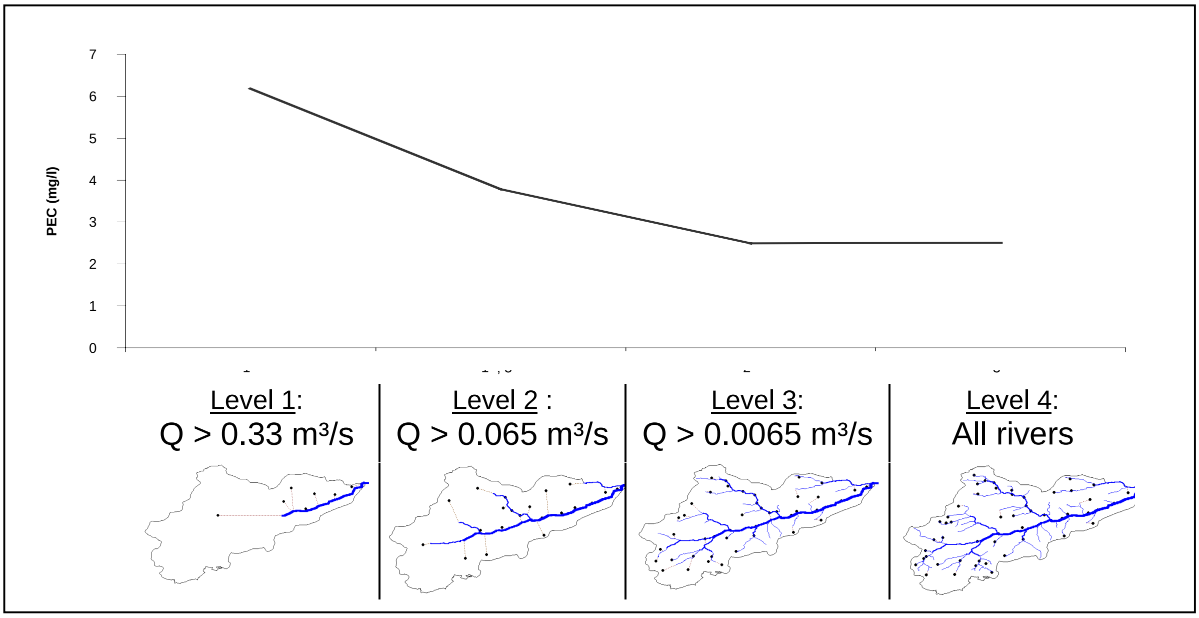

Figure 3: Aggregated $PEC_{catchment,volume}$ for different levels of geographic detail for the Zuunbeek basin, a subbasin of the Rupel basin (Q = flow in m^3/s)

If the level of detail increases (for the same emissions of LAS), the total length and residence time in the river will increase (more distance travelled by the chemical in the modelled basin). Hence, the impact of biodegradation will increase, and as a consequence the predicted concentration will decrease. However, the concentration at level 3 and 4 were found to be practically the same. Hence, simplifying the network to level 3 appeared possible and allows to reduce the required effort in terms of data collection (less geographical detail) and calculations (fewer stretches to evaluate). This is an important conclusion in view of the pan-European application of GREAT-ER.

CONCLUSIONS

- The final deliverable of the first stage of the GREAT-ER project is a CD-ROM which contains the exposure assessment software, the validation data for boron and for LAS in six pilot study areas, and consumption data for these substances. The results illustrate that GREAT-ER can deliver accurate simulations of chemical concentration in a river basin, provided reliable datasets are used.
- A first version of the GREAT-ER implementation for the Rupel basin was developed. The GREAT-ER simulations for the Rupel are realistic, but further refinement of the data such as inhabitants, in-stream removal, in-sewer removal and flows can increase the predictive power.
- This case study also showed the feasibility of implementing a new catchment and indicated which efforts are required to apply GREAT-ER on a large, ultimately pan-European scale. Problems concerning data collection may possibly occur. Fortunately, this was not the case in Belgium. Integrating the data in the GIS was the most time consuming work package. Data incompatibility and inconsistencies could induce some problems, but generally it appeared feasible to implement a large catchment in a short period of time using (semi-) automatic procedures.

ACKNOWLEDGEMENTS

The authors thank the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC), the Environmental Risk Assessment Steering Management committee (ERASM) of the Association Internationale de la Savonnerie, de la Détergence et des Produits d`Entretien (A.I.S.E.) and the Comité Européen de Agents de Surface et Intermédiares Organiques (CESIO) and the UK Environment Agency for their financial and management support.

REFERENCES

Boeije G, Wagner J-O, Koormann F, Vanrolleghem PA, Schowanek D & Feijtel TCJ (in press) New PEC definitions for river basins applicable to GIS-based environmental exposure assessment. Contribution to GREAT-ER #8. Chemosphere

Ecetoc (1999) Personal communication

Feijtel T, Boeije G, Matthies M, Young A, Morris G, Candolfi C, Hansen B, Fox K, Holt M, Koch V, Schröder R, Cassini G, Schowanek D, Rosenblom J & Niessen H (1997) Development of a geography-referenced regional exposure assessment tool for European rivers - GREAT-ER. Contribution to GREAT-ER #1. Chemosphere, 11:2351-2373

Schowanek D, Fox K, Holt M, Schroeder, FR, Koch V, Cassani G, Matthies M, Boeije G, Vanrolleghem P, Young A, Morris G, Gandolfi C & Feijtel TCJ (submitted) GREAT-ER: a new tool for management and risk assessment of chemicals in river basins. Contribution to GREAT-ER #10. Submitted to IWA Paris 2000 Congress.

Verdonck F (1999) Toepassing van een geografisch gerefereerd regionaal blootstellingsmodel voor chemicaliën op het Rupelstroombekken. Master's thesis, Universiteit Gent, Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen