EU Groundwater Policy Development

Good Status Objectives and Integrated management Planning

13-15 November 2008
UNESCO, Paris, France

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Programme of presentations

DAY 1 – THURSDAY 13 NOVEMBER

13:00 Welcome and registration

13:30 Opening ceremony (UNESCO, French Ministry of Ecology, European Commission)

Session 1 – Groundwater bodies chemical and quantitative status assessment

14:00 Johannes GRATH (Federal Environment Agency, Austria)
Assessment of groundwater chemical status and trends

14:30 Rob WARD, Vincent FITZSIMONS (Environment Agency, UK)
Assessment of groundwater quantitative status

15:00 Mario CARERE (Istituto Superiore di Sanità, Italy)
The European "environmental quality standards (EQS)" for surface water bodies: a link with groundwater chemical status assessment

15:25 Short overvieuw of the case studies presented in the poster session

15:30 Poster session and coffee break

16:15 Felip Josef ORTUNO-COBERN (Agencia Calalana de l'aigua, Spain)
The quantitative and chemical status of groundwater bodies in Catalonia: state of the art on the implementation of the WFD and groundwater directive

16:45 Hans Peter BROERS (TNO, Netherlands),
Assessing and aggregating trends in groundwater bodies. Exemples of varius European ground bodies

17:00 Andreas SCHEIDLEDER (Federal Environment Agency, Austria)
Trend and trend reversal assessment. Methodologies proposed by CIS WG 2.8

17:15 End of session 1

DAY 2 – FRIDAY 14 NOVEMBER

Session 2 – Programmes of measures and risk assessment

9:00 Philippe QUEVAUVILLER (European commission, Belgium)
European regulatory framework of integrated groundwater management. Theory versus realities

9:20 Dominique GATEL (EUREAU)
Management of groundwater bodies used for drinking water supply under the WFD requirements. The view of the European Federation of National Associations of Water and Waste Water Services

9:35 Y. MOREAU-LE GOLVAN (KWB, Germany), Boris DAVID (Veolia)
Challenges and opportunities of Managed Aquifer Recharge from an operator's point of view

9:50 Philippe NOUVEL (Ministry of Ecology, France)
Programmes of measures and diffuse pollutions in groundwater. General types of measures and case studies

10:25 Short overview of the session 2 posters

10:30 Poster session and coffee break

11:15 Susanna BORNER (Saxon State Ministry of Environment and Agriculture, Germany)
Management of point source pollution in Germany

11:45 Award ceremony of the IAH French chapter (CFH)

12:15 Lunch

Session 3 – Science and policy interface: how science supports groundwater management

13:45 Jacques GANOULIS (UNESCO Chair and Network INWEB, Greece)
Bridging the gap between science and policy in transboundary groundwater management: lessons learned from South Eastern Europe (SEE) and the Mediterranean

14:15 Bjorn KLOVE (University of Oulu, Finland)
GENESIS, an integrated research project to support groundwater systems management

14:45 Mette DAHL (GEUS, Denmark)
GSI typology – Typology of Groundwater / Surface interaction

15:15 Short overview of the session 3 posters

15:20 Poster session and coffee break

16:00 Nicole BARAN (BRGM, France)
Knowing the transfer time of solutes to manage better the groundwater bodies. Example of the Loire-Bretagne river district

16:30 Jaroslav SLOBODNIK (Environment Institute, Slovakia)
NORMAN permanent network in support of WFD and groundwater directive implementation

16:45 Maria J. GARCIA-GALAN (IEAWR, Spain)
Occurrence of sulphonamide antibiotics in two groundwater bodies of Catalonia (Spain)

17:00 Round table and closing ceremony (UNESCO, European Commission, French Ministry of Ecology, Eurogeosurveys, IGRAC, IAH)

17:45 End of the conference

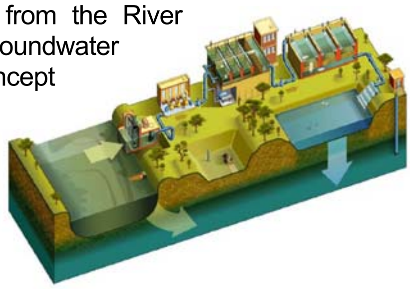
18:00 General assembly of the IAH French capter

Field trip

DAY 3 – SATURDAY 15 NOVEMBER

8:00 **Departure by bus from UNESCO**

10:00 Presentation and visite of the SUEZ – LYONNAISE DES EAUX "groundwater artificial recharge site (Le Pecq-Croissy, Yvelines).
Aquifer artificial recharge is one of the measures implemented to reduce the impact of the overexploitation of groundwater bodies. Treated water from the River Seine is artificially injected into the alluvium/chalk groundwater bodies of the Seine Valley. After a presentation of the concept of artificial recharge followed by the particular characteristics of the pilot project, participants will be able to discover the water treatment plant for themselves.



12:00 **Lunch break and transfer to Versailles by bus**

14:30 The fountains in Versailles. Water management at the time of King Louis XIV and to present day.
Participants will be able to visit the outstanding achievement of Louis XIV's engineers, who, at his request, installed a series of basins and fountains within the royal gardens at Versailles. The water supply systems, most of which still exist today, are no longer entirely managed by the castle and its park. Instead a different system for collecting rainwater has been set up on the site, which means the fountains function for 6 or 7 months of the year exactly as King Louis XIV would have enjoyed them at the end of his reign. The ecological management of Versailles's ornamental lakes and its waters has been achieved with the aim of collecting a maximum volume of water without it being discharged into the sewers.

18:30 **End of the day and drop off to UNESCO**

Poster sessions

DAY 1 – THURSDAY 13 NOVEMBER

Session 1 – Groundwater bodies chemical and quantitative status assessment

M. ANDJELOV (Environmental Agency, Slovenia)
Slovenian groundwater quantitative status in the period 1990-2006

F. BROWN (Environment Agency, UK)
Water Framework Directive: case study, classifying groundwater impact on surface water status

M. CARERE (National Institute of Health, Italy)
Towards an Italian approach for the derivation of groundwater threshold values

M. DOBNIKAR-TEHOVNIK (Environmental Agency, Slovenia)
Influence of the data aggregation method on the chemical status of groundwater bodies

C. GARNIER (Seine-Normandie Water Agency, France)
Chemical status assessment of a multilayers groundwater body (Champigny limestones, France)

K. HINSBY (GEUS, Denmark)
The challenge of deriving threshold values and background levels for groundwater in Denmark

O. JOHANNSON (Swedish geological survey, Sweden)
Characterisation of groundwater chemistry in Sweden based on geographic region and environmental factors

E. KARRO (University of Tartu, Estonia)
Derivation of threshold values for naturally F- and B- rich Silurian-Ordovician groundwater, body, Estonia)

R.L. LIESTE (RIVM, Netherlands)
Conceptual models of groundwater systems. Definition, example and availability in the Netherlands

E. NEDVEDOVA (Ministry of Environment, Czech Republic)
Chemical status assessment of groundwater bodies in the Czech Republic

E. PREZIOSI (IRSA-CNR, Italy)
Threshold values establishment for groundwater bodies where natural contamination occurs: a methdological case study in Central Italy

L. RAZOWSKA-JAWROEK (Polish Geological Institute, Poland)
Quantitative status of groundwater bodies in the Upper Silesian Region in Poland

A. ROSCA (Banat Water Directorate, Romania)
Natural background values and threshold values required by the groundwater directive, applicable for Banat hydrographical area

A. ROTARU (INHGA, Romania)
Upgrade of the Romanian monitoring network according to the WFD requirements. How the European guidances where applied and what guture changes are needed. Some examples.

W. VERWEIJ (RIVM, Netherlands)
Threshold values: the Dutch approach

T. WALTER (Landesamt fûr Umwelt- und Arbeitsschutz, Germany).
Determining Natural background values with probability plots

R. WARD (Environment Agency, UK)
Water framework directive: groundwater resources – risk characterisation to classification

R. WARD (Environment Agency, UK)
Water framework directive: groundwater quality – risk characterisation to classification

R. WOLTER (Federal Environment Agency, Germany)
Implementation of the groundwater directive in Germany

DAY 2 – FRIDAY 14 NOVEMBER

Session 2 – Programmes of measures and risk assessment

B. BRACIC ZELEZNIC (Public Water Utility of Ljubljana, Slovenia)
Management of drinking water in city of Ljubljana, Slovenia

B. CENCUR CURK (IRGO – Institute for Mining, Slovenia)
Spatial decision support system (SDSS) as a tool for integrated groundwater resources management

D. CUPIC (Crotia Waters, Croatia)
Potential pressures and impacts of Economic activities in accordance with the WFD

H.G.M. EGGENKAMP (Technical University of Lisbon, Portugal)
Protection of mineral water resources, a case study from northern Portugal

P. GOMBERT (INERIS, France)
Hydrodynamical and physicochemical perturbations of superficial and underground waters due to mining abandonment

R. MACALET (INHGA, Romania)
The monitoring of the groundwater body at risk from point of view of oil products and applying of the remediation techniques

J. NAVRATIL (University of Defence, Czech Republic)
Hazard sources identification and contamination assessment of ground waters usable for emergency water supply of population

J.S. SAMBRA (National Rainfed Area Authority, India)
Integrating groundwater science into management decisions: the Indian scenario

J.F. VERNOUX (BRGM, France)
Delineation of groundwater protection areas against diffuse pollution

M. ZIJP (RIVM, Netherlands)
Overview on WFD-objectives for groundwater

Session 3 – Science and policy interface: how science supports groundwater management

L. BOUMAIZA (Université du Québec à Chicoutimi, Canada)
The groundwater flow simulation in the river Valin paleodelta

M. BUSSETTINI (for Environmental Protection and Research, Italy)
Groundwater reference framework for Italy in order to implement the European directives 2000/60/CE and 2006/118/CE – First results

C. COURBET (Univ. P&M. Curie, Paris, France)
Environmental quality standards limitations towards immiscible organic compounds in groundwater: The case of organochlorine compounds

W.J. DE LANGE (Deltares, Netherlands)
WISE-RTD – Transfert of science results, technologies and practices into water policy implementation

E. GILLI (Université Paris 8, France)
Regional groundwater balance and submarine springs. Examples in South-eastern, France.

J. GRIMA (IGME, Spain)
Statistical procedures for trend analysis. Application to small data sets

B. HANSEN (GEUS, Denmark)
Proficiency tests of Danish groundwater sampling

F. HUNEAU (Université Bordeaux 1, France)
Groundwater vulnerability assessment in carbonate aquifers of semi-mountainous areas, case study from the French Western Pyrenees

C. INNOCENT (BRGM, France)
Constraining the residence time of groundwaters using short-lived U isotopes: the Trias aquifer (Paris Basin, France) and the Mid-Eocene aquifer (Aquitanian Basin, France)

H. PAUWELS (BRGM, France)
Emerging substances in groundwater: detection and fate of manufactured nanoparticles

E. PETELET-GIRAUD (BRGM, France)
Characterisation of groundwater systems: how to choose the isotope tool to answer a question? Application to the Eocene sands aquifer water body (SW France); CARISMEAU project

E. PETELET-GIRAUD (BRGM, France)
Improving the management of nitrate pollution in water in the Alsace Plain (France/Germany) through isotopic monitoring: ISONITRATE Life Demonstration Project

J.A. LUQUE-ESPINAR (IGME, Spain)
Influence of climatic cycles in the trend of the time series

J. MARQUES (IST/CEPGIST, Portugal)
About the impact of snowmelt as a source of hydromineral resources at a high mountain area (Serra de Estrela, Central Portugal)

F. TAMTAM (UPMC, Paris, France)
Antibiotics in groundwater

R. VAN EK (Deltares, Netherlands)
Several cases of groundwater – surface water interaction in the Netherlands

V. VERGNAUD-AYRAUD (LADES, France)
Groundwater age determination: a tool for understanding nitrate concentration in Brittany (western France)

D. WIDORY (BRGM, France)
How isotopic monitoring can improve management of nitrate pollution in water: ISONITRATE Life Demonstration Project

Table of contents

Framework and objectives of the conference

The European Commission has lead a groundwater experts group (**Working Group C** – WGC) composed of Member States and stakeholder representatives since 2002; the main aims and objectives of which are to ensure exchanges in support of the implementation of the **Water Framework Directive** 2000/60/EC (WFD) and of the new **Groundwater Directive** 2006/118/EC (GWD).

The autumn 2008 plenary session of the WGC, organised under the auspices of the French EU Presidency, coincides with some important milestones in the WFD and GWD. By the end of 2008 Member States will have had to define **threshold values** for groundwater bodies and by 2009 published the River Basin Management Plans (RBMP). The RBMP will include an initial assessment of the "**good chemical and quantitative status**" of the groundwater bodies as well as a **programme of measures** to achieve the objectives of the WFD.

Latterly WGC's activities and related technical guidelines, have highlighted a significant dearth of knowledge within the field (chemical and quantitative relationships with surface water and terrestrial ecosystems, the transfer and time scale of pollutants, cost-efficiency assessment, climate change, etc.) which represents a genuine obstacle in terms of the effective implementation of the WFD and GWD. Consequently, communication and interaction between **science and policy** remain a priority to thus enable successful implementation of the WFD/GWD.

The **Paris 2008 Groundwater Conference** aims to bring together the different communities involved in the implementation of the WFD/GWD (national and European policy makers, scientists and stakeholders) as well as experts interested in issues surrounding groundwater integrated management. On the eve of the publication of the River Basin Management Plans, this conference offers a forum that seeks to encourage the sharing of experiences on this particular question.

The views expressed in the following abstracts are purely those of the authors. Abstracts have not been reviewed. Authors are responsible for the content including potential mistakes.

Session 1 – Groundwater bodies chemical and quantitative status assessment

Fin 2008, conformément aux exigences de la directive fille sur la protection des eaux souterraines 2006/118/CE, les États membres devront avoir défini les valeurs seuils de bon état chimique des masses d'eau souterraine. Afin de préparer la publication des plans de gestion en 2009, ils devront en outre fournir une première évaluation du bon état chimique et quantitatif des masses d'eau souterraine. À la veille de ces échéances importantes de la Directive Cadre sur l'Eau (DCE) et de sa directive fille sur les eaux souterraines, cette session a pour objectif d'offrir aux États membres et aux experts un lieu d'échange d'expériences en relation avec ce thème. Après un aperçu des recommandations adressées par la Commission Européenne pour l'évaluation du bon état des eaux souterraines, des cas d'études seront présentés. Ces études de cas permettront d'illustrer les guides européens, de les rendre plus pragmatiques et de discuter des applications à l'échelle locale. Il s'agira également de mettre en valeur la diversité des systèmes aquifères en Europe. Dans cette session, les posters sont particulièrement bienvenus dans les domaines suivants : cas d'étude appliquant les guides européens pour l'évaluation du bon état chimique et quantitatif des masses d'eau souterraine au titre de la DCE, méthodologies pour l'évaluation de l'état chimique et quantitatif des eaux souterraines, estimation des interactions eaux souterraines – eaux de surface (ou écosystèmes terrestres associés) dans la perspective de l'évaluation de l'état des masses d'eau souterraine, évaluation du bon état des masses d'eau transfrontalières, définition des valeurs seuils pour l'évaluation du bon état chimique.

By the end of 2008, Members States will have to establish groundwater bodies threshold values for good chemical status assessment. In addition, they are required to provide information about groundwater bodies good quantitative and chemical status in the 2009 river basins management plans (RBMP).
At the eve of these important milestones of the Water Framework Directive and of the Groundwater Directive, this session aims at offering member states and experts a place to exchange experiences in relation to this topic. In particular it is expected to give an overview of the technical recommendations addressed by the European CIS (Common Implementation Strategy) guidance documents. In order to illustrate these guidelines, to make them practical and to give an overview of the diversity of European groundwater bodies, case studies will be presented and discussed.
In this session, posters are particularly expected on the following topics: case studies applying CIS recommendations for the status assessment, methodology to assess groundwater chemical and quantitative status, groundwater – surface water interactions in the light of groundwater bodies status assessment, assessment of transboundary groundwater bodies good status, derivation of threshold values.

Assessment of groundwater chemical status and trends

GRATH J.[1], SCHEIDLEDER A.[1], WARD R.S.[2], BLUM A.[3]
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[2] Environment Agency – England and Wales, Olton Court, Solihull, UK-West Midlands B927HX, United Kingdom.
[3] Bureau de Recherches Géologiques et Minières (BRGM), 3 avenue Claude Guillemin, FR-45060 Orléans cédex 2, France.

Introduction

The Water Framework Directive (2000/60/EC; WFD) is a comprehensive piece of legislation that sets out, inter alia, environmental objectives for all waters in Europe. The Directive requires sustainable and integrated management of river basins. This includes binding objectives, clear deadlines and comprehensive programme of measures based on scientific, technical and economic analysis including public information and consultation. Soon after its adoption, it became clear that the successful implementation of the Directive would be challenging for all the countries, institutions and stakeholders involved.

In order to address the challenges in a co-operative and coordinated way, the Member States, Norway and the Commission agreed on a Common Implementation Strategy (CIS) for the Water Framework Directive. Furthermore, the Water Directors stressed the necessity to involve stakeholders, NGOs and the research community in this joint process as well as participation of Candidate Countries.

Within this process WFD CIS Working Group on Groundwater (WG C) is now in its third phase (2007–2009) aiming at supporting the implementation of the new Groundwater Directive (2006/118/EC; GWD) and the groundwater elements of the WFD along the CIS principles. In particular one main objective of WG C in view of the preparation of the First River Basin Management Plan was the development of a guidance document on groundwater status and trend assessment. The following text is based on this guidance document which is currently available as a final draft (Drafting Group WG C-2, 2008).

Purpose and Scope of the Guidance

The mandate of WG C required the development of practical guidance and technical specifications for the derivation of threshold values, the assessment of status (both quantitative and chemical) and the assessment of groundwater trends and trend reversal. The current article deals with the establishment of groundwater threshold values, chemical status assessment and trend assessment only. The mentioned guidance builds on, and complements existing WFD guidance. Its primary focus is on delivering a number of the groundwater requirements of the WFD and the new GWD. These include the obligations set out in Annex V of the WFD and Articles 3, 4 and 5 and Annex II, III and IV of the GWD.

The GWD establishes a requirement for Member States to derive threshold values for pollutants (or groups of pollutants) that are related to the pressures identified as putting groundwater bodies at risk. These threshold values and standards are then to be used to assess groundwater chemical status, as defined in the WFD. In addition to assessing the impacts of pollutants the WFD also requires consideration of the impacts of groundwater abstraction on groundwater bodies, dependent surface water bodies and ecosystems, and an assessment of quantitative status.

The WFD and GWD also require that trends in pollutant concentrations are identified and that these trends are assessed to determine whether they are environmentally significant. Where significant upward trends exist they must be reversed through the application of programmes of measures to ensure that there are no future failures of environmental objectives. The GWD starting point for trend reversal must be defined as a proportion of the threshold value or quality standard (75% by default).

In developing the guidance the outputs of R&D projects and other guidance documents have been used. For groundwater threshold values the method presented in this document is based on the outputs of the BRIDGE project (Müller *et al.,* 2006). For chemical status assessment the technical specification for chemical analysis and monitoring of water status developed by the EU Chemical Monitoring Activity (CMA) and the resulting Commission Directive laying down technical specifications for chemical analysis and monitoring of water status has been consulted (QA/QC Commission Directive). For trend and trend reversal assessment, special attention has been paid to Technical Report No. 1 (European Commission, 2001).

The purpose of the guidance is to provide a practical approach that will support Member States in implementing and delivering the groundwater requirements of the WFD and GWD. It:

- sets out a methodology for deriving threshold values;
- establishes frameworks for assessing both chemical and quantitative status;
- identifies a method for identifying environmentally significant trends;
- outlines the reporting requirements;
- provides case study examples to illustrate the application of the guidance in different Member States.

The guidance has been produced following widespread consultation with groundwater experts across Europe and represents an approach based on current good practice. The guidance is not legally binding and Member States are free to adapt the guidelines presented in this document in view of the characteristics of groundwater bodies and/or national or regional groundwater management strategies and regulations. It is also recognised that with further experience improved methodologies may emerge.

The guidance highlights and summarises the legal requirements laid down in the WFD and GWD and provides practical assistance on meeting each of the requirements. The guidance is structured as follows:

- General principles;
- Common principles of status assessment;
- Chemical status assessment;
- Quantitative status assessment;
- and Trend and trend reversal assessment.

The following chapters try to give an overview of the content of the guidance rather than the detailed recommendations proposed.

General Principles - Status and Trend Assessment

Some issues within the assessment of groundwater status and trend are common and therefore are summarised in the chapter “general principles”. The chapter covers the need for conceptual models, the definition of dependent terrestrial ecosystems relevant for the status and trend assessment, the definition of background levels for naturally occurring substances, the treatment of values below the limit of quantification and the reporting requirements under the WFD and GWD.

To implement the WFD and the GWD and for effective management of groundwater, a clear understanding of the environmental conditions required for the achievement of the environmental objectives, and how these could be affected by human activities is needed. This understanding is supported by the development of a **conceptual model** or **conceptual understanding** of the groundwater system in which the general scheme of flow and transport conditions and of the hydrogeochemical properties are defined. Conceptual models are not necessarily numerical models but are a working understanding of the geological and hydrogeological system being studied.

The chapter highlights the need of conceptual models within the establishment of groundwater threshold values, the status assessment and the trend assessment. Even in certain Articles and Annexes of the WFD and GWD the consideration of conceptual models is explicitly required.

The treatment of values below the limit of quantification (LOQ) needs special attention when comparing data within an area or within time. Specific procedures are laid down in the GWD when assessing chemical status and when assessing trends and trend reversal. Provisions in the QA/QC Commission Directive should be considered and applied accordingly, in particular Article 5. The guidance highlights the need for distinction between status assessment and trend assessment.

Common Principles of Chemical Status Assessment

According to the WFD groundwater chemical status needs to be reported in the RBMP on maps. The achievement of good chemical status in groundwater involves meeting a series of conditions which are defined in the WFD and GWD. In order to assess whether those conditions have been met, a series of classification tests has been developed. There are five tests for the assessment of chemical status with some elements of the tests common to both the assessment of chemical and quantitative status. Each relevant test (considering classification elements which are at risk) should be carried out independently and the results combined to give an overall assessment of groundwater body chemical status. The worst case classification from the relevant chemical tests is reported as the overall chemical status of the groundwater body.

In accordance with the GWD, status assessment only needs to be carried out for groundwater bodies identified as being at risk and in relation to the receptor and each of the pollutants which contribute to the groundwater body GWB being so characterised (Annex III 1 GWD). Groundwater bodies not at risk are automatically classified as being of good status.

The individual classification tests are described in detail in the guidance chapters on status assessment.

Chemical Status assessment

The definition of chemical status is set out in WFD Annex V 2.3.2. The GWD goes on to lay down the criteria as well as the procedure for assessing chemical status. The chemical classification tests specified in the guidance derive from these legal requirements. In the assessment of groundwater chemical status the following elements should be considered:

- criteria for assessing groundwater chemical status (groundwater quality standards and threshold values);
- the need for data aggregation;
- the extent of an exceedance;
- the location of an exceedance; and
- the confidence in the assessment.

Depending on the conditions defined in the WFD and GWD which have to be met, the relevant elements were considered in the elaborated classification tests.

The criteria for assessing groundwater chemical status as laid down in Article 3 of the GWD is a very important element of chemical status assessment. Groundwater quality standards are already laid down in Annex I of the GWD but threshold values need to be established by Member States in accordance with the guidelines set out in Annex II of the GWD. According to the GWD Member States need to establish threshold values for parameters that are causing a GWB to be at risk of not meeting the WFD Article 4 objectives and such threshold values should be set at the most appropriate scale (national, river basin district, or groundwater body level) and be used in the assessment of good chemical status. Furthermore, Member States need to take into account at least the list of substances in Annex II.B.

Groundwater threshold values

The guidance on groundwater status and trend assessment proposes a methodology for establishing threshold values based on the legal requirements of the WFD and by making use of the outputs of the R&D project BRIDGE. The guidance considers environmental criteria and usage criteria as well as the background concentrations of naturally occurring substances when establishing threshold values. Environmental criteria threshold values will be based on environmental quality standards or other relevant ecotoxicological values and usage criteria threshold values on relevant use based standards, such as drinking water standards, irrigation standards, etc.

The guidance also considers the determination of threshold values for associated aquatic ecosystems and groundwater dependent terrestrial ecosystems, considering natural attenuation and dilution factors, the determination of threshold values for legitimate uses and the establishment of threshold values in case of saline or other intrusion.

Link between threshold values for status assessment and the 'prevent and limit' objectives

A separate chapter discusses the difference and the linkage between the threshold values for status assessment and the 'prevent or limit' objectives of the WFD and GWD.

The 'prevent or limit' objective in the WFD and GWD (Article 6) aims to protect all groundwater from unacceptable inputs of pollutants. Preventing or limiting pollutants in groundwater protects a wide range of receptors and protects groundwater from pollution at local scale.

The assessment of good chemical status is carried out over the whole of a groundwater body, which in most cases will be a large area. The assessment is carried out once every RBMP period, i.e. every six years, and supplies information on the current condition of groundwater bodies. This assessment reflects whether the groundwater body meets good chemical status specified in the WFD and GWD or not. The definition of good chemical status is limited to only a few receptors and specific circumstances. Achieving good status does not necessarily protect groundwater quality at local scale.

In principle, prevent or limit measures are the first line of defence in preventing unacceptable inputs of pollutants to all groundwater (and thereby avoiding pollution). The effective implementation of the 'prevent or limit' objective via routine regulation should ensure that groundwater quality is protected. This day to day regulation can consist of permits, general binding rules or codes of practice to control specific activities on the land surface. Permit conditions and/or 'limit values' may be used to ensure that no unacceptable input of pollutants into groundwater occurs. Notwithstanding the time that is required to enable the historical legacy of prior releases to be degraded or dispersed, if all prevent or limit requirements were met everywhere within a groundwater body, the body would be of good chemical status.

The threshold values described in the guidance are needed for assessing good chemical status, but these values (and the associated compliance regime) are not meant to meet the requirements of the 'prevent or limit' objective. This is because they will not protect groundwater from pollution at local scale.

Procedure for assessing groundwater chemical status

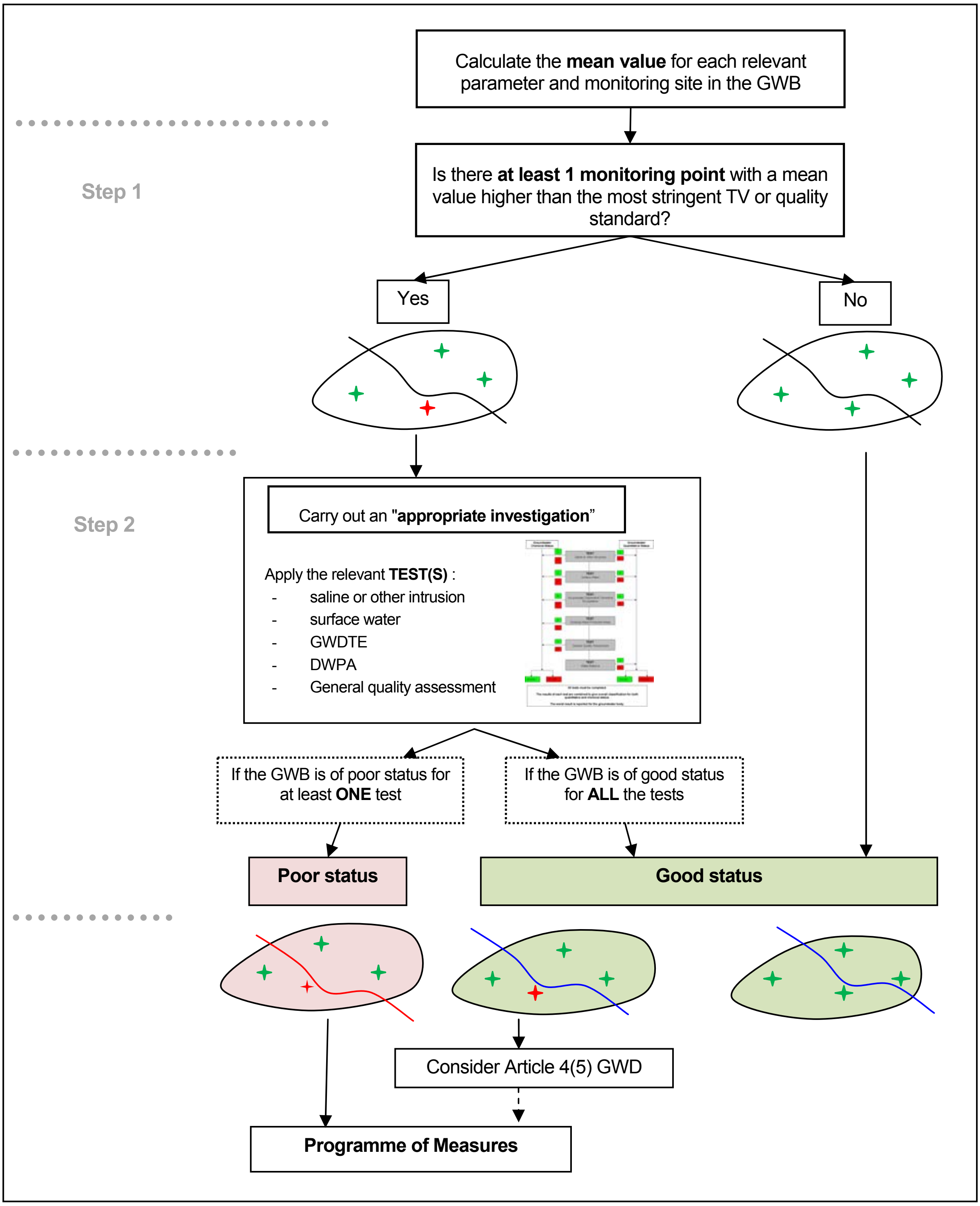
Depending on the results of the risk assessment several tests need to be performed to assess groundwater chemical status. According to WFD and GWD objectives, the main criteria to be considered in these tests are:

- Environmental criteria, which include:
  - . Protection of associated (connected) surface water bodies,
  - . Protection of groundwater dependent terrestrial ecosystems (GWDTE),
  - . Protection of groundwater bodies from saline or other intrusion;
- Usage criteria, which include:
  - . Protection of drinking water in drinking water protected areas (DWPA),
  - . Protection of other legitimate uses: crop irrigation, industry…

Based on the GWD the principal chemical status follows a two-step procedure:

- **Step 1**: Check for any exceedance of a threshold value or a quality standard. If there is no exceedance at any monitoring point the groundwater body is of good status. The threshold value to use in step 1 will be the most stringent value derived. This approach is consistent with the precautionary principle.

Figure 1: General procedure to assess a GWB chemical status.



- **Step 2**: Where there is one (or more) exceedance(s) of a quality standard or TV, an 'appropriate investigation' should be carried out. This will involve carrying out the different steps in the relevant classification test(s) to determine whether the exceedance is causing a failure of good chemical status or not.

The guidance describes in detail each classification test in a stepwise approach and illustrates the approach by flow charts. Each classification test considers specific elements of chemical status as already mentioned above. For chemical status assessment five classification tests have been elaborated:

- General assessment of chemical status of the groundwater body as a whole;
- Saline or other intrusion;
- No significant diminution of surface water chemistry and ecology due to transfer of pollutants from the GWB;
- No significant damage to GWDTE due to transfer of pollutants from the GWB;
- Meet the requirements of WFD Article 7(3) - Drinking Water Protected Areas.

Trend and Trend Reversal assessment

The WFD and GWD require Member States to identify any significant and sustained upward trend in concentrations of pollutants, groups of pollutants or indicators of pollution found in groundwater bodies or groups of bodies identified as being at risk (WFD Annex V 2.4.4 and GWD Article 5). A significant and sustained upward trend is 'any statistically and environmentally significant increase of concentration of a pollutant, group of pollutants, or indicator of pollution in groundwater for which trend reversal is identified as being necessary in accordance with the GWD. A statistically significant trend is one that has been identified using a recognised statistical trend assessment technique and an environmentally significant trend is one that is statistically significant and would lead to the failure of one or more of the WFD's environmental objectives if not reversed.

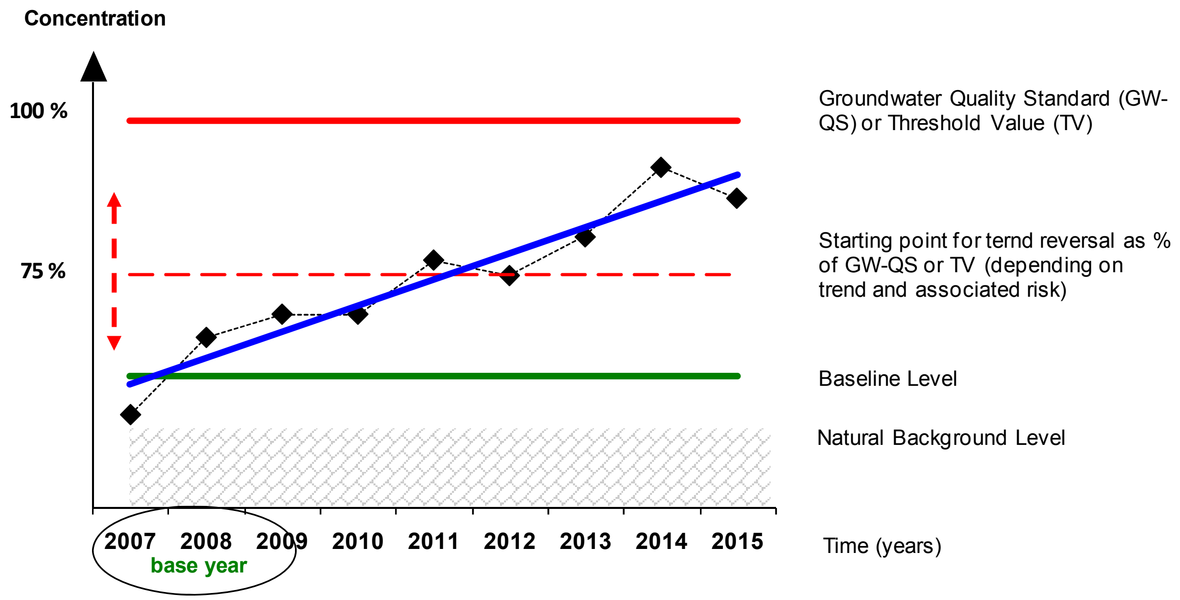
Member States are required to reverse such trends by the implementation of measures which should aim to progressively reduce pollution and prevent further deterioration of groundwater.

Within the assessment of significant and sustained upward trends and the assessment of trend reversal the following elements need to be considered (see also Figure 2). The guidance document provides information on the following issues:

- What parameters are subject to trend assessment;
- The importance of monitoring network design, monitoring and monitoring data
- What is a correct statistical method for assessing trends at each monitoring point (such as regression analysis);
- How to deal with monitoring values which are below LOQ;
- What length of time series is appropriate;
- How to consider baseline levels1 for substances which occur both naturally and anthropogenically;
- What is an acceptable level of confidence in the trend assessment;
- How to establish a starting point for trend reversal;
- and How to statistically demonstrate the trend has been reversed stating the level of confidence in the identification.

[1] 'Baseline level' means the average value measured at least during the reference years 2007 and 2008 on the basis of monitoring programmes implemented under Article 8 WFD or, in case of substances identified after these reference years, during the first period for which a representative period of monitoring data is available [Article 2(6) GWD].

Figure 2: Elements of trend and trend reversal assessment.



According to the mandate of the drafting group, the guidance on trend assessment and trend reversal assessment considers the Technical Report N°1 on 'Groundwater Statistics' (European Commission, 2001). Development of new methodologies and experience gained in Members States should also be considered as well.

The need for trend and trend reversal assessment due to WFD and GWD can be summarised as follows:

- Identify and reverse trends that present a significant risk of harm to actual or potential legitimate uses of the water environment;
- Identify and reverse trends that present a significant risk of harm to the quality of aquatic ecosystems;
- Identify and reverse trends that present a significant risk of harm to terrestrial ecosystems.

The guidance gives recommendation on the degree of data (either on GW-body level or based on the relevant monitoring points) to be considered within the single tests. Within the first mentioned trend test regarding the environmental significance of the widespread environmental risk from pollutants (e.g. due to diffuse sources of pollution) it is proposed to consider the data across the whole body as all monitoring points could be considered relevant. In case where the risk is to a specific groundwater dependent ecosystem (either aquatic or terrestrial), trends at certain individual, or groups of, monitoring points may be considered significant or relevant in terms of the groundwater body not achieving its environmental objectives.

Moreover, trend assessment is needed (where relevant) to verify that plumes from contaminated sites do not expand and it is needed as a supporting tool within the status assessment (linked to the criteria for saline and other intrusion and to assess the non deterioration in quality of waters for human consumption).

For both assessments it is proposed to consider relevant monitoring points and relevant parameters within the trend tests.

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A European framework for assessing quantitative status

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Introduction

The Water Framework Directive requires Member States to introduce classification schemes that describe whether groundwater bodies are at good or poor status. The WFD's principal objectives for groundwater, and consequently the measures that may be needed to meet these objectives, rely on these status classification systems. Good status groundwater bodies must be protected from deterioration and poor status bodies restored, where possible, to good status by the end of 2015. Where achievement of this deadline is not technically feasible or is disproportionately expensive alternative objectives can be set. These include time extensions and improvement objectives to achieve the least possible deviation from good status. The results of status assessment and reasons for alternative objectives must be reported in the river basin management plans published every six years.

The status of a groundwater body depends primarily on the impact of changes to groundwater that effect future availability, the ecosystems that depend on it, associated surface water bodies and directly dependent terrestrial ecosystems. These changes include both level/quantity of groundwater and chemical quality. To reflect this, the WFD sub-divides its definition of good status into good quantitative status and good chemical status. Both must be achieved for a body of groundwater to be classified as being at good status.

Quantitative status considers the effects of changes to the level of groundwater resulting from groundwater abstraction. For a groundwater body to be at good quantitative status there must be an appropriate balance between abstraction, the water needs (level and flow) of dependent ecosystems and the recharge to the groundwater body. Groundwater can be recharged or replenished from rainfall, snow melt, irrigation and even leaking water pipes. It is clearly unsustainable, in the long-term, to allow abstraction to continue to exceed recharge. Therefore to achieve good quantitative status long-term abstraction must not exceed long-term average recharge. However many groundwater bodies feed into wetlands and surface water bodies (rivers and lakes) and so all of the recharge is not available for abstraction if the flow and ecological requirements of the associated water bodies and wetlands are to be maintained. For a groundwater body to be at good quantitative status these ecological and flow requirements must also be met.

The WFD definition of good quantitative status is shown in Table 1. For a groundwater body to be at good status each of the elements covered by this definition needs to be met. In order to test compliance with each element a classification system has been developed by an EU Working Group comprised of experts from across Europe. The recommended approach builds on existing experience (*e.g.* UKTAG, 2007) and is presented in a WFD Common Implementation Strategy guidance document (EU, 2008). The classification system splits out each of the elements that make up good quantitative status and provides an outline procedure for testing that is applicable across Europe. This paper describes the key elements of the system and presents a case study of its application in Scotland, UK.

Classification principles

Although the principles of good quantitative status are straightforward, translating them into practice is more challenging. This is for a number of reasons including the hydrogeological and climatic variability across Europe, the historical legacy of groundwater abstraction and management and the fact that groundwater and surface water have previously been studied and managed independently. The WFD requires that all these factors are addressed and that we consider the interrelated parts of the water environment together. The objective being to manage groundwater in a sustainable way by achieving the right balance between groundwater replenishment, ecosystem needs and water abstraction.

Table 1. Definition of Quantitative Status (WFD, Annex V, 2.1.2).

Element	Good Status definition
Groundwater Level	The level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term rate of abstraction Accordingly, the level of groundwater is not subject to anthropogenic alterations such as would result on: - Failure to achieve the environmental objectives specified under Article 4 for associated surface waters, - Any significant diminution in the status of such water, - Any significant damage to terrestrial ecosystems that depend directly on the groundwater body. And any alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion, and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result in such intrusion.

An assessment of quantitative status is required for all groundwater bodies (or groups of bodies). However where the pressures and impacts analysis (risk assessment) indicates, with a high degree of confidence, that there are no abstraction pressures then the body can be considered to be at good quantitative status. Additionally where there are no risks related to any of the individual component elements, *e.g.* there are no risks to wetlands, then this element does not need to be assessed. By using this approach the application of the compliance testing process is risk-based and cost-effective.

The WFD indicates that the parameter to be used for quantitative status is groundwater level. However although level is important when assessing long-term trends, it is widely recognised as being insufficient on its own (EU, 2007). Other relevant parameters, *e.g.* spring flows and levels in lakes and wetlands, etc. The combination of a range of supporting information is essential ensure a reliable assessment of status.

Classification tests

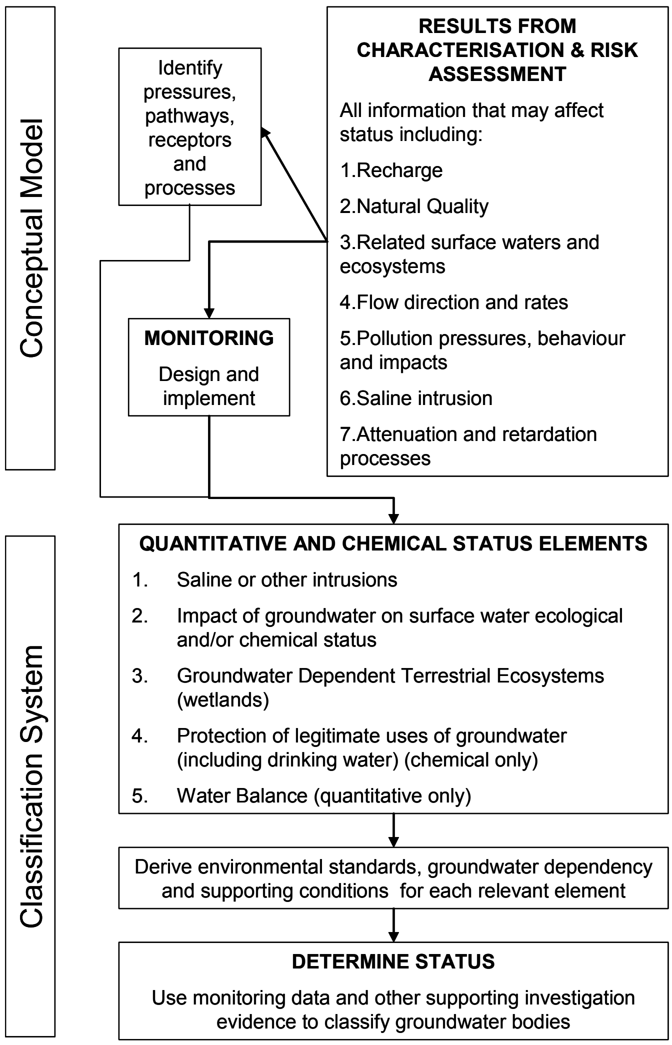
A series of four tests have been proposed to test compliance with good quantitative status. Each of the tests is described in Table 2. The tests recognise the variability that exists not only in hydrogeological and environmental conditions across Europe but also the amount and precision of monitoring data and the inherent uncertainties in our understanding of groundwater flow. The characteristics of a groundwater body often make it difficult to determine how the system works, and how it interacts over time with rivers, lakes and wetlands. Because of this the development of a conceptual understanding (or model) of the groundwater body is an essential precursor to determining status. This conceptual model is a simplified representation of how the groundwater body behaves and interacts with other parts of the water environment. This has led to an approach that is based on weight of evidence and uses monitoring data complemented by conceptual understanding and risk assessment. An outline of the weight of evidence-based approach is shown in Figure 1.

It is also important not to determine quantitative status in isolation from chemical status and trend assessment. Chemical changes in groundwater and associated surface water bodies and wetlands may be indicative of the impacts of abstraction. Because of this there is overlap between the framework presented here and chemical status assessment. This is particularly relevant for the assessment of saline intrusion. In this case the compliance testing for both chemical and quantitative status can use a single test. For other tests the overlap is not so great, but there is need to share information between the two assessments.

Table 2. Quantitative Status classification elements and tests.

Classification Element	**Test**
Water Balance Groundwater body-wide assessment to determine if abstraction is exceeding the available groundwater resource.	a) Do groundwater levels across the groundwater bodies indicate a long-term sustained decline in water level? b) Calculate a water balance for the groundwater body to assess balance between abstraction, recharge and ecological flow requirements. c) If groundwater levels are not showing a decline and long term abstraction is not exceeding recharge minus ecological flow requirements then the groundwater body is at GOOD STATUS.
No saline or other intrusion Test to determine whether there is sustained alteration to flow direction resulting from abstraction that is leading to salt water or other intrusion.	a) Identify any deterioration in groundwater quality indicated by elevated chloride, conductivity or other indicator(s) of intrusion. b) Identify upward trends in concentrations of intrusion indicators. c) Identify significant impacts on groundwater abstractions (*e.g.* requiring abandonment or treatment) caused by intrusion. d) If there is no statistically significant upward trend or significant impact on an abstraction caused by intrusion then the groundwater body is at GOOD STATUS.
Surface water (rivers and lakes) Test to determine if a reduction in groundwater level (or flow) is causing a surface water body to fail its environmental objectives.	a) Identify linkages between surface water body(ies) and the groundwater body. b) Identify whether surface water body is failing to meet its environmental objectives and reasons for failure. c) Identify whether groundwater abstraction is a significant cause for the surface water failure(s). d) If groundwater abstraction is not the significant cause of surface water failure then the groundwater body will be at GOOD STATUS.
Groundwater Dependent Terrestrial Ecosystems (Wetlands) Test to determine whether a reduction in groundwater level (or flow) is causing significant damage to wetlands which depend directly on the groundwater body.	a) Identify groundwater dependent wetlands that have been significantly damaged. b) Identify the environmental supporting conditions for the wetland(s) relating to water level and/or flow. c) Identify if groundwater abstraction is causing the deviation from the supporting conditions that is leading to significant damage. d) If groundwater abstraction is not causing significant damage to the wetland then the groundwater body will be at GOOD STATUS.

Figure 1. Relationship between conceptual model and classification – weight of evidence approach.



To recognise the variability in the scale of groundwater bodies both within and between Member States the classification tests are sufficiently flexible to be applied at a range of scales. For example the water balance test is aimed at a groundwater body scale assessment whereas the groundwater dependent terrestrial ecosystem (wetland) test can address local impacts on significant wetlands for which WFD objectives apply. In addition, it is also possible to apply the water balance test to individual component parts of a very large groundwater body and then combine the results to derive an overall water body assessment where this is practical.

The overall groundwater body quantitative status is defined by the result of the classification test which gives the least favourable result of all the tests applied. For example if all four tests are applied to a groundwater body and three indicate good status and the fourth poor status then the groundwater body should be reported as being at poor quantitative status. It is important that all of the relevant tests are applied to a groundwater body even if the first test applied indicates poor status. This is to ensure that all the necessary measures can be implemented to ensure that the body meets all its relevant environmental objectives.

Example of status assessment

A case study is provided from the further characterisation and draft classification exercises that were undertaken on a groundwater body in the East Lothian area of Scotland in 2007. Formal results will be presented in the Draft River Basin Plan at the end of December 2008 (follow the links from www.sepa.org.uk).

Conceptual model and characterisation of risks

A groundwater body was originally delineated across an area of 1,600 km^2, being centred approximately on Edinburgh. The whole area was identified as being at risk of failing WFD environmental objectives in 2005. A range of pressures including coal mining, urban and diffuse pressures are distributed across the body. As part of further characterisation, the groundwater body was sub-divided into a number of individual groundwater bodies to better represent the variation in pressures and enable classification.

The groundwater body described in this case study is one of the bodies created after sub-division of the original larger body. It is less than 150 km^2 is size and lies in East Lothian, to the east of Edinburgh. It lies on the coast, extending no further than 11 km inland.

The groundwater body comprises fractured sandstones and volcanics of Carboniferous age, which are hydraulically connected with localised sand and gravel aquifers in the valleys of the larger streams. One of the largest surface water catchments in the water body is 40.5 km^2 in size. The river flows from east to west for about 9km before discharging to the sea. The area is one of the driest in Scotland. Long-term (1968 to 2006) daily mean flow for the burn near its tidal limit is equivalent to approximately 160 mm/year per km^2 of catchment. The Q95 flow is approximately 6% of average annual flows, indicating a great difference between summer and winter flows and very little natural storage capacity within the catchment.

Porosity in the bedrock aquifer is dominantly secondary (fracture flow) and groundwater flow is expected to be shallow. There is evidence from the distribution of groundwater levels that the groundwater and surface water catchments are the same and that the river is the main discharge zone for groundwater in the catchment. Some initial supporting evidence was provided by groundwater level data from a logger installed in one observation borehole. These data (Figure 2) indicate a very similar response to rainfall for both surface and groundwater. Note that no water level data were available before the study began in 2006.

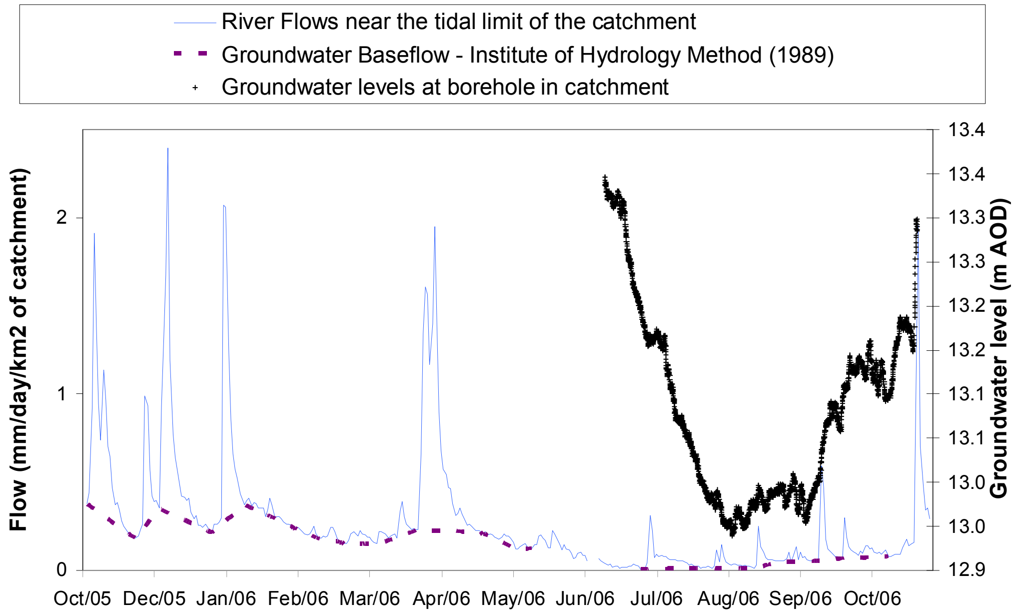
Groundwater baseflow inputs to surface water were estimated using the standard Institute of Hydrology (1989) method of baseflow separation. The average annual “Base Flow Index” (BFI) was estimated to be 48% in this catchment. This equates to an estimated long-term average flow of approximately 80 mm/year over the catchment as a whole. Using this figure and soil moisture budgeting calculations, typical groundwater recharge in the groundwater body is estimated to be 80-100 mm/year. The proportion of groundwater baseflow is much lower in winter than in summer. The burn is almost wholly reliant on baseflow contributions in the summer (Figure 2).

Agriculture is the dominant land use. The agricultural land of East Lothian has historically been one of the most intensively cropped areas in Scotland. This is a result of the combination of suitable soils and a favourable climate which, for Scotland, is comparatively sunny, warm and dry. The area has been used for market gardening, and vegetables such as potatoes, leeks, brussel sprouts and broccoli are grown as well oil seed rape and grain crops, primarily wheat. Given these factors, together with the intensive usage, irrigation is often required to optimise crop production, especially in the freely draining sandy soils which occupy the coastal areas and broad floors of the river catchments.

Taking the largest catchment as an example of conditions elsewhere in the groundwater body, a total of 3.64×10^5 m^3/year is licensed for abstraction in the catchment. This is equivalent to only 9 mm/year/km^2 of catchment. Whilst this is a relatively low figure compared to effective rainfall in the catchment, it should be noted that it is concentrated both spatially and temporally. Some 84% of abstraction is for irrigation and all the main abstractions occur within 3 km of the coast in the April-October period. This is a time when effective rainfall is negligible and when surface water ecology is most sensitive to abstraction impacts. The total licensed abstraction across the groundwater body as a whole is approximately 8.96×10^5 m^3/year.

Further characterisation of these pressures, the natural characteristics of the aquifer and the proximity of the sea indicated that there was a risk that abstraction pressures could cause the groundwater body to fail the saline intrusion and surface water flow tests. Additional monitoring was therefore introduced, with a focus on continuous water level measurement to help assess seasonal impacts.

Figure 2. Comparison of measured river flow and groundwater baseflow at the tidal limit of the largest catchment.



Classification

Long term water balance. The total annual amount of licensed abstraction is between 5%-10% of total recharge. Using figures derived from SNIFFER (2005), it was considered that this proportion of recharge to abstraction would be too small to impact the water needs (level and flow) of dependent ecosystems. As the proportion was less than this amount, more complex assessments of the water needs of dependent ecosystems were not carried out. The draft classification for the groundwater body was "good" for this test. Long term monitoring has been instigated to allow further assessments in the next River Basin Cycle.

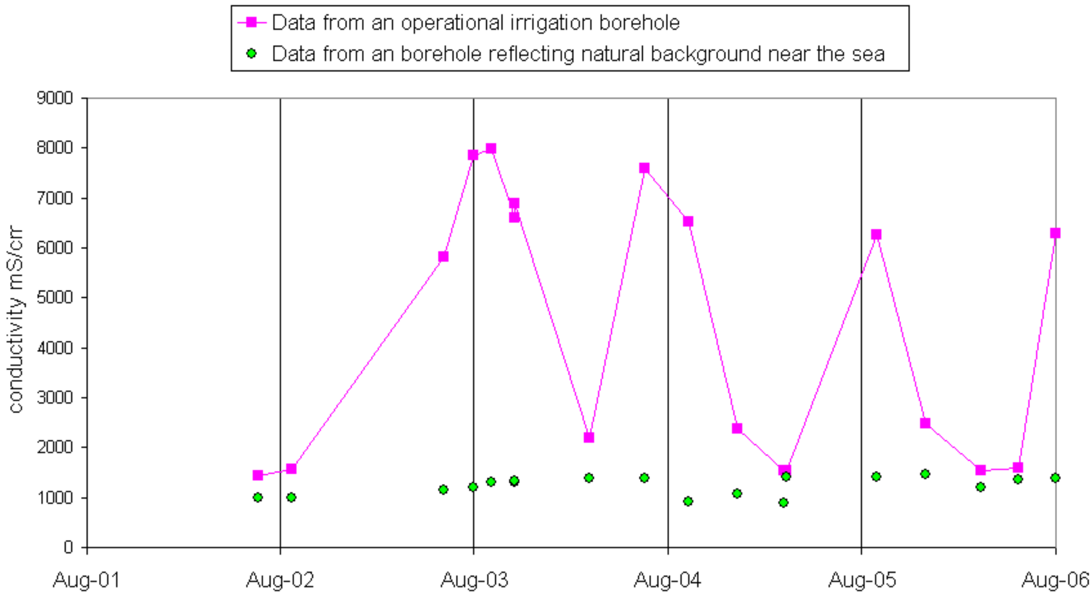
Saline intrusion. Table 3 provides an indication of the range in electrical conductivity and chloride concentrations from boreholes across the groundwater body. Clearly, there is a significant range, reflecting variation in abstraction volumes and proximity to the sea, with some salinity levels being significant.

Table 3. Electrical Conductivity and Chloride Results 2002 – 2006.

		Abstraction Borehole	**Abstraction Borehole**	**Observation Borehole**	**Abstraction Borehole**	**Abstraction Borehole**
Electrical Conductivity	*Min*	1160	1447	2990	880	571
	Max	3380	7980	4320	1450	772
	Mean	2490	4576	3536	1216	635
Chloride	*Min*	212	255	840	90	42
	Max	1280	2400	1320	240	59
	Mean	520	1314	1056	168	50

Figure 3 shows the variation in quality over time from two of these boreholes. The high levels typically occur in summer time, coinciding with the period where irrigation pumping can occur.

Figure 3. Electrical conductivity data from the groundwater body.



Although monitoring results show elevated electrical conductivity due to abstraction, there is no long-term sustained deterioration in quality over time. There is good evidence that the aquifer recovers to background conditions over the winter. Accordingly, the draft classification for the groundwater body was "good" for this test.

Impacts on river flows. The assessment of groundwater abstraction impacts on river flows was undertaken by comparing the "natural" flow in the burn with the impacted flow in the burn, taking account of a) total groundwater and surface water abstraction and b) groundwater abstraction alone. Although there are high quality data on river flows within the largest catchment of the groundwater body, these data represent flows which have already been influenced by abstraction. Natural, pre-abstraction, flows could only be estimated using a predictive model. Similarly, only total impacts on river flow could be measured. The relative effects of groundwater and surface water abstractions have not been measured in the river and must therefore also be estimated using a predictive model. Low Flows 2000 (Holmes *et al*., 2002) is the standard hydrological model used in Scotland for these purposes. It is used in this study to assess the impact of abstractions on river flow from both surface water and groundwater. It models (a) the naturalised flow *i.e.* the theoretical flow in the absence of any impacts and (b) the influenced flow *i.e.* including the impacts of abstractions and discharges on the naturalised flow.

The model requires a number of simplifications and assumptions, particularly when assessing groundwater impacts. These assumptions are reduced in significance where there is a direct hydraulic linkage between surface and groundwater, when groundwater and surface water catchments are similar, and where groundwater abstractions are relatively shallow. The conceptual model of the groundwater body suggests that these assumptions are generally valid. It is noted that the model does not currently include the element of abstracted groundwater which is used to augment river flows, and it does not account for the additional impacts from groundwater abstractions lying just outside the catchment. As a consequence, the model was regarded as a reasonable initial approximation of groundwater impacts on surface water. Where uncertainties occur, more detailed analyses would be required.

Table 4 summarises the results of the modelling exercise for the largest river catchment in the groundwater body. One model output shows predicted impacts from all surface and groundwater abstractions. The second output shows predicted impacts from only the groundwater abstractions. In both bases, the key indicator of impact is the "influenced Q95". This represents the predicted low flow in the river as a consequence of abstraction.

Abstraction standards have been developed for rivers of different typologies. These standards are based on the proportion of the Q95 which can be taken by abstraction. For the typology to which the main river catchment belongs, the standard is 20% - *i.e.* only 20% of the Q95 flow can be abstracted.

Table 4. River Flow Modelling Outputs.

	Q95 m^3/sec *(Surface Water and Groundwater)*	**Q95 m^3/sec** *(Groundwater only)*
Natural Q95	0.027	0.027
Influenced Q95 *(using currently licensed abstraction rates)*	0.001	0.013
Minimum allowable Q95 using 20% flow standard	0.022	0.022
% reduction of influenced Q95 from natural Q95	96%	52%

Both model outputs in Table 2 show that the influence of abstraction is substantially greater than the allowable standard of 20%. Even in the absence of all surface water abstraction, currently licensed groundwater abstraction rates would reduce the low flow in the river to below the allowable level. In accordance with UKTAG (2007) guidance, this means that groundwater abstraction is a significant cause of the surface water failure(s) in the catchment. Accordingly, the draft groundwater classification for this groundwater body was “poor”. Note that only one impacted river body is required for the whole groundwater body to be classed as poor. Whilst this calculation contains a number of assumptions on both surface and groundwater flow, the conceptual model of the groundwater body and the magnitude of failure are such that these assumptions are not considered to have significantly influenced the final classification. As a consequence, more detailed analyses are not required for classification. Further assessments are being considered to help support River Basin Management Planning.

Impacts on wetlands. There was insufficient information on environmental supporting considerations to carry out quantified assessments. However, based on best judgement of the condition of wetlands and potential groundwater pressures, the draft classification for the groundwater body was “good status” for this test.

Overall Quantitative Status: The draft status assessment in 2007 was “poor status”, reflecting the worst result of all four tests.

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The opinions expressed in this paper are those of the authors and do not necessarily reflect the view of the European Commission, the Scottish Environment Protection Agency or the Environment Agency (England and Wales).

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The European "environmental quality standards (EQS)" for surface water bodies: a link with groundwater chemical status assessment

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The Water Framework Directive (WFD) (EU, 2000) has established a legal framework in which the protection and management of water resources shall be integrated at river basin level with the aim to achieve the good status for all surface and groundwater bodies of the European Union; this means that the definition of environmental regulation and tools at European and national level has to be based also on the concept that surface and groundwaters are often strictly interconnected.

The new Groundwater (GW) Directive (EU, 2006) following the philosophy of the WFD recognises that the environmental objectives of a groundwater body are set not just for the protection of groundwater body itself but also for the protection of associated surface waters such as rivers, lakes, marine-coastal waters and other dependant terrestrial ecosystems such as wetlands which are significantly dependent upon groundwater; the groundwater chemical status assessment foreseen by the new Directive is strictly linked to the surface water environmental objective.

The article 3 of the groundwater directive states that the threshold values applicable to good chemical status shall be based on the protection of the body of groundwater having particular regard to its impact on, and interrelationship with, associated surface waters and directly dependent terrestrial ecosystems and wetlands and shall inter alia take into account human toxicology and ecotoxicology knowledge.

Is it recognised by the scientific community that chemical pollution of groundwater can affect in a considerable way the surface water ecosystems included wetland. Groundwater discharges in springs and feeds streams and rivers (Sophocleous M.A., 2002). Also for marine coastal areas, at least in some cases, submarine groundwater discharge may be both volumetrically and chemically important, some are as high as 10 percent of river flow (Field J.G., 2002).

The key concept included in the GW Directive drives the legislator to set groundwater quality standard taking into account the possible risks for environment and human health due also to the interaction of surface and groundwater bodies.

The future publication of the Directive of the European Parliament and of the Council on environmental quality standards (EQS) in the field of water policy (EU, 2008) can represent an important link and a key tool to help the Member States of the European Union to define also threshold values for groundwater required by the GW Directive.

The process for the elaboration of the EQS Directive has been long and has started in the year 2001 with the publication of the decision 2455/01/CE (EU, 2001) that defines the list of priority and priority hazardous substances for surface waterbodies. The priority substances (PS) have to be reduced and the priority hazardous substances (PHS) have to be eliminated from all emissions, discharges and losses within 20 years from the publication of the proposal Directive.

The list of PS and PHS include heavy metals, organometals, pesticides, PAH, chlorinated hydrocarbons and other emerging pollutants that pose a risk for European surface waterbodies.

The WFD in the annex V defines a procedure to derive EQS for the protection of aquatic ecosystems that is taken by the Technical Guidance Document (European Commission, 1993); the procedure is based on the quality and quantity of acute and chronic bioassays in relation to different trophic levels and application of uncertainty factors as mentioned in the TGD.

With the establishment of the Expert Advisory Forum on Priority Substances in the context of the Common Implementation Strategy (CIS) of the Water Framework Directive a new methodology for the setting of EQS has been put into place (Lepper P., 2005) that covers some of the missing point of the WFD procedure.

The methodological framework elaborated for the derivation of environmental quality standards has intended to concomitantly protect freshwater and marine ecosystems from adverse effects on pelagic and benthic community as well as top-predators and human beings from all impacts on health by drinking water uptake or ingestion of food originating from aquatic environments.

For the entire set of objectives of protection, for which a possible risk is identified, specific quality standards have been derived. In a subsequent step the lowest of the standards derived for the individual protection objectives is selected as the overall environmental quality standard.

Table 1: Methodology for the setting of EQS for surface waters.

Protection Objectives	Criteria
Pelagic comunity (inland and marine waters)	Acute and chronic bioassay Use of assessment factors
Benthic community (inland and marine coastal waters)	Equilibrium partitioning method-toxicity data benthos
Top predators (marine mammals)	Toxicity data-birds diet-use of BCF e BMF
Human Health (consumption of fish products)	Tolerable daily intake- Use of BCF
Human Health (consumption of drinking water)	European Directive 75/440/CE – Drinking water directive – 98/83/CE Treatment Removal Efficiency

NOAEL: No Observed Adverse Effect Level - BCF: Bioconcentration Factor - BMF: Biomagnification factor.

The methodology has been also reviewed by the CSTEE (Scientific Committee on Toxicology, Ecotoxicology and Environment) (European Commission, 2004).

The EQS for the priority and priority hazardous included in the Directive have been derived on the basis of the described methodology. All Member States have contributed to the setting of EQS through the submission of ecotoxicological and toxicological data.

The key components of the Directive are the setting of EQS for the water phase for 33 priority and priority hazardous substances, the setting of EQS for the biota for hexachlorobenzene, mercury and hexachlorobutadiene, the identification of 2 new priority hazardous substances and a list of new substances, mostly emerging compounds, for which the European Commission will do a review to evaluate their inclusion in the list of priority substances.

In order to cover both long-term and short-term effects resulting from exposure to a chemical, two kinds of EQS referring to the annual average concentration and to short-term concentration peaks have been derived. The long-term environmental quality standard refers to the annual arithmetic mean concentration (AA-EQS) and, in addition, the so-called maximum acceptable concentration EQS (MAC-EQS) refers to protection against acute toxic effects caused by exposure to short-term peak concentrations. The MAC-EQS have been derived only for some substances and are standard that should not be never exceeded in any monitoring point.

The EQS for some substances have different values between inland waters (rivers, lakes) and other waters (transitional, coastal and territorial waters) due also to the different biodiversity in particular of the marine waters respect to inland waters.

For metals, the Directive set different provisions: for cadmium the EQS vary with respect to the concentration of $CACO_3$ and for all the metals (lead, cadmium, mercury and nickel) Member States can take into account, when assessing the monitoring results, the natural background concentration if they prevent compliance with the EQS value, the hardness, pH or other water quality parameters that affect the bioavailability of metals.

The setting of QS for biota is useful because for the 3 mentioned substances bioaccumulation is relevant and the setting of a water EQS can not guarantee the protection of water bodies.

After the second agreement of the Parliament and Council of 17 June 2008 there is a new provision that concerns the sediment matrix: there is the possibility for Member States to set EQS for sediment for specified substances and for some specific types of water bodies; in the Directive there also EQS for 8 pollutants derived by the “daughter directives” of the dangerous substances directive (EU,1976); but the EQS for these substances have not been elaborated through the described methodology.

The groundwater quality standard, due to the fact that a main part of groundwater is used for human purposes, have been mainly based in the past on the possible effects for human health due to the consumption of drinking water and the standard derived were often analogous to those defined in the drinking water legislation. The groundwater Directive set EQS of nitrate and pesticides (including relevant metabolites, degradation and reaction products) that are based on human health toxicity, although the values of pesticides is a normative value taken by the drinking water directive (EU, 1998).

This approach has created different environmental objectives between surface and groundwater that cannot be approved by the scientific community considering for example the possible influence of the quality of groundwater for aquatic organisms that live in surface waters,

The methodology for the setting of EQS for the protection of the environment and human health is completely different because the objectives of protection are not the same; the elaboration of EQS for the protection of aquatic ecosystems is based mainly on ecotoxicological effects and usually these effects occur at very low concentrations, often much lower than human health based quality standard (*e.g.* arsenic, mercury, cadmium, copper, zinc, some pesticides). In some cases, in particular for carcinogenic substances the standard based on human health can be lower (for example Benzene).

The differences in the values are justified because the drinking water directive has the aim to guarantee the quality of drinking water for the protection of human health at the tap; while the elaboration of the environmental EQS should guarantee the protection of all aquatic organisms included man from the direct and indirect effects of chemical pollutants.

The elaboration of quality standard for the protection of human health in relation to the drinking water consumption (W.H.O., 1993) takes into account the Tolerable daily intake (TDI) that is an estimate of the amount of a substance in food or drinking water, expressed on a body weight basis that can be ingested daily over a lifetime without appreciable health risk. The NOAEL (no observed adverse effect level) is defined as the highest dose or concentration of a chemical in a single study found by experiment or observation, that causes no detectable adverse health effect; whenever possible, the NOAEL is based on long term studies, preferably of ingestion of drinking water. In the derivation of drinking water standard uncertainty factors are applied to the lowest NOAEL or LOAEL (low observed adverse effect level) for the response considered to be the most significant biologically. For carcinogenic and genotoxic compounds a different approach is used taken into account mathematic models and guideline value is presented as the concentration associated with an extimated lifetime cancer risk of 10^{-5} or 10^{-6}.

The GW directive go towards a new approach in which the groundwater EQS should be based also taking into account ecotoxicological effects on aquatic ecosystems; the determination of threshold values should be based infact on: the extent of interactions between groundwater and associated aquatic and dependent terrestrial ecosystems; the interference with actual or potential legitimate uses or functions of groundwater; the hydro-geological characteristics including information on background levels and water balance; the origins of the pollutants, their possible natural occurrence, their toxicology and dispersion tendency, their persistence and their bioaccumulation potential.

Furthermore the European Guidance on groundwater chemical status and threshold values (European Commission, 2007) in the context of the Common Implementation Strategy of the WFD suggests to derive threshold values based on the objectives of protection; when a groundwater body includes different objectives of protections (for example human health and environment) the threshold values applied should be the more stringent between both human health and ecotoxicological approaches. This approach is similar to those applied for the setting of surface water EQS.

The guidance states also that when groundwater and surface waters are linked and especially when surface waters or dependent terrestrial ecosystems are fed by groundwater, the criteria value(s) relevant to protection of the associated surface water or groundwater terrestrial dependant ecosystems will be derived using environmental quality standards (EQS) for surface water (or any other relevant ecotoxicological value).

In conclusion there is a need to harmonise the approaches for the derivation of EQS for groundwaters and surface waters. The GW quality standard based only on the protection of human health due to the drinking water consumption brings to define quality standard in surface and groundwaters (e.g. for mercury the differences vary between 0,05 and 1 µg/L) totally different. The human health approach can be justified for groundwater bodies in which water intended for human consumption is the only use.

In this context the EQS set by the new European Directive, based mainly on ecotoxicological effects, should be taken fully into account by Member States where they set EQS for groundwaters in particular when there are interactions with surface water-bodies; the threshold values for groundwater can be applied at local or at national level and the criteria should fully taking into account the presence of natural background in particular when they are higher than the threshold values.

Furthermore the harmonisation of the environmental quality standard between surface and groundwaters should be also highlighted in relation to the new emerging issues as climate change linked to extreme weather events like for example flooding that can change the transport and fate of the pollutants that can be transferred in both the systems in an unpredictable way.

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Keywords: Environmental quality standard, priority substances, groundwater, surface waters.

The quantitative and chemical status of groundwater bodies in Catalonia: state of the art on the implementation of the WFD and groundwater directive

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Abstract

The Water Framework Directive states that, once the groundwater bodies in Catalonia have been characterised and those that are at risk of not attaining the objectives set for 2015 have been identified, the Catalan River Basin District Management Plan must be drawn up by the end of 2009. The prioritisation of the pressures that generate risk for bodies of water allows the basic lines of action to be defined in order to package the programmes and measures required to attain the above mentioned objectives and at the same time permits a focus on the citizen participation process, which aims to involve society in drawing up said Management Plan. An overview of the current state of the groundwater bodies in Catalonia is given here, with an analysis of the main pressures they face. The lines of action anticipated by the Catalan Water Agency in order to attain the objectives of the Water Framework Directive and the Groundwater Directive will then be presented.

1 - Introduction

The Catalan Water Agency is the public entity of the Government of Catalonia assigned to the Department of the Environment and Housing and founded in 1998 as the hydraulic authority in Catalonia, in charge of the governing policies concerning water and based on the principles of the Water Framework Directive. The Agency manages and plans the complete water cycle through an integrating vision for aquatic systems that keeps the balance of all ecosystems in mind. Water is undoubtedly a basic structural and functional element for both the environment and life itself. Its management must be compatible with the growing demands for stability, universal access and immediacy from the citizens of an advanced society, guaranteeing quality and good service. The basic principle governing the policies and management of the water in Catalonia, according to the Water Framework Directive, is that of sustainability, defined by 4 important pillars: environmental, guaranteed, economic and social sustainability.

Catalonia is divided in two hydrographic river basins: the “inner basins” and the “shared basins” (Ebro, Garona and Xúquer). The Catalan Water Agency has complete and exclusive authority of the complete water cycle in the inner basins, and shared or delegated authority, except concessions, planning and authorizations, in the shared basins (Figure 1). The mission of the Agency is to ensure the quality, quantity and sustainability of Catalonia’s water resources with efficiency and effectiveness, in collaboration with other administrations and the different water users, by protecting the associated water bodies and ecosystems and managing the activities carried out, and by regulating and managing the different uses of water.

The recovery of a good status for and the protection of water, in particular groundwater, is the objective of Directive 2000/60/EC establishing a framework for community action in the field of water policy or the Water Framework Directive (WFD), complemented by Directive 2006/118/EC on the protection of groundwater against pollution and deterioration, also known as the Groundwater Directive (GWD). Complying with the calendar set out in the WFD means that by the end of 2009, the River Basin District Management Plan must be established, in line with the WFD criteria. This plan must contain the whole package of measures and programmes required in order to attain the objectives established in Article 4.1.b).

Figure 1: Location of Catalonia and division in hydrographic river basins.

Geographic diversity in Catalonia

- ✓ **32.000 km2, with 580 km of coast line.**
- ✓ **7 millions of inhabitants.**
- ✓ **41 political districts and 946 municipalities**
- ✓ **70% of population concentrated in 45 municipalities that 20.000 inhabitants surpass.**
- ✓ **Mediterranean climate: hot summers, and warm winters whit hard rain in spring and autumn, average 400- 600 mm.**

2 - Groundwater bodies in catalonia and the risks affecting them

The process of delineation and characterisation of the bodies of groundwater in Catalonia, completed in 2004, is contained in the document Characterisation of Bodies of Water and Analysis of the Risk of Non-Compliance with the Objectives of the Water Framework Directive in Catalonia (IMPRESS document). The document identifies those groundwater bodies that are at risk of failing to comply with the objectives of the WFD by 2015. In Catalonia, where there are significant variations in the types of aquifers and the problems affecting them, 53 groundwater bodies were delineated (Figure 2). Once the bodies of water were defined, the pressures affecting them were analysed. Pressure is understood as the potential of those human activities that may affect the flow or the chemical composition of groundwater. The main pressures affecting the groundwater bodies in Catalonia are those listed in Table 1.

Figure 2: Delimitation of the groundwater bodies in Catalonia (2004).

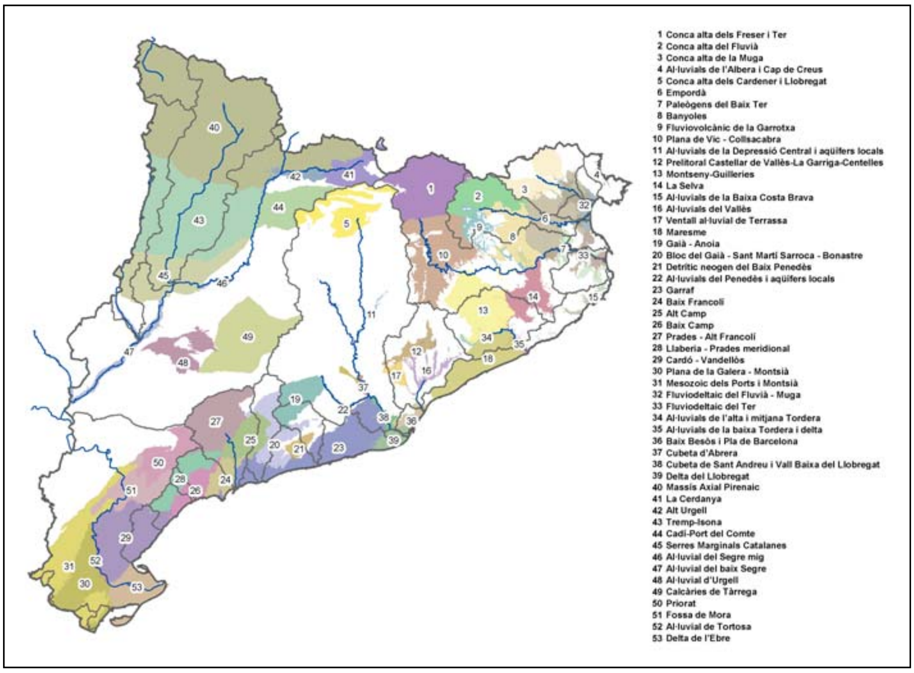


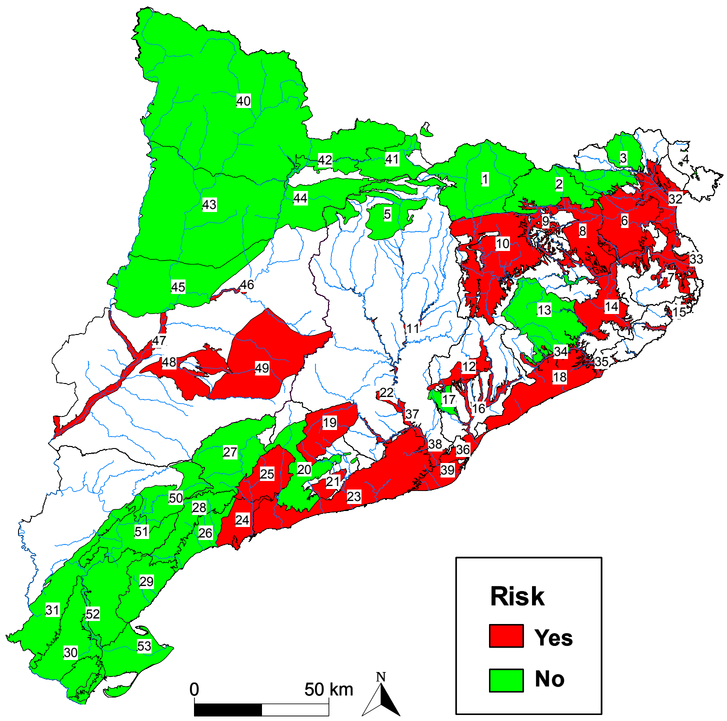
Table 1. Main pressures affecting the groundwater bodies in Catalonia.

Afection to the state	Kind of pressure	Pressure
Quantitative	Extraction of water	Pumping
		Forestry and ornamental plants
		Extraction activities
		Returns of irrigation
Chemical	Local pressures	Industrial spills
		Waste disposal
		Construction and demolition waste
		Contaminated soils
		Waste Water Treatment Plant
		Tip mining
		Buried tanks
	Diffuse pressures	Application of livestock manure
		Fertilisation practices
		Returns of irrigation
		Sewage system
		Pipe lines

Table 2. Number of groundwater bodies in Catalonia at risk of non-compliance with the Directive objectives.

GWB at risk in Catalonia	nº *GWB*	%
Risk by the quantitative state	11	21%
Risk by the chemical state	27	51%
Total risk (quantitative and chemical)	**29**	**55%**

Figure 3: Groundwater bodies in Catalonia at risk of non-compliance with the Directive objectives.



The evaluation of the effect produced by the pressure is the impact, which is established using chemical or groundwater level data or the water balance of each body of water. The level of this impact and the anticipated response of the measures based on the Management Plan allow the concept of risk to be calculated, understood as the assumption of the inability to meet the quantitative and chemical objectives set out in the WFD for 2015. Thus the groundwater bodies in Catalonia considered to be at risk are those indicated in Table 2 and in Figure 3.

3 - Origins of the main problems facing groundwater in Catalonia

3.1. Negative balance of pumping and recharge

The fundamental pressure on groundwater bodies comes from the extraction of water, particularly water intended for public supply in the most densely-populated areas. The extraction of groundwater in Catalonia and its uses are shown in Table 3.

Table 3. Groundwater extraction in Catalonia (2006).

	Supply	Industrial	Agriculture	Total
Internal basins	180	78	200	**458**
Intercommunity basins	20	10	39	**69**
Total	**200 (38%)**	**88 (17%)**	**239 (45%)**	**527**

The impact of pumping is seen in terms of the availability of water in inland aquifers and in salination as a result of marine intrusion in coastal aquifers. This leads to a lack of resources by lowering the quality of water available for public supply. In this respect, the following corrective measures are anticipated:

- Planning of extraction.
- Reuse of regenerated water.
- Interconnection with supramunicipal supply systems or networks.
- Artificial recharging.
- Barriers against marine intrusion.
- Desalination plants.

Where exploitation is fully consolidated, replanning extractions is a difficult measure to put into practice. One of the main factors conditioning this is the economic aspect, and unless it is absolutely necessary, neither local administrations nor users' communities usually welcome the need to substitute the exploitation of their wells with water from external suppliers, due to the budgetary repercussions this will have.

However, the reuse of water that has been regenerated by means of a tertiary treatment, partially complemented with membrane treatment for certain uses, is increasingly practiced in Catalonia and is promoted by the Agency. Potential uses for this type of water are for agricultural, environmental and industrial purposes and the recharging of aquifers. In fact, one of the points of the River Basin District Management Plan focuses specifically on artificial recharging and the Agency is currently carrying out recharge projects both using ponds and through the construction of hydraulic barriers.

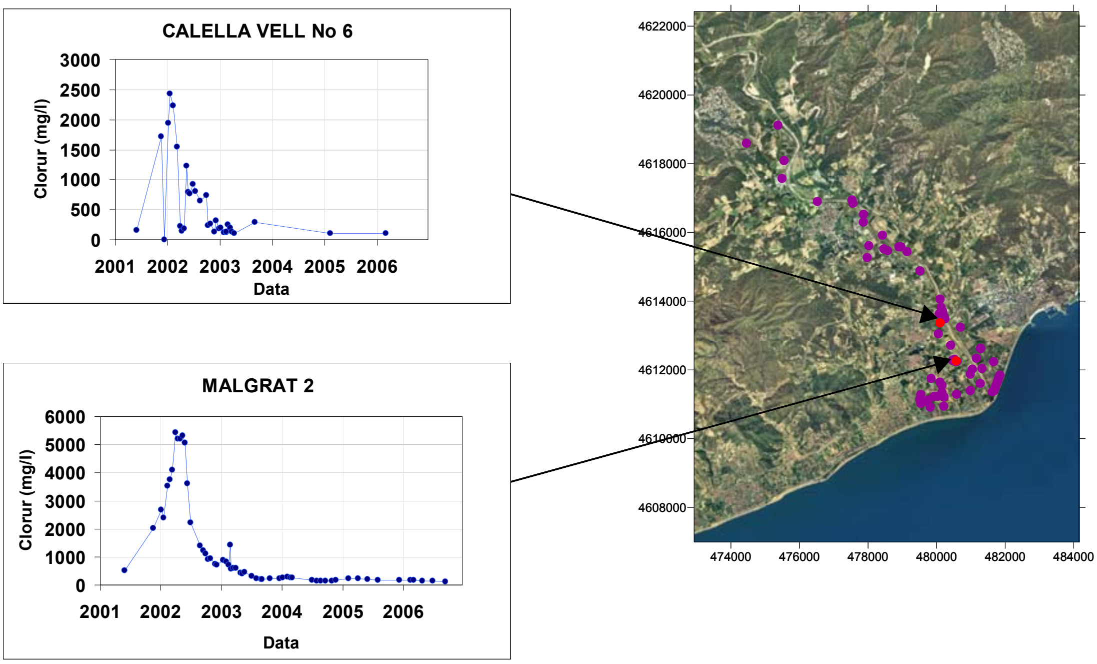
The quantity control parameter required by the WFD is the level of groundwater and, where this is unavailable, the water balance is used. The Catalan Water Agency’s network for monitoring groundwater levels consists of 405 water level points that are read on a monthly basis. Series dating back over 30 years are available for more than 300 of these points. To complete the network and adapt it to the criteria of the WFD, 160 new water level points with a total forecast perforation length of approximately some 13,000 m are under construction.

3.2. Marine intrusion

The impacts generated by the intrusion of saline water affect coastal supplies and are a consequence of the over-exploitation of aquifers that flow into the sea. The Catalan Water Agency has an operational control network to monitor saline intrusion in Catalonia that consists of 174 observation points that are read every six months. The parameters that are monitored are T, pH, conductivity and chlorides.

Figure 4: Chloride at the Tordera deep aquifer.

Overexploitation of the aquifer and marine intrusion was the main problem until 2002, when the desalination plant started, reducing the pumpings in 10 hm^3/y. The artificial recharge of the aquifer was also implemented with reuse water, refilling the lower Tordera in 3.8 hm^3/y.



In terms of aquifers affected by marine intrusion, there are two examples in Catalonia that are particularly interesting: 1) the Tordera aquifer and 2) the Llobregat aquifer.

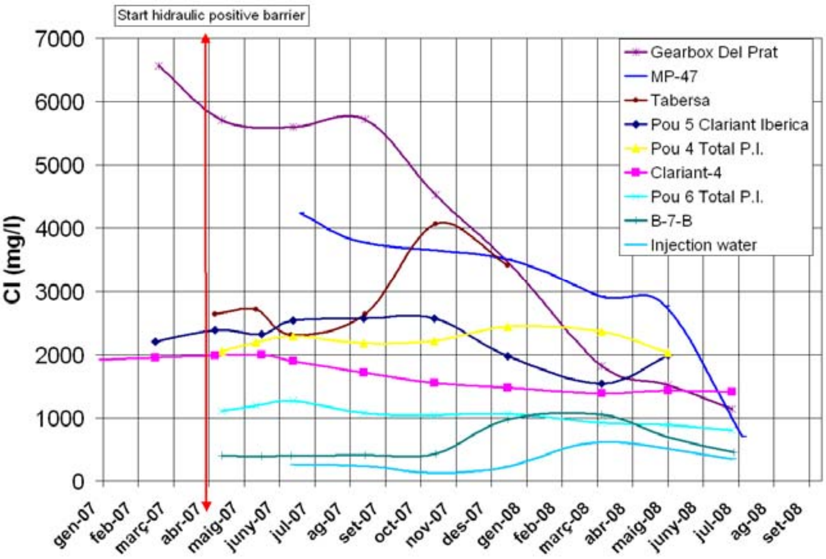
The alluvial aquifer of the lower stretch of the river Tordera on the Costa Brava showed signs of over-exploitation due to the extraction of water for supply purposes that took place mainly in the summer season, due to the increased demand caused by tourism. In 2001, chloride levels increased greatly in some wells and in 2002 the salination of the aquifer was generalised, even reaching several kilometres inland. In that same year, the Agency began the artificial recharge of the aquifer using the flow of effluent from the Blanes WWTP following tertiary treatment. This meant that up to 5 hm^3/year extra were entering the aquifer simply by discharging this water into the river. In 2002, pumping was also reduced by its incorporation into the drinking water distribution network running from the Tordera desalination plant (10 hm^3/year). In just a few years, these factors led to a significant reduction in the salination of the Tordera aquifers (Figure 4).

Another case of an aquifer affected by marine intrusion in Catalonia is the Llobregat aquifer, strategic for the water supply to Barcelona. In the Lower Llobregat, aquifers have been recharged by AGBAR for some years now by means of the scarification of a section of the riverbed and through direct injection through wells. At present, the Agency is also planning the construction of recharge pools in this area, some of which will be filled with regenerated water. It is expected that the aquifer will be recharged with between 10 and 15 hm^3/year through this process.

An injection hydraulic barrier is also in progress on the deep Llobregat aquifer, in order to prevent marine intrusion through the direct injection of 15,000 m^3/day. The water used for injection is regenerated from the WWTP and subsequently put through tertiary treatment + ultrafiltration + UV. In addition to this, 50% of the water is treated by inverse osmosis before the injection. Phase 1 has been underway since March 2007, with an injection flow of 2,500 m^3/day in three wells, a process that has been very successful. No clogging has as yet been observed in the injection wells after the injection of over 500,000 m^3 of water, and the quality of water in the aquifer has been increased significantly at all of the observation points located at 1,000 m from the injection wells (Figure 5).

Figure 5: Effects of the first Phase 1 of the hydraulic positive barrier at the Llobregat aquifer.

Chloride at the observation points near the injection wells (1 Km). Results show that a good groundwater quality status can be expected in the aquifer, and indicate that the barrier is effective to stop the marine intrusion.



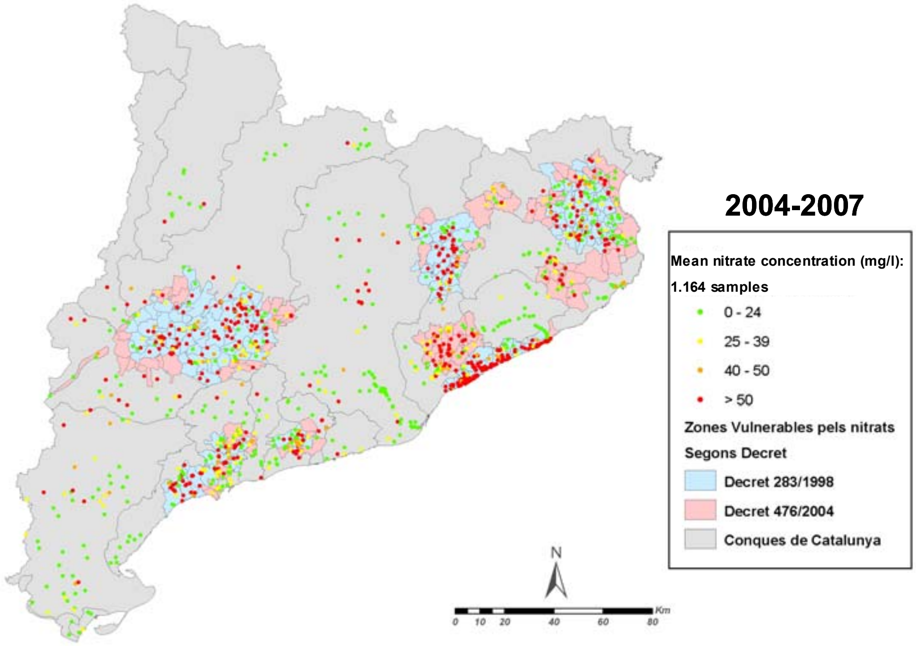
3.3. Agricultural source nitrates

The most widespread impact and probably the one that is most difficult to solve in Catalonia today comes from the high nitrate concentration in groundwater. This is essentially a result of fertilisation practices and particularly of the application of livestock manure.

The WFD states that prevention and protection criteria must be coherent with all legislation concerning nutrients, and in particular with Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources (designation of vulnerable zones) and with Directive 91/271 concerning urban waste water treatment (designation of sensitive areas). The transposing of the Nitrates Directive into Spanish law establishes the fact that the autonomous communities are responsible for designating the zones, particularly the vulnerable zones that are most relevant in the management of groundwater. This means that the definition of bodies of water that are at risk of pollution and the designation of vulnerable zones are not always the responsibility of the same administrative area, the river basin organisation being responsible for the former and the autonomous community for the latter. The very nature of the problem means that both the designation criteria and the code of good practice and action plans stretch beyond the powers of the water authority, which means that establishing measures and applying such measures requires transversal policies that take into account agricultural, livestock farming, public health and municipal interests, which do not usually coincide and which are not always easy to harmonise. In any case, the water authority must respond to the evolution of water quality, which means that every four years it must ensure the revision of the vulnerable zones and report to the EU following a legally established protocol.

By their very definition, there is no reason for the territory included in vulnerable zones to coincide with that of the GWB affected, or with the aquifer or aquifers included in them. Following the 2004 revision, nine zones in Catalonia were designated as vulnerable to pollution from nitrates, covering an area of 6,327 km^2 (19.8% of the territory) and 321 municipal terms (33% of the municipalities). The nitrates operational control network in these zones consists of 765 control points with sampling every six months, using the parameters T, pH, conductivity, redox potential, nitrates, nitrites and ammonia. In addition to these points, annual controls are made of 694 additional wells that form part of the surveillance network.

Figure 6: Nitrate groundwater concentration (mean of the 2004-2007 period). Nitrate is the main problem of the groundwater quality in Catalonia.



The evolution of the concentration of nitrates in groundwater in Catalonia between 1994 and 2006, based on 13,335 samples, shows that over 45 % of the total samples exceed concentrations of 40 mg/l, the value after which measures must be applied to invert the tendency for an increase in pollution, according to the GWD (75% of the quality standard for nitrates, set at 50 mg/l). In terms of evolution for the periods 2000-2003 and 2004-2007, concentration increased in 53% of the samples and a reduction was noted for only 34% of samples (Figure 6). This shows that, despite the complex legislation that has been drawn up, the situation is not yet enough on track to obtain satisfactory results.

The Catalan Water Agency has various agreements with other departments of the Government of Catalonia, including the Departments of Agriculture and the Environment, and with the main professional agricultural organisations and associations in the pig-farming sector, with the goal of improving the criteria for agricultural fertilisation. 200 pilot plots are also being studied and monitored in central Catalonia. Reliable research into winter cereal and maize crops carried out in Girona by the Institute of Agrifood Technology and Research (IRTA) - Mas Badía Foundation, which comes under the umbrella of the Department of Agriculture, suggests that a fairly optimistic view can be taken in terms of the reduction of excess nitrates. However, several years may pass before these practices are accepted by the sector and become widespread, and it will take still longer before results can be seen. In view of evolution to date and for the anticipated four-yearly revision, several technical proposals are being analysed and submitted to the Agency's decision-making bodies for consideration.

3.4. Pesticides

Besides nitrates, pesticides are the only substances with concentrations that are subject to quality regulations. Organochlorine compounds (23), organophsosphorous compounds (10) and herbicides from the triazine family (7) have been analysed since 1996. The Catalan Water Agency's pesticides operational control network has 88 control points with a six-monthly testing frequency and the Pesticide monitoring and control plan came into operation in 2007, in compliance with Article 8 of the Water Framework Directive.

Persistent traces of the organochlorine pesticide lindane and the herbicides simazine, atrazine, its metabolite desethylatrazine and compounds from the endosulfan family can be found in the majority of the GWB analysed in Catalonia. Of the phosphorous compounds that can be found, chlorpyriphos and diazinon are ubiquitous in GWB 47 and 48 (Lleida) and 35 (the Tordera Delta). Dieldrin is characteristic of El Maresme (GWB 18) and the abovementioned GWB 35.

With the exception of atrazine, more than 90% of the concentrations measured are below the limits set out in the quality regulation. Failures to comply, both in the case of individual pesticides and in the sum of all of the pesticides involved, occur in those GWB with greatest agricultural potential. The measures to prevent pollution by pesticides are outside the sphere of authority of the Catalan Water Agency, which means that at present, groundwater is simply subject to an impact that will need to be resolved through deep-rooted changes in the philosophy of agricultural practices.

3.5. Point source pollution

There are currently over 250 decontamination files open within the Catalan Water Agency as a result of episodes of pollution from industrial sources. Since RD 9/2005 of 14 January establishing a list of potentially soil-polluting activities was passed, along with the criteria for the declaration of polluted soil, there has been a marked increase in the detection of episodes of point source pollution. It is mainly present in Catalonia in aquifers that are subject to pressures from industrial sources. The main pollutants are hydrocarbons (58%) associated with storage and distribution establishments, and organohalogenated compounds (25%).

The Catalan Water Agency's operational control network for episodes of pollution currently consists of 173 control points. The control parameters depend on the pollutant, but they are mainly trichloroethylene, perchloroethylene, other organohalogenated compounds, BTEX, MTBE, hydrocarbons, dioxanes and metals. The lines of action in progress or established by the ACA include different decontamination protocols and practical guides for the management of polluted sites.

4 - Water policy for at-risk groundwater bodies

The WFD establishes that integrated management criteria must be applied to bodies of groundwater with good status in order to prevent their deterioration. However, for those that are at risk, a programme of measures must be implemented that is to be included in the River Basin District Management Plan. In line with Article 11 and Annex VI of the WFD, the programme of measures must include, as a minimum, all of those measures established in European legislation for the protection of water.

The main lines of action established within the Catalan Water Agency's policies are:

- Treatment and improved quality;
- Environmental recovery of rivers and environmental planning (flood prevention);
- Regeneration and reuse of treated water;
- Aquifer recovery;
- Improved efficiency of distribution systems and encouragement of the saving of water;
- Desalination;
- Improvements to upstream supply networks and support to local supplies.

Based on these lines of action, a package of measures (plans and programmes) has been set out that will govern the development of water policy between now and 2010. Many of these measures are already underway. Numerous plans and programmes have resulted from the package of measures (treatment, river areas, supply, saving, the efficient use of water for irrigation, reuse, droughts, etc.) The following programmes apply solely to groundwater within the Catalan River Basin District Management Plan and are currently under study or being drawn up:

- Programmes for the efficiency of use and improved quality of bodies of groundwater:
  . Programme for managed aquifer recharge,
  . Programme for the establishment of protection areas and perimeters,
  . Quantification of groundwater resources,
  . Distribution programme for extraction,
  . Programme for the use of brackish water;
- Nitrates programmes:

  . Programme to reduce pollution from agricultural source nitrates,
  . Programme of action for vulnerable zones;
- Programmes for establishing legislation:
  . Criteria for evaluating the impact of infrastructures on the underground environment,
  . Arid extraction,
  . Localised pollution.

With regard to social participation and in line with Article 14 of the Water Framework Directive, the anticipated consultation for drawing up the Management Plan for Catalonia is being carried out. Information sessions for the analysis of pressures and impacts referred to in the IMPRESS document are being carried out in each river basin council. Sector-specific debate workshops, suggestions workshops, a plenary session to present the proposals of the working groups and a feedback session in which the measures adopted for the implementation of these proposals are presented also being held. The protocol for the participation process is complex and it is implemented within each river basin council over a six-month period.

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Keywords: Directive, management plan, groundwater bodies, pressure, impact, plans and programmes, extractions, artificial recharge, vulnerable zones, nitrates, pesticides.

Assessing and aggregating trends in groundwater bodies. Examples of the FP VI Aquaterra-project

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The aquaterra work package 'Trends in groundwater'

The Aquaterra work package TREND 2 was dedicated to the development of operational methods to assess, quantify and extrapolate trends in groundwater systems. Trend analysis techniques were tested at a wide range of European cases, including unconsolidated lowland deposits in the Netherlands and Germany, chalk aquifers in Belgium and a fractured aquifer with a thick unsaturated zone in France.

A trend was defined as' a change in groundwater quality over a specific period in time, over a given region, which is related to land use or water quality management'. Trend analysis for the Groundwater Directive is dedicated to distinguishing these anthropogenic changes from natural variation with an adequate level of confidence and precision (GWD, Annex V, art 2(a)(i)). Obviously, temporal variations due to climatological and meteorological factors might complicate trend detection, but also spatial variability is a complicating factor, especially when aggregating trends on groundwater body scale which is requested (section 2.2.1, this Guidance). Relevant spatial variations include 1. flow paths and travel times, 2. pressures and contaminant inputs and 3. chemical reactivity of groundwater bodies. These variations result in very variable trend behaviour over the scale of the groundwater body, because wells might as well be on a flow path which traces back to an area with high contaminant inputs, but also one tracing back to low inputs.

Trend analysis techniques aim to reduce the variability which is not related to the anthropogenic changes themselves. Therefore, trend detection becomes more efficient when forementioned spatial and temporal variability are reduced by taking into account the physical and chemical temporal characteristics of the body of groundwater, including flow conditions, recharge rates and percolation times (GWD, Annex V, art 2(a)(iii)). Several statistical techniques, modelling techniques and combinations of both are available for trend analysis and some promising techniques were tested in the TREND2 work package, including age dating and transfer-function approaches (Visser *et al*., 2008).

Trends in relation to pressures, monitoring set-up and properties of groundwater systems

The TREND2 comparative approach showed that there is no unique approach which works under all hydrogeological conditions and monitoring settings across Europe. However, reducing variability by including information on pressures, hydrology and hydrochemistry did help to improve the detection of relevant trends in each of the hydrogeological settings studied. Specific conclusions are:

- grouping of wells is recommended to improve trend detection efficiency;
- grouping is preferably done according to pressures (often land use related), hydrologic vulnerability (travel time frequence distributions, unsaturated zone depth) and chemical characteristics (rock type, oganic matter contents) (Figure 1);
- grouping of wells for trend analysis should also consider the depth dimension because groundwater generally becomes older with depth and changes at larger depth might be completely different from changes at shallow depth (Figure 2).

Figure 1: Grouping of wells according to pressures (land use), hydrologic vulnerability (geohydrological situation) and chemical vulnerability (soil type).

The resulting combinations were called homogeneous areas and used for determining trends and assessing chemical status (Broers and van der Grift, 2004).

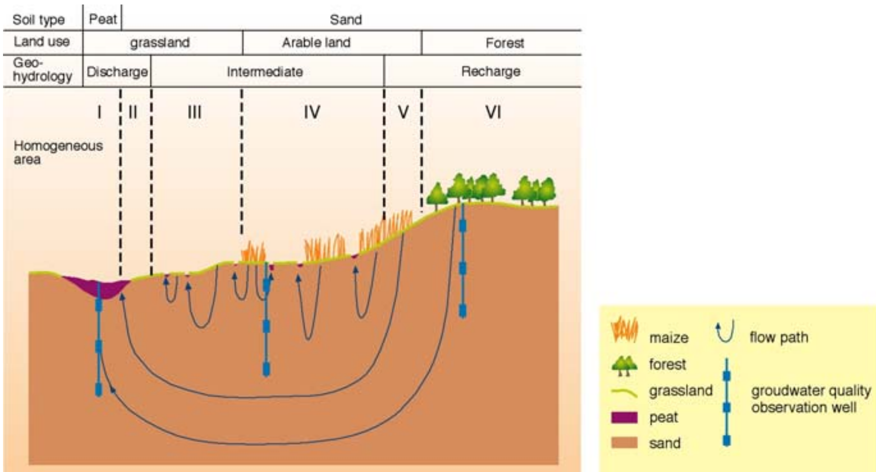
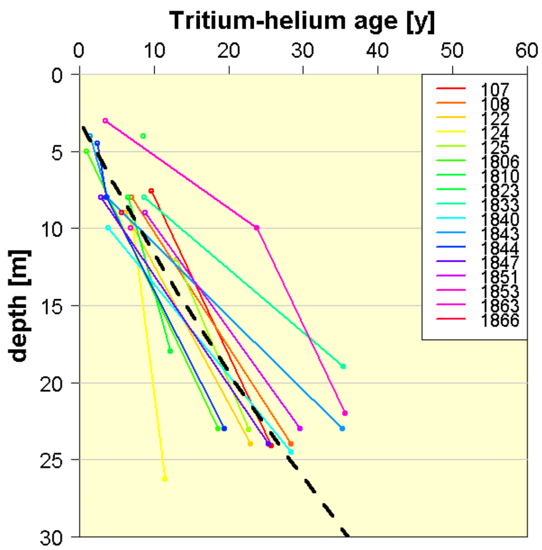


Figure 2: Increase of groundwater age with depth as determined by an analytical equation (dashed line) and tritium-helium age dating in 14 multi-level observation wells (separate colours for each well).



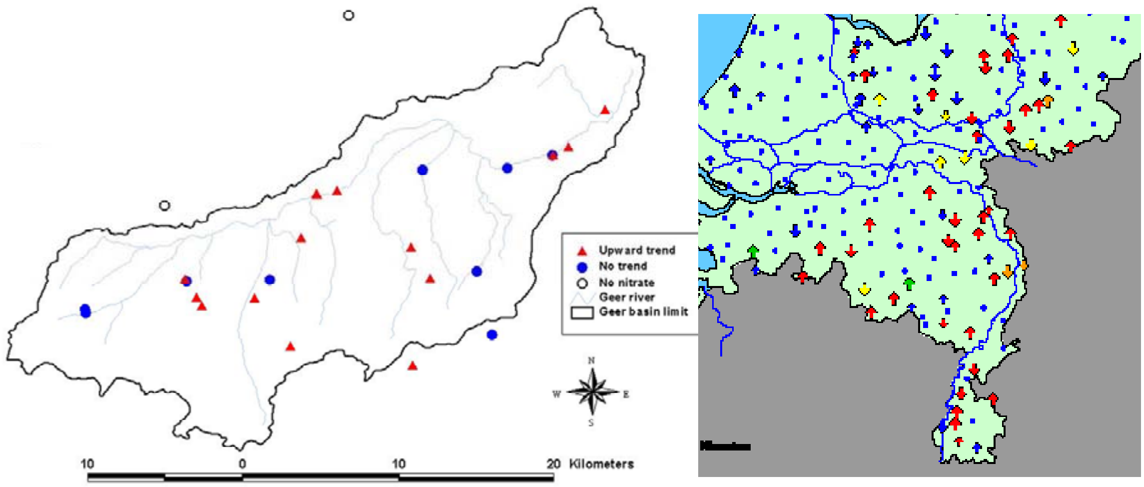
- it is essential to distinguish between abstraction wells and springs on the one hand and observation wells which are not pumped on the other.
  . Pumping wells and springs normally have water mixed from different layers and the resulting water quality is a result of mixing water with a broad range of travel times. As a complicating factor, the contributions of young and old water in the mixture may change with time.
  . Water quality measured in observation wells is normally related to a distinct groundwater age, and time series can be related to a specific infitration period once the age has been determined.

  If different monitoring types occur in a groundwater body, trend detection is best done by grouping these types separately.
- Unsaturated zone thickness is one of the controlling variables in choosing trend analysis techniques. Thick unsaturated zones lead to long response times which trouble fast detection of trends related to anthropogenic changes.

Aggregation of trends at groundwater body scale

Although grouping of wells according to pressures and monitoring depths already helps to identify trends (previous section), often large spatial variability is oberved in trend directions and trend slopes over a whole groundwater body (Figure 3). The implementation of the GWD requires a procedure wherein the individual trend assessments (for individual monitoring points) contribute to identify a significant and sustsained trend at the groundwater body (section 2.1.4 this Guidance).

Figure 3: Spatial variability in trends in the Geer basin, Belgium (left) and southeast Netherlands (right).



Two possible ways of aggregating individual trends at groundwater body scale are illustrated below using data of the Dutch monitoring network in Noord-Brabant. The monitoring network comprises of standardized monitoring wells with fixed screens at specific depths. The wells consist of purpose built nested piezometers with a diameter of 2” and a screen length of 2 meters at a depth of about 8 and 25 meters below surface (Broers, 2002). The subsurface of Noord-Brabant consists of fluvial unconsolidated sand and gravel deposits from the Meuse River, overlain by a 2–5 m thick cover of Middle- and Upper-Pleistocene fluvio-periglacial and aeolian deposits consisting of fine sands and loam. Noord-Brabant is a relatively flat area with altitudes ranging from 0 m above Mean Sea Level (MSL) in the north and west to 30 m above MSL in the south-east. Groundwater tables are generally shallow, usually within 1-5 meters below the surface.

As a first step in aggregating trends it was recommended to group monitoring wells on the basis of pressures/vulnerability and hydrological properties such as the probable travel time distribution in the groundwater body (previous section). Now, two ways of aggregating are possible:

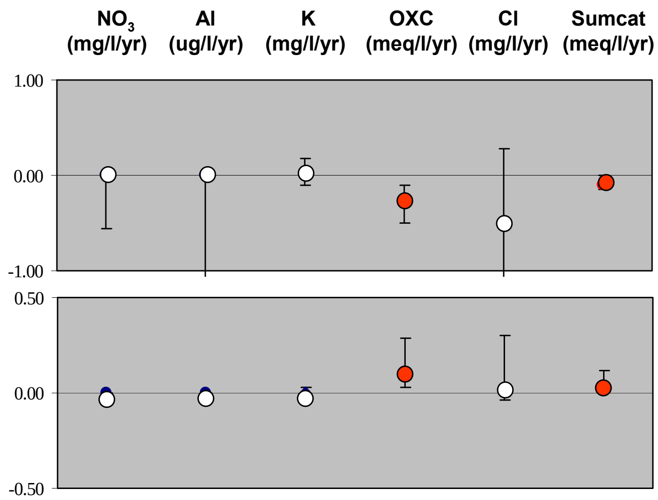
- a statistical way, for example by defining the median trend slope and the corresponding confidence interval;
- a deterministic way, for example using age dating to aggregate time series along a standardized X-axis showing recharge time.

Both approaches are illustrated below using Aquaterra results.

Example 1: Aggregation using median trend slopes

First, all trend slopes of individual monitoring points were determined, through linear regression or a Kendall-Theil robust line (Helsel and Hirsch, 1992). Aggregated trends were then determined by taking the median of all trend slopes and test whether the median of all trend slope differs signficantly from zero (Broers and van der Grift, 2004). A significant upward aggregated trend for the group of wells is established when the 95% confidence level of the median is completely above the zero slope line (Figure 4). A downward trend is identified is the complete confidence interval is below the zero slope line. Here. confidence intervals around the median slope were determined non-parametrically following Helsel and Hirsch (1992, p.70) using a table of the binomial distribution. It should be noted that trends could have reversed directions at different depths of the aquifer, due to differences in groundwater age and the corresponding contaminant inputs during the period of infiltration. One of the conclusions of aggregating trends in a statistical manner is that often a relatively large number of observation wells (20 to 40) is necessary to statistically demonstrate trends because of the observed large temporal and spatial variability which is inherent to groundwater quality datasets.

Figure 4: Aggregated median trend slopes for agricultural recharge areas in the province of Noord-Brabant for 6 chemical indicators for shallow screens (upper graph) and deeper screens (lower graph). Source: Visser* et al.*, 2005.



OXC= oxidation capacity, Sumcat = sum of cations. Significant upward trends (filled symbols) were detected for OXC at shallow level and Sumcat at deeper level and downward trends for Sumcat at shallow level and OXC at deeper.

Example 2: Aggregation based on recharge time using age dating

A new promising aggregation technique is using age dating to determine the recharge period of the groundwater and relate the measured concentration data to the derived recharge time. This technique proved to work well for monitoring systems based on multi-level observation wells in areas with porous aquifers. In the example, tritium-helium ages were used to determine the travel time to the monitoring screens. These travel times were used to relate time-series of measured concentrations to the time of recharge, instead of the time of sampling (Figure 5).

Subsequently, the results of all 28 time series in the area type ‘intensive agricultural land use in recharge areas’ were aggregated in one graph and analysed using LOWESS smooth (Cleveland, 1979) and ordinary linear regression approaches (Figure 6). The method succesfully identified trend reversal of nitrate concentrations for this area type. The observed trend compares well with the known input history of agricultural pollutants based on historical data series of production and use of fertilizer and manure under various crop types. Trend reversal was most easily demonstrated for conservative solutes and indicators, such as ‘oxidation capacity’ (Visser *et al.,* 2007). Downward trends in the most recent groundwater could also be demonstrated for reactive solutes such as nitrate, which is transformed to nitrogen when it encounters denitrification by reactive organic matter or sulfides at some depth in the subsurface.

Figure 5: Translating time series measured in individual observation multi-level wells at shallow depth (10 m –sl) and deep (25 m –sl) into an aggregated time series plot using recharge year as X – axis after age dating using tritium-helium (Visser* et al.*, 2007). The aggregated time series shows a sustained upward trend with higher concentrations with recharge time

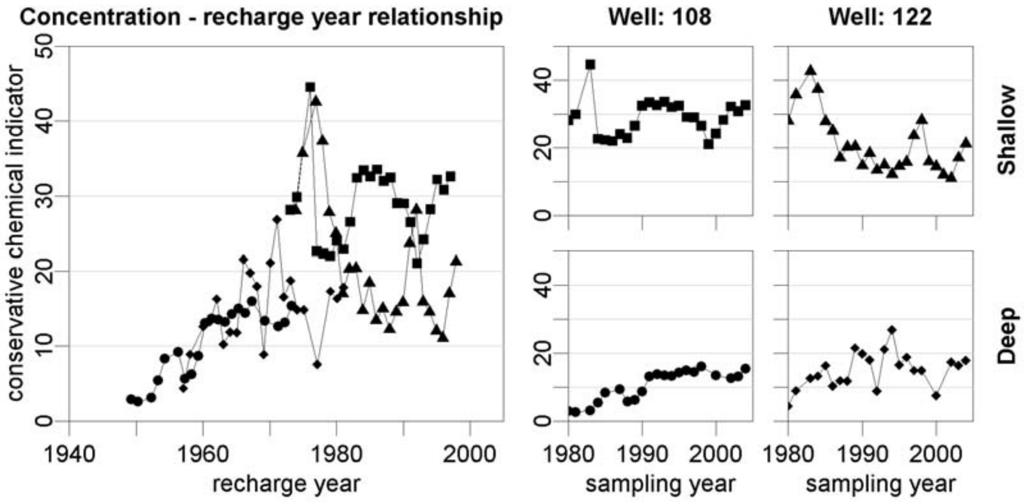
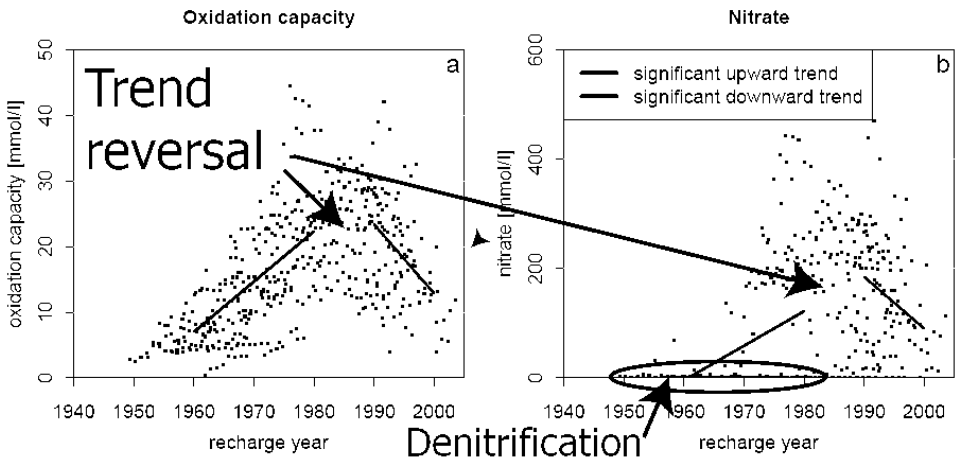


Figure 6: Aggregation by using age dating to determine recharge year corresponding to the measured concentrations. Trend reversal was demonstrated significantly (P<0.005) for oxidation capacity and nitrate.



Conclusions

The Aquaterra results show that it is feasible to detect trends and demonstrate trend reversal at the groundwater body scale and to assess the corresponding level of confidence. The results show that trend detection is preferably tuned to pressures to the groundwater system, to the monitoring set-up and and to the hydrological and chemical properties of the system. It also illustrates how groundwater age dating can improve trend detection.

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Keywords: Groundwater Directive, trends, pressures, monitoring, travel times, age dating, aggregation procedure.

Trend and trend reversal assessment. Methodologies proposed by CIS WG 2.8

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Introduction

In 2000 and 2001, Common Implementation Strategy (CIS) Working Group (WG) 2.8 formed a consortium of partners from 16 EU Member States (11 partners, 5 observers) under the leadership of the Umweltbundesamt-Austria to establishment, amongst others, an appropriate and pragmatic statistical method for trend and trend reversal assessment at groundwater body scale for meeting the requirements of the Water Framework Directive (WFD) in identifying and reversing any significant and sustained upward trend in the concentration of pollutants (Annex V 2.4.4).

The project was commissioned and financed at approximately 1/3 by DG Environment of the European Commission and 2/3 by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management. In kind contributions from the partners constituted another important input. Sub-contractor in the project and responsible for the development of the statistical concepts was the German company "quo data". The final report is published by the European Commission as Technical Report No.1 (European Commission, 2001).

Objectives and Procedure

The main goal of the project was to establish appropriate and pragmatic, statistically correct methods for the assessment of trends and trend reversal at the groundwater body level respectively for groups of groundwater bodies. One method should be applicable for all groundwater bodies and all types of parameters.The methods had to be suitable for EU-wide application and implementation based on the provisions of the WFD taking into account diffuse and point sources of pollution.

Test data sets from 21 GW-bodies and 69 parameters were provided from the partners as well as an inventory of already applied methods. The outcome of the project comprises a method for assessing the monitoring network, methodologies for data aggregation, trend assessment and trend reversal assessment, treatment of values below LOQ, statistical minimum requirements, comprehensive documentation and a software tool for test and demonstration purposes, which is all available for download from the project website (www.wfdgw.net).

The whole procedure of trend and trend reversal assessment considers following steps:

1. Treatment of values below LOQ;
2. Temporal regularisation of groundwater quality data at monitoring point level;
3. Data aggregation at groundwater body level;
4. Trend (reversal) test.

Trend assessment

Proposed trend test

The generalized linear regression test (ANOVA test) based on the LOESS smoother is proposed for assessing statistically significant (monotonic) trends at GWB-level. With regard to extensibility and power the linear methods (based on a linear model) outperform non-parametric methods based on the test of Mann-Kendall, and therefore the decision was in favour of the linear methods. The proposed methodology considers following specific requirements:

- applicability to all types of parameters,
- extensibility to potential adjustment factors,

- and sufficient power for the detection of a trend.

Robustness was considered less important than power and extensibility (data validation needs to be an integral component before trend and trend reversal assessment).

Power of test

One of the findings during the data assessment phase was that a significant upward trend is to be detected with a power of 90% (for most substances) if the increase in pollutant concentration is at least 30% or even higher, depending on the type of pollutant. In the light of the default starting point for trend reversal at 75% of a quality standard or threshold value an increase of 33% of the pollutant concentration would mean that good status is failed.

The importance of data from operational monitoring for trend assessment was pointed out, as otherwise insufficient data would not allow for trend detection in due time.

Minimum length of time series

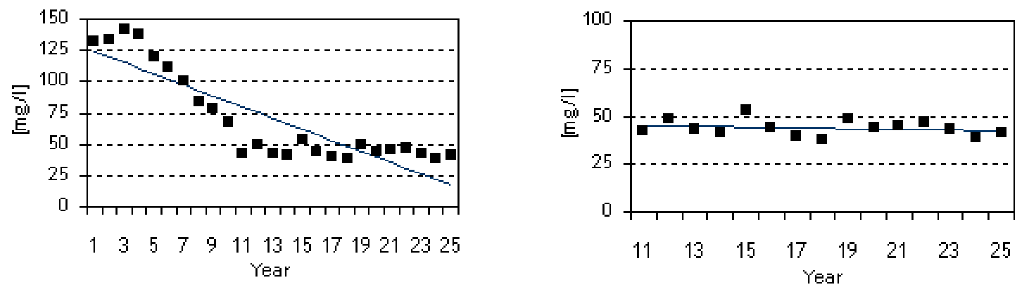
For the minimum length of time series for trend detection the power of trend detection, the timetable for WFD implementation as well as its minimum requirement regarding monitoring frequency (once a year) were taken into account. As monitoring started in 2007 and in 2015 a review and update of river basin management plans is required, it is assumed that in 2015 data from 2007 to 2014 are available. This means a time series of 8 years with at least 8 values as a minimum.

As with less than 8 yearly measurements a statistical trend assessment may be critical, it is recommended to perform a trend analysis with at least 8 measurements. In case of half-yearly measurements the total sample number should not be less than 10, in case of quarterly measurements it should not be less than 15. In each case the time span of measurements should be at least 5 years since short-term changes may distort the detection of long-term trends.

Maximum length of time series

If long-term time series are assessed, there is a risk of obtaining trend results which are clearly affected by changes in the earlier years of the time series. Therefore it is proposed to restrict the time series to the most recent 15 years.

Figure 3: Influence of the length of time series on the detection of a trend.



An alternative would be the application of an adaptive method to check whether there is a significant break of the (linear) trend (*e.g.* by a trend reversal method (two-section method)). If there is a significant break then the recent section could be subject of trend assessment. Anyhow, the conceptual model of the groundwater body and groundwater residence time should be considered in the consideration of the length of time series considered in the assessment.

Seasonality

In order to avoid bias by seasonal effects, samples should be taken within a certain period of a year. In particular for yearly measurements it should be guaranteed that the measurements are taken in one and the same quarter or within a certain time period of the year. Seasonality effects might also be induced due to different monitoring frequencies from site to site. Seasonality causes a high random variation which reduces the power of the trend analysis. The proposed method also allows for testing seasonality.

Data gaps

In the time series some observations may be missing, but the missing of two or more subsequent values should be avoided, as this would cause a bias due to extrapolation.

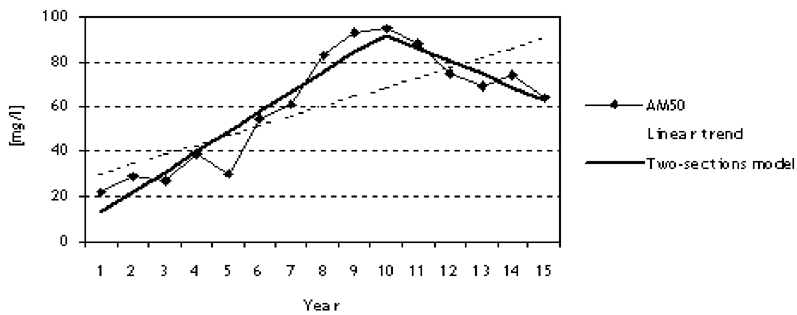
Trend reversal assessment

Proposed trend reversal test

For the assessment of a trend reversal the 2-sections model is proposed, due to its simple interpretability, flexibility and high sensitivity to detect a trend reversal. The 2-sections model is a linear method, based on an extended linear regression model fitting a linear trend with one break in the interval.

For half-yearly or quarterly data seasonality can be considered in the method.

Figure 4: Two-sections model for assessing trend reversal.



Minimum length of time series

In the light of the second review and update of river basin management plans in 2021 (with data from 2007–2020), at least 14 measurements (with yearly regularisation) are recommended in order to guarantee a certain level of power for the detection of a trend reversal. With data on a half-yearly or quarterly basis 10 years are considered to be the minimum. For half-yearly measurements at least 18 values and for measurements on a quarterly basis at least 30 values would be necessary.

Maximum length of time series

It is not recommended to apply the trend reversal test to a time span of more than 30 years. If even after 30 years no trend reversal can be detected, this has to be stated clearly. Anyhow, the conceptual model of the groundwater body and groundwater residence time should be considered in the consideration of the length of time series considered in the assessment.

Data preparation

Treatment of values below the limit of quantification (LOQ)

As limits of quantification may change over time, there is a need for consistent treatment of measurements. For the treatment of "less than LOQ" measurements a 'minimax approach' (minimize maximum risk) is applied. In order to avoid bias (induced trend phenomena) the trend analysis should be performed with a constant LOQmax. All measurements (above or below LOQ) where the LOQ exceeds LOQmax should be eliminated; LOQs not exceeding LOQmax should be replaced by LOQmax (Definition of LOQmax and examples are given on the project website and in the technical report).

Replacement of values below LOQ

It is recommended to calculate trends based on AM50 (50 means that <LOQ values are replaced by 50% LOQ) as long as AM0/AM100 ≥ 0.6. Under these circumstances the maximum bias does not exceed 25%. If a quality standard or threshold value is available, the LOQ should not exceed 60 % of the quality standard or threshold value. In general if AM0/AM100 < 0.6 any trend assessment should be based on sampling site level as far as sufficient data are available.

Regularisation

For each monitoring point and for each aggregation period the arithmetic mean of the concentration data is calculated considering the treatment of values below LOQ. Possible aggregation (regularisation) periods are quarterly, half-yearly, or yearly and they should be the same for each monitoring point within a groundwater body that is subject of trend assessment to avoid bias.

Spatial aggregation

The trend assessment method is proposed to be based on the arithmetic mean value at the groundwater body level (*i.e.* the arithmetic mean of the arithmetic means at monitoring point level).

Accessibility of results

The project was finished in December 2001. Reports, data, and a software tool for testing the proposed methodologies are available at the project website (www.wfdgw.net). A final report is published by the European Commission as Technical Report No.1 (European Commission, 2001).

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Keywords: Water Framework Directive, groundwater, trend assessment, trend reversal assessment.

Poster session

Derivation of threshold values for naturally F- and B-rich Silurian-Ordovician groundwater body, Estonia

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Drinking water supply in Estonia is based mainly on groundwater and in many areas, especially in Silurian-Ordovician groundwater body (S-O GWB), the natural concentrations of boron (B) and fluorides (F) exceed remarkably the limit values set for drinking water quality. S-O GWB is an important and often the only source of drinking water in central and western Estonia. It consists of diverse limestone and dolomite with K-bentonite interlayers composed of altered volcanic material. The dissolution of carbonate rocks and clayey K-bentonite beds, providing adsorption and ion exchange sites, are the probable sources of F and B in groundwater.

The results of the hydrogeochemical studies enabled to delimit the F and B anomaly (up to 7.2 and 2.1 mg/L, respectively) in S-O GWB in western Estonia. Groundwaters with high F and B contents are generally Na-Cl-HCO_3 chemical type waters with low Ca concentration. Thus, the chemical type of the groundwater is an important factor controlling the dissolution of F and B in water. The amount of F is proportional to the pH value and the highest F and B concentrations are detected in deep wells, where the groundwater has a long residence time in the host rock (Karro *et al.,* 2006). F exhibits a good relationship (r = 0.70) with the B content, which points to a similar natural origin (marine, volcanic) of those elements.

The threshold values (TV) have been set up for the pollutants in order to estimate the chemical status of groundwater. A methodology for derivation of such environmental thresholds was worked out within the EU 6th FP project "Background criteria for the identification of groundwater thresholds (BRIDGE)". The originally proposed method (Müller *et al.,* 2006), which has been applied, suggests to derive TVs for the following two cases defined on the basis of the ratio between the estimated natural background levels (NBL) and a relevant reference value (REF) - *e.g.* a drinking water standard (DWS) or environmental quality standard (EQS):

Case 1: if NBL < REF then TV1 = (NBL+REF)/2 and Case 2: if NBL ≥ REF then TV2 = NBL.

In case of S-O GWB the receptor is drinking water, thus limit values set by Estonian DWS were used as reference values. The NBLs of the studied substances are derived from the long-term (1988–2006) groundwater monitoring data checked with ion-balance calculations. For TV calculations, a BRIDGE methodology was used for two different NBLs (percentiles 90 and 97.7).

The NBLs for F concentration are 5.5 and 3.6 mg/L (97.7 and 90 percentile, respectively). The NBLs for B content are 1.8 (97.7) and 1.3 (90) mg/L. The corresponding TVs (Case 2) for F are 5.5 and 3.6 mg/L and for B, 1.8 and 1.3 mg/L. The effect of calculated TVs on the chemical status of groundwater body was assessed. Fluoride content is above TV in 33 of 340 monitoring points, if 90 percentile is used for NBL calculations. The B contents exceed the TV only within the range of some percent. Applying the 97.7 percentile for NBL calculations results in 10% of points exceeding the TV in case of B. It means that the content of B is the component that could change the S-O GWB into poor chemical status.

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Keywords: Threshold values, Silurian-Ordovician groundwater body, fluorides, boron.

Water Framework Directive: Groundwater Resources - risk characterisation to classification

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The WFD requires us to assess the status of all groundwater bodies. This assessment will determine whether their overall status is good or poor. The overall classification takes into account both the groundwater body's chemical status (in relation to pollution pressures) and its quantitative status (in relation to groundwater abstraction pressures). Groundwater status objectives set by the WFD rely in part on the protection of, or objectives for, other associated waters and dependent ecosystems. *The objectives for these must be known before groundwater classification can be fully completed*. These associated waters and dependent ecosystems may have different sensitivities to water level and/or pollutants.

A series of tests have been developed for groundwater body classification, based on WFD requirements. Each test addresses one, or more of the criteria that defines good status. For quantitative status, four tests consider the impacts of groundwater abstraction both on the groundwater body and also on the ecological receptors which depend on it. The tests are:

- **Groundwater Body Resource Balance** - where the available groundwater resource is less than long term abstraction, the body will be at poor status,
- **Surface Water Element for Groundwater Quantitative Status** - where groundwater abstraction is causing a surface water body to be at less than good ecological status, the groundwater body will be at poor status,
- **Saline & other intrusions** - where intrusions, caused by abstraction, impact on receptors, the groundwater body will be at poor status,
- **Groundwater Dependent Terrestrial Ecosystems (GWDTE)** - where groundwater abstraction is causing significant damage to a GWDTE, the groundwater body will be at poor status.

Each of the four tests results in a body being defined as at good or poor status with an associated level of confidence (high or low). The assessment is based on the impact of recent actual (RA) rates of groundwater abstraction. The same tests are also carried out using fully licensed (FL) abstraction scenarios to identify the future risk of failing to achieve good status over the 1st River Basin Planning cycle. The final combined quantitative status and risk results are based on the worst outcome from all four tests.

The poster illustrates the progression from characterisation and risk assessment to status assessment for groundwater bodies in England and Wales (UK).

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Keywords: Water Framework Directive, classification, quantitative status.

Water Framework Directive: Groundwater Quality - risk characterisation to classification

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The Water Framework Directive requires that an assessment is made of whether groundwater is meeting its environmental objectives. This includes an assessment of whether groundwater bodies are at good status. For groundwater bodies that are not at good status, we will need to identify the measures needed to improve groundwater quality and restore these bodies to good status.

The first stage in this process is the delineation of groundwater bodies and a subsequent risk assessment to identify those water bodies that are at risk of failing to achieve good status (and their other environmental objectives). For bodies identified as being at risk, the next stage is status assessment (classification), which will need to be completed by 2008 for publication in the first River Basin Management Plan.

The main pressures and risks have been identified for each groundwater body in England and Wales and a series of tests developed to determine whether groundwater bodies will achieve the criteria for good status specified in the Water Framework and Groundwater Daughter Directives. These tests are consistent with the recommendations in the draft EU guidance document on Classification. Assessment of status will rely on appraising a wide range of information on pressures and impacts, including groundwater quality data, to determine whether the criteria for good status are being met.

The chemical classification tests are:

- **Saline & other intrusions** - where intrusions caused by abstraction impact on receptors, the groundwater body will be at poor status;
- **Significant diminution of surface water chemistry and ecology** - where groundwater pollution is causing a surface water body to be at less than good status, the groundwater body will be at poor status;
- **Groundwater Dependent Terrestrial Ecosystems (GWDTE)** - where groundwater pollution is causing significant damage to a GWDTE, the groundwater body will be at poor status;
- **Drinking Water Protection** - where groundwater pollution requires an increase in the level of drinking water treatment, the groundwater body will be at poor status;
- **General assessment of groundwater quality** - where there is widespread pollution of a groundwater body it will be at poor status.

A requirement of status assessment is the derivation of Threshold Values (groundwater quality standards). These values relate to the protection of the individual receptors and so may differ between each of the tests and between groundwater bodies. Threshold Values will be defined for each pollutant that is putting the groundwater body at risk. Where an exceedance of a threshold value occurs, further investigation is carried out before groundwater body status is determined.

To support the classification process the Environment Agency has established a monitoring programme that includes 3,500 boreholes and springs. The results from the monitoring are enabling the Environment Agency and others to refine the initial risk assessments, and identify the main reasons for not achieving good status. This information is also being used to identify the Programmes of Measures needed to restore bodies to good status and ensure that there is no future deterioration in status of bodies that are currently at good status.

The poster illustrates the progression from characterisation and risk assessment to status assessment for groundwater bodies in England and Wales (UK).

Keywords: Water Framework Directive, classification, chemical status.

Water Framework Directive: Case Study – classifying groundwater impact on surface water status

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The Water Framework Directive requires that an assessment is made of whether groundwater is meeting its environmental objectives. This case study describes the method adopted for assessing the impact of pollutant concentrations in groundwater on the chemical and ecological status of surface water.

Where pollutant concentrations in groundwater are elevated above natural background and this polluted groundwater is contributing significantly to a corresponding surface water body failure then the groundwater body will be at POOR status. This is a complex test so a GIS tool was developed to gather the required information and to assess status. The tool guides regional experts through the steps required to assess the impact of groundwater on the ecological and chemical status of surface water bodies over a groundwater body. These steps are detailed below:

- The expert user is first asked to determine the variation in risk and the hydraulic links between groundwater and surface water in each groundwater body. Understanding of groundwater-surface water interaction is limited and so the assessment is based on relatively simple assumptions.
- For those groundwater bodies confirmed as being at risk and connected to a surface water body, the GIS tool displays compiled groundwater monitoring data for the groundwater body. The tool accounts for dilution effects by using an estimate of the contribution of groundwater to the overall flow or volume in the surface water. The expert user can supply further information to take into account attenuation (degradation) potential within the groundwater system where this is known. Using these dilution and attenuation factors appropriate groundwater threshold values are derived from the surface water Environmental Quality Standards.
- The user then screens the individual monitoring points to ensure that they are representative for this test and that any exceedances of Threshold Values indicate pollution impacts. This process removes any elevated concentrations caused by natural conditions. Those groundwater bodies with an exceedance of one or more Threshold Values are assessed as “provisionally POOR” by the GIS tool.
- The GIS tool then looks for an equivalent surface water failure, *i.e.* the same chemical that fails in groundwater must also fail in associated surface waters. If a matching surface water failure is found the groundwater body is at POOR status. Where no matching surface water failure occurs, or where there is no data, the groundwater body is at GOOD status but will remain at risk.
- The user records any additional evidence of groundwater impacts on surface water bodies. For example, the body will be at POOR status if they record evidence of long term (more than 3 years) groundwater impacts on a surface water protected area or impacts that extend over more than 500m length of river.
- The impact of mining on surface water is a major component of this test. The GIS tool checks the national assessment of mining impacts to identify groundwater bodies where pollution from mining activities (current and historical) is causing surface water bodies to fail their environmental objectives. The assessment makes use of a variety of information sources, including mining-related failures of River Quality Objectives, the Coal Authority’s national priority list of sites, and the Welsh Assembly Government’s metal mine strategy. Where there is clear evidence of failures in surface water objectives due to mining the groundwater body will be at POOR status.
- The GIS tool then assigns confidence in the status assessment on the basis of the availability of monitoring data and any supporting evidence. Where there is extensive monitoring in the groundwater body relevant to this test and/or good supporting evidence of impacts on surface water by groundwater pollution then confidence will be HIGH, else confidence will be LOW.

This poster illustrates some of the data available within the GIS tool. By working through the information gathering screens of the GIS tool, the expert user produces an assessment of the impact of pollutant concentrations in groundwater on the chemical and ecological status of surface water.

Keywords: Water Framework Directive, classification, status, groundwater – surface water relationships.

Slovenian groundwater quantitative status in the period 1990-2006

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The groundwater quantitative status of the 21 groundwater bodies in Slovenia was defined in the national legislation with the level of the groundwater use impact on the groundwater body through the abstraction of significant quantities. This has to be reflected as a change of piezometric groundwater level, groundwater discharge and the direction of flow (Official Journal of the Republic of Slovenia, no. 65/2003).

With respect to the type of porosity and the availability of hydrological data covering the assessment period, two methods were selected for the assessment of the quantitative status of groundwater. The first method analysis of the impact on quantitative status was carried out for five water bodies with prevailing aquifers with intergranular porosity, on the basis of determining the critical groundwater levels and the assessments of trends. A regression line was calculated for the mean annual averages of the groundwater levels and its extrapolation was given for the period of the forecast. The statistical significance of the trend was tested using Spearman's rank correlation coefficient and the Student t statistics at the level of 95%.

Second method analysis of the impact of significant pressures on the quantitative status of groundwater bodies was carried out for sixteen water bodies with prevailing aquifers with karstic, fractured, intergranular and mixed porosity based on the method of establishing renewable quantities of groundwater. The method of assessing the quantitative status is based on the analysis of data sets on the discharges at gauging stations at the intersections of the outflow from the groundwater body and on the assessments of the water balance of catchment areas. The procedure based on determination of the low flow statistics in the measurement cross-section, from which the available groundwater quantity can be calculated. Wundt's method (Holler, 2004) was applied though, taking into account the supplementation by Kille (Deutschen Geologischen Gesellschaft, 1977), we used different measures of central tendency. The impact of significant pressures on the quantitative status of the groundwater bodies is calculated by subtracting the used portion from the entire available quantity or as a coefficient between the abstraction and the available quantity of groundwater expressed in percentages.

The assessed available groundwater quantity in Slovenian groundwater bodies in the period from 1990 to 2001 amounts to 1.43 10^9 m^3 per year, and 727.4 m^3 per capita per year respectively. In the year 2002 abstracted groundwater (0.23 10^9 m^3 per year) represents about 15 percent of the available groundwater reserves in Slovenia. For all Slovenian groundwater bodies quantitative status was assessed as good (Andjelov *et al.,* 2006). Poster represent the difference in assessment results of groundwater quantity status in Slovenia in period 1990-2001 and period 1990-2006.

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Keywords: Water Framework Directive, groundwater quantitative status, Slovenia.

Upgrade of the Romanian Monitoring Network according to the WFD requirements. How the European guidances where applied and what future changes are needed. Some examples

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Romania have an historical groundwater monitoring starting from the '60-ies of the last century. The monitoring was focused mainly on the shallow aquifers, the number of monitoring wells for these aquifers being over 5,000. Meanwhile, the deep aquifers where somehow neglected, even the largest part of the exploited groundwater comes from these aquifers. Only 550 deep observation wells (over 50 m deep) where drilled between 1970 and 2005. Moreover, an important number of the deep monitoring wells have no selective screening.

So, the design of the Romanian groundwater monitoring network was, in fact, an upgrade of the oldest National Hydrogeological Network according to the WFD requirements and following the EU CIS "Groundwater Monitoring Guidance". The main problem was to find enough appropriate monitoring sites for the deep groundwater bodies, but also for the mountain karst water bodies.

The monitoring results from the first year of network operation raised some problems and some future changes will be needed. The paper gives some examples from the Crişuri, Banat and Dobrogea hydrographic spaces of how the monitoring was upgraded, the problems encountered and what future changes are needed.

Keywords: Water Framework Directive, Monitoring, Romania.

Chemical Status Assessment of Groundwater Bodies in the Czech Republic

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Chemical status assessment of the groundwater bodies is an important part of the implementation of the Water Frame Directive (WFD) and also the new Groundwater Directive. It is also unnecessary part of the River Basin Management Plans (RBMPs).

Due to the timetable adopted in the Czech Republic, during period July 2008 - December 2008, first drafts of RBMPs have been opened to public consultation, which implied their finalization on early April 2008.

Based on the results of river basins characterization and the risk assessment, 35 parameters were decided to be use for purposes of the chemical status assessment of groundwater bodies. For these 35 substances and parameters, threshold values and quality standards (nitrates and pesticides) were established.

First threshold values establishment was made on the national level. This means that the same threshold value is applicable for all groundwater bodies. Threshold values for synthetic substances, except sulphates and metals, were decided to be the same value as limit for dinking water. Threshold value for sulphates and metals was set up at the natural background level.

Initiate phase of chemical status assessment was made for individual monitoring sites separately for each parameter. Due to the frequency of measures (2 measures/year); the limit value was compared with the mean value in 3-year period (2003-2006). Apart from monitoring results, results from indirect assessment were taken account, *e.g.* impacts of significant anthropogenic pressures. The indirect assessment plays a key role especially for point sources of contamination. This is because the monitoring network has been created stepping aside from close proximity of possible point source influence. This fact implicates the insufficient representation of results of groundwater monitoring assessment for this kind of source contamination. Chemical status assessment was firstly made on small parts of groundwater bodies. Subsequently, the synthesis of chemical assessment was composed. The percentage of total area with the unsatisfactory status was used as a basic criterion.

For purposes of the Programs of Measures (RBMPs), the chemical status assessment was divided into 3 categories - good, potentially bad and bad. The second category was used for those cases where the chemical status was established as unsatisfactory, but without clear and concrete reasons (impossibility of setting up the specific programs of measures)

Identification of the significant upward trend assessment was also part of the chemical status assessment using the 6-years period (2001-2006). In accordance with the WFD the significant trends were marked with black point.

Results from chemical status assessment made on River Basin District sub-unit are shown on the figure.

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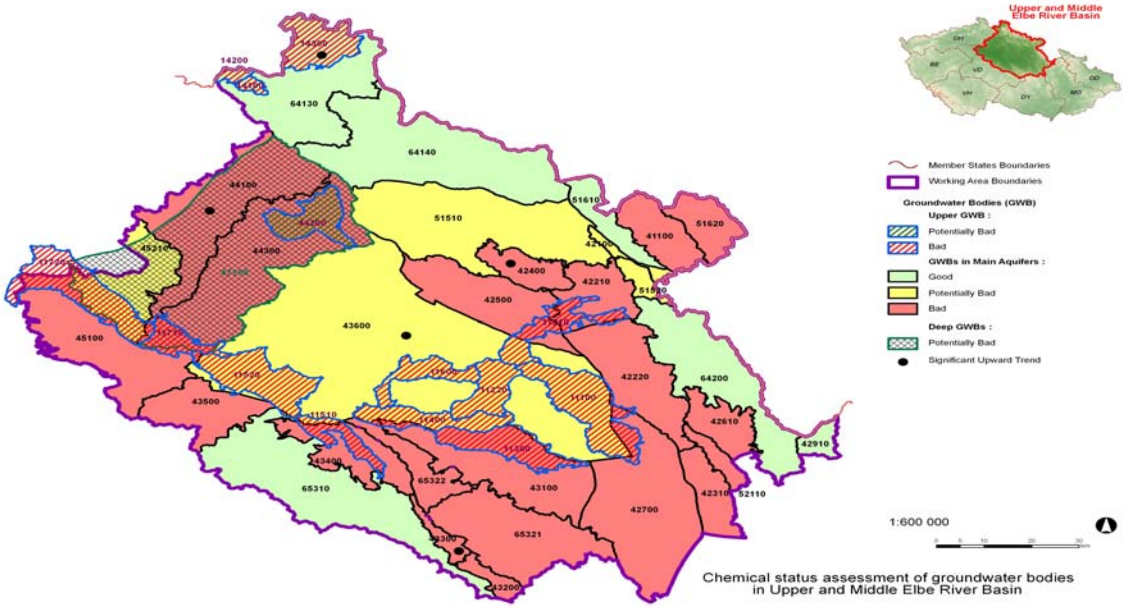
Keywords: Chemical status assessment, Water Framework Directive, Groundwater Directive, threshold values, groundwater bodies, nitrates, pesticides, monitoring, point source of contamination.



Chemical status assessment of groundwater bodies in Upper and Middle Elbe River Basin

The challenge of deriving threshold values and background levels for groundwater in Denmark

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Selected examples of groundwater threshold values and background levels derived in the Danish river basin management plans according to the Water Framework and Groundwater Directives are presented below.

Groundwater threshold values and status assessment based on Environmental obejctives for associated estuaries

In the Horsens Fjord estuary, the coastal waters suffers from eutrophication and thus the river basin management plans require reduction of nitrate and phosphorus loads as the measure to reach "good status". Identification of pressures has taken place through evaluation of data from the national monitoring programmes. The pressures are *e.g.* expressed as annual nitrogen (N) and phosphorus (P) loads to the estuary (*e.g*. ton/year). The river basin management plan estimate that the annual N load to the estuary needs to be reduced from about 980 ton to 450 ton/year *i.e.* by 54% to meet the environmental objective. The groundwater discharge currently has a mean nitrate concentration of 18 mg/l as estimated from baseflow measurements. If we assume that the groundwater nitrate input has to be reduced by the same relative amount, and that no attenuation and dilution is taking place in the groundwater body before discharge the groundwater threshold value will be 8 mg/l. However, a combined dilution and attenuation factor of ~0.5, which was estimated for the Odense Pilot River Basin (Hinsby *et al*., 2008) may also be applicable for the catchment of the Horsens Fjord Estuary. This seems to be a reasonable assumption as the average and median value of nitrate concentrations in streams in 86 Danish catchments is ~25 mg/l (Kronvang *et al.,* 2008) and ~50 mg/l in oxic Danish groundwater (Thorling, 2007). Therefore a more reasonable estimate of a nitrate threshold value is probably 8/0.5 = 16 mg/l for the shallow oxic part of the groundwater bodies in the river basin. This value is similar to a groundwater threshold value for nitrate of 18 mg/l derived for the Odense Pilot River Basin (Hinsby *et al*., 2008). The data presented above clearly indicate that the majority of the oxic Danish groundwater has poor status due to nitrate pollution based on environmental objectives for associated surface waters.

The transport dynamics for phosphorus are currently not well understood. This is illustrated by the fact that groundwater loads often are estimated to be negative, in contradiction to the relative high phosphorus loads calculated from the monitoring data of the streams. A need for new and more integrated monitoring strategies that take into account groundwater/surface water interaction and water and pollutant fluxes can thus be identified from the first experience with the new planning tools derived from the EU Water Framework and Groundwater directives.

Background Values

Systematic monitoring of groundwater in Denmark has produced a considerable amount of data during the last 20 years. Most of the monitoring screens are placed in farmlands, a few in rural and urban areas and only a limited number in unaffected surroundings such as extensive plantations and forests. When determining (natural) background values the task at hand is to single out data not affected by human activity. Müller *et al*. (2006) suggests to use data sets with nitrate less than 10 mg/l to approximate (natural) background levels for the other solutes. Here we have used 2 mg/l for Danish groundwater corresponding to the 90th percentile of the median of all screens in the oxic zone (O_2 > 1 mg/L) outside agricultural areas. This background value is similar to what was estimated by Hinsby and Rasmussen (2008) for a specific groundwater body. Preliminary background values has been calculated for the majority of main components and inorganic trace elements for the greater part of the aquifer rocks and sediments forming the ground water bodies of Denmark. Selected results are presented below. In some groundwater bodies (natural) background levels may breach drinking water standards *e.g.* for arsenic.

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Threshold values: the Dutch approach

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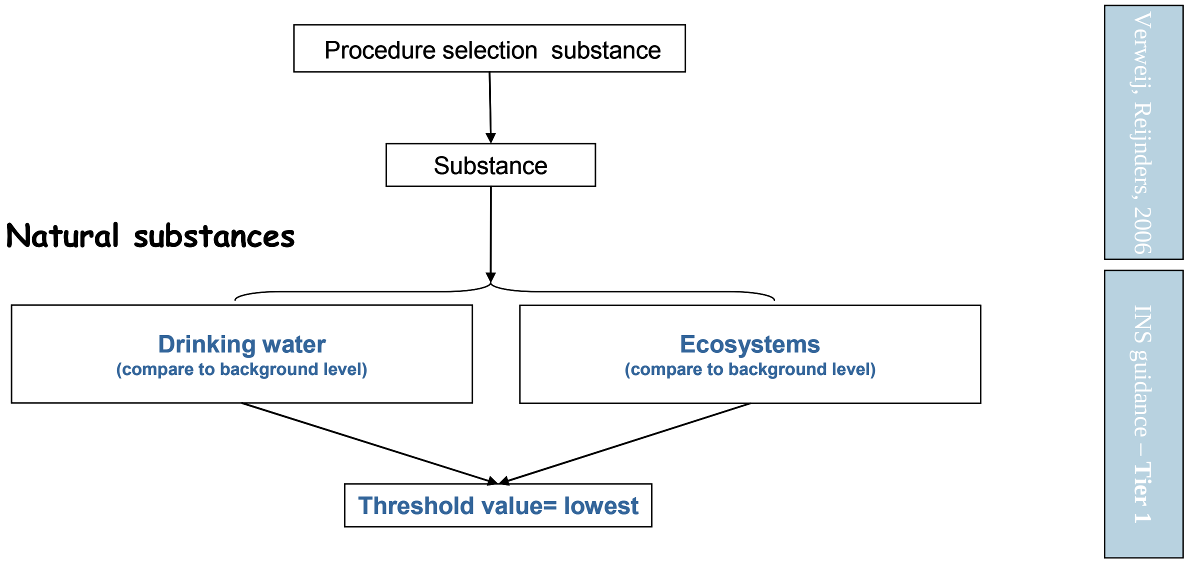
The Groundwater Directive (GWD; EU, 2006) establishes measures to prevent and control groundwater pollution. These measures include criteria for the assessment of good groundwater chemical status. These criteria consist of groundwater quality standards (currently for nitrates and pesticdes) and threshold values. Threshold values can be established by Member States. The GWD gives some clues as to how to establish threshold values, but there also is freedom for Member States to choose their own approach. This paper deals with the way threshold values were derived for the Netherlands. Topics to be dealt with include:

- choice of receptors to be included;
- specific approach for some toxic substances (Added Risk Approach);
- determination of background levels (why and how);
- choice to derive threshold values per groundwater body;
- choice not to include attenuation and dilution yet;
- why no threshold values were derived for some of the substances mentioned in Annex II, part B.

The basics of the procedure are explained in figure 1 (to be translated).

The work is based on scientific work at our institute. It was formulated as a recommendation to the Dutch Ministry of the Environment. Not all recommendations were accepted, so the formal Dutch policy may be different at certain points from our recommendations.



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Keywords: Water Framework Directive, groundwater, threshold values.

Natural background values and threshold values required by the groundwater directive, applicable for Banat hidrographical area

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According to the new Directive 2006/118/EC on the protection of groundwater against pollution and deterioration, by the end of 2008, Members States will have to establish groundwater bodies' threshold values, for good chemical status assessment.

The Banat hidrographical area is limited in the north part by the Mures River and in the south part by Danube, until the junction with Cerna, with 18,393.15 km^2 total surface, that represents 7.7% from Romanian territory. The Banat District is situated in the south-west part of Romania, between 20o18`and 22o52`east longitude and between 44o26`and 46o08`north latitude (Figure1 Banat hidrographical area). The rivers that collect waters from this area have characteristics specific to the southwest part of the country, but in the same time they are individualized like river systems with specific characteristics to each river basin. The human influence has an important role over the water flow in this space, some of the hydromechanics' facilities are been used for more than 250 years (Romanian WFD Art.5 Report, 2004).

In the year 2004, Romania deliniated the groundwater bodies based on the following criteria: geology, hydrodinamics, waterbody status: quality and quantity (Figure 2: Groundwater bodies).

Threshold values (TV) are derived for a regional area and not for a site specific or local area. Romania decided TV to be derived on the scale of groundwater bodies. In the year 2007 Banat Water Directorate, together with Grontmij Nederland bv, Witteveen+Bos and Ecorys, started the project "Establishing measures to rehabilitate the polluted groundwater altered due to landfill, in order to reach the environmental objectives required by the Water Framework Directive and the Groundwater Directive". The project is funded by EVD (Agency for International business and cooperation) within the Netherlands Pre-accession Programme – Environmental Facility. Within the project, Natural Background Levels (NBL) and Threshold values (TV) for groundwater body GWBA03 were derived (Figure 3: Groundwater body GWBA03), considering this groundwater body as a pilot for Romania. The TV is derived using the NBL as a starting point and these values are compared with a standard or reference value. The reference values to be selected for Romania are the drinking water standard and the surface water standard (Table 1: diferent standards in Romanian legislation).

For the derivation of NBL and TV a database has been created including all monitoring data. (Figure 4: Database). The database includes all available monitoring data: a list of wells, observations and substances, including: local well name, official well name and number, x and y coordinates, screening of the wells (upper and lower level), official well name and number (EUCD-GWST), year of sampling, sampling date, sampling technique (bottle, pumping, others), analyzing results for all substances (like pH, Na, K, NH_4, etc.). The database includes data from the years 1976-2007. Grontmij Nederland elaborated a step by step procedure to derive TV, based on the draft EU-Guideline on Threshold Values. The obtained results are described in the Tabel 2: Derivation of TV. Romanian guidelines developed includes a full description of the methodology and techniques to be used.

What is necessary to do after this? To implement the new Groundwater Directive 2006/118/EC and the groundwater aspects of the Water - Framework Directive it is necessary to get experienced in implementation on local scale. DAB completed the derivation for the pilot groundwater body GWBA03, now the knowledge should be extrapolated to all other groundwater bodies in Romania. This will be the basis to develop the program of measures in next phase.

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Keywords: Romania, groundwater bodies, Groundwater Directive (2006/118/EC), Water Framework Directive, natural background levels (NBL), threshold values (TV).

Threshold values establishment for groundwater bodies where natural contamination occurs: a methodological case study in Central Italy

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The WFD (2000/60/EC) requires Member States to periodically assess the “Status” of water bodies (at the beginning of each river basin management plan (RBMP) cycle, that is every six years). The “Status” is to be assessed against predetermined quality criteria referred to as “Threshold Values”. Concerning groundwater bodies, the GWDD (2006/118/EC) points out that a Threshold Value (TV) should be determined for pollutants causing groundwater bodies, or associated surface water bodies /terrestrial ecosystems, to be characterised “at risk”. A minimum list of pollutants is given by the Directive.

However, the GWDD doesn’t provide a formal methodology on the TVs establishment. A tiered approach has been developed by the EU research project “BRIDGE” (Background cRiteria for IDentification of Groundwater thrEsholds), based on the knowledge of the nature of the final receptor at risk. The first tiers take account of the natural background level (NBL) and refer to existing standards or reference values for substances/pollutants. Further tiers allow to take into account dilution and attenuation processes. Deciding on a threshold requires knowledge on both the intrinsic properties of the potential pollutants and on the hydro-geological and biogeochemical characteristics of the media through which they move.

In this paper an example of application of the Bridge methodology in a mainly volcanic study area in Central Italy (5,500 km^2) is described, where natural contamination due to arsenic, vanadium, fluoride and, locally, chloride occurs (Vivona *et al.,* 2007); hence the natural background levels for these substances should be properly assessed in order to correctly establish pertinent threshold values as requested by the GWDD (Art.3). Moreover nitrate and chloride concentration along the coastal area is high because of anthropogenic activities and seawater intrusion.

Possible alternative choices in the procedure application to a real world study case are discussed, and results on TV establishment are described.

As a main outcome of the study, the importance of the correct definition of the hydro-geological and hydro-geochemical setting of the area is enhanced, underlying the key role of groundwater bodies delineation in the evaluation of ground water chemical status. The importance of the correct design of the monitoring network is also enhanced.

The suggested Bridge pre-selection of samples, by using thresholds for NO_3 and NaCl concentration, revealed critical because it can dramatically diminish the number of samples especially where the human presence overland is widespread, Hence the statistics used for the NBL assessment and TV establishment could be meaningless and distinction between natural background and anthropogenic pollution cannot be guaranteed.

In the study case different options on groundwater bodies delineation and pre-selection thresholds for nitrate concentration are compared and the results in terms of significance of the resulting NBL are discussed.

In several sampling points the concentration of the four substances (As, V, F, Cl) considered exceeds the TVs resulting from the procedure application. However, the status of ground water bodies resulted “good”, when the criteria of the exceedence calculation, as a percentage of the number of points exceeding the TVs (Grath and Ward, 2007), is applied separately to each contaminant.

As concluding remarks, some critical aspects deserve particular attention: 1) the variability of the concentration of the geogenic substances with respect to TVs derivation; 2) the possibility of using schemes with multiple substances for execeedences calculation; 3) the significance/value of each individual monitoring point, in which TVs are exceeded, when assessing the status of the overall groundwater body.

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Keywords: Water Framework Directive, groundwater - natural background level - threshold value.

Towards an Italian approach for the derivation of groundwater threshold values

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The new Groundwater Directive 2006/118/EC states that MS shall define threshold values for the pollutants that characterise groundwater bodies at risk of not achieving the good chemical status objective. Guidelines for the establishment of threshold values are included in the annex II of the Directive. The derivation of threshold values for groundwater bodies is traditionally based on the risk for human health due to the consumption of drinking water. This criteria can be particularly appropriate for the specific areas designed for drinking water purposes, but it doesn't take into account the interaction that often occurs between ground and surface water bodies. The pollutants in groundwater bodies can be transferred in surface water bodies and can cause ecotoxicological effects in the aquatic ecosystems. The Italian approach currently in discussion takes into account, in compliance with the criteria set in the Groundwater Directive, also the ecotoxicological risk for aquatic ecosystems in the case of interaction between surface and groundwater bodies; for some pollutants the threshold values are those defined in the new Directive proposal that set environmental quality standard for surface water bodies; dilution factors should be taken into account. For heavy metals and pollutants of natural origin the local background levels and hydrogeological characteristics shall be considered.

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Keywords: Threshold values, human health, ecosystems, groundwater.

Quantitative status of the main groundwater bodies in the Upper Silesian Region in Poland

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Parametres describing quantitative status of groundwater bodies

In order to assess and describe the quantitative status of the main groundwater bodies the specific sustained resources have been analysed. The specific sustained resources ($m^3/d/km^2$) is the amount of naturally occurring groundwater in cubic meters per day, which can be withdrawn from an area of one square kilometre of an aquifer, without causing environmental damage.

Description of the Upper Silesia

Upper Silesia located in the southern Poland, is a big metropolitan area which consists of 37 cities (population nearly 4 mln).The region has become highly urbanized and industrialized causing a big needs for drinking and industrial waters. Mining activities of Carboniferous hard coal deposits have been conducted for over 200 years, now there are 30 operating and 32 abandoned coal mines in this region.

Groundwater bodies in the Upper Silesia are of Carboniferous and Permian, Triassic, Jurassic, Cretaceous, Neogene's and Quaternary age. The resources of these aquifers are dependent not only on typical hydrogeological parameters and recharge conditions but also on the degree of the depletion of these aquifers by industrial and municipal water supplies in the numerous cities and settlements of high population and on the degree the mine drainage by underground and opencast mining. The resources have changed for the last twenty years due to mine abandoning and large economic changes in the region.

Quantitative status of groundwater bodies in the Upper Silesia

Basing on 28 map sheets of the Hydrogeological Map of Poland at a scale 1:50,000 as well as on the several reports on the groundwater resources and discharge in this region, the verified resources of the main groundwater bodies in the Silesia Region are presented on the poster along with the trend of changes caused by above-mentioned factors. Waters pumped from the active and abandoned coal, lead and zinc mines as well as sand pits have also been considered, which can be the valuable sources of usable waters and they are used in very small degree at present.

The estimated total sustained resources of the Quaternary, Neogene's, Cretaceous, Jurassic, Triassic and Carboniferous groundwater bodies in the Silesia Region are of 759,200 m^3/d, and the average specific sustained resources are 213.7 $m^3/d/km^2$. Nearly 94% of these resources are in the Quaternary, Triassic and Carboniferous bodies (which cover 87% of the area).

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Keywords: Groundwater, groundwater body, aquifer, water supplies, water resources.

Determining Natural Background Values with Probability Plots

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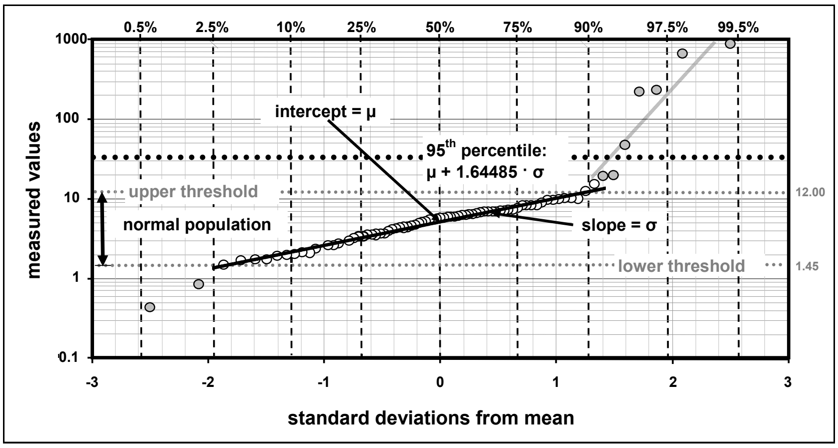
The probability plot is essentially a cumulated frequency plot with the discrete data plotted against their cumulative percentage (fig. 1, upper horizontal axis), distorted in a way that the data plot on a straight line. The resulting trend line's intercept (cumulative sum = 50%) is equivalent to the mean and its slope to the standard deviation of the underlying population. Deviations from linearity or presence of inflection points indicate mixed distributions or other deviations from normality. The plot allows an excellent and fast optical determination whether a sample is obeying a certain distribution law or a mixture of distributions is present. According to Sinclair (1976), overlapping populations obey to the formula $P_{(A+B)} = f_A \cdot P_A + f_B \cdot PB$ (with $P_{(A+B)}$ being the cumulative probability of the combined subpopulations A and B, P the cumulative probability and f the fraction of total data of the respective subpopulations). Therefore, it is easy to derive the respective subpopulation's statistical distribution parameters and so to identify normal and anomalous components.

The Excel-tool in an iterative way fits a trend line to the portion of the distribution identified as background population. Based on the resulting distribution parameters, the 90th or the 95th percentile of the normal population is calculated as background level. Goodness of fit for the background population is tested by the comparing correlation coefficient to the correspondent critical values (Ryan & Joyner, 1976). Additionally, the d'Agostino-Pearson-Test, a strong normality test is also calculated.

Values below detection limit can also be taken into consideration. Even for data sets with a considerable proportion of values below detection limit (up to 40 - 50%), reasonable values for mean and standard deviation can be calculated, as long as there is no reason to reject the basic assumption of normality for the distribution of the data set.

Fig 1: Filtering of anomalies, fitting of line of best fit to the remaining data and derivation of their relevant distribution parameters (μ = mean, σ = standard deviation).



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Keywords: Background value, probability net, Excel.

Characterisation of groundwater chemistry in Sweden based on geographic region and environmental factors

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Information on chemical composition of groundwater is used in a variety of situations, *e.g.* drinking water quality and environmental monitoring. To ensure a sustainable use and protection of groundwater by fulfilling the requirements of the Water Framework Directive (WFD), more analyses of the chemical composition of groundwater reservoirs is needed for the chemical characterisation and methods to facilitate required monitoring must be used.

The aim of this project is to analyse the possibilities to group groundwater reservoirs, in coarse Quaternary glaciofluvial deposits, based on both various environmental factors and the chemical properties of their neighbouring groundwater reservoirs. The chemical parameters that have been used in the characterisation are Conductivity, pH, Sulphate, Calcium, Magnesium, Sodium, Chloride, Nitrate, Potassium and Fluoride. The environment factors included are the area, thickness and altitude of the groundwater reservoirs as well as groundwater recharge rates and the average temperature and precipitation of surrounding areas.

We found that there are good possibilities to group groundwater reservoirs in regions of Sweden when using existing analysis data as input. These regions where groupings of groundwater reservoirs are applicable, as well as where not applicable, have been identified and a spatial dataset representing them have been created.

The results from comparing groundwater chemical composition with environment factors indicates that there are strong relationships between chemical composition of the groundwater and several environmental factors. Together with the dataset of where grouping of groundwater reservoirs are applicable the relationships can be used to develop a method of how to estimate groundwater reservoir chemical composition where scarse chemical analysis data are available and/or retrievable.

Further testing to estimate chemical composition of groundwater reservoirs in the ongoing hydrogeological mapping at the Geological Survey of Sweden utilises the opportunity to improve sampling strategy and *e.g.* use existing boreholes for sampling. By developing a method to estimate groundwater chemical composition we anticipate that we have started to develop a cost and work efficient way to estimate the chemical composition of groundwater reservoirs and give a basis for status classification and further monitoring where required.

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Keywords: Water Framework Directive, Sweden, groundwater, Quaternary glaciofluvial deposits, grouping.

Influence of the data aggregation method on the chemical status of groundwater bodies

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Water Framework Directive1 (WFD) requires chemical and quantitative status assessment of groundwater bodies with the challenging aim of achieving good status of all waters by the end of 2015. The criteria for chemical status assessment of groundwater bodies are precisely defined in the new Groundwater Directive (GWD)[2] which for the first time defines European-wide quality standards for the most problematic parameters in groundwater – for nitrates and pesticides. EU-wide quality standards are the basis for the common criteria and finally comparable groundwater chemical status assessment in all European countries. For the effective implementation of both directives, different guidelines were prepared which help to common understanding and exchange of best practices between Member States.

General requirements for good groundwater chemical status are defined in Annex V of the WFD. Groundwater body has good chemical status when there is no indication of saline intrusion, when the pollutants do not exceed quality standards or threshold values and do not cause significant deterioration of the ecological and chemical quality of associated surface water bodies nor cause the damage to terrestrial ecosystems which are dependent on the groundwater body. The new GWD defines more precisely that in the case of the exceedance of quality standards or threshold values in one or more monitoring points, member states shall estimate the extent of the groundwater body pollution and assess the actual risk for the overall groundwater body and its usages. In assessing of the status of groundwater body as a whole, the results of individual monitoring points shall be aggregated in a proper way.

In 2005, in Slovenia, 21 groundwater bodies were defined. In the poster, different aggregation methods[4,5] (arithmetic mean of groundwater body and percentage of monitoring points exceeding quality standard, percentile, upper confidence limit of arithmetic mean, weighted arithmetic mean) are compared for the general quality assessment of some Slovenian groundwater bodies. The status compliance assessment is carried out using data of surveillance and operational monitoring collected in the last years. The assessment is limited to the nitrates and pesticides, most problematic parameters in groundwater in Slovenia. Compliance checking is made by comparing results of different aggregation methods with EU wide quality standards, prescribed in new GWD. It is presumed that all other relevant classification tests[3] (saline intrusion, influence on the quality of surface water, etc.) result in good status. The results show that the use of different data aggregation method can strongly affect the final groundwater body chemical status, especially when the results are close to quality standard.

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Keywords: Groundwater, chemical status, statistical aggregation method, groundwater body, nitrates, pesticides.

Conceptual Models of Groundwater systems
Definition, example and availability in the Netherlands

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Introduction

The Groundwater Directive (2006/118/EC) and several EU guidance documents[2] recommend the use of conceptual models in different parts and phases of the implementation of the Water Framework Directive. In literature different definitions of the term conceptual models are given. Even the EU guidance documents on the implementation of the WFD[3] do not use the same definition, although the different definitions are quite similar. This study intends to provide a proper definition of the term conceptual model.

Definition of the term conceptual model

A conceptual model is a stage in model development and usually will be used in setting up a monitoring network, deriving threshold values, determining the status of groundwater bodies, etc.

Definitions used in the EU guidance documents are:

- Guidance Document No. 7, Monitoring: A conceptual model/understanding is a simplified representation, or working description, of how the real hydrogeological system is believed to behave.
- Guidance Document No.15, Guidance on Groundwater Monitoring: Conceptual models/understanding are simplified representations, or working descriptions, of the hydrogeological system being investigated.
- Guidance Document No. 17, Preventing or Limiting Direct and Indirect Inputs: A conceptual hydrogeological model (CHM) is the schematisation of the key hydraulic, hydro-chemical and biological processes active in a groundwater body.

Also in literature no general definition is found. For clarity and mutual understanding a single, fixed definition of a conceptual model should be developed and decided upon. There are different types of models, for different purposes (Min, 2000). Models used to think, and to discuss about the ideas they are based on, are called conceptual models.

In our opinion the following definition would do: **A conceptual model is a qualitative, schematised representation of (part of) reality.**

All the definitions in the guidance documents do fit in this definition. In some guidance documents quantitative elements are added to the idea of conceptual models. Remarkable, because a typical basic feature of conceptual models is that the variables are not yet operationalised (*i.e.* not quantified, not assigned a value). There are several other models which do have quantified elements a.o. mathematical models, black-box models, scale models, analogue models. When the term conceptual model is used for a model with quantitative elements, at least the name of the model should be specified (*e.g.* conceptual model of the Central Rhine Basin).

Elements of a conceptual model

Usually a conceptual model consists of three elements, described at an abstract level (van Baest, 2004):

- the research element, *i.e.* the independent variable(s) subject to investigation;

[2] no 3, Pressures and Impacts; no 7, Monitoring; no 15, Groundwater Monitoring ; no 17, Guidance on Preventing or Limiting Direct and Indirect Inputs; Towards a guidance on Groundwater Chemical Status and Threshold Values (version 3.1, 27-06-'08); Concept on Groundwater Trends (version 2.0, 27-06-'08).
[3] not taking into account the guidance documents that are in concept on the moment of writing.

- the concepts *i.e.* theoretical variables, all relevant variables with respect to the investigation;
- the hypotheses (*i.e.* relations between concepts).

A conceptual model is built by identifying the above mentioned items.

Take for example an investigation into the diminution of variety of species in a nature reserve:
- the research element is variety of species;
- theoretical variables are, amongst others, changes of seepage, water table, permeability of the soil, natural recharge, discharge, chemical substances and nutrients in the nature reserve;
- hypotheses are the relationships supposed to exist between the above mentioned variables and between the variables and the research element.

Availability in the Netherlands

In the Netherlands the conceptual hydrogeological model at the national scale is well known (Figure 1). However for issues at the local scale the national conceptual model is of insufficient detail. More detailed conceptual models are not available on paper or in digital format. Local conceptual understanding is available in the minds of (ground)water managers though. To preserve and elaborate on this conceptual understanding, documentation, on paper as wells as in digital format is considered to be very valuable.

Figure 1. General conceptual hydrogeological model of the Netherlands, E-W cross-section, looking southward (note that the vertical scale is relatively large compared to the horizontal scale).

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Keywords: Water Framework Directive, Groundwater Daughter Directive, Conceptual Model.

Implementation of the Groundwater Directive in Germany

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The implementation of the Groundwater Directive in German law is still under debate and some aspects may be modified during the ongoing discussion. Generally groundwater is seen as a protected asset in its own right in German law.

More than 70% on average - in some of Germany's Federal States 100% - of drinking water stems from groundwater, making it Germany's most important drinking water resource. However, groundwater is also an important habitat possessing great biological diversity. It is therefore of great importance for sustainable development and safe future water supplies to ensure comprehensive precautionary protection for groundwater all over the country.

Establishment of threshold values

In Germany threshold values will be established at the national level. This ensures a uniform and comparable procedure in all of our Federal States, reduces the administrative burdens and leads to more cost efficiency. Moreover national threshold values are the basis for further legal regulations (*e.g.* waste management or soil protection).

The German methodology for deriving threshold values for groundwater follows the concept of so-called insignificance thresholds (Lawa, 2004). This takes into account health protection requirements as well as requirements for protection of aquatic and terrestrial ecosystems. The threshold values derived apply in principle to all groundwater bodies. The complex and time-consuming approach of deriving individual threshold values for each individual body of groundwater can therefore be dispensed with. The derivation is primarily based on human-toxicological and ecotoxicological aspects. Threshold values will be set according to the lower values of the human-toxicological and ecotoxicological derivation respectively. For the substances of Annex II of the Groundwater Directive the following threshold values will be established:

Substance	National Threshold Value		Substance	National Threshold Value	
Arsenic	10	µg/l	Ammonium	0.5	µg/l
Cadmium	0.5	µg/l	Chloride	250	mg/l
Lead	7	µg/l	Sulphate	240	mg/l
Mercury	0.2	µg/l			

Substance	National Threshold Value	
Total content of trichloroethylene and tetrachloroethylene	10	µg/l

Locally, natural background concentrations may be higher than the threshold values. For affected groundwater bodies, new threshold values can be derived on the basis of the local natural background concentrations, corresponding to the 90% percentile of the distribution of natural background levels.

Status assessment and land use

For the assessment of the chemical status of groundwater land use plays an important role. Within each groundwater body the area of land occupied by the land use types "forest", "meadows", "farmland", "settlements and industry" as well as "specialised crop" is determined. If quality standards or threshold values are exceeded under more than one third of one of these types of land use and the contaminated area is larger than 25 km², the groundwater body will be classified as having poor status. For small groundwater bodies (< 75 km²) the contaminated area has to be smaller than 1/3 of the total area of the body.

Trend assessment

Trend assessment has to be carried out for all groundwater bodies at risk. Additionally trend assessment should be done at sites where the concentration has reached 75% of the relevant threshold value. Trends are calculated as a linear regression. The calculation is carried out stepwise for sliding periods of six years.

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Keywords: Groundwater Directive, groundwater, implementation in Germany, threshold value.

SESSION 2 – Programmes of measures and risk assessment

En plus d'une première évaluation du bon état des masses d'eau souterraine, les plans de gestion que les États membres publieront en 2009, doivent comprendre des programmes de mesures visant à respecter les objectifs environnementaux de la DCE. Cette session a pour principal objectif d'échanger des expériences sur la mise en place des mesures (difficultés rencontrées, évaluation de leur efficacité, coûts, etc.). Les discussions porteront en particulier sur l'évaluation du risque de contamination des eaux souterraines et les programmes d'action de lutte contre les pollutions diffuses et ponctuelles. Les recommandations de la Commission Européenne dans ce domaine seront présentées. Des cas d'études et des présentations de mesures menées à l'échelle locale devraient permettre de compléter ce tableau et d'alimenter les discussions par des cas concrets. Ceci devrait en particulier permettre d'identifier les difficultés potentielles rencontrées par les États membres à l'échelle locale. Les domaines dans lesquels les posters sont attendus sont : mesures et actions menées pour réduire la pollution diffuse et ponctuelle des eaux souterraines (actions menées à l'échelle locale comme à l'échelle du district hydrographique), évaluation du rapport coût-efficacité des mesures, surveillance de l'efficacité des programmes de mesures, gestion quantitative des eaux souterraines (article 11 de la DCE), gestion des zones protégées (écosystèmes terrestres dépendants des eaux souterraines, eaux souterraines utilisées pour l'alimentation en eau potable, etc.).

In addition to the first assessment of groundwater bodies good status, the 2009 river basins management plans (RBMP) must includes a programme of measures to reach the Water Framework Directive (WFD) objectives.

This session aims at exchanging proposals, experiences and difficulties on the implementation of efficient measures which will lead to the achievement of the WFD environmental objectives. This should include discussions on groundwater risk assessment, measures to reduce groundwater diffuse and point source pollutions. CIS guidance documents presenting recommendations from the European Commission to member states will be presented. Case studies and local experiences will complete the discussion and provide concrete and field experiences including difficulties met by the member states.

In this session, posters are particularly expected in the fields of: measures and experiences to reduce groundwater diffuse and point source pollutions (at the local level as well at the river district level), assessment of measures cost-efficiency, groundwater quantitative management (WFD article 11), management of protected areas (groundwater dependent terrestrial ecosystems, drinking water protected areas, etc.).

European regulatory framework of integrated groundwater management. Theory versus realities

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Introduction

Groundwater is a "hidden resource" which is quantitatively much more significant than surface water and for which pollution prevention, monitoring and restoration are more difficult than for surface waters due to its inaccessibility. This "hidden" character makes it difficult to adequately locate, characterise and understand pollution impacts. This often results in a lack of awareness and/or evidence regarding the extent of risks and pressures. Recent reports, however, show that pollution from domestic, agricultural and industrial sources is, despite the progress in some areas, still a major concern, either directly through discharges (effluents), indirectly from the spreading of nitrogen fertilisers and pesticides or through leaching from old contaminated industrial or waste disposal sites (*e.g*. landfills, mines, heavy manufacturing industry, etc.). While point sources have caused most of the pollution identified to date, there is evidence that diffuse sources are having an increasing impact on groundwater. For example, nitrate concentrations currently exceed the nitrate guideline values in around one third of groundwater bodies in Europe.

The EU regulatory framework for groundwater started life at the end of the 1970s with the adoption of the directive on the protection of groundwater against pollution caused by certain dangerous substances (European Commission, 1980). This Directive provides a groundwater protection framework that requires prevention of the (direct or indirect) introduction of high priority pollutants into groundwater and limiting the introduction into groundwater of other pollutants so as to avoid pollution of this water by these substances. It will be repealed by 2013 under the Water Framework Directive, but it will remain one the effective EU legislative instruments for preventing or limiting pollution until this date, and then be relayed by the new Groundwater Directive. The declaration of the Ministerial Seminar on groundwater held at The Hague in 1991 recognised the need for further action to avoid long term deterioration of quality and quantity of freshwater resources. It called for a programme of actions to be implemented by the year 2000 to promote the sustainable management and protection of freshwater resources. This resulted in a proposal for an action programme on the Integrated Protection and Management of Groundwater, which was adopted by the European Commission on 25 November 1996 (European Commission, 1996a). The proposal identified the need to establish procedures to regulate the extraction of freshwater and monitor freshwater quality and quantity. The European Parliament and the Council subsequently asked the Commission to establish a framework for a European water policy. This request led to the Water Framework Directive (WFD) adopted in October 2000 (European Commission, 2000).

In addition to protecting groundwater as a resource with multiple uses the WFD establishes for the first time that groundwater should be protected for its environmental value. In this context, the WFD put forward a challenging legislative framework by establishing environmental objectives for all waters – surface, coastal, transitional, and ground waters – to be achieved by the end of 2015. This modern piece of EU legislation establishes clear objectives but allows Member States flexibility in how they are achieved. It is based on milestones such as risk evaluation of anthropogenic pressures and impacts, monitoring programmes, development of river basin management plans (the first one to be published in 2009) and design and operation of programmes of measures. Groundwater is one of the key components of the WFD with the focus for groundwater on both quantitative and chemical status objectives. The objectives for surface waters concern ecological and chemical status. The quantitative status objectives are clear in the WFD. The aim is to ensure a balance between extraction and recharge of groundwater, but the chemical status

[4] The views expressed in this paper are those of the author and does not necessarily reflect a formal position of the European Commission.

criteria are more complex and were not fully resolved at the time the WFD was adopted. The European Parliament and the Council therefore requested that the Commission develop a proposal for a "daughter" directive clarifying the criteria for good chemical status criteria and specifications related to the identification and reversal of pollution trends. This new Groundwater Directive was adopted in December 2006 (European Commission, 2006a).

This paper describes the regulatory framework to protect groundwater against pollution, and highlights current challenges being faced while attempting to match theory and realities.

The policy context

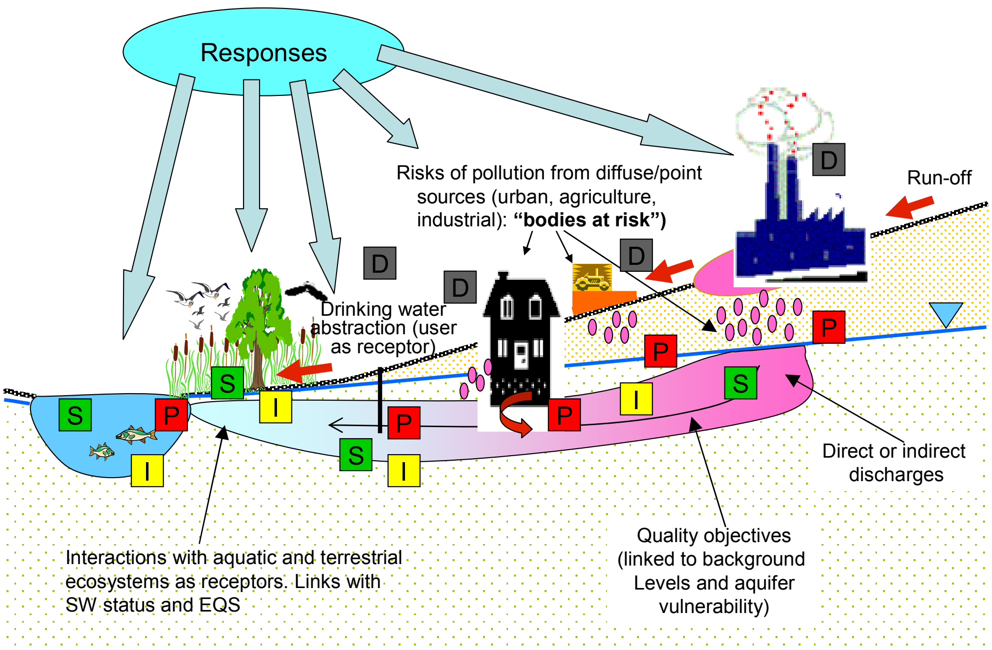
Groundwater in the Water Framework Directive

The components of the Water Framework Directive dealing with groundwater cover a number of different steps for achieving good (quantitative and chemical) status by 2015. They require Member States to:

- Define and characterise groundwater bodies (management units) within River Basin Districts that must be reported to the European Commission. The characterisation relies on system understanding, in particular on the knowledge of drivers (D), pressures (P), status (S), impacts (I) and responses (R) which constitutes the backbone of river basin management planning. It involves analysing the pressures and impacts of human activity on the quality of groundwater with a view to identifying groundwater bodies at risk of not achieving WFD environmental objectives. This assessment has to evaluate risks linked to water uses and interactions with associated aquatic or terrestrial ecosystems in relation to the types of pressures and aquifer vulnerability (Figure 1). Member States had to carry out this classification between 2004 and 2005 and report the results to the European Commission. A report giving a synthesis of Member States' reports was prepared by the European Commission and published in March 2007.

Figure 1: Main driving forces (D) and related pressures (P) affecting groundwater.

The status (S) and impacts (I) concerns both the groundwater resource and the associated and dependent aquatic and terrestrial ecosystems. The responses (R) are the action programmes of relevant EU legislations (primarily the programme of measures of the Water Framework Directive).



- Establish registers of protected areas within each river basin districts, which have been designated as requiring specific protection of their surface and ground waters or for the conservation of habitats and species directly dependent on water. The registers must include all bodies of water used for the extraction of drinking water and all protected areas covered under the following directives: the Bathing

Water Directive (European Commission, 1976), the vulnerable zones under the Nitrates Directive (European Commission, 1991a), the sensitive areas under the Urban Wastewater Directive (European Commission, 1991b), and the areas designated for the protection of habitats and species including relevant Natura 2000 sites designated under the habitats and wild birds directives (European Commission, 1979, 1992). The registers are to be reviewed under the River Basin Management Plan updates.

- Establish groundwater monitoring networks based on the results of characterisation and risk assessment to provide a comprehensive overview of groundwater chemical and quantitative status. Member States had to design a monitoring programme to be operational by the end of 2006. In this context, data monitoring data constitutes an essential element of the overall groundwater management cycle.
- Produce a river basin management plan (RBMP) for each river basin district which must include a summary of pressures and impacts of human activity on groundwater status, a presentation in map form of monitoring results, a summary of the economic analysis of water use, a summary of protection programmes, and control and remediation measures. The first RBPM is scheduled to be published by the end of 2009. A review is then planned by the end of 2015 and every six years thereafter.
- Take into account by 2010 the principle of recovery of costs for water services, including environmental and resource costs in accordance with the polluter pays principle.
- Design by the end of 2009 a programme of measures for achieving WFD environmental objectives (*e.g.* abstraction control, prevent or control pollution measures) that should be operational by the end of 2012. Basic measures include, in particular, controls of groundwater abstraction, controls (with prior authorisation) of artificial recharge or expansion of groundwater bodies (providing that it does not compromise the achievement of environmental objectives). Point source discharges and diffuse sources liable to cause pollution are also regulated under the basic measures. Direct discharges of pollutants into groundwater are prohibited subject to a range of provisions listed in Article 11 of the WFD. The programme of measures has to be reviewed and if necessary updated by 2015 and every six years thereafter.

Other related directives

Laws designed to protect groundwater against pollution and deterioration constitute a larger regulatory framework that can be traced back to the 1990s. The different pieces of legislation are directly linked to the Water Framework Directive and to the new Groundwater Directive. They are part of a set of measures that need to be operational to achieve "good environmental status" objective by the end of 2015. They all seek to prevent or limit pollutant inputs into groundwater. Their main features are summarised below:

- The Nitrates Directive (European Commission, 1991a) aims to reduce and prevent water pollution caused by nitrates from agricultural sources. It requests Member States to designate vulnerable zones of all known areas of land in their territories, which drain into the waters – including groundwater – that are, or are likely to be, affected by nitrate pollution. Such waters are those, among others, which contain a nitrates concentration of more than 50 mg/l or are likely to contain such concentrations if measures are not taken. The link with groundwater policy is clear in this respect, *i.e.* nitrate concentrations in groundwater should not exceed the trigger value of 50 mg/l. Action programmes under the Nitrates Directive are one of the basic measures of the Water Framework Directive (Annex VI) and a mechanism for reversing nitrate pollution trends under the Groundwater Directive (Annex IV, part B).
- The Urban Wastewater Treatment Directive (European Commission, 1991b) aims to protect the environment from the adverse effects of discharges of urban waste water and waste water from certain industrial sectors. In this context, the identification of “sensitive areas” relates essentially to freshwater, estuaries or coastal waters which are found to be eutrophic, lakes and streams reaching lakes/reservoirs with poor water exchange, and surface freshwater intended for drinking water which could contain concentrations of nitrates of more than 50 mg/l. Links with the groundwater regulatory framework is mainly through obligations to prevent or limit inputs of pollutants (including from urban origin) into groundwater.
- The Plant Protection Products Directive (European Commission, 1991c) and The Biocides Directive (European Commission, 1998) concerns the authorisation, placing on the market, use and control of commercial plant protection products and biocidal products such as pesticides, herbicides, or fungicides. Regarding groundwater, authorisation is only granted if products have no harmful effect on human

health or on groundwater, and that do not have undesirable affects on the environment, particularly on the contamination of water, including drinking water and groundwater. The new Groundwater Directive (European Commission, 2006a) has set maximum permissible concentrations in groundwater as groundwater quality standards.

- The Integrated Pollution Prevention and Control (IPPC) Directive (European Commission, 1996b) lays down measures designed to prevent or reduce air, water, or ground pollution. The directive applies to a significant number of mainly industrial activities with a high pollution potential such as the energy sector, the production and processing of metals, the mineral and chemical industries, waste management facilities, food production and non-industrial activities such as livestock farming. It establishes provisions for issuing permits for existing and new installations. The permits include requirements to ensure the protection of soils and groundwater and set emission limits for pollutants. This directive, like other directives cited in this paragraph, is part of the basic measures of the WFD.
- The Landfill Directive (European Commission, 1999) seeks to prevent or reduce the negative effects of landfill waste on the environment, including groundwater. Like the IPPC Directive, the Landfill Directive establishes provisions for issuing permits based on a range of conditions including impact assessment studies and is part of the basic measures of the WFD. For each site, the groundwater, geological, and hydrogeological conditions in the area must be identified. The sites must be designed so as to prevent groundwater from entering landfill waste, collect and treat contaminated water and leachate, and prevent the pollution of soils, groundwater or surface water by using the appropriate technical precautions such as geological barriers and bottom liners. The directive establishes criteria for waste testing and acceptance taking into consideration the protection of the surrounding environment, including groundwater.
- Other directives have indirect links to the groundwater regulatory framework. These include the Waste Framework Directive (European Commission, 2006b) which requires waste to be recovered or disposed of without endangering the environment and groundwater and the Construction Product Directive (European Commission, 1989) which provides provisions for regulating construction products that could pose a threat to the health of future occupants or neighbours as a result of water or soil pollution or poisoning.

Building blocks of the new Groundwater Directive

The new Groundwater Directive (GWD) establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater. The directive establishes quality criteria that take into account local characteristics and allows for further improvements to be made based on monitoring data and new scientific knowledge. The directive thus represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive (WFD) as it relates to assessments on chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations. Member States will have to establish the standards (threshold values) at the most appropriate level and take into account local or regional conditions. Complementing the WFD, the Groundwater Directive requires that:

- groundwater threshold values (quality standards) be established by Member States by the end of 2008;
- pollution trend studies be carried out using existing data and monitoring data which are mandatory under the WFD (referred to as "baseline level" data obtained in 2007-2008);
- pollution trends be reversed so that environmental objectives are achieved by 2015 using the measures set out in the WFD;
- measures to prevent or limit inputs of pollutants into groundwater be operational so that WFD environmental objectives can be achieved by 2015;
- reviews of the technical provisions of the directive be carried out in 2013 and every six years thereafter;
- compliance with good chemical status criteria (based on EU standards of nitrates and pesticides and on threshold values established by Member States) be achieved by the end of 2015.

Theory versus reality

Technical features related to WFD groundwater monitoring have been discussed in a separate paper (Quevauviller, 2005) while an analysis has been made to evaluate actions taken at policy level from the 1996 Grounwater Action Programme to the 2006 Directive (Quevauviller, 2008). The sections below discuss the three pillars of the Groundwater Directive in the light of expected challenges.

Good chemical status

The good chemical status compliance regime is based on quality objectives (compliance to relevant standards, no saline intrusion) that have to be achieved by the end of 2015. The direction chosen is based on compliance with EU-wide groundwater quality standards (nitrates and pesticides) which reinforce the parent directives. Regarding other pollutants, the adoption of numerical values at community level was not considered to be a viable option, considering the high natural variability of substances in groundwater (depending upon hydrogeological conditions, background levels, pollutant pathways, and interactions with different environmental compartments). In addition, the management of groundwater pollution should focus on actual risks identified by the analysis of pressures and impacts under Article 5 of the WFD. Consequently, the regime of the new directive requests Member States to establish their own groundwater quality standards (referred to as “threshold values”), taking identified risks into account and the list of substances given in Annex II of the directive. Threshold values should be established for all pollutants that characterise groundwater bodies at risk of not achieving the good chemical status objective and this should be done at the most appropriate level, *e.g.* national, river basin district or groundwater body level. The directive provides general guidelines on how to establish threshold values (Annex II). Let us note that the list of threshold values established by Member States may be prone to regular reviews within the river basin management planning framework, which may lead to additional substances being considered (in case of new identified risks) or the deletion of substances (in case formerly identified risks no longer exist).

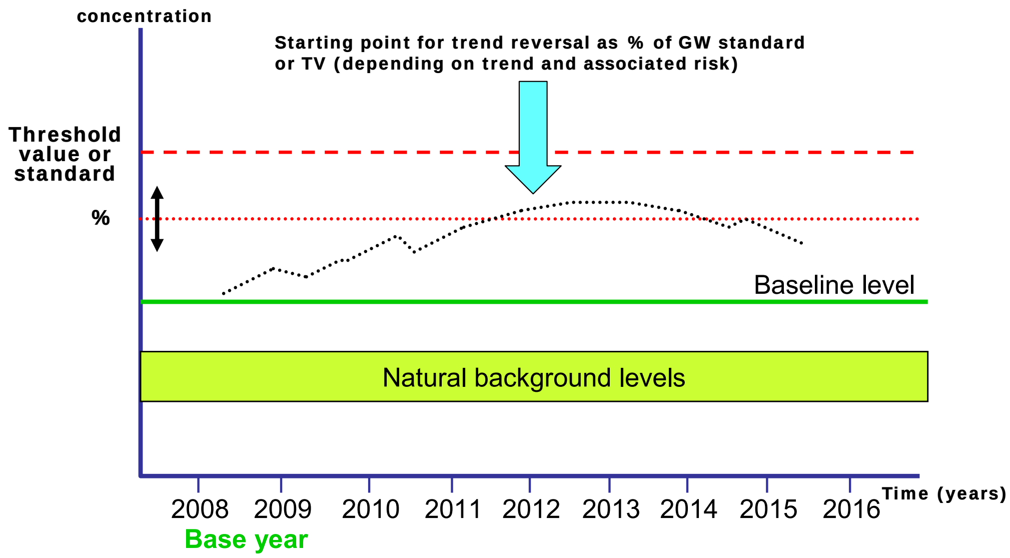
Regarding compliance, evaluation will be based on a comparison of monitoring data with numerical standard values (EU-wide groundwater quality standards and/or threshold values). In principle no groundwater body will be allowed to exceed these standard values. It is recognised that standard values being exceeded may be due to a local pressure (*e.g.* point source pollution) that does not endanger the status of the overall groundwater body concerned. Therefore, the directive opens the possibility to investigate the reasons why values are exceeded and decide on the chemical status classification on the basis of actual risks for the overall groundwater body (*i.e.* risks to human health, associated aquatic ecosystems or related terrestrial ecosystems, and legitimate uses and functions of groundwater). This means that situations might occur where standard values having been exceeded will correspond to local pressures needed to be controlled and possibly remedied without classifying the groundwater body with “poor status”. Other situations will show that one or more cases of standard value overruns may represent a serious threat to a groundwater body and thus lead it to reach “poor status” classification. Decisions will be taken on a case-by-case basis in the WFD river basin management planning framework.

The efficient implementation will thus depend upon several steps and primarily the identification of groundwater bodies ‘at risk’ and the substances characterising these risks. This certainly represents as drawback as the analysis of pressures and impacts under Article 5 of the WFD has not been tailored for the establishment of groundwater threshold values, *i.e.* the risk assessment linked to this establishment will have to be complemented to fulfil the requirements of the GWD. Linked to this, the knowledge about groundwater and aquatic/terrestrial ecosystems interactions is still scarce, which will likely affect the threshold values’ estimate in the first round. Increased knowledge is therefore required about groundwater systems to enable the referential system (representative threshold values) to improve along with scientific progress in the light of the review of threshold values at the end of each river basin management plan.

Trend identification and reversal

The identification of sustained upward pollution trends and their reversal is the second “pillar” of the new directive, which stipulates that such trends will have to be identified for any pollutants characterising groundwater as being at risk (this is linked to the analysis of pressures and impacts carried out under the WFD). The issue of “significance” is clarified in Annex IV of the directive. This is linked to statistical significance (purely mathematical) and environmental significance, which itself relates to actual risks represented by the identified upward trends. The reversal obligation establishes that any significant and sustained upward trend will have to be reversed when reaching 75% of the values of EU-wide groundwater quality standards and/or threshold values (Figure 2). This principle rule may be adapted according to local circumstances justifying a different percentage value. In other words, situations might justify a trend reversal when values reach 50% of the standards (in case of high aquifer vulnerability) whereas values higher than 75% could be accepted in cases where the risks of exceeding the quality standards are unlikely. Trend reversals have to be undertaken through the programme of measures of the WFD where the parent legislations are the implementation tools for ensuring effective actions (*e.g.* Nitrates Directive, IPPC Directive, etc.).

Figure 2: Principle of the identification and reversal of statistically and environmentally significant upward trends.



Similarly to good status compliance, the trend identification and reversal will be closely linked to the accuracy of the risk assessment of pressures and impacts, and the above commented drawbacks are thus relevant. In addition, there will be a need to study the way trends have been identified and reversed in various groundwater body typologies in order to evaluate whether the groundwater regulatory management framework is implemented in a comparable way throughout the European Union.

Measures to prevent or limit pollutant inputs

This is the third core element of the directive. Measures to prevent or limit the introduction of pollutants into groundwater are covered by the existing Groundwater Directive (European Commission, 2006a). It contains elements which are now covered by other directives such as the Landfill Directive, which makes it redundant in some aspects in relation to the WFD programme of measures. This is why it was decided to repeal this directive under the WFD in 2013 (*i.e.* one year after the programmes of measures are made operational). But some provisions would have been lost without an appropriate follow-up after the directive is repealed, especially the specific requirements on the prevention of inputs of hazardous substances into groundwater and the limitation of inputs of other pollutants. Consequently, the new directive (GWD) includes legal requirements to prevent or limit inputs of pollutants intro groundwater that coincide with existing provisions under the old directive while being in line with the WFD. This implies that measures to prevent or limit pollution under the GWD are those established by the WFD (which will have to be operational by 2012). This by no means implies that nothing should to be done before 2012 while the old Groundwater Directive remains in place and other parent legislations remain in force. Under the new directive, the prevention and limiting provisions will be streamlined and be consistent with WFD river basin management planning. This is closely linked to conceptual modelling needs described above.

This protection regime has proven to be efficient in some Member States. However, the implementation of the Directive 80/68/EEC (European Commission, 1980) is prone to technical difficulties with respect to assessing the actual introduction of pollutants in comparison to groundwater background levels (generally absent from impact studies in the context of this directive). The prevent/limit regime under this directive will remain enforceable until 2013, date at which the GDW Article 6 will come into force. In this context, WFD measures will be those to be used for preventing or limiting inputs of pollutants. In practice, impact studies should then be facilitated by the fact that groundwater background levels should be determined under the GWD and a reference system based on the threshold values should help to better assess deterioration risks. Technical challenges will obviously remain, *e.g.* linked to the estimate of the hazardous character of heavy metals prior to deciding which type of measures should be implemented (prevention or limitation).

Towards effective implementation

Summary of WFD milestones – Paving the way

The new Groundwater Directive is an integral part of a comprehensive regulatory framework represented by the WFD. The success of its implementation will thus closely depend upon the effective implementation of relevant groundwater parts of the WFD as well as of parent legislations in the agricultural, industrial, urban and waste sectors. The following series of WFD milestones pave the way for further implementation steps:

- Analysis of pressures and impacts under Article 5 of the WFD: this has already been reported by Member States and used to identify groundwater bodies “at risk”. This analysis represents a key element of the new directive as it has a direct implication on the setting of threshold values and trend obligations.
- Monitoring programmes were designed and made operational by the end of 2006 on the basis of the above identification. The gathering of data will also be of key importance for refining the risk assessment, thus helping to clearly identify the substances which have to be considered by Member States for establishing threshold values.
- The development of the first River Basin Management Plan is obviously a core milestone for the overall WFD, and thus also for groundwater. The first plan is being developed by Member States for public consultation by the end of 2008 and will be published at the end of 2009. In this context, programmes of measures will have to be designed and made operational by 2012 in order to meet the WFD good status objectives by 2015.

Specific milestones of the new directive

Specific milestones of the new directive relate to:

- The establishment of threshold values which have to be reported by Member States for the first time by the end of 2008. As highlighted below, a high level of cooperation is required to ensure that threshold values will be set in a consistent and comparable manner throughout the EU. Updates of the threshold values (substances considered and numerical values) will be possible in the framework of the RBPM reporting.
- Trend studies based on new monitoring data and existing information. Identified trends should in principle be included in the first RBMP with associated measures to reverse them, if appropriate, but it is recognised that it might be too early (with only two years worth of data) to guarantee such reporting. In practice, this means that trends will likely only be reported at the end of the RBMP in 2015. This does not infer that measures should not be operational before then since these would are likely to have a positive effect on pollution trends.
- Another specific milestone concerns the review of the directive on the basis of scientific developments scheduled to take place in 2013.

Supporting guidelines – cooperation on implementation

As highlighted above, effective implementation will depend on a high level of cooperation between Member States’ environment agencies or ministries, stakeholders representing different sectors (agriculture, industry, and urban), NGOs, the scientific community and the European Commission. In this respect, awareness is at the heart of the Common Implementation Strategy (CIS) of the WFD, which has been operational since 2001 (see Quevauviller, 2008). In this context, the Groundwater Working Group gathers more than 80 experts who meet twice a year to exchange best practices, discuss technical difficulties about implementation, and develop guidance documents. This working group has been active since 2002 in helping the Commission to develop the directive proposal published in 2003. It then focused its energy on the development of key guidance documents published in 2006, namely:

- Guidance document on groundwater monitoring (CIS Guidance N°15), providing practical information about WFD groundwater monitoring provisions;
- Guidance document on groundwater in protected areas (CIS Guidance N°16), clarifying the links between the WFD groundwater provisions and the drinking water regulatory framework;
- Guidance document on the clarification of the terms 'direct and indirect' inputs (CIS Guidance N°17), aiming to provide recommendations on how to design measures for the prevention or limitation of pollutant inputs into groundwater.

Other guidance documents are being developed or planned, they concern in particular:

- Compliance issues, including recommendations on the establishment of threshold values and related compliance requirements, as well as technical specifications about trend identification and reversal. Discussions about compliance concern chemical as well as quantitative status.
- Land use and groundwater, seeking to clarify links with the agriculture regulatory framework (including cross-compliance under the CAP reform) as well as provisions concerning large-scale contaminated sites. This document will also discuss aspects of climate change and how it may affect groundwater management.

Bridging science and policy for a better implementation

An effective groundwater management can only be operational if it is conceived along IWRM principles. The combined implementation of the WFD, its daughter Groundwater Directive and all the parent environmental legislations designed as programmes of measures, is the sole guarantee to enable meeting the good status objectives by 2015. This integrated approach is closely linked to the way risk assessments will be carried out and the effectiveness of action programmes, with related implications for the directive' implementation. Examples are the delineation of water bodies 'at risk' (having an impact on the way monitoring programmes are designed) and their visualisation upon reporting, economic analysis (forming the basis of the future water pricing policy), establishment of threshold values for 'risk substances' (with direct link to good status compliance), design of programmes of measures, etc. The complexity of this management makes it necessary to proceed in a stepwise, iterative, manner, ensuring an effective participation of water actors and a full integration of scientific knowledge.

The successful implementation of integrated risk-based groundwater management in the light of the WFD and its daughter Groundwater Directive will hence closely depend upon an efficient participatory approach, including an active involvement of the scientific community. This requires an effective and sustained operational bridging between scientific stakeholders, policy-makers and water managers. The example of the BRIDGE ("Background Criteria for the Identification of Groundwater Thresholds"), a project funded by the European Commission under the 6th Framework Programme, shows that a close collaboration may be established among the research and policy worlds to tackle well identified technical knowledge gaps. This science-policy bridging is not a straightforward process and requires a clear motivation from different actors as the dialogue and communication are not well established. These difficulties of communication and transfer of knowledge are discussed in depth in a recent book, which compiles examples of research projects supporting the EU groundwater legislation (Quevauviller, 2007).

The experience of linking scientific and policy developments has opened the way for innovative partnerships, which is now reflected in further science-policy undertakings in the framework of a research project on "Groundwater Systems" (GENESIS) resulting from the 2nd call for proposals of 7th Framework Programme, which is still in negotiation at the time of publication of this paper.

Networking needs

The Working Group on Groundwater under the Common Implementation Strategy of the Water Framework Directive is collaborating with the International Hydrological Programme (IHP) of UNESCO to exchange information and ensure that the recommendations on good groundwater management practices are disseminated worldwide[5]. Of particular interest in this respect are the methodological guides, guidelines and reviews concerning groundwater contamination and trans-boundary aquifers which are available on the IHP-UNESCO website. These are especially relevant to the current drafting of the EU technical guidance documents on the implementation of the future groundwater directive.

Other links are being established with stakeholder organisations through the Working Group C, representing the industrial and agricultural sectors and civil society, the scientific community, and Member State's environment agencies/ministries. Active exchanges also take place with international associations such as the International Association of Hydrogeologists (IAH), Eurogeosurveys, the European Water Association (EWA), the International Groundwater Resources Assessment Centre (IGRAC) and organisations representing industrial sectors (*e.g.* CEFIC, EUREAU, Eurometaux, COPA-COGECA, etc.) and ecological interest groups (represented by the European Environment Bureau).

Conclusions

The years to come will require active multi-sectoral and multi-disciplinary cooperation to ensure the development of a sound integrated groundwater management regime at EU level and guarantee the effective implementation of the new directive. This represents a continuous process which started more than 10 years ago with the adoption of the Groundwater Action Programme (Quevauviller, 2008) and this will strongly – but not solely – rely on effective integration of different environmental policies. Integration will also be crucial with respect to research inputs (effective transfer of scientific results to policy-makers), sharing practices and practical demonstration activities. The actual cooperation under the Groundwater Working Group (WG C), associated with large-scale research developments, will be an indispensable element supporting this implementation through a participatory approach, in particular in view of the preparation of the first River Basin Management Plan expected for publication at the end of 2009. This represents a unique opportunity to build-up a knowledge-based regulatory framework for groundwater (chemical and quantitative) in the run up to 2013 when the directive is to be reviewed.

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Keywords: Water Framework Directive, Groundwater Directive, integrated groundwater management, good chemical status, trend identification and reversal, prevention and limitation, science-policy bridging.

Management of groundwater bodies used for drinking water supply

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1 - Introduction

The Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishes a framework for Community action in the field of water policy (WFD) and its daughter directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration (GWD) provides objectives and principles, which the European water suppliers expect to deliver:

- Sufficient availability of water resources to meet the needs of European citizens for drinking water and sanitation;
- A quality of resources that not only meets ecological standards, also meets the needs of a sustainable drinking water supply in order to produce drinking water with natural purification methods such as bank filtration or sand filtration;
- Full implementation of the polluter pays principle to provide incentives to control pollution at source and promote water conservation;
- There should be no unsustainable transfer of costs to water consumers;
- Full implementation of the cost recovery principle, consistent with the polluter pays principle.

Coherence in European legislation, especially with the Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (Drinking Water Directive (DWD)) is also needed. The water suppliers and waste water services are committed to play their part in delivering the goals of these Directives, which means:

- Contributing to sustainable management of water demand;
- Supporting other sectors in developing sustainable water-management practices (*e.g.* agriculture), and working in collaboration with polluters (*e.g.* plant protection industry and agriculture) to reduce pollution at source;
- Developing new approaches for sustainable ground water management costs (*e.g.* artificial recharge for balancing abstraction, see hereafter);
- Seeking sustainable technical solutions and avoiding measures that would lead to high carbon-emissions wherever possible.

Huge investments are undertaken by water services providers, in the implementation of the Urban Waste Water Treatment Directive and DWD. These directives had an enormous impact on investment levels in the different member states. Further investments in drinking and waste water infrastructure must be sustainable and reasonable, in line with the WFD's focus on environmental and society objectives. An ambitious dialogue between Government planning bodies and stakeholders is underway to ensure that standards are based on sound science supported by robust data. Since the objectives of the WFD are integral and river basin oriented, the proposed measures should also be integral and subject to a transparent cost benefit analysis per basin. For each action proposed the cost over say a 20 year period should be compared to the projected benefit for the water ecology but also for related issues as drinking water provision, recreation, as well as the potential impacts on climate change from emissions resulting from treatment processes. This will allow a better explanation to the public and acceptance of the proposed measures.

2 - Pollution

The first issue raised by water suppliers deals with diffuse pollution by nitrates, individual pesticides and total pesticide concentrations. Many water facilities now have pesticide treatment steps (paid for by the consumer), with further projects in hand at other sources to either to close wells, blend the water, or install further treatment to ensure safety of supply. These processes are underway as a consequence of the DWD, with some still limited improvement due to Directive 91/414. The proposed directive on sustainable use of pesticides will also complement existing and planned changes in several useful directions. National action plans to reduce the hazards and risks of pesticides are a necessity, in line of the provisions of the GWD. In this respect, certificates and the compulsory inspection of pesticide spraying equipment, improved handling and storage of pesticides are effective measures which must be enacted in the farming sector. Enhanced protection of surface waters through the use of buffer strips and hedges also proved efficient in the past and should be used as good practice, recognising that defining areas of reduced or zero pesticide application may sometimes be needed to meet objectives in Article 7 under the WFD. There is however scope for further improvement in the protection of water resources intended for drinking water abstraction purposes.

Nitrate is also of concern for many EUREAU members. Despite the specific EU Directive designed to control nitrate pollution at source, concentrations are still rising in a large number of water resources, thus conflicting now or in the future with the GWD values. The work which has begun in application of the GWD will adequately complement the actions already taken under the Nitrate directive.

Apart from these well know elements, a large number of EU water utilities are faced with major pollution from a variety of organic and inorganic micro-pollutants. These, for most of the time, result from historical pollution, from abandoned process plants and landfills, resulting in leaching of pollutants into groundwater resources. Site remediation and/or treatment are underway at a large number of locations, partly or totally paid by customers water bills. The new GWD will also provide a suitable framework to limit further pollution, ensuring that current practices do not result in future pollution.

Finally, the avoidance of raw water pollution with pathogenic micro-organisms is the core of the preventive risk management approach as recommended by WHO under the Water Safety Plan terminology. This type of pollution may arise from a variety of sectors: urban, rural, etc. This is no longer covered in the EU legislation, but is nevertheless subject to close surveillance by the water supplier.

3 - Artificial recharge

The primary sources for drinking water in the EU are surface water and groundwater. Especially in surface waters the quality and availability will vary over the year. Surface water discharge may decrease dramatically in dry summer periods and during these low flow periods, water quality (*e.g.* temperature) may also limit the usability of surface water for drinking water production. In these cases there will be need for storage, which may be found in lakes, and reservoirs, or in artificial recharge of subsoil reservoirs. This allows bridging periods of insufficient availability of surface water as a direct source for drinking water production. Underground storage of water has a number of important advantages. The residence time of water in the subsoil levels out fluctuations in quality and temperature of surface water and thereby provides for a stable drinking water quality. It also provides for natural purification by removal of pathogenic and other micro-organisms that will be present in all surface waters. Another important advantage of artificial recharge is that in the subsoil no loss of resource due to evaporation can take place. Finally, the production capacity in terms of m^3 drinking water per square km will increase considerably by artificial recharge as compared tot the natural production capacity of the subsoil. Artificial recharge has therefore become a very important method for drinking water production in Europe. In a number of EU-countries a substantial part of the drinking water production capacity is based on artificial recharge. In many cases it will be very well possible to combine artificial recharge with nature conservation. In the Netherlands for example the coastal dune area that is used for artificial recharge has also been designated under Natura 2000 and drinking water production and nature conservation go hand in hand. The area is furthermore largely open for the public for low-intensity recreational activities. This creates win-win situations both for water supply, nature conservation and society as a whole. The WFD fully recognizes artificial recharge as an important tool for drinking water production, with a scope for an even wider use to be explored.

4 - Role of water suppliers

Cost effective drinking water production largely depends on good quality resources. Water suppliers are therefore strongly dependent on proper protection of these resources. The primary role of water suppliers in Drinking Water Protected Areas implementation and maintenance is to share knowledge on the groundwater system, and to provide knowledge on groundwater quality problems that are threatening water supply. Water suppliers can also help in identifying possible and necessary measures for groundwater protection or remediation. Water suppliers can also support polluters in defining and adopting necessary changes in order to prevent further pollution.

Financial support can only be temporarily for measures that go beyond legal requirements; structural payments to polluters in order to prevent them from polluting are not a sustainable or desirable solution. Water suppliers can only create awareness of water quality problems and threats that other stakeholders may be causing for water supply. However, Water suppliers have no legal instruments in order to safeguard groundwater systems or to enforce necessary measures. Protection of drinking water resources is therefore primarily a task for governmental institutions, to which water supply companies are willing to contribute as much as is in their competence.

A word about EUREAU

EUREAU is the European federation of national associations of water suppliers and waste water services. Our members collectively provide sustainable water services to around 405 million European citizens. They reflect the full diversity of the European water services sector and represent both public and private operators. As the focus of a European network, EUREAU represents a unique concentration of technical, scientific and managerial knowledge and practical experience in water services.

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Keywords: Water Framework Directive, groundwater, potable water supply, pesticides, artificial recharge.

Challenges and opportunities of Managed Aquifer Recharge

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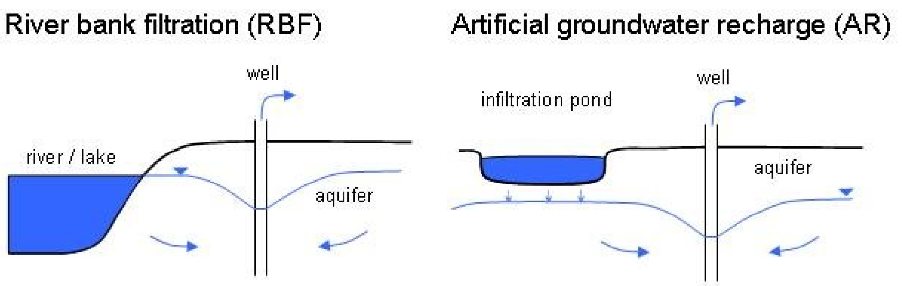
Managed Aquifer Recharge (MAR) comprises a wide variety of systems in which water is intentionally introduced into an aquifer and subsequently recovered, *e.g.* for drinking water or irrigation purposes. The objective is i) to store excess water for times of less water availability and/or ii) to introduce an additional barrier for purification of water from different sources (*e.g.* surface water, treated waste water) for a specific use.

Common MAR techniques in Europe are (Figure 1): river bank filtration (RBF) and artificial groundwater recharge – usually via ponded infiltration (AR).

Figure 1: Most common MAR techniques in Europe:
Bank filtration (BF), artificial groundwater recharge (AR).



Riverbank filtration (RBF) has a long history as a process for generating safe water for human consumption in Europe. During industrialization in the 19th century drinking water facilities in England, the Netherlands and Germany started using bank filtered water due to the increasing pollution of the rivers. The systematic production of bank filtrates started around 1870-1890 (BMI, 1975, 1985). Since then, RBF and in case of insufficient quantity, artificial groundwater recharge (AR) have been generally applied as a first barrier within the drinking water treatment chain. The most common and widely used method for artificial groundwater recharge (AR) are infiltration ponds (Asano, 2007). These simple surface spreading basins provide added benefits of treatment in the vadoze zone and subsequently in the aquifer. Advanced pretreatment of the infiltration water by coagulation, and advanced post-treatment of the recharged water, *e.g.* with activated carbon or ozonation became necessary in many cases after the 1960's as the quality of the source water further decreased.

Today the water supply of many European cities and densely populated areas relies on riverbank filtration or artificial recharge. In the Netherlands 13% of drinking water is produced from infiltration of surface water, such as bank filtration and dune infiltration (Hiemstra *et al.,* 2003). In Germany riverbank filtration and artificial groundwater recharge are used in the valleys of the rivers Rhein, Main, Elbe, Neckar, Ruhr, and in Berlin along the Havel and Spree (Grischek *et al.,* 2002). In Berlin, 75% of the drinking water is derived from riverbank filtration and artificially recharged groundwater (Schulze, 1977). Riverbank filtration is also applied in the United States as an efficient and low cost drinking water pre-treatment technology (Ray *et al.,* 2002), also to improve the removal of surface water contaminating protozoa.

In most applications, MAR is intended to act as a buffer in terms of water availability (quantity) and water quality. In general, the level of knowledge of natural treatment systems, notably in aquifers, is not as high as in engineered systems, because the biogeochemical environment in aquifers that modify water quality for sure, will vary in space and time (Dillon *et al*., 2008). The heterogeneity of the system, strengthens its buffer potential on the one hand, but makes it more difficult to describe and control on the other hand.

Key parameters that determine the quantitative storage capacity of the system are the specific hydrogeology of the aquifer (*e.g.* transmissivity and porosity) and the clogging potential at the entry point of the recharge water (infiltration pond, well or river bank). Clogging occurs due to physical, chemical and biochemical processes and needs to be regarded carefully as it may reduce the systems performance substantially. From literature it is known, that increased clogging reduces the oxidation state of the clogging layer. At a bank filtration site at Lake Tegel, Berlin, it was observed that intensity and spatial distribution of clogging strongly depends on the extent and thickness of the unsaturated zone. Geochemical observations suggest, that atmosperic oxygen induces redox processes which lead to a reduction of the clogging layer (Wiese & Nützmann, 2008). This is possibly due to the complex interaction of hydrochemical and biological processes within the uppermost centimetres of the aquifer (Hoffmann *et al*., 2006). If these processes are likewise found in AR system, they may be influenced as to minimize basin-cleaning efforts. This needs to be further investigated.

Water quality aspects of MAR are governed by: i) the quality of the infiltrated/injected water; ii) physical straining of particulate and particle-bound substances; iii) adsorption and desorption; iv) biogeochemical degradation / deactivation processes within the aquifer; v) the geochemical composition of the aquifer and vi) the quality of the ambient groundwater.

The process most important for MAR applications is usually the physical straining of particulate and particle-bound substances, lessening the effort for subsequent drinking water treatment. In Berlin, *e.g.* disinfection of drinking water can usually be avoided due to complete removal of pathogens during underground passage of up to 6 months. Cyanobacterial toxins (*e.g.* microcystins) that are primarily cell-bound are efficiently removed as well (Grützmacher *et al.,* 2007). On the other hand there is still a lack of understanding under which circumstances microcystins or other cyanobacterial toxins like cylindrospermopsin (currently observed in growing quantities in Germany) are released, thus becoming potentially more mobile in the subsurface.

Adsorption to the aquifer matrix contributes to the elimination of organic substances and heavy metals. Although this does not remove the substances completely, peak loads – *e.g.* from oil spills – are retarded and maximum concentrations reduced. In addition, sorption prolongs the detention time in the aquifer which multiplies the time for biodegradation. Biological degradation in the subsurface is responsible for the elimination of dissolved organic carbon (usually resulting from natural organic matter, NOM) and organic trace substances that occur at varying extent. Investigations have shown that the redox potential in the aquifer is decisive for the degree of elimination (Stuyfzand, 1998; Massmann *et al*., 2007).

Due to increasingly sensitive analytical methods trace organics present in surface waters (*e.g.* pharmaceutical residues) have been detected in many MAR systems *e.g.* in Berlin and the Netherlands (Massmann *et al*., 2007; Stuyfzand *et al*., 2007). Advanced numerical models including reactive flow and transport can simulate the complex interactions between the hydrogeochemical environment and degradation of trace organics (Greskowiak *et al.,* 2006). However, so far this has only been applied for a limited number of compounds at very few sites. Further research is needed to apply these methods for risk assessment. A second method for predicting the removal of organic micropollutants is the more statistically based approach of linking substance properties (molecular weight, number of double bonds, number of aromatic rings, etc.) to biodegradation via quantitative structure-activity relationship (QSAR) type models. This has been applied successfully to other water treatment methods – a transfer to MAR is lacking so far.

As MAR is a technology that relies on the interaction of natural processes framework conditions like climate and hydrogeology play an important role. There is a need for testing the transferability from central European conditions to other regions, and for an assessment, how temperature changes affect the system's elimination capacity. With ongoing climate change, reducing precipitation in some regions of Europe and increasing peak flow events in others, MAR is the ideal technology to act as a buffer for quantity and quality. The European Water Supply and Sanitation Platform (www.wsstp.org) for example has identified MAR as a technology potentially fit for future challenges.

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Programmes of measures and diffuse pollutions on groundwater. General types of measures and case studies. The case in France

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Summary

The risk of not meeting the good status set by the Water Framework Directive (WFD) for groundwater is mainly linked to agricultural diffuse pollutions (nitrates, pesticides). In accordance with the WFD, the programmes of measures planned at the level of the river basin include measures to address diffuse pollutions. These measures need to be specified at a territorial level and follow a regulatory, contractual or farm advisory framework. The impact of these measures can be assessed with the help of overall available evaluations looking at the types of regulatory or contractual actions implemented, or on the basis of the follow up of territorial projects. Some territorial projects show the effectiveness of the measures implemented to address diffuse pollutions. But the overall evaluation of the nitrate programmes of action (2004-2007 period) or of the agro-environmental measures (2000-2006 rural development programme) seem to reveal only limited changes in agricultural practices and a limited impact on water quality. The low level of adaptation of the measures to the territorial conditions, with some consequences on the effectiveness and acceptability of the measures, can be one of the reasons of these conclusions. The definition of a methodology aimed at setting up measures adapted to the diversity of the territorial conditions seems to be a major issue that needs to be addressed in order to recover a good quality of water.

Introduction

The environmental and economic report drafted in France in 2004-2005, in application of Directive 2000/60EC of 23 October 2000, the "Water Framework Directive" (WFD), demonstrated the relative importance of groundwater bodies with a known risk of not meeting the good status (43%) or with a potential risk (19%). Currently, the main blocking elements, at least for shallow aquifers, correspond to diffuse pollution (nitrates and pesticides), essentially caused by agriculture (IFEN, 2006)[6].

With regard nitrates, close to 50% of the measurement stations recorded medium (20 - 50 mg/l) to low (content in excess of 50 mg/l) quality, essentially in the northern half of France (figure 1).

The observation of aquifers between 1992 and 2001 shows that nitrate concentrations are globally increasing (figure 3).

The contamination of groundwaters by phytosanitary products is also a source of concern: in 2004, one of the active substances tested for was detected on at least one occasion at more than 61% of measurement stations selected for the general monitoring of the quality of groundwaters. With regard the use of "drinking water", 24% of stations in the network indicated "low quality" (requiring specific treatment for the removal of pesticides before distribution), and 1% "poor quality" (content exceeding regulatory standards, making the corresponding aquifers unsuitable for the production of drinking water, except with the exceptional authorisation of the Ministry of Health).

It is therefore necessary to carefully consider the impact of the measures implemented or envisaged to combat diffuse pollution from agriculture in view of the objectives and timescale inherent to the Water Framework Directive.

[6] This reference applies for all "nitrate" and "pesticide" data presented in the introduction.

Our aim is to identify the main types of measures envisaged, to present available data which can be used to appraise the impact of these measures on water tables and finally to identify some of the factors liable to determine the effectiveness of these measures.

The following considerations relate to water tables. However, most of these considerations are applicable for all water resources, whether surface waters or groundwaters, in view of the extensive interaction between surface water and a certain number of groundwaters (alluvium in particular), the multiple measures liable to act on both types and the uniqueness of the legal and regulatory framework involved.

These issues are hereby discussed in the context of France only.

1 - Measures to combat diffuse pollution

The measures

The Water Framework Directive provides for the implementation of programmes of measures for river basin districts (article 11) in accordance with the "river basin management plans" (article 13)[7].

A European catalogue of measures compatible with these programmes of measures was created at the initiative of the European Commission[8]. The aim of the catalogue, which is in the form of an Access database, is to help Member States to develop measures dedicated to agricultural pressures, by providing basic information on the different types of current and future possible measures (general description of the measure, targeted agricultural pressures, effects, environmental benefits and risks, geographical scale and the speed of action, costs, potential synergies between measures, feedback from implementation in different European countries, possibility of adaptation, bibliography).

In France, these key categories of measures are included in draft programmes of measures, which are currently under consultation.

Measures are generally defined in a generic manner[9], are liable to act on various phases of the process behind the pollution of groundwater resources (limiting of losses to the plot; limiting of transfers) and have several application methods depending on the region. Measures should therefore be applied at regional level via the different available means of action.

Potential means of action

The measures to be implemented on a regional level are included in different frameworks of action (table 1):

- A regulatory framework with:
  - . the "Nitrates action programme", in application of European directive n° 91/676/EEC ("The Nitrates Directive") which applies to "vulnerable areas" (figure 3),
  - . regulation relating to the sale and use of phyto-pharmaceutical products, defined in a decree by the French ministry of agriculture and fishing of 12 September 2006,
  - . regulation relating to “certain areas subject to environmental restrictions (ASER)”, including the protective areas of the water supply catchment areas, as defined by decree 2007-882 of 14 May 2007 and the related enforcement order of 30 May 2008.

The measures of the nitrate programmes of action are part of the basic measures set by the WFD (Article 11 – 3, implementation of existing European legislation). The measures taken in the framework of the other

7 Master plan for water development and management (SDAGE), in France.
8 http://circa.europa.eu/Members/irc/env/wfd/library?l=/framework_directive/thematic_documents/wfd_agriculture&cookie=1&cookie=1
9 Examples of measures mentioned in the draft programmes of measures for the Seine Normandie basin: "Improving knowledge of phytosanitary risk areas", "Encouraging reasonable fertilisation by adapting yield targets to soil potential ". Other measures refer more specifically to certain practices: "Implementation of CIPAN"; "Creation and maintenance of grass strips …(*Comité de basin Seine Normandie, 2008*).

regulations mentioned above aim at introducing more ambitious measures on specific areas and are part of the complementary measures of the WFD (Article 11 – 4).

The cross-compliance rules (that notably apply to the CAP payments of the 1st pillar – European Regulation n°1782/2003) can be mentioned. These rules are not strictly regulatory rules but are applied in a similar way. The payment of direct aid to farmers requires compliance with "Good agricultural and environmental conditions" (GAEC), established at European level and adapted by Member States in application of the principle of subsidiarity. Although the regulation of 2003 does not stipulate the quality of water as part of the priorities ("themes") to be considered, certain standards for the conditions defined in France are likely to have an impact on surface and groundwater resources (table 1).

- A contractual framework with the "agro-environmental measures (AEM)" defined in the French Rural Development Plan, in application of the European regulation n° 1698/2005 on support for rural development.
- Some farm advisory measures, historically focused on improving agricultural practices on the basis of agronomic criteria only, have increasingly integrated environmental considerations in the past twenty years. They have included advisory measures on crop fertilization, organised by the chambers of agriculture and recognized in the framework of the ‘Fertimieux’ approach (ANDA, 2000).

However, the measures implemented to tackle diffuse pollution in groundwaters can differ in terms of the scope of the region of application and the level of restrictions (table 1), for the same technical content, depending on the applicable regulatory and contractual framework.

The evaluation of the effectiveness of these measures must therefore take into account not only the inherent characteristics, but also the context of implementation.

2 - Assessing the effectiveness of measures against diffuse pollution

Evaluating effectiveness includes two aspects: the overall evaluation of the framework for action in which the measures are implemented, and the observation of results in certain specific regions.

2.1 – Evaluating the frameworks for action

Two recent studies could be quoted, one relating to nitrate action programmes and the other to the agro-environmental measures of the French National Rural Development Programme (NRDP) 2000 - 2006.

a) Nitrates action programme report

Article 10 of the nitrates directive requires that Member States submit an implementation report to the Commission every 4 years. The most recent report to be submitted was for 2004-2007. This report analyses changes in agricultural practices and nitrogen pressure and the consequences for the quality of water.

The impact of the action programmes on changes in practices was assessed by comparing practices in 2001 (implementation of the 2nd action programme) and in 2006 (half way through the 3rd programme), based on national investigations on "farming practices" lead by the SCEES - (Central Office of Statistical Surveys and Studies), concerning crops, and measuring differences between vulnerable and non vulnerable areas.

Certain changes were more evident in vulnerable areas. This particularly applies to surfaces with "intermediate nitrate catch crops", which remain far more extensive in vulnerable areas (figure 2). However, the predominance of bare soil in winter, even in vulnerable areas, remains a high-risk factor for the leaching of nitrogen into groundwaters.

Other changes were detected which were, in principle, positive in terms of impact on water resources, but similar levels were detected in and out of vulnerable areas, implying that the changes are not directly linked to the application of the nitrates directive. This was the case, for example, for total mineral nitrogen content, which decreased equally throughout the country but remained higher in vulnerable areas, which include a substantial percentage of land with the highest agronomic potential.

An analysis of the impact of these nitrate action programmes on groundwaters could be carried out using the data obtained via the monitoring of nitrate levels over 4 successive periods (1992-1993; 1997-1998; 2000-2001; 2004-2005)[10].

Changes between 1992-1993 and 2004-2005 reflect a substantial (between +5 and + 10 mg/l) or very substantial (> +10 mg/l) increase in nitrate content at measurement points, especially those located in vulnerable areas (figure 3).

The action carried out in this regulatory framework therefore demonstrates the following limits: little differentiation of measures according to regional contexts within very large surface areas, and, above all, insufficient restrictions to seriously deflect current trends. The fourth programmes of action taken in respect of the Nitrate Directive for the 2009-2012 period will necessarily have to reinforce these constraints, including the obligation to have winter cover crops by 2012 and the obligation to protect all water courses with buffer strips from 2009.

b) Evaluation of the agro environmental measures (AEM) implemented in 2000- 2006

The final evaluation of the implementation of the NRDP 2000-2006 and the MAE implemented in this context is currently being completed. One of the objectives of this evaluation is to study the impact of the AEM on the quality of water resources, by analysing the effects of these measures. The conclusions of this evaluation still need to be confirmed and checked, however the provisional conclusions available will probably not be radically modified during the final phase of this study.

The evaluation of the impact of the AEM on the quality of water is difficult and requires a distinction between the impact of the AEM and that linked to "external" factors: consultancy - development operations, other public aid programmes (Programme –to reduce agricultural diffuse pollutions, etc.), regulations, etc.

The effects of the AEM depend on their impact on the processes controlling the production and transfer of polluting elements (nitrates, pesticides) and the speed of application of these measures.

Two elements make it possible to assess the effectiveness of agro-environmental measures:

- The questions asked to farmers in the framework of this evaluation show that the implementation of agro-environmental measures had in general a weak impact on the implementation of new practices even if variable according to the agricultural sectors.
- The implementation of water quality measures on key priority territories has been rather limited during the period considered. There is no positive correlation with the evolution of the water quality on the same period.

The evaluation made for the 2000-2006 period concludes that “the agro-environmental measures’ have had no significant impact on the improvement or the preservation of the quality of water’. The main reason of these limited results is the diffuse nature of the commitments taken by farmers, linked with a lack of attractiveness of the measures.

The definition of the AEM to be implemented in the 2007-2013 programming period was highly influenced by these conclusions, that mainly and already came from the 2003 mid-term evaluation of the RDP. The evolutions compared to the previous programming period are:

- The zoning of the measures, focused on the territories with key priority water issues, with a sufficiently high level of commitments by farmers in order to get a positive impact on water resources,
- The content of the measures, by a flexible combination of ‘unitary commitments’ in order to adapt the selection of the measures to territorial specificities,
- The effort put on territorial measures of communication and technical advices.

[10] However, these campaigns were carried out in very different hydrological conditions.

But it is still too early to assess the impact of these AEM evolutions.

2.2 – Results obtained from local implementation – Case study

There are examples of territorial actions leading to significant results on water quality (picture 4, example of the 'plateaux du Haut-Saintois').

The reasons of the success of these projects are well known. They are as follows:

- The detailed identification of the practices or characteristics of the systems of production responsible of an environmental issue (for instance, in the above mentioned example, spatial and crop distribution of farm effluents),
- The selection of measures adapted to the territorial conditions,
- The implementation of a high level of communication on the territory, in order to get a good level of commitment to the project by farmers and provide the technical support needed for the evolution of practices,
- A deep partnership between the different parties involved in the project (water agencies, territorial municipalities, chambers of agriculture, research centres, etc),
- Complementary types of action (nitrate programmes of action, farm advisory measures, agro-environmental measures).

The monitoring of regional projects relating to the improvement of resources used for the production of drinking water shows highly variable results depending on the hydrogeological context, the characteristics and the functioning of aquifers, pedoclimatic data, the land use, the technico-economic factors and the characteristics of agricultural systems, the nature of agricultural practices, the nature of the measures applied and implementation methods, etc.

This monitoring demonstrates the difficulty of obtaining a reference framework and global analysis, enabling the appraisal of the relative effectiveness of the different measures, and of adapting these measures to specific regional contexts:

- The characteristics of the transfer of pollution (nitrates or pesticides) to aquifers, and movements within aquifers are often unknown due to a lack of knowledge on hydrogeological and pedoclimatic contexts (aquifer renewal speed, etc.).
- It is often difficult to identify which elements would optimise the effectiveness of action, with regard the improvement of the quality of water resources. With nitrogen pollution, key elements can be:
  . the total level of fertilisation,
  . the difference between current fertilisation and optimal fertilisation for farming needs (this difference will depend on crop targets),
  . the characteristics of rotations,
  . covering the soil during winter,
  . control of fertilisation techniques (fractionation, distribution dates, adaptation of fertilisation during cycles), etc.
- Finally, once a "target action" has been chosen, the determination of a level of restriction adapted to the regional situation, with regard water priorities, allowing specific environmental objectives to be met in a given amount of time, is complex.

The solution adopted to overcome these various difficulties is often of a standard nature, and involves a contractual (AEM) or regulatory (Nitrates directive, ASER) framework. This solution may not therefore be entirely compatible with the set target, and its actual impact on water resources will be complex to predict.

Modelling work has contributed to the objective establishment of correlation between the modification of agricultural pressures and changes in the status of water resources (INRA-BRGM, 2008). However, a method adapted to the range of existing regional situations is not currently available.

Conclusions

Several examples emerging from the research or monitoring of regional approaches demonstrate the effectiveness of a certain number of technical measures aiming to limit the loss of polluting elements (nitrates, pesticides) in plots or to reduce their transfer to water resources.

The results obtained relating to the quality of these resources are highly dependent on the framework for action chosen for the implementation of these measures: voluntary, contractual or regulatory. This framework largely determines the level of restrictions applied to agricultural practices. The definition of this level of restrictions remains subject to existing balances between the actors concerned. With regard regulatory or contractual measures defined in application of the European regulation supporting rural development, this framework also imposes a standardized structure which limits the possibility of adapting to regional contexts.

Furthermore, regardless of the framework for action, the measures adopted and the limiting of restrictions remain problematic due to the relative uncertainty of their impact on water resources, and the lack of available knowledge on the processes occurring in the organic horizon, the transfer to groundwater resources, and the renewal of groundwaters.

This scientific obstacle combines with the difficulties inherent to the frameworks for action themselves. The adoption (contracts) or enforcement (regulations) of measures based on uncertain scientific principles is difficult in a specific regional context.

The launch of interdisciplinary research programmes, bringing together agronomists and hydrogeologists, with the aim of defining a reliable method for the creation of measures adapted to the wide range of regional contexts, is now a major priority, to meet the objective of renewing the quality of water.

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Keywords: Diffuse pollutions - Water Framework Directive, Programmes of measures - Groundwater - Modelling work – Nitrate action programme – Agro-environmental measures.

Figure 1: Nitrates in groundwaters in 2004-2005 (in : MEEDDAT, 2008).

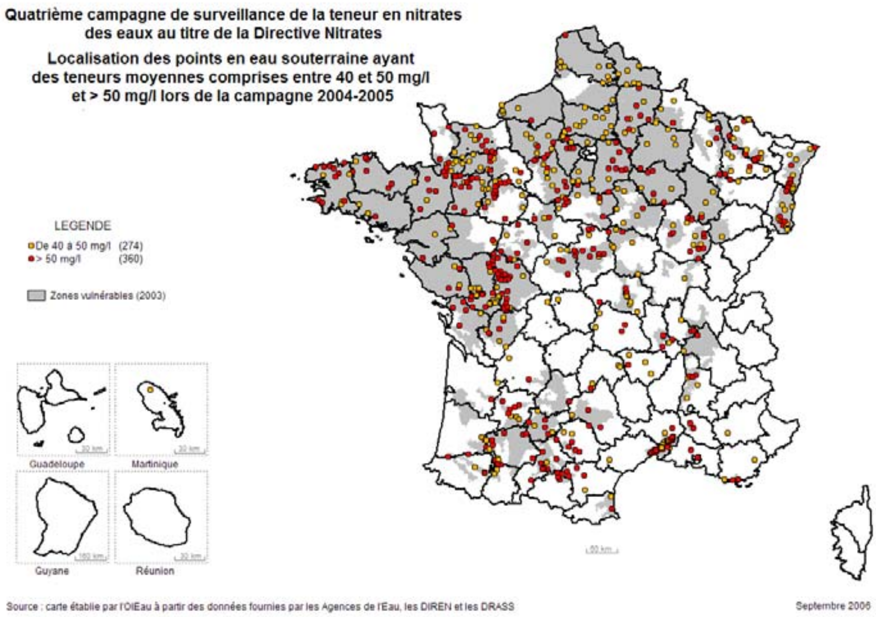


Figure 2: Intermediate nitrate catch crops, prior to maize (in : MEEDDAT, 2008).

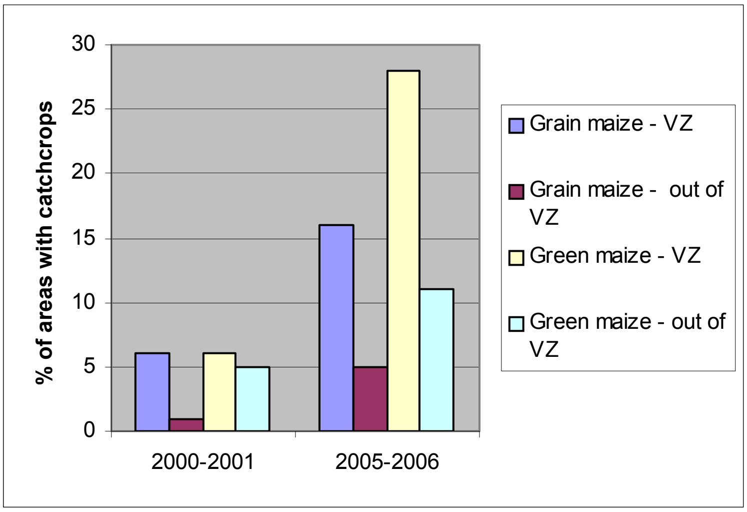


Table 1 – Examples of measures against diffuse pollutions on groundwaters.

Frameworks for action	Principles	Exemples of measures	Region of application
Nitrates action programmes	Decree of prefect, defining a mandatory action programme for 3 years, adapted to the local situation.	- Obligation to draw up a fertilizing plan and to fill in a document for land application. - Input of nitrogen in livestock effluents limited to 170 kg/ha/year. - Quantities of N nutrients limited, considering the balance between the crops requirements and any kind of inputs. - Rules concerning periods of forbidden fertilisers spreading, fractioning of inputs, conditions of spreading, minimal distances to the rivers and catchment points to be respected	Vulnerable zones: areas concerned by pollution, where the nitrates concentration is over 40 mg/l.
Regulation relating to the use of phyto-pharmaceutical products	Mandatory general rules defined at national level (decree of 06.09.12) and mandatory rules that may been specified by prefect decree.	- General rules to limit point source pollution by phyto-pharmaceutical products (protection during filling up the tanks, during spreading the bottom of the tanks and their emptying…). - Respect of a breadth of non treated area, near the water points (minimum 5 m, 20, 50 or more than 100 m).	- All the national territory - In the proximity of the water points
Regulation relating to certain areas subject to environmental restrictions (ASER)	Delimitation by prefectoral decree of a safeguard zone (on drinking water protected areas, or wetland with a particular environmental interest), then definition of an action programme including agricultural measures, open to get mandatory, if results of implementation are not achieved.	- Permanent or periodical cover crop- Management of inputs, aiming to reduce the nitrogen inputs or the use of pesticides - Diversification of crops - Maintenance and management of permanent elements of landscape (hedges, slopes…) - Restoration or maintenance of wetlands	Drinking Water Protected Areas Wetlands
Agri environmental measures	Set up of agri-environmental measures (AEM) at a territorial level, by grouping of "unitary commitments" defined in the Rural development programme, and validated by the European Commission. Voluntary implementation (contractualization of commitments paid considering the additional costs and the income foregone resulting from the AEM implementation).	Examples of "unitary commitments": - Implementation of temporary catch crops, during period of risk - Implementation or maintenance of areas covered with grass. - Limitation of nitrogen fertilizing on arable crops: global fertilizing limited to 140 kg/ha/year; mineral fertilizing limited to 20 kg/ha/year (out of vulnerable zones), or 80 kg/ha/year (in vulnerable zones).	Territories of projects, delimited in a relevant way, considering the environmental issue (for example: Drinking Water Protected Areas)
Cross-compliance rules of the CAP payments	Set up at national level of « good agricultural and environmental conditions (GAEC)	- Maintenance of area with environmental coverage, at least 3% of the eligible hectares. - Diversity of crop rotations - Maintenance of permanent grass-lands (considering ratio grassland areas/usable agricultural areas, in 2005)	All cultivated areas for which CAP payments are received.

Figure 3: Location of the measurement points with more than 40 mg/l nitrates, in 2004-2005, and their evolution between 1992-1993 and 2004-2005, in groundwaters (in : MEEDDAT, 2008).

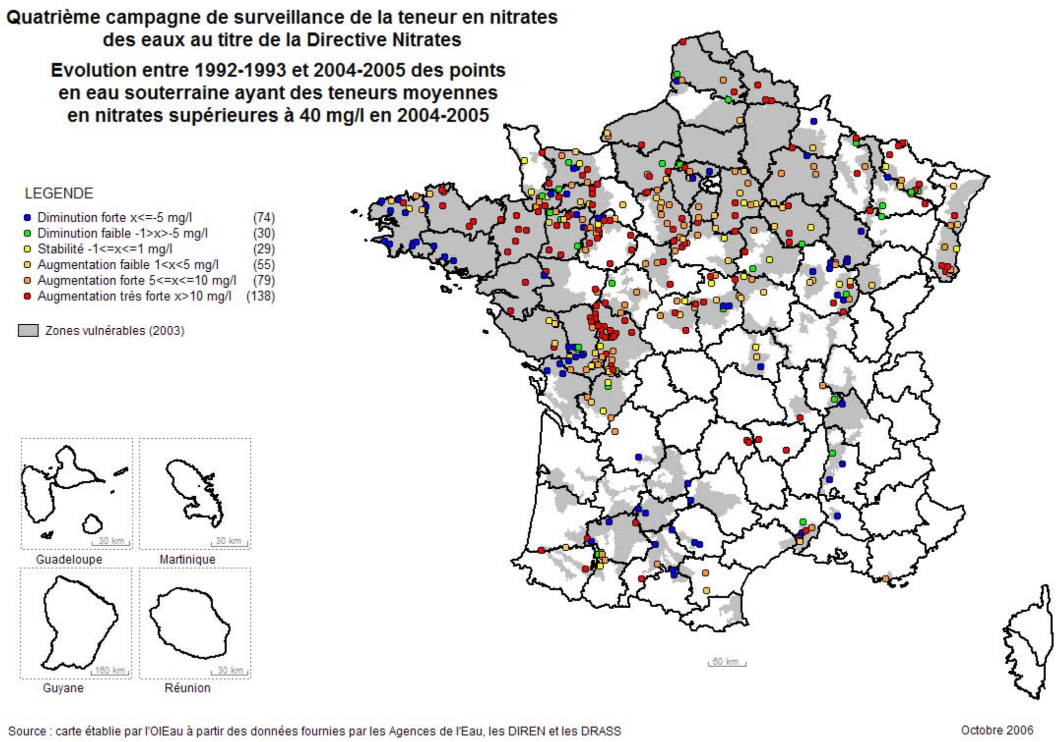
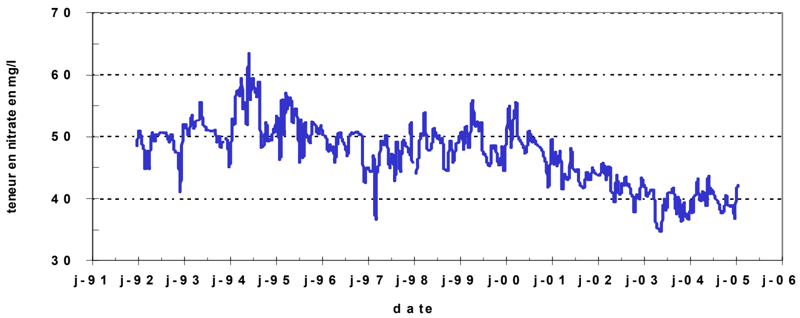


Figure 4: Evolution of the concentration in nitrates in the springs of Haut-Saintois: everage of 17 measurement points (in : CORPEN, 2006).



Management of point source pollution in Germany

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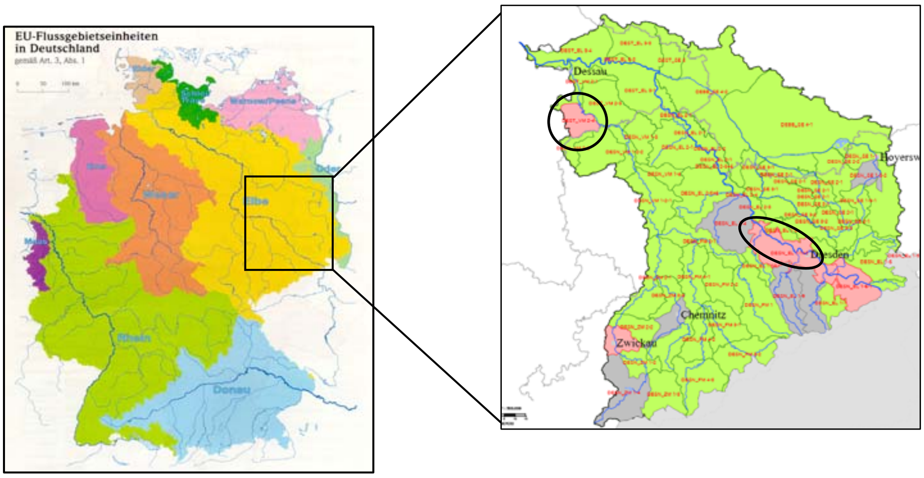
1. Introduction

The German management of point source pollution will be exemplified through two groundwater bodies of the Elbe River Basin District. 224 groundwaterbodies were delineated there. About 100 of them are considered to be in a poor chemical status, mostly owing to difuse N-sources, but some also owing to contaminated sites as point sources. In some of these cases exemptions must be used, both extension of deadlines and less stringent objectives. One example of each case will be presented.

Figure 1: Position of the groundwater bodies of the casestudies.



2. Point source management - European vs. German legal situation

2007/2008-results of the WFD Monitoring network and additional, elder information (monitoring and other data) were basis of status assessment. Directive 2006/118/EG (GWD) is not yet implemented in Germany. But a guidance document was developed in anticipation of the future federal regulation (LAWA, 2008).

A set of threshold values was established, developed under consideration of human- and ecotoxicologic criteria (LAWA, 2008; Part 2: Threshold values after Annex II GWD, Part 3: Threshold value Ammonium). Table 1 shows the threshold values of the parameters of the minimum list of GWD (Annex II, Part B) as an example:

Status assessment (LAWA, 2008; Part 1: Method of chemical status assessment after Art. 4 and Annex III GWD): The extent of a relevant pressure within a groundwaterbody was determined as the area of exceedance of quality standards / threshold values. The method varied with data availability and issue in question (*e.g.* dealing with point or diffuse sources). A groundwaterbody was at least rated as "poor status" due to point sources if the area of exceedance of quality standards / threshold values

- exceeds 25 km² or
- exceeds 1/3 of the area of the groundwaterbody, if its area is less than 75 km².

More stringent criteria were allowed.

Table 1: Assortment of German Threshold Values under the GWD.

	substance	threshold value[1] (proposed)
natural and/or anthropogenic substances	Arsenic Cadmium Lead Mercury Ammonium Chloride Sulphate	10,0 µg/l 0,5 µg/l 7 µg/l 0,2 µg/l 0,5 mg/l 250 mg/l 240 mg/l
synthetic substances	Trichlorethylene Tetrachlorethylene	∑: 10 µg/l
indicator of (saline) intrusions	Conductivity	-

[1] The threshold values were modified in some groundwater bodies on the account of specific background concentrations.

Trend: GWD generally demands the identification (and reversal) of significant and sustained upward trends and additional trend assessment in the case of point source/contaminated site plumes. Investigation of plumes (extent, expansion) is a long proved element of the German technical guidelines of contaminated site treatment. The existing experiences were used at WFD-work by application to the guidance document (LAWA 2008; Part 4: Method of trend assessment after Art. 5 and Annex IV GWD).

Measures: Identification of remediation measures is an iterative process, depending on level of knowledge, technical feasibility, proportionality. If remediation of the plume itself is impossible, the soil point source must be cleaned up at least. Therewith the further discharge of pollutants should be prevented and the remaining groundwater pollution might be kept at a stable state. This common technical standard (i.a. LAWA, 2006) fully meets the requirements of Article 5(5) GWD (Table 2).

Table 2: Implementation of article 5 (5) GWD keypoints in Germany.

GWD keypoints	German water and soil protection law	German groundwater guidelines
no further expansion of plumes	Federal regulation is still in progress.	Avoiding further plume expansion is remediation goal for both soil and groundwater. It is part of a guideline for general derivation of soil and plume remediation goals (in: LAWA 2006).
no deterioration of the chemical status of a gwb	Implementation of GWD is still in progress, Federal Water Act implements Art. 4 WFD.	
no risk for human health and environment	Federal Soil protection Act (BBodSchG,1998) requires remediation of contaminated soil and groundwater pollution as far as no hazards for human health and environment remains. The requirements to be fullfilled in connection with rehabilitation of waters shall be determined by law pertaining to water.	LAWA (2006): Groundwater contamination assessment guideline to define: - steady lokally limited increased pollutant concentrations (reme-diation required?), caused by - low pollutant loads (negligible?) - small plume without further input from soil into the groundwater (remediation required?) A lot of other detailed technical guidelines are available.

3. Casestudy - Megasite[11]

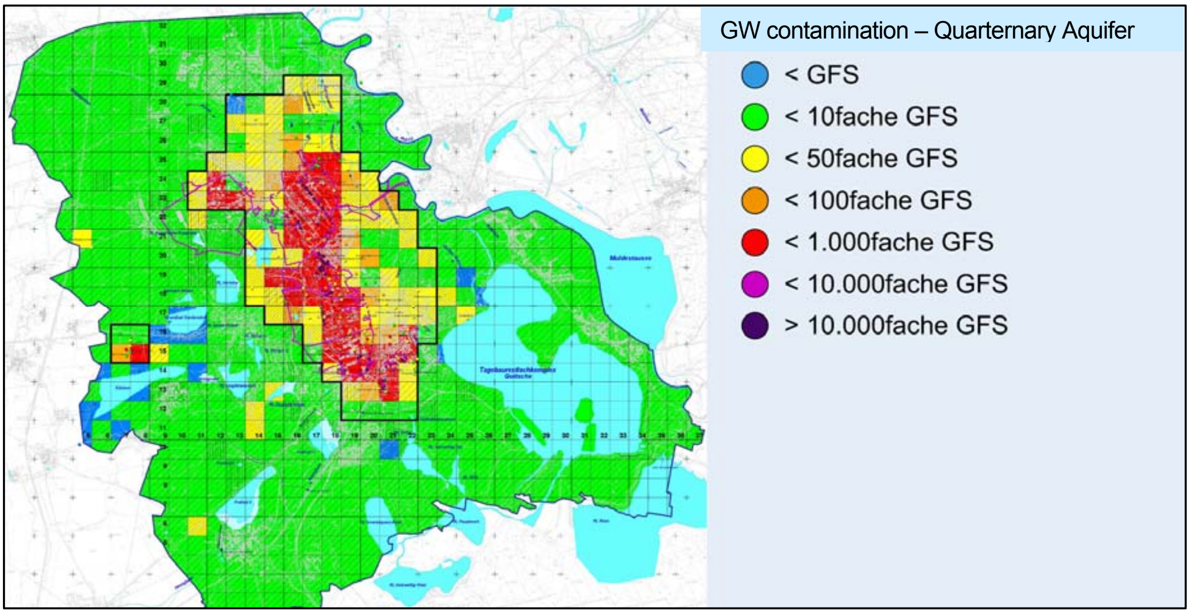
The contaminated megasite covers the groundwaterbody VM 2-4 “Pilotarea Bitterfeld-Wolfen” (~ 170 km²) of the river basin distirct Elbe and is situated in the south-east of Sachsen-Anhalt in middle Germany. It was already object of the EU-project WELCOME (Water, Environment and Landscape Management at COntaminated MEgasites). The groundwaterbody has a history of more than a century of both mining and chemical industry operating side–by-side. It entailed large scale soil contamination as well as a large groundwater contamination of about 100 million m³. The main contaminants are aromatic hydrocarbons (BTEX), chlorinated phenols (Chlorophenols) and chlorinated benzene (Chlorobenzens).

Soil and groundwater contamination were investigated, trend assessment was carried out. A four-step remediation concept was developed as a framework. The various different and detailed measures belong to four main groups (hydraulic downstream as well as upstream protection, source remediation, enhanced natural attenuation / permeable reactive barriers) and they all fit into the remediation concept. It is basis for the prognosis of future pollutant distribution and trend. In the case of such large scale groundwater contaminations like the one in Bitterfeld-Wolfen the effects of the remediation measures are difficult to assess, longterm prognosis is possible only along general lines. Despite a provisional trend assessment showed a slight increase of the groundwaters constitution, but good chemical status will not be achieved in the next 50 years as far as predictable today, because of the natural conditions and because there are no technical means to clean up the huge groundwater contamination. Therefore less stringent environmental objectives were developed:

- no further deterioration of the groundwater body within poor status;
- decrease of pollutants concentration in the long term (trend reversal);
- sustain recent conditions under consideration of the future impact of diffuse source “mining” as status quo.

With further progress of on going remediation measures todays less stingent objectives will be verified in 2015.

Figure 2: Exceedance of threshold values (GFS) in groundwaterbody “Pilotarea Bitterfeld-Wolfen” (VM 2-4).



[11] The facts were extracted from a presentation at the IKSE Mageburger Gewässerschutzseminar 2008 (Keil M. *et al.,* 2008) and from kind information of the Ministry of Agriculture and Environment of Sachsen-Anhalt State.

4. Casestudy - Amassment of different sized contaminated sites (accumulated site)

The groundwater body "Elbe" (EL 1-1+2, 483 km²) is stretches along both sides of the river Elbe around the city of Dresden. The area has a long urban and industrial tradition. The city and its industrialised surroundings cover a large part of the groundwater body and count alone more than 1000 contaminated sites (Fig. 3). Not all but many of them caused not only soil but also groundwater contamination. All can be find in the state site register "Sächsisches Altlastenkataster". They are investigated to a different degree (Fig. 4).

Figure 3: Groundwaterbody "Elbe", contaminated sites.

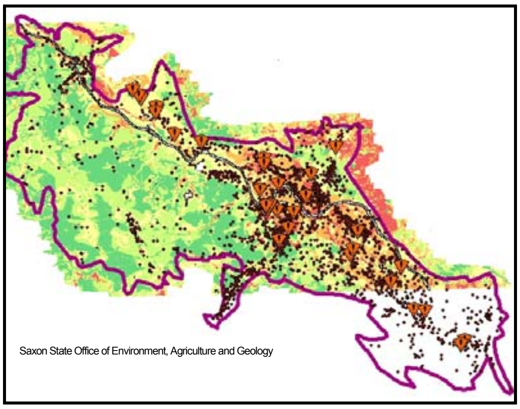


Fig. 4: Site treatment in Dresden.

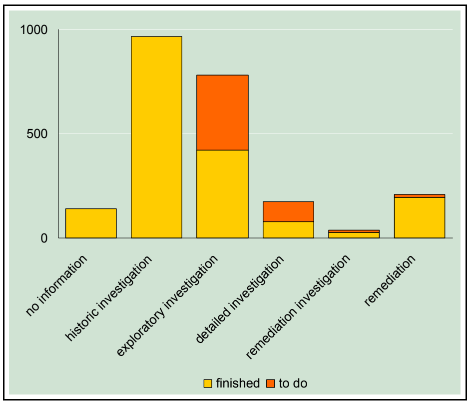
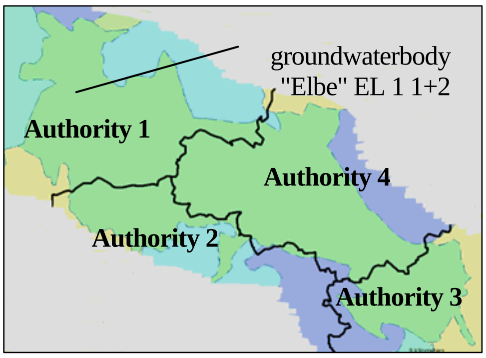
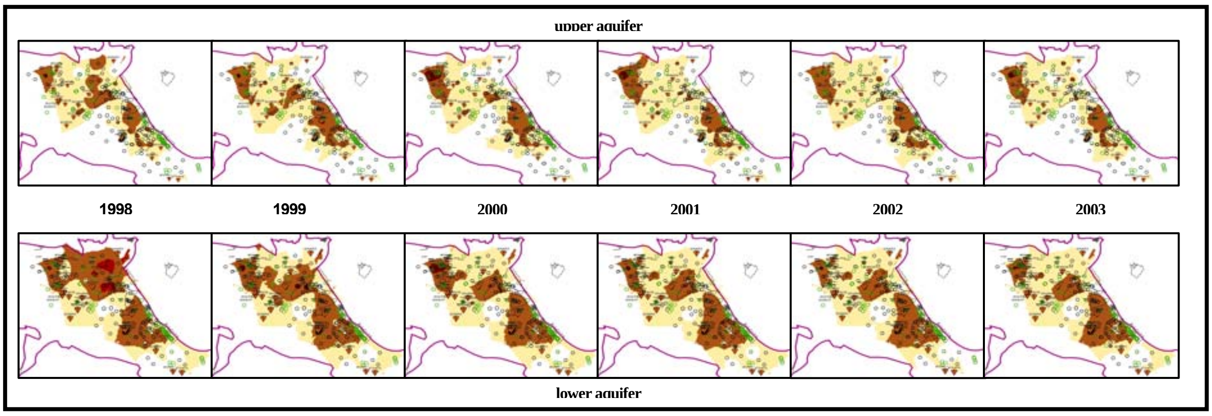


Figure 5: Groundwaterbody "Elbe".



Various polluters and proprietors are responsible for remediation measures and different authorities for water and soil protection law enforcement (Fig. 5). The steps of investigation and remediation are well known in general but the progress in detail depends on the special conditions of the single case. Groundwater contamination investigation, migration prognosis incl. trend assessment (Fig. 6) are constant part of the site investigation and basis to define the remediation goals.

Figure 6: Groundwater pollution trend (lightly volatile halogenated hydrocarbons) of the central part of groundwaterbody "Elbe".



Measures after WFD (groundwaterbody level) stand in this case for the summation of all measures wich answer the legal demands of water and soil protection (single site level) and its complex interpretation aiming the groundwaterbody. It is expected that good chemical status will not be achieved in time and the exemption "exceeding deadline" is necessary. Groundwater decontamination in the whole groundwaterbody is technically not feasible. Therefore the focus is set on soil remediation to eliminate the sources of groundwater pollution and therewith to reduce the input of pollutants into the groundwater. Not in all but in many cases the reduction of pollutants in the groundwater itself must left to its own resources, to natural processes, which last longer than six years. Furthermore long lasting administrativ law enforcing measures must be reckond, for example in the case of lawsuits. This has to be taken in account especially were so many single sites must be managed.

5. Conclusion

The ***legal situation*** in Germany is sufficiant and meets all demands of WFD and its daughter directive 2006/118/EG.

For ***megasites*** the official management of the contamination and the WFD-management also is comparatively simple, because there is one competent authority and often only one or just a few polluters in charge. One - even though complex - site goes with one groundwaterbody, which was megasite-pressure-indicated delineated. WFD-measures and those planned after the national technical law as remediation measures are identical. The technical management is good: complex remediation plan, site model, planning consultant etc. Therefore from todays view can be concluded that the already running site-measures are also the maximum that can be done on groundwaterbody level;

In contrast the official management for ***accumulated sites*** is very complex (several competent authorities, many polluters in charge). The WFD-management is comparatively difficult: groundwaterbody was hydrogeological based delineated, investigation and remediation levels of the single sites differ widely, there is no complex remediation plan. Therefore a framework plan for the groundwaterbody should be designed and established as a first measure, which requires a series of additional prior investigations. This plan could serve as an official guidance for the lokal authorities, containing priorisation (time and technical measures), deadlines, controlling and report obligations.

Exemptions: The extend of the already known groundwater contamination of the megasite requires less stringent objectives because complete groundwater remediation is impossible both because of technical feasibility and costs. Natural attenuation exceeds deadlines because of the natural conditions in the aquifer. Monitoring of the remediation success and the site model update will show what pollutant concentrations and loads in the aquifer can be achieved. The first less stringent objectives will be adapted to this progressively. In accumulated sites are many single measures necessary which take effect just slowly because of natural, judicical and management reasons. The development of a framework plan could help to assess, if good chemical status can be achieved after eceeded deadlines.

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Keywords: Water Framework Directive, groundwater, point sources, contaminated sites, trend, threshold values, exemptions.

Posters session

Integrating groundwater science into management decisions: the Indian scenario

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More than a billion population and high growth in industrialization and urbanisation in India have huge stakes in groundwater utilities including domestic supplies. A sudden boom in groundwater development for irrigation since 1970s with the introduction of tube-well and pumping technology, rural electrification and demand for increasing crop production has triggered the groundwater level declines in 370 out of 603 districts. Second generation problems of wells running dry, rising energy consumption and pumping costs, salinity ingress in coastal areas and health hazards due to arsenic, fluoride, iron or other geo-genic toxins and agro-chemical residues became alarming (Samra and Sharma, 2008). This presentation highlights the major issues concerning groundwater assessment, development, augmentation, utilization, contamination and governance for enhanced livelihoods of the farmers.

Groundwater development and utilization

Application of simulation models integrating groundwater dynamics into the management options to evaluate the potential and fate of resource under different constraints, and optimization studies for the over-exploited aquifers of northwest India has been quite helpful. Using such an approach Sondhi and Kaushal (2006) gave an option to reduce the area under paddy or reduce the pumping and meet the remaining irrigation demand by transferring canal water from rising water table areas to the declining water table area. Future reduction in fresh water supplies to agriculture will induce farmers to make conjunctive use of 32-84% of the shallow saline groundwater in the arid and semi-arid regions. Research efforts have demonstrated the possibilities of using such waters through selection of salinity tolerant crops (cotton, mustard, tree crops, etc.), varieties and cropping patterns. Maintaining low levels of salts in the root-zone through appropriate irrigation schedules, application methods and conjunctive use of groundwater, canal and rainwater and optimal use of chemical amendments and land configurations to mitigate harmful impacts has several possibilities (Minhas, 1996). In the hard-rock regions of central and southern India, groundwater depletion have invoked wide spread community-based interventions for groundwater recharge. The Central Ground Water Board has developed a blueprint for groundwater recharge with surplus runoff of $36.4*10^9$ m^3 in about 450,000 km^2 identified in various parts of the country experiencing a sharp decline in groundwater levels. About 71% of groundwater in the high productivity potential but poverty ridden eastern zone is unexploited. Larger investment portfolios, rural electrification and technical support is necessary for optimizing groundwater utilization to enhance productivity and sustain inclusive rural development. The Indian farmers have installed about 20 million groundwater abstraction structures through private investment, institutional credit and subsidised electricity and diesel supplies. There is a very strong nexus among overutilization of groundwater, subsidised energy utilities, marketing, support prices and procurement policies of agricultural produce.

Groundwater policy

There are large inter regional variations in terms of governance, policies, advocacy, infrastructure and farmers initiatives for optimized utilization of groundwater. In northwest India imposing restrictions on banks for financing the groundwater development did not work and farmers invested their own savings or borrowed from private money lenders even at very high interest rates. In poverty and out migration afflicted eastern India with vast and reliable unutilized groundwater resources there is no taker of even subsidised credit due to fragmented or scattered holdings, lack of governance and infrastructure. Withdrawing subsidy on energy is a very difficult political question and can be resolved by recovering full charges of utilities by the farmers' organisations and investing into groundwater recharging as a community benefit. Improving competitiveness of water guzzling crops in groundwater surplus eastern India and less water requiring commodities in overexploited south and northwest India through technological, marketing, incentives and disincentives interventions can rationalize the groundwater use.

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Keywords: Simulation models, conjunctive use, recharge, water-energy nexus, investment, subsidy, livelihoods.

Protection of mineral water resources, a case study from Northern Portugal

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In continental Portugal a large number of mineral water resources are found. Many of them are used as bottled waters and recreational resources (spa facilities, tourism, etc.) or as geothermal resources. Hence, their economic importance is very large, especially when looking at the local scale. For example in 1998 the São Pedro do Sul Spa brought in almost 3 million Euro in direct revenue for the Municipality, and it was calculated that the indirect revenues even accounted to over 15 million Euro to the local economy (Ferreira Gomes *et al.,* 2001). Because of this economic importance legislation is set up to regulate the exploration and production for these resources (Decreto-Lei no 86/90). To protect the sources also protection areas around them are defined in which activities that may contaminate the mineral water resources are restricted (Ferrieira Gomes *et al.,* 2001).

A case study; Mineral and fresh water between Chaves and Peders Salgadas

In order to show that this protection is important, a study of 127 fresh surface and shallow spring waters have been conducted in Northern Portugal between Vilarelho da Raia and Vila Pouca de Aquiar. We measured the chemical composition on these water samples and hoped to be able to relate them to the geology of the area and to mineral water sources. However, when we analysed the data we found three basic groups: group 1 – samples with little fertilizer influence, group 2 – samples with contamination due to gypsum fertilization, and group 3 – samples with contamination due to nitrate fertilization. A few samples had, for example, nitrate concentrations above the limits set in the 2006 Groundwater Directive (Quevauviller, 2008), which indicates that action has to be taken upon this. This study however was conducted several years before this Directive came into force.

On the other hand, we did not find any contamination in the mineral water resources. This is probably mainly due to the very deep circulation of these waters, and their distant origin. Aires-Barros *et al.* (1998) and Marques *et al.* (2001, 2006) used isotopic techniques to determine the ultimate source for several of the mineral waters in this area. The ultimate source of the mineral waters is meteoric water which is captured high in the hills at altitudes of 900 to 1,200 meter.

For the efficient protection of the mineral water sources it is important to determine the pathway of these water bodies. To begin with also the ultimate source should be protected. In this case, the sources are high in the hills and there is very little economic activity in that region. It takes however quite a long time for the original water to reach the sources, so contamination could have a long lasting effect. Also potential interactions between the surface domain and the developing mineral water body should be assessed.

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Keywords: Groundwater – surface water relationships, mineral water protection, fertilizer contamination, isotopes.

Delineation of groundwater protection areas against diffuse pollution

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In order to preserve, and even to restore, the quality of underground water, the french water agencies have included agro-environmental measures in their aid programs. The aim of these measures is to protect underground water, especially when used for human water supply, against persistent chemical contaminants, such as nitrates and pesticides. At the same time the french Ministry of Environnement reinforced the means of pollution control by creating wellhead protection areas. The cost of such measures, which can be very important if considering the whole catchment zone, requires having a specific and optimized approach based on the identification of areas where the actions will be the more efficient. This paper presents a methodology helping to delineate such protection areas. This methodology was developed according to the type of aquifers present France: alluvial, sedimentary (karstic or non karstic), basement. Nevertheless, it can be applied to any type of aquifer as long as the considered aquifer was classified among three proposed types: continuous aquifer, discontinuous fractured aquifer, discontinuous karstic aquifer. The methodology consists of three steps: (i) identifying the aquifer area that supplies the groundwater source or well, (ii) defining on the ground surface the catchment zone of the well or source in question (fig. 1), (iii) mapping the vulnerability of the catchment zone from a multicriteria analysis (fig. 2).

Figure 1 - Definition of catchment zone (Bussard* et al.*, 2006)

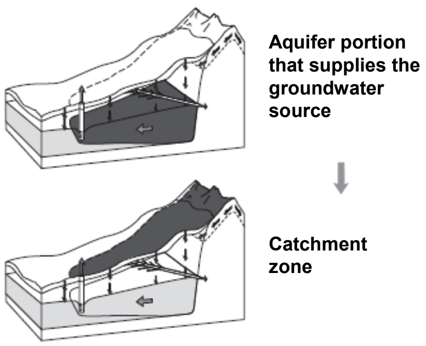
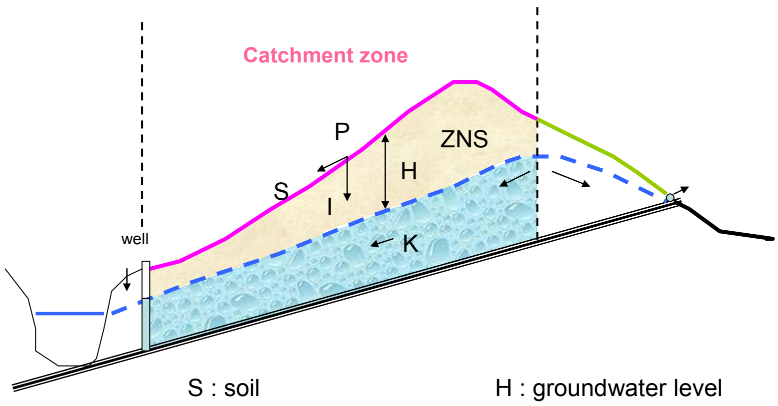


Figure 2 - Parameters used for vulnerability mapping in a case of continuous aquifer



The aquifer area that supplies the groundwater source or well depends on structural geology and hydrodynamic criteria. In the same way, different methods were developed for vulnerability mapping, according to the type of aquifer. So the geological and hydrogeological study of the whole underground basin is a key point in order to define the type of aquifer and corresponding methodology and to acquire the data available for delineating the catchment zone and mapping the vulnerability. The proposed methods of vulnerability mapping were adapted from existing methods (DRASTIC, RISK and DISCO). The needed parameters for multicriteria analysis are: soil characteristics, efficient rainfall, infiltration in the overlying layers, unsaturated zone thickness, aquifer permeability and karst specific parameters (karst network development and epikarst). The proposed methodology was tested on five pilot basins, selected according to different hydrogeological contexts.

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Keywords: Wellhead protection, catchment area, vulnerability, protection zone.

Hydrodynamical and physicochemical perturbations of superficial and underground waters due to mining abandonment

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Many mines were exploited below the groundwater level and protected by pumping all during their exploitation. Abandonment of mining sites has induced an increase of groundwater level and flooding of mining voids (INERIS, 2006). The highly transmissive medium due to mining voids (and surrounding uncompressed zone) forms a mining reservoir which can have a great volume. Moreover, groundwater becomes in direct contact with ores of which some are potential water pollutants (metals, metalloids, hydrocarbons, other ions, see figure 1). When a new hydrostatic level is reached, some mining openings become the discharge systems of these new reservoirs. Thus, they can reject in the surface network large quantities of water with more or less satisfactory quality (figure 2). When the flooded mining voids do not directly overflow into the surface network, they can constitute a groundwater reserve in relation with the aquifers. These problems mainly appear in the great mining zones like French north coal and iron basins. But small abandoned mines may also have a local quantitative and/or qualitative influence on natural water. Thus, in these areas, it is important to take into account hydrodynamic and physic-chemic characteristics of the mining reservoirs (already flooded or being flooded) in the evaluation of the “chemical and quantitative good state” of groundwater bodies.

Figure 1: Piper diagram of natural and mine groundwaters (southern France, INERIS).

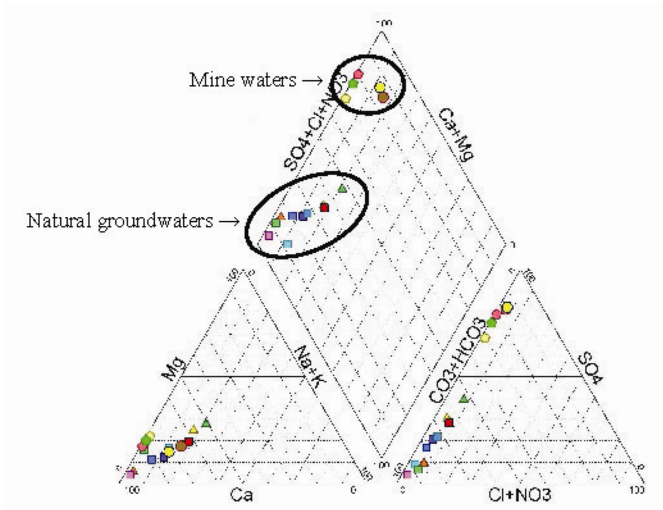
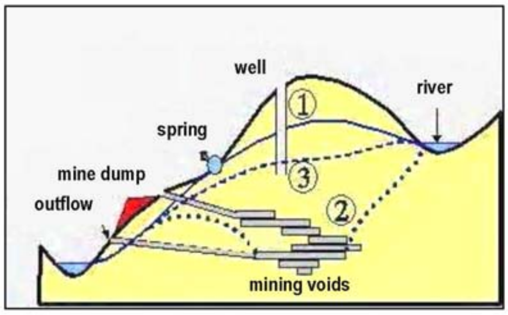


Figure 2: Perturbation of groundwater circulations due to mining works and abandonment (INERIS) (Legend: ① initial state, ② state during mining works, ③ final state after mining abandonment).



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Keywords: Groundwater – surface water relationships, mine water, mine flooding, mineral and organic micropollutants.

The monitoring of the groundwater body at risk from point of view of oil products and applying of the remediation techniques

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In Romania, a number of 142 groundwater bodies where identified, delineated and characterized. These bodies were attributed for the management to all eleven Water Directorates.

In the Ialomita-Buzau River Basin was delineated a number of 18 groundwater bodies, three of these being at risk from a qualitative point of view, and one of those three is at risk from point of view of the oil pollution (ROIL15- Prahova alluvial fan).

The monitoring of the qualitative status is made both by wells from National Hydrogeological Network and by local monitoring network situated in the area of main pollutants.

The pollution with oil products has been evidentiated since the 1970's, when the first studies have been carried out in order to show the spreading area and phreatic water pollution indicators.

The technical solutions for the groundwater remediation include all techniques which aim to neutralize the oil products or to stop the input of such products in the subsoil. Those techniques were applied with good results and the floating oil products strata were reduced. In the last years was observed a decreasing trend of the pollution with oil products in the Ploiesti area.

Keywords: Groundwater body at risk, monitoring wells, remediation, oil pollution.

Overview on WFD-objectives for groundwater

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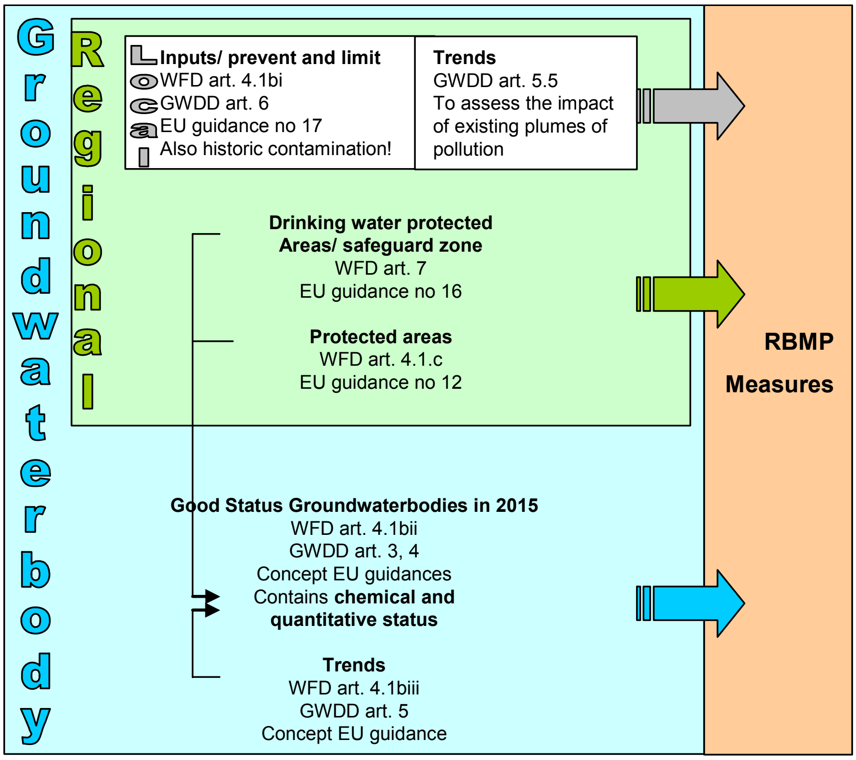
The Water Framework Directive (WFD; EU, 2000) contains objectives for groundwater. Most of them are mentioned in article 4.1b (prevent or limit input of substances, good groundwater status (chemical and quantitative) and reverse upward trends). Article 4.1c formulates objectives for protected areas which can have a relationship with groundwater. Also for drinking water objectives have been formulated; these may have a relationship with groundwater as well.

All these objectives have different deadlines, different obligations, different exemptions, and so on.

In practice, we noticed confusion on what situation belongs to which objective. Therefore we made for ourselves an overview (see Figure 1 for draft version), which may be helpful to you too. The overview states the articles in WFD and Groundwater Directive (GWD; EU, 2006) referring to each objective, the presence of a guidance document (if any), relationships between objectives and the scale at which an object is relevant (local, regional, groundwater body).



This overview can, *e.g.,* be used to explain to people (especially administrators at regional and local level) that even if an groundwater body is at good status, measures may be necessary (*e.g.* to reverse a trend, limit inputs or protect a safeguard zone for drinking water purposes).

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Keywords: Water Framework Directive, groundwater, objectives.

Potential pressures and impacts of economic activities in accordance with WFD

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The paper analyses potential pressures from economic activities and their impact on groundwater bodies in the Kupa River basin, based on a study under the title of "Characterisation of water bodies in the Black Sea basin in the context of implementation of the EU Water Framework Directive" prepared in 2005 by the Croatian Geological Survey, Department of Hydrogeology and Engineering Geology, Zagreb. Geological composition of the Kupa River basin area is described with presented lithostratigraphic units and structural-tectonic features. Hydrogeological characteristics of karst and lowland parts of the basin area are presented through hydrogeological units in terms of their permeability. Groundwater bodies have been selected and characterised in accordance with the requirements of the EU WFD (2000/60/EC), and characterisation approach in the lowland area differs from the one applied in the karst area. A map of natural vulnerability of groundwater bodies in the Kupa River basin has been prepared on the basis of available data. The following potential pressures from economic activities have been selected:

- point (industry, waste dumps, population);
- diffuse (agriculture, roads);
- and accidental pollution (oil pipeline).

On the basis of all available data analysis has been performed and assessment of risks to groundwater bodies in the Kupa River basin has been made.

References

Croatian Geological Survey, Department of Hydrogeology and Engineering Geology, 2005 - Characterisation of water bodies in the Black Sea basin in the context of implementation of the EU Water Framework Directive, Study.

Water Framework Directive, 2000.

Keywords: Groundwater bodies, characterisation of groundwater, vulnerability, economic activity, pressures, impacts.

Management of drinking water in city of Ljubljana, Slovenia

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Most of the practical problems that we face today with the on-site management of drinking water sources and distribution of healthy drinking water, originate from past actions, interventions and political decisions. Point and dispersed sources of pollution are the result of many different human activities.

Two aquifers, Ljubljansko Polje (Ljubljana Field) and Ljubljansko Barje (Ljubljana Moor), with mutual dynamic capacity about 4.0 m^3/s, represent drinking water resources for almost 300,000 inhabitants. The major part of the vulnerable Ljubljansko Polje porous aquifer, enabling water supply for 90% of the whole population, lies beneath urban and agricultural areas. Sava river sediments that built-up the aquifer can reach thickness of more than 100 m in the deepest part of the aquifer. The average groundwater level is 13 m under the surface and the groundwater level oscillation is about 3 m. The mean annual rainfall over Ljubljana is approximately 1,400 mm/yr, with less than 50% lost to evapotranspiration. The aquifer is also replenished from influent recharge from the river Sava and from the Barje multi-aquifer system. The combination of the humidity of the local climate, the snow-rain flow regime of the Sava regime (as the main source of groundwater recharge), a large regional groundwater gradient and the high porosity of the sediments creates fast flow (around 20 m per day) and high regeneration of the dynamic reserve of the Ljubljansko Polje aquifer. The lowland area covering the aquifer is partly urbanised, with large parts of the town of Ljubljana built over the Ljubljansko Polje sediments. However, most of it is farmland with various crops, dominated by wheat, maize, potatoes and vegetables, whilst the mountainous part of the catchment is dominated by forest.

Ljubljana citizens have been supplied with untreated water, even not disinfected, for more than 110 years uninterruptedly. Water protection zones for Ljubljana water resources have been established since 1955, early enough to prevent the urbanisation on main areas of water resources. These zones have been defined and developed on the basis of capture zones and infiltration areas of the abstraction wells. However, for political and economic reasons and against professional advice some borders of water protection zones avoided industrial areas that are, in reality, in the area of influence of water fields. This was the cause of the problems of chromium (VI) pollution in the mid-eighties. Ljubljana is clearly entirely dependent on groundwater for public, industrial, agricultural and other water supply. During recent years the water supply has faced several problems with the deterioration of groundwater quality and other unacceptable consequences of groundwater exploitation. Major parts of the exploited aquifers are not sufficiently protected, leaving the water supply vulnerable to pollution from various sources. None of the pumping stations within the Ljubljana water supply system are safe from sudden pollution (*e.g.* TCE, herbicides).

The management of groundwater in urban, industrial and agricultural areas require professional knowledge and the possibility of taking immediate steps in case of accidents and malfunctions. For this purpose a mathematical model of groundwater flow has been developed for better drinking water exploitation and protection. The task of the model is to help the groundwater manager to better understand the dynamics of the system. The development of mathematical models begins with the conceptual understanding of the physical system. A numerical groundwater flow model was established for the wider area of the Ljubljansko Polje aquifer. However, a transport model was not established due to a lack of experimental data on solute. The transport model needs to calculate reliable scenarios of pollution dispersion, which can only be achieved, with the application of real transport parameters. These were provided from tracer experiments in the Ljubljansko Polje aquifer.

On the other hand the Decree on Water protection area for Ljubljansko Polje aquifer water body (2004), which is in harmony with the WFD, determines monitoring, inspection and reporting of the protection zones. Three water protection zones are defined around the water pumping fields (zone 0), with prescribed restrictions of activities and land use. The irregularities that happened in the past, exceptions that were allowed and very heavy pressures of investors to change the land use and regulations on protection zones, cause every day problems in managing the drinking water source. Groundwater management in Ljubljana demands strong and effective co-operation between state, municipality, public water supply company and consumers.

Keywords: Groundwater protection areas, Drinking water management, Land use.

Spatial decision support system (SDSS) as a tool for integrated groundwater resources management

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In many European countries karstic areas are essential for public water supply. Sustainable development of karstic areas means a maximum use of the environment with simultaneous conservation of natural resources. This is difficult to achieve in practice. Integrated water resource management has to balance water resource protection requirements with a variety of demands for land-use activities. This complex issue could be supported by a spatial decision-support system (SDSS), in which legal frameworks and socio-economic aspects with emphasis on land-use activities could also be implemented. SDSS integrates data from various sources and helps to make the decision processes more effective and transparent. Successful application of a SDSS depends on its acceptability by stakeholders, which can be improved by integrating a broad range of practical experiences of stakeholders with formal knowledge of experts in a knowledge base.

Such a decision support system has been developed in a transnational and interdisciplinary Interreg IIIB project KATERII (www.kater.at). Land-uses considered include summer and winter tourism, settlements, transport, forestry, agriculture and pasture management, studied at pilot areas in Austria (Hochschwab, Schneealpe, Rax and Schneeberg), Croatia (Lika Region), Italy (Molise Region and Veneto Region) and Slovenia (Krvavec). These areas were surveyed and assessed in relation to water cycle, environment and specific land-use activities.

Decision support system (DSS)

DSS consists of multiple parts, such as special database (*e.g.* GIS of the pilot area), knowledge base and models for data analysis and interactive modelling process. The formal methods applied for the decision making process include multi-criteria decision-making and techniques of fuzzy evaluation. They are used to define a system of rules describing the concrete forms of impact of land-use activities (derived from an activity-impact matrix) on the natural environment. This system of rules is the formalised knowledge base and is the core of the decision support system, which helps to make decisions and their potential impacts transparent as well as integrative, bridging the gap between different institutions and experts involved in groundwater protection. Knowledge base is organised in an ontology, which is a catalogue of the types of things that are assumed to exist in a certain domain of interest. An ontology together with a set of individual instances of classes constitutes a knowledge base. For developing the ontology a world known ontology DOLCE (a Descriptive Ontology for Linguistic and Cognitive) was selected, where a lot of expressions has already been explained and qualified. In KATER II we used DOLCE as a basic ontology and for the needs of DSS we implemented new expressions and terms.

Discussion

The decision support system is a tool for solving decision problems in water management. The basic tasks of water management can be divided into administration, crisis management and planning activities. A detailed analysis of tasks shows that the nature of decision making and the time scale of decisions are clearly different between task categories. Planning needs long-term decisions under conditions of low time-pressure, whereas administration and above all crisis management need immediate decisions. The support of decisions in water management must take into account the differing information needs and tailor the decision support system (including the structuring of data access, the way of data presentation and the system functionality) according to user needs.

Keywords: Spatial Decision Support System, groundwater protection, karst, land use, water management.

Hazard sources identification and contamination assessment of ground waters usable for emergency water supply of population

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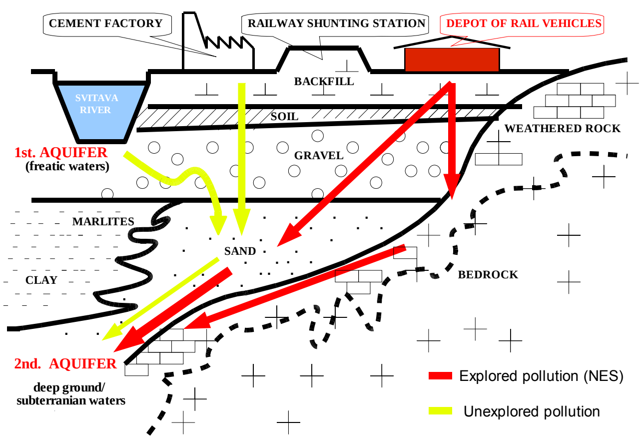
The paper is aimed at discussing possible contamination of ground (also subterranean, deep ground or artesian) waters which represent significant source for supplying population with high-quality drinking water during emergency situations. Water supply reservoirs may be contaminated and public water supply networks destroyed as a result of emergency state. In such cases the emergency water supply has to be ensured by local authorities with the help of standby supply in required quality and capacity in relation to the range of affected area.

Sources of shallow and especially surface waters are very often contaminated during emergency state and they are unusable for the above mentioned purpose. The delivery of packaged water is uneconomical, time-consuming, and it is usually impossible to ensure the water supply swiftly in required sufficiency, especially for heavily populated areas (AWWA, 1994). Subterranean waters of artesian type comprise a highly valuable raw material with regard to their easy and cost-effective withdrawal, natural quality and low vulnerability. It is necessary to seek out, investigate and register hydrogeological structure of artesian waters and guarantee their sufficient protection. The effective protection includes both conservation of appropriate water quality and also safeguarding sufficient accumulation of ground waters and yield of water sources.

The case study aimed at the occurrence of subterranean waters and their possible contamination was carried out in Brno town agglomeration in the Czech Republic. At the same time the significant standby source of deep artesian waters in Brno basin was proved (Caslavsky, 1990). Simultaneously hazard sources of potential artesian waters contamination caused by direct seepage, or the leakage of polluted shallow ground waters were identified. Characteristics of contaminants, general conditions of the region, and natural conditions of investigated locality, mainly geological, hydrogeological, geochemical, and hydrological data were considered.

The second part of submitted paper deals with the risk assessment of artesian waters contamination by one of identified critical hazard source. This source represents pollution of shallow underground waters by non-polar extractable substances (NES) resulting from an environmental burden in a depot of rail vehicles (see Figure 1).

Figure 1: Geological section and the ways of contamination.



The implementation of counter-measure is presented to reduce risk contamination of deep artesian waters by NES. The determination of NES concentration in subterranean waters and subsequent heath risk assessment is the basis for making a decision on acceptability of using subterranean waters for supplying inhabitants with drinking water during emergency state.

Introduced procedure can be generally applied in different regions and for other contaminants with threshold effects because of its objective and demonstrative character.

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Keywords: Artesian Waters, Contamination, Ecological Burden, Emergency Water Supply, Hazard Source, Health Risk Assessment, Identification, Non-Polar Extractable Substances, Shallow Ground Waters, Subterranean Waters.

Session 3 – Science and policy interface: how science supports groundwater management

Tous les documents publiés sous l'égide du groupe C ont mis en évidence des lacunes de connaissances importantes (relations quantitatives et chimiques entre les eaux souterraines et les rivières ou les écosystèmes terrestres, temps de transfert des polluants, évaluation du rapport coût – bénéfice, changement climatique, etc.). Tout ceci représente une limite réelle à une mise en œuvre efficace de la DCE et de sa directive fille sur les eaux souterraines. Dans ces conditions, la communication et la création d'interfaces entre les gestionnaires et les scientifiques reste une priorité pour que l'application de la DCE soit un succès. Dans cette session, des exemples de projets de recherche locaux, nationaux ou européens, utiles à la mise en œuvre de la DCE et de la directive fille sur les eaux souterraines, seront présentés. Des discussions sont également attendues pour identifier les pistes d'amélioration en termes de communication entre les deux communautés. Les posters sont particulièrement les bienvenus dans les domaines suivants : projets de recherche en appui aux échéances récentes de la DCE et de sa directive fille sur les eaux souterraines (évaluation du bon état chimique et quantitatif des masses d'eau souterraine, mise en place de mesures efficaces de réduction des pollutions diffuses et ponctuelles, caractérisation détaillée des masses d'eau souterraine y compris connaissance des relations nappes-rivières, nappes-zones humides, temps de transfert des polluants, mécanismes de transfert dans la zone non saturée, etc.), nouveaux enjeux de la gestion des eaux souterraines (changement climatique, écologie des eaux souterraines, substances émergeantes, etc.), communication (comment améliorer le transfert des résultats des programmes de recherche vers les gestionnaires ? comment mieux identifier les besoins des gestionnaires ? etc.).

All activities and all technical guidance documents published under WGC activities raised important lacks of knowledge (chemical and quantitative relationships with surface water and terrestrial ecosystems, pollutants transfer and time scale, cost-efficiency assessment, climate change…). This represents a real limit for an efficient implementation of the Water Framework Directive (WFD) and of the Groundwater Directive (GWD). Hence, communication and interfaces between science and policy remain a priority for a successful implementation of the WFD/GWD.
In this session, examples of local, national and European research projects supporting the implementation of the GWD will be presented. Exchanges and discussions are also expected to improve communication between both communities.
Posters are particularly expected in the following fields: recent research projects supporting the latest milestones of the WFD/GWD directives (groundwater bodies chemical and quantitative status assessment, implementation of efficient measures to reduce diffuse and point source pollutions, groundwater bodies further characterisation including the knowledge of relationships between groundwater-surface water-dependent terrestrial ecosystems, transfer times…), new challenges of groundwater management (climate change, groundwater ecology, emerging substances, etc.), communication (how to improve dissemination of research project results? How to better identify policy makers needs? etc.).

GENESIS, an integrated research project to support groundwater systems management

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Abstract

Groundwater resources are facing increasing pressure from consumptive uses (irrigation, water supply, industry) and contamination by diffuse loading (*e.g.* agriculture) and point sources (*e.g.* industry). This cause major threat and risks to our most valuable water resource and on ecosystems dependent on groundwater. New information is need on how to better protect groundwaters and groundwater dependent ecosystems (GDE) from intensive land-use and climate change. The impacts of land-use changes and climate changes are difficult to separate as they partly result in similar changes in the ecosystems affected. The effects are highly interwoven and complex. The EU groundwater directive (GWD) and the water framework directive (WFD) provide means to protect groundwater (GW) aquifers from pollution and deterioration. At present, the maximum limits for groundwater pollutant concentrations have been set for nitrate and various pesticides. Also, water of sufficient quality and quantity should be provided to ecosystems dependent on groundwater. The European aquifers differ by their geology, climate, and threats to aquifers. This must be considered when general guidelines for management of these systems are developed. The poster present the layout of the GENESIS project which is a large scale project on groundwater systems with 25 European partners undergoing contract negotiations with European Commission. Different relevant aquifer sites in various European countries to test scientific issues and find new results to important problems.

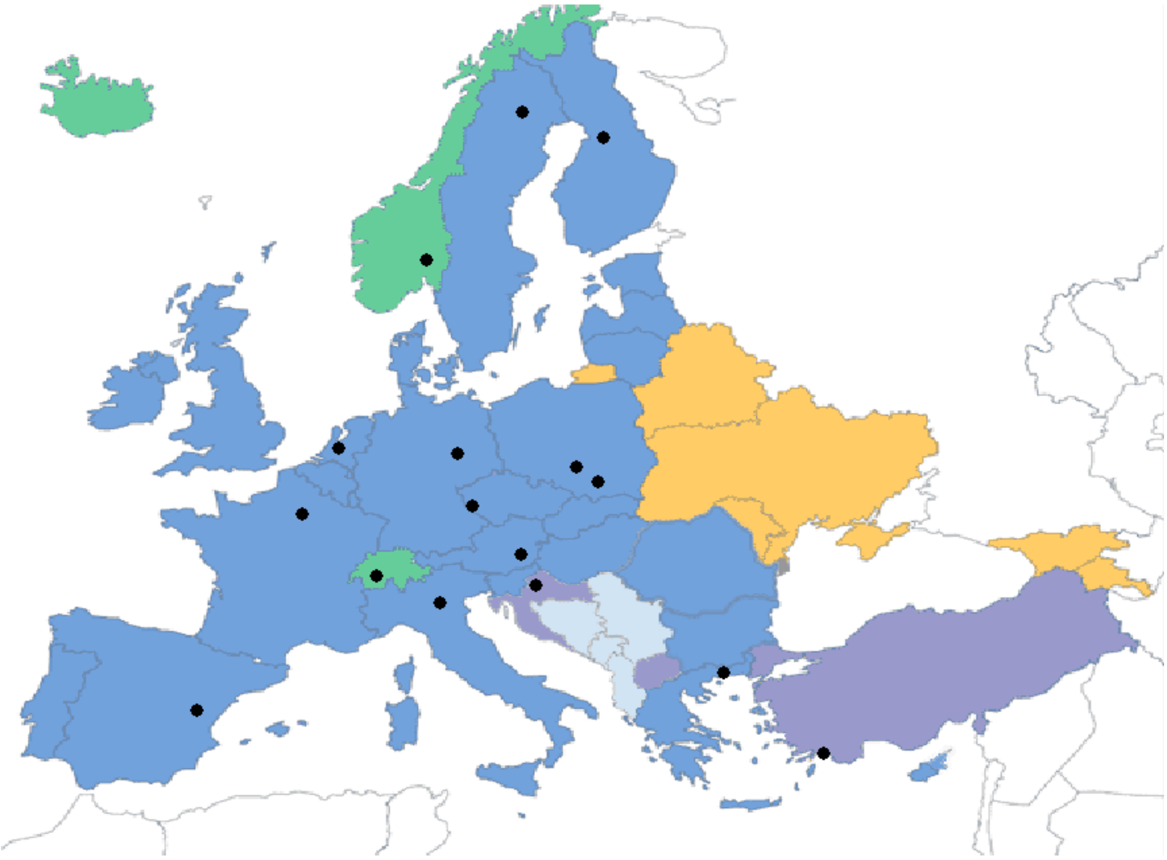
Introduction

Groundwater resources are facing increasing quantitative pressure from land-use and consumption pressures. In some areas, groundwater levels have been reduced and this has resulted in negative impacts on water quantity and quality and important ecosystems relying on groundwater. In many areas, groundwater has been contaminated by diffuse loading resulting from land-use activities (*e.g.* agriculture) or point sources (*e.g.* industry). There is a strong need to reduce input of pollutants to prevent groundwater pollution. Additional threats from climate change are unknown, highly interwoven and complex.

The EU Water Framework Directive (WFD), Groundwater Directive (GWD) and also Nitrates Directive, Landfill Directive, and the proposed Soil Framework Directive provide means to protect groundwater (GW) aquifers from pollution and deterioration. The legislation intends to safeguard groundwater resources while maintaining important land-use such as agriculture, forestry, urban development and industry. In the GWD, maximum limits of pollutant concentrations have been set for nitrate and pesticides in groundwater bodies. Actions must be taken i) not to exceed these limits, ii) reverse trends in pollution, iii) prevent completely emission of hazardous pollutants. The criteria set should provide groundwater for human consumption as well as for ecosystems depending on groundwater.

Future groundwater management should provide safe drinking water and safeguard important ecosystems. The European aquifers differ by their geology, climate, and threats to aquifers, which must be taken into account when new policies are developed. The objective of GENESIS is to integrate pre-existing and new scientific knowledge into new methods, concepts and tools for the revision of the GWD and better management of groundwater resources. Tools for management and monitoring will be developed and tested on data from carefully selected case study aquifers. In Europe, groundwater is abstracted from various types of aquifers, from large fissured rock and karst to porous sedimentary and granular glacifluvial deposits. The case studies in GENESIS (Fig. 1) will cover these important geological formations and aquifers, different climatic regions, different ecosystems (wetlands, springs, streams, lagoons), different inputs, different levels of economical development and different drivers for environmental change (*e.g.* new sustainable agricultural practices). Some cases are connected to particular important European ecosystems protected by Natura 2000 and by the Ramsar convention. Others are connected to important and unique aquifers (*e.g.* Po aquifer).

Figure 1: Location of GENESIS case aquifers (modified from http://www.europeanmovement.org).

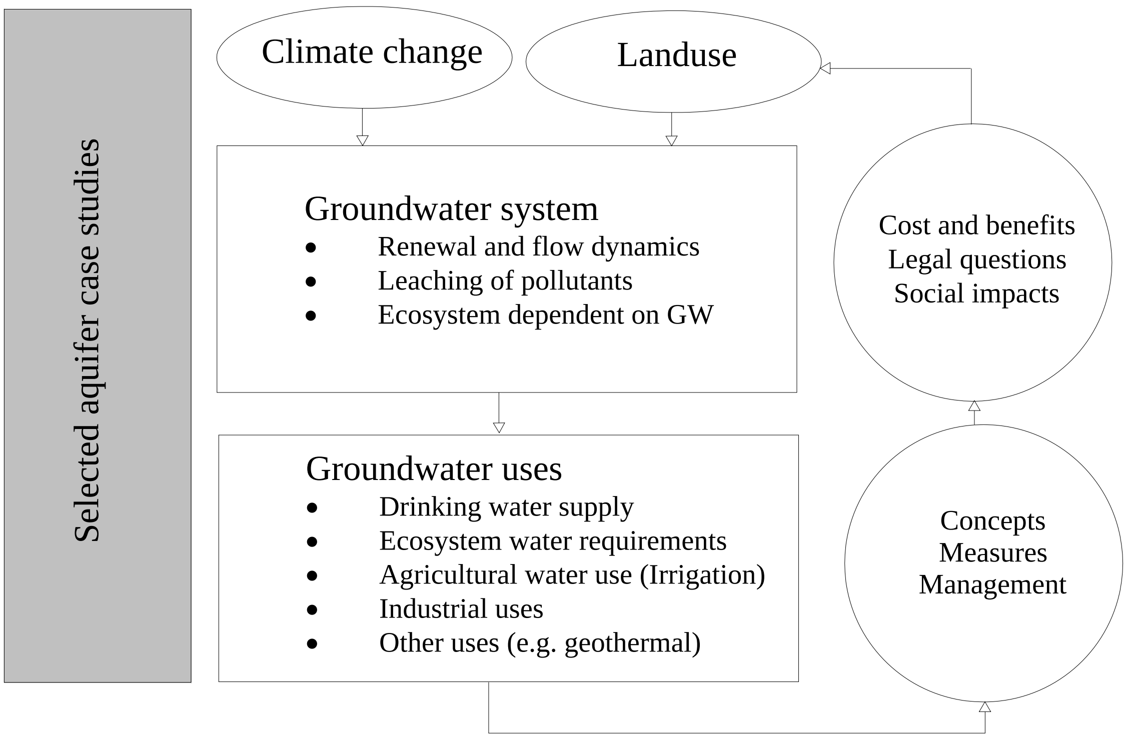


The overall concept of GENESIS is outlined in Fig. 2. The groundwater status is affected by several direct and indirect drivers (boundary conditions) the most important being various land-use activities and the climate change. These drivers cause changes in groundwater recharge and flow dynamics, leaching of pollutants and groundwater quality. Changes in water quantity and quality directly effect ecosystems relying on groundwater. Scientific research is needed to improve the understanding of how different drivers affect groundwater systems. New process understanding must be incorporated into mathematical models and assessment tools. Scenarios will be simulated to assess impacts in an integrated way taking account of uncertainties present in such simulations. Changes in the groundwater system have impacts on the functions that groundwater provides to socio-economical uses (water supply, irrigation, industry) and ecosystems. Research is needed to develop methods to safeguard these functions.

The way forward to safeguard the groundwater resource requires modifications in land-use and water use practices. These changes may be costly and can affect many European citizens. To ensure that new practices are adopted, a legislatively sufficient frame must be provided. The socio-economical consequences of changing practises on *e.g.* agriculture, farmers and forestry must be better known. Also the measures suggested must fit into common agricultural policies. Adaptations should be based on scientific evidence, as well as cost-benefit analyses of the consequences to better justify and communicate suggested changes. GENESIS will include development of new scientifically based methods for analysis of economical impacts of changing land and water uses as shown in Fig. 1. This provides a link between legitimate water uses and efficient land-use management. The change in uses and increases of benefit of protective measures will be quantified and demonstrated for decision makers.

Figure 2: Concept of the proposed work.
Climate change and various land-use activities affect groundwater.

This changes the groundwater capacity to provide legitimate uses. New criteria are needed for groundwater system protection and the update of the GWD. New concepts, measures and management are needed to change land-use and water use patterns. For these measures the costs and social impacts must be assessed.



Objectives

GENESIS will review and develop new scientific knowledge on groundwater systems and incorporate this knowledge into i) Ground Water Directive and ii) new tools for better integrated groundwater management.

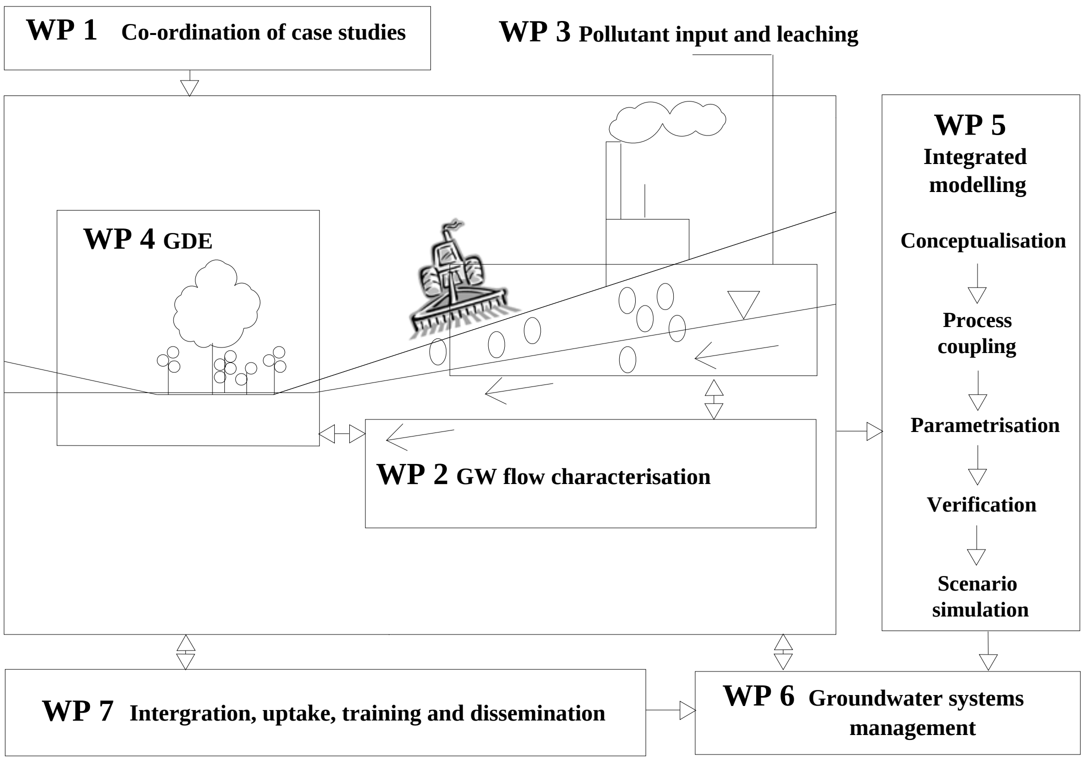
The research will: i) link the present knowledge to an integrated model from sources of pollution to the recipient ecosystem, ii) improve the understanding of pollutant leaching from different land-uses both in time and space considering also uncertainty, iii) develop a better understanding of how ecosystems depend on groundwater, iv) understand how changes in land-use and climate affect the groundwater and dependent ecosystems, and v) develop better cost-efficient management and monitoring tools and transfer the research results to stakeholders and end-users for better management. The final output for the directives are *e.g.* guidelines for the protection of ecosystems, indicators to test vulnerability, best management practices to reduce pollution, guidance for the design of monitoring networks and action criteria for trend reversal.

Methods and work content

The work to be undertaken is divided into work packages as shown in the figure below (Fig. 3). The work is divided into eight Work Packages (WPs). The first WP1 “Co-odination of case studies” provides the starting point for the project. Common strategies and quality assurance on measurement protocols and handling of data will be developed. Researchers of different background (geology, hydrology, ecology, geochemistry, agronomy, economy, climatology, geophysics, engineering, modelling) will contribute to integrate procedures and methods. This will include an assessment of cases of well documented groundwater systems studied by project partners in previous and on-going research projects. Metadata availability and the suitability of the site to test new scientific hypothesis to advance the present knowledge has been a prerequisite for the case selections. This provides the best starting point for further research. The main output of WP1 is to form a state of the art on present groundwater issues and harmonize monitoring practices between partners. The WP also ensures the focus on data quality assurance and control procedures.

The main scientific research work on groundwater and ecosystems processes starts after WP1 and is divided into various WorkTasks of WP2, WP3 and WP4. Workpackage WP5 (Integrated Modelling) focus on integrating results from WP2-WP4 and new model development. WP6 on groundwater management develops and integrates engineering, modelling, economics, social sciences and legal aspects. The workpackages WP2-WP4 form a clearly defined theme. The work tasks are solved by a interdisciplinary group of specialist from different partners. The results of WP2 on groundwater flow characterization provides residence times and groundwater renewal rates that is need in WP3, WP4 and WP5. WP3 provides information on biogeochemical processes and consequences of input of pollutants from the top soil layer to the groundwater table. WP4 studies groundwater dependents ecosystems and surface-groundwater interactions. Here new indicators for ecosystem vulnerability are developed to sense changes in water quantity and quality that are hazardous for ecosystems. The results from WP4 will provide the scientific basis for WP5 to better integrate ecosystem interaction to groundwater flow models. In WP5, information on groundwater hydrology, ecosystems, land-use and pollutant input can be incorporated in modelling to understand the groundwater system as a whole and how it is integrated to the ecosystems at the appropriate scale. This includes new concepts of processes occurring in the groundwater-surface water interface *e.g.* in different type of wetlands, springs and river hyporeich zones. The development of new model components in WP5 provides generalization of the science form results in WP2-WP4.

Figure 3: Linkages between work packages adopted to better understand the ground water system in an integrated way.



Conceptual models development will go on through out the project. Simulations on changes in land-use and climate will be made to the integrated groundwater system from point of pollution to recipient (or receptor). This will show how land-uses, ecosystems and other water uses are connected and how water and potential harmful substances move through theses systems and how the substances are attenuated by biogeochemical processes. In WP6, groundwater flow modelling approaches from WP5 and knowledge from WP1-WP4 will be integrated in groundwater management simulation-optimization models to derive optimal management strategies and identify cost-efficient measures to protect groundwater quality. The end-user and stakeholder participation is taken into account in a separate study in WP6. A main end-user communication platform is part of WP7. Here the advisory board also plays a significant role. Results will be presented to EC working group C on groundwater. GENESIS will have a continuous dialog with policy development and provide technical assistance for the development needs addressed in EC working group C and the GWD.

The results developed will be integrated into user-friendly tools. A conceptual framework and user friendly information shearing methods will be a key essence of WP7 (integrating, uptake, training and dissemination). A course will be developed to disseminate the results into practice. Here, new methods such as eLearning will be applied. Several methods of dissemination are used. Workshop and courses will be made at various levels to ensure that the new results are transferred into practice.

Conclusion

GENSIS is a project that focus on ground water systems. Groundwater is one of our most important resources that must be protected to maintain a good quality of life. Groundwater in many aquifers are at risk of pollution and deterioration. The EU Groundwater Directive focus on issues related to groundwater quality and quantity as well as ecosystem requirements. The multidisciplinary GENESIS project will make progress in our knowledge on hydrology, geochemical processes, and ecosystems. These are linked together by mathematical modelling. Socio-economic issues and legal aspects are also covered through a special research work package. New tools are developed for better management of groundwater under external pressure. Dissemination and knowledge uptake are key task in GENESIS. GENESIS will provide the scientific basis for the planned update of the directive.

Keywords: Hydrogeology, water resources, groundwater – surface water relationships, pesticides, nitrates, pollution, land use, agriculture, modelling, climate change, socio-economy, groundwater ecosystems, Ground Water Directive.

GSI typology – Typology of Groundwater / Surface interaction

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1. Introduction

The EU Water Framework Directive (WFD) outlines an approach to water administration in which interaction between groundwater bodies, groundwater dependent terrestrial ecosystems and surface water bodies take on a central role. Recognition of the interdependency between components of the hydrological continuum is a major strength of the WFD as a management framework. A main purpose of the WFD is to promote sustainable water and land use protecting associated aquatic ecosystems and water requirements of dependent terrestrial ecosystems and wetlands. Despite its significance, a terrestrial ecosystem is not well defined in the WFD, however, but the term covers areas where the water table is at or near ground surface. Riparian areas and wetlands are encompassed within this term.

To obtain good quantitative and chemical status of a groundwater body, the directive requires that groundwater level and chemical composition of the body must cause neither the associated surface water bodies (rivers, lakes and coastal waters) to fail in achieving their environmental objectives, nor cause any significant damage to groundwater dependent terrestrial ecosystems. A typology primarily addressing the quantitative status must reflect physical processes that control spatial, temporal and quantitative interaction with dependent ecosystems.

The directive calls upon two features of riparian areas to be evaluated: (1) their water requirements, and (2) their capability of maintaining high water quality of adjacent surface water bodies. To evaluate the water requirements it is of equal importance to conceptualize how a site works hydrologically and by what mechanisms water requirements of the ecosystems are met. Consequently, a typology must characterize processes controlling riparian water sources. The water requirements form part of the quantitative status assessment of the contributing groundwater body.

Finally, assessment of ecological status of streams and rivers requires evaluation of biological, hydromorphological and physico-chemical elements of the stream and its riparian area, if the structure and condition of the riparian area is relevant to achieve the environmental objectives of the stream. In this context the effects of the biogeochemical processes in the riparian area form part of the status assessment of the adjacent stream or river.

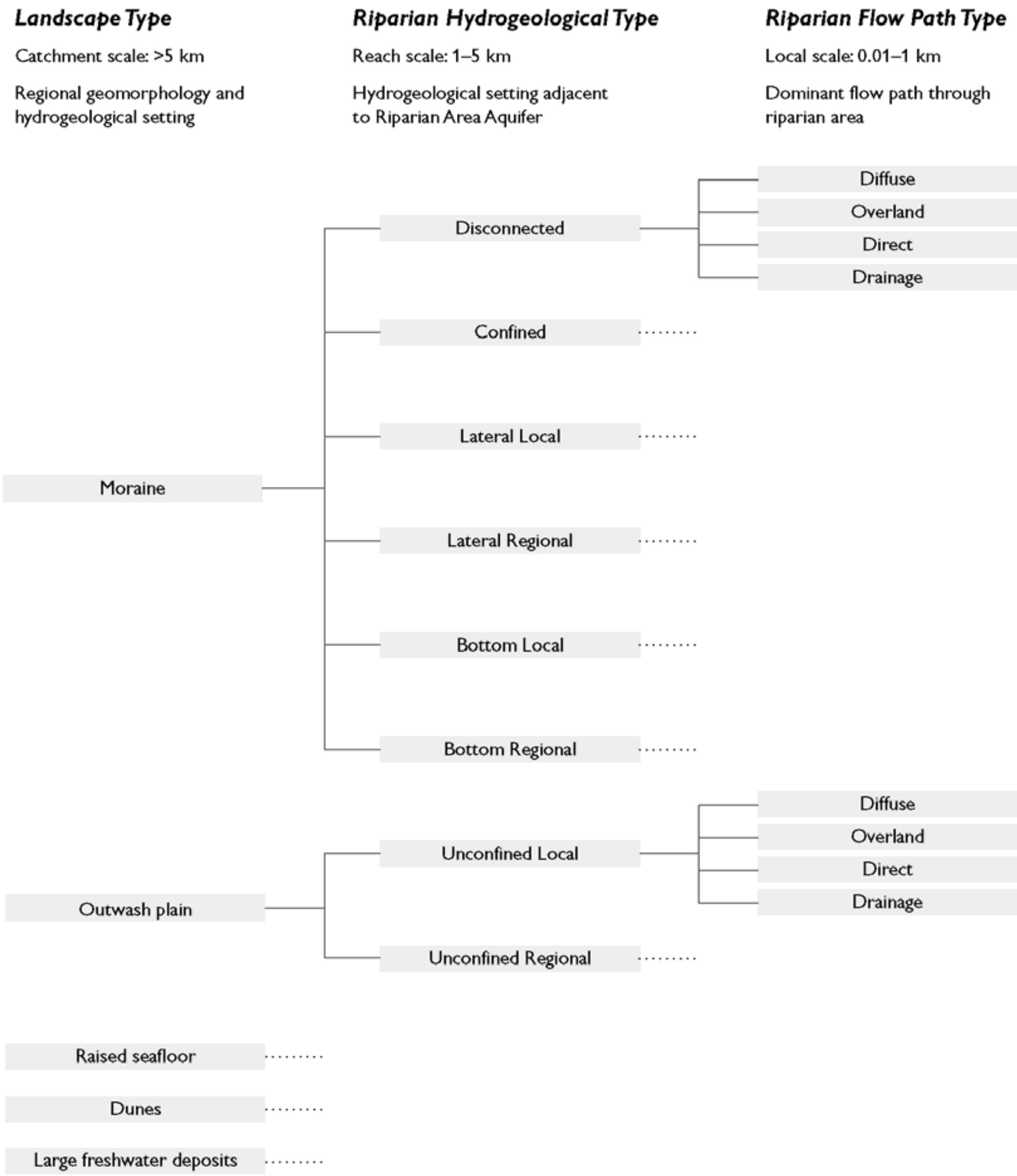
To facilitate monitoring and status assessment, the directive allows grouping of both groundwater and surface water bodies according to typologies. Previous typologies or classification systems, however, commonly characterize only one component of the hydrological continuum as reviewed by Dahl *et al.* (2007). Therefore, a need exists to develop an integrated typology characterizing functional linkages and controlling flow processes between groundwater bodies, riparian areas and streams.

2. Typology of Groundwater– Surface water Interaction

In the GSI typology, controlling processes are characterized using an eco-hydrological approach based on geomorphology, hydrogeological setting and flow paths on a gradually smaller scale (Dahl *et al.,* 2007). The hierarchy includes three scales as illustrated in Figure 1.

As the deposits of riparian areas are extremely heterogeneous and often organic-rich caused by a changing flow regime, water logging, sediment delivery, and channel displacement over time, these characteristics give rise to a perception of the deposits as a unique type of aquifer termed Riparian Area Aquifer in the typology.

Figure 1: Terminology, scale hierarchy and classification criteria of the GSI typology. Applying the typology in Denmark results in five most important Landscape Types and eight Riparian Hydrogeological Types. Four Riparian Flow Path Types are common to all Riparian Hydrogeological Types.



2.1. Landscape Type

On a catchment scale of more than 5 km, the Landscape Type classifies the groundwater flow systems and the groundwater system as a regional frame controlling the complexity of flow processes and discharge patterns. The classification criteria are regional geomorphology and regional hydrogeological setting, respectively. The typology includes an unlimited number of regional geomorphologies forming landscapes characterized by a typical pattern of regional and local slopes. The typology distinguishes between four regional hydrogeological settings:

- A single dominant unconfined aquifer;
- Two interconnected aquifers of equal importance;
- A three-unit system consisting of an unconfined aquifer, a confining layer, and a confined aquifer;

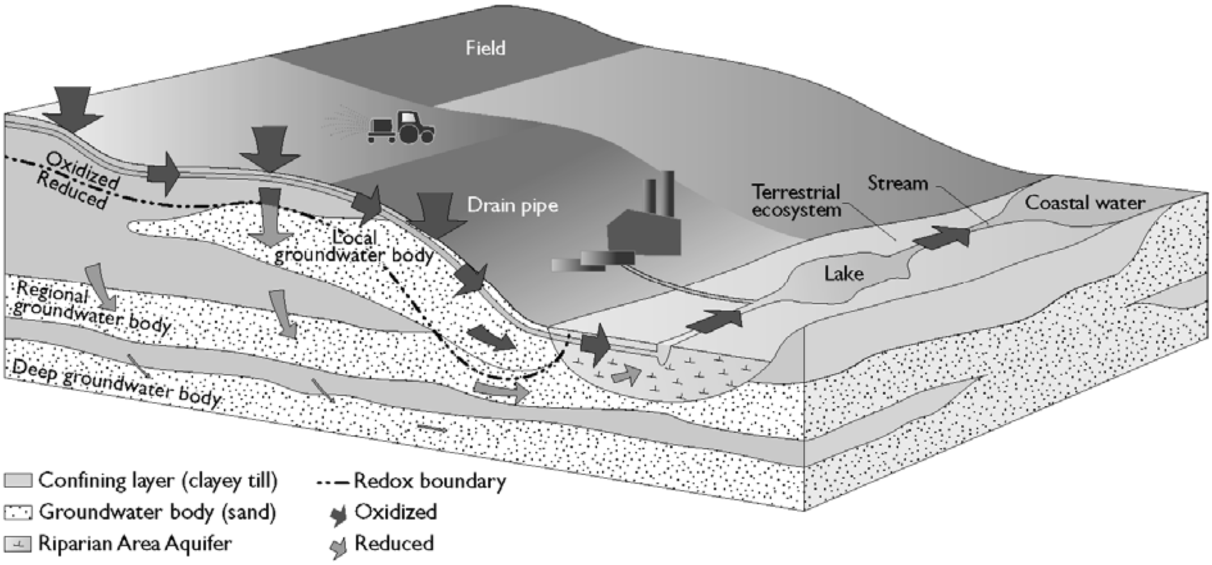
- A complexly interbedded sequence of aquifers and confining layers with no dominant aquifer.

The position, magnitude and confineness of these aquifers give way to perceive them as specific groundwater body types as defined below.

Through landscape forming processes, the geomorphology is often linked to geology and, subsequently, to the hydrogeological setting of the groundwater system. Figure 2 illustrates an example of a regionally sloping and locally undulating moraine landscape with a hydrogeological setting comprising a complexly interbedded sequence of sand aquifers and confining layers of clayey till.

Figure 2: Moraine landscape with a groundwater system comprising a complexly interbedded sequence of aquifers and confining layers.

The regionally sloping and locally undulating geomorphology creates local, intermediate and regional flow systems directing groundwater through Local, Regional or Deep Groundwater Bodies and Riparian Area Aquifers to various surface water bodies.



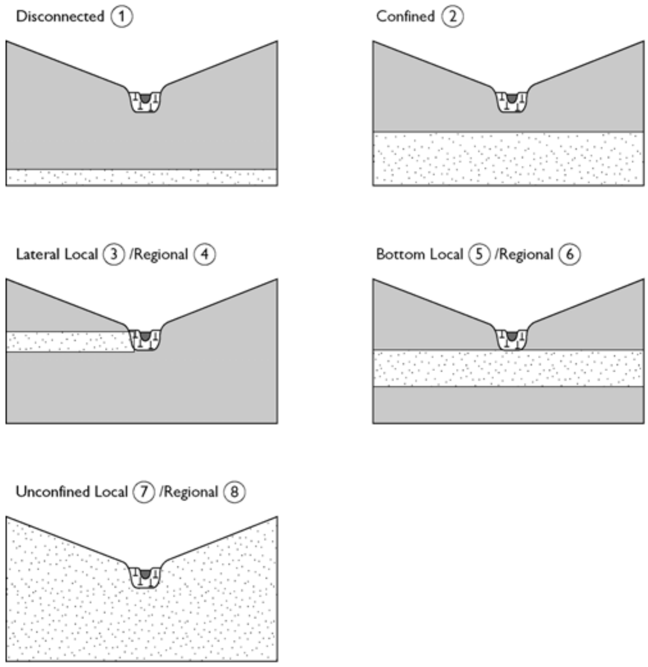
2.2. Riparian Hydrogeological Type

On an intermediate or reach scale of 1-5 km the Riparian Hydrogeological Type classifies the hydrogeological setting adjacent to a riparian area aquifer. This scale characterizes the exchange of groundwater between a groundwater body and a riparian area aquifer. The hydrogeological settings are defined by a combination of two features, namely the Contact Type and the Groundwater Body Type.

The typology distinguishes between five Contact Types (Figure 3) characterizing the physical contact between a groundwater body and a riparian area aquifer. The Contact Types are arranged in order from no contact to full contact. They determine groundwater ability to enter the riparian area aquifer and, to a large extent, the entry point.

- Disconnected. An impermeable confining layer between a groundwater body and a riparian area aquifer permits no groundwater to enter the riparian area aquifer.
- Confined. A low-permeable confining layer between a groundwater body and a riparian area aquifer permits some groundwater to enter the riparian area aquifer.
- Lateral. A riparian area aquifer is in contact with a groundwater body at a hillslope side of the riparian area aquifer. Groundwater enters the riparian area aquifer at the hillslope.
- Bottom. A riparian area aquifer is in contact with a groundwater body at the base of the riparian area aquifer. Groundwater is conveyed to the riparian area aquifer along its base.
- Unconfined. A riparian area aquifer is in contact with an unconfined groundwater body on all three sides. Groundwater is easily conveyed into the riparian area aquifer along all sides.

Figure 3: Riparian Hydrogeological Types. The hydrogeological legend corresponds to Figure 2.



The typology encompasses two Groundwater Body Types (Figures 2 and 3). They control the temporal contact, stability and flux of groundwater to the riparian area aquifer.

- Local Groundwater Body. A shallow and generally small groundwater body in which groundwater tends to connect with an adjacent riparian area and stream through a local flow system. This groundwater body generally has the largest recharge rate, shallowest flow penetration depth, shortest flow path and residence time, and it discharges seasonally unsteady amounts of water. Consequently, baseflow is quite small and may even cease in the dry season.
- Regional Groundwater Body. A deeper and generally larger groundwater body in which groundwater tends to connect with riparian areas along medium-sized streams and large rivers through a larger scale flow system. Generally, this groundwater body has a smaller recharge rate, a deeper flow penetration depth as well as a longer flow path and residence time. Discharge from this type of groundwater body is continuous and seasonally steadier. Discharge flux, however, depends on size of recharge area and leakage properties of possible confining layers overlying the groundwater body.

When an extensive groundwater body lies at great depth, and groundwater flows along a regional flow system only connected to transitional or coastal waters, the groundwater body is defined as a Deep Groundwater Body (Figure 2). Generally, this groundwater body has the smallest recharge rate, deepest penetration depth, and longest flow path and residence time. Because this kind of groundwater body does not exchange water with a riparian area aquifer along a stream, it is not included in the GSI typology.

Eight Riparian Hydrogeological Types as described in Figures 1 and 3 are defined through combining Contact Types and Groundwater Body Types: Disconnected, Confined, Lateral Local, Lateral Regional, Bottom Local, Bottom Regional, Unconfined Local, and Unconfined Regional. In case of a Disconnected or Confined type there is no need to characterize the corresponding Groundwater Body Type because the discharge is nil or very small, respectively. However, this must be done in case of a Lateral, Bottom or Unconfined type.

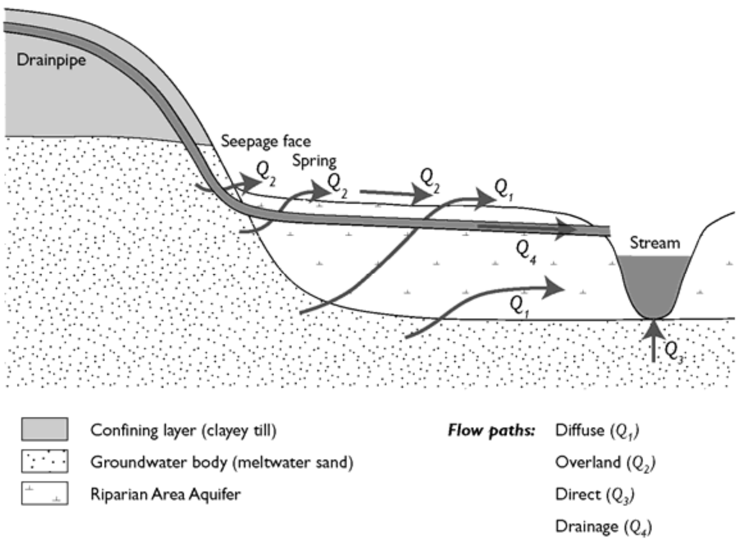
2.3. Riparian Flow Path Type

On a local scale of 10-1,000 m the Riparian Flow Path Type classifies the dominant flow path through the riparian area to the stream based on the flow path distribution in the riparian area.

Four flow paths have been identified as the most important transferring water through the riparian area to the stream (Figure 4). They are defined based on type of flow (matrix, preferential, overland, channel or pipe), and contact time between water and riparian deposits with an organic content. To a large extent, these flow paths control transport and attenuation processes and, consequently, the capability of the riparian area to maintain high water quality of an adjacent stream.

- Diffuse Flow. This flow path (Q1) passes slowly through the riparian area aquifer as matrix flow with a long contact time between water and deposits. Groundwater may recharge the aquifer upwards or laterally. Water may infiltrate into the aquifer from seepage faces or drains. Groundwater may also exfiltrate onto the riparian surface as return flow, or it may stay in the aquifer until it discharges into the stream. Residence time is expected to range from weeks to years.
- Overland Flow. This flow path (Q2) passes across the riparian area as overland flow. Water has a short contact time to riparian deposits. Water may enter the riparian area from drains ending at the hillslope or it may flood the riparian area from the stream. Water may also reach the riparian surface as springs in areas with preferential flow. Residence time is expected to range from hours to days.
- Direct Flow. This flow path (Q3) transfers groundwater beneath the riparian area aquifer, through an underlying groundwater body, directly through the stream bed. Within the order of a few days water may or may not have contact with riparian deposits beneath the stream bed.
- Drainage Flow. This flow path (Q4) transfers flow through drainpipes or ditches bypassing the riparian area aquifer, conducting water directly into the stream. The transfer is expected to take place in the order of hours.

Figure 4: Flow paths through a riparian area to a stream.



3. Discussion

3.1. Landscape Type

Regional geomorphology to a large extent controls which groundwater flow systems operate in the catchment (Toth, 1963). Dependent ecosystems are affected by these systems because they control a number of important factors like location of recharge and discharge areas, flux and stability of discharge, flow penetration depth, and residence time within biogeochemical environments affecting quality of discharging water. Subsurface heterogeneity, however, strongly influences water flux and travel time in the flow systems. The heterogeneity also influences groundwater ability to enter riparian areas and streams resulting in a more patchy discharge pattern. The classification of groundwater systems by Heath (1982), adopted in the GSI typology, is very applicable to characterize the heterogeneity through types of regional hydrogeological setting. The setting divides groundwater flow through specific Groundwater Body Types defined in the GSI typology. Subsequently, several functional aspects of a groundwater body can be evaluated such as response to climate and abstraction, susceptibility to pollution, water quality, and interaction pattern with dependent ecosystems. Consequently, both features are important classification criteria on catchment scale.

3.2. Riparian Hydrogeological Type

Hydraulic properties of aquifers and confining layers adjacent to riparian areas and streams significantly impact the spatial distribution of groundwater discharge on an intermediate scale. Riparian Hydrogeological Types provide a new framework classifying this heterogeneity in greater detail through combining Contact Types and Groundwater Body Types.

From the Riparian Hydrogeological Types several functional aspects concerning the groundwater discharge to riparian area aquifers and streams may be evaluated, i.e. physical contact between the contributing groundwater body and the riparian area aquifer controlling ability of groundwater to enter the riparian area aquifer, and to a large extent the entry point. Temporal contact, stability and flux of groundwater discharge controlling the seasonal stability of the flow path distribution in the riparian area may also be evaluated. These factors are all critical for maintaining diverse ecosystems (Wheeler *et al*., 2004) as they together with riparian permeability, depth and width determine the riparian hydrological regime.

Likely redox conditions and water quality of groundwater recharging a riparian area aquifer may also be deduced. As illustrated in Figure 2 there is a tendency for groundwater originating from Regional (and Deep) Groundwater Bodies to be reduced and nitrate free. In Odense Pilot River Basin about half of the nitrate leaching from the agricultural fields are reduced in anoxic groundwater bodies (Hinsby *et al*., 2008b; Thorling *et al*., 2008). The opposite is expected for groundwater originating from shallow Local Groundwater Bodies, where water presumably is oxidized and maybe nitrate polluted depending on land use. Hence, it is likely that riparian area aquifers with Lateral Local or Unconfined Local Contact Types, where the groundwater body is in contact with the terrain near the valley hillslope, receive oxidized nitrate polluted groundwater. However, when the contributing groundwater body of a Lateral Local Contact Type in the upland is completely covered by a confining layer, the riparian area aquifer probably receives reduced nitrate free groundwater. This is probably also the case for riparian area aquifers of Confined, Bottom and Unconfined Regional Contact Types. This suggests that supply of nitrate, which is critical for maintaining or damaging specific riparian habitat types, may likely be evaluated through Riparian Hydrogeological Types.

3.3. Riparian Flow Path Type

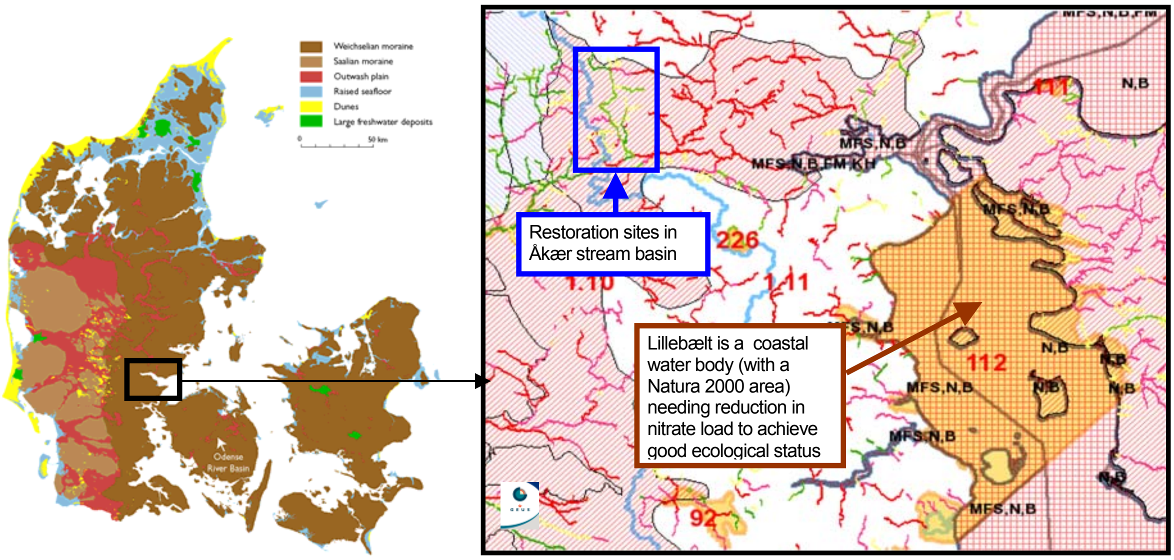
The Riparian Flow Path Type provides a new classification of the capability of riparian areas to maintain high water quality of adjacent streams based on flow paths controlling transport and attenuation through the riparian area.

Various researchers have studied which geomorphologic and hydrogeological parameters control the flow path distribution through riparian areas in glacial landscapes in temperate climate (Vidon and Hill, 2004; Banke, 2005; Langhoff *et al.,* 2006). Their research demonstrate that the most important parameters are: predominantly bulk permeability of the riparian area aquifer; less pronounced the total extent of the contributing groundwater body and the riparian area; presence or absence of a confining layer between the riparian area aquifer and the contributing groundwater body; and to a small degree thickness of this confining layer.

Nitrate and other elements and compounds are gradually transformed through the changing redox zones observed during passage of a riparian area aquifer. For this reason the entry point and flow paths to a large extent control where transformation processes take place. As groundwater recharges the riparian area aquifer at the hillslope or at the base of the aquifer, this is where the important zone of denitrification is found. Compared to this zone the hyporheic zone immediately beneath the stream bed is of only minor importance in Denmark.

By reviewing nitrate attenuation capacities of many riparian areas in Denmark Dahl *et al.* (2007) proposed very general path-specific attenuation capacities. The capacity of Q1 and Q3 is close to 100% if the organic content of the riparian deposits is more than 3%, and the capacity is close to 0% if the organic content is less than 3%. For Q3 this implies that the water contacts riparian deposits beneath the stream bed. If it does not the attenuation capacity is close to 0% instead. The attenuation capacity of Q2 is approximately 50%, and the capacity of Q4 close to 0%. These capacities result from hydrogeochemical environments composing different redox conditions, contact time with riparian deposits, and carbon availability along the flow paths.

Figure 5: Case study area in a moraine landscape in Denmark. Åkær Stream (blue square) is recharged by a nitrate polluted Local Groundwater Body (red cross hatched) of poor status. The receiving Lillebælt coastal water body also has a poor status (red square hatched). A Natura 2000 area (yellow) is situated in Lillebælt.



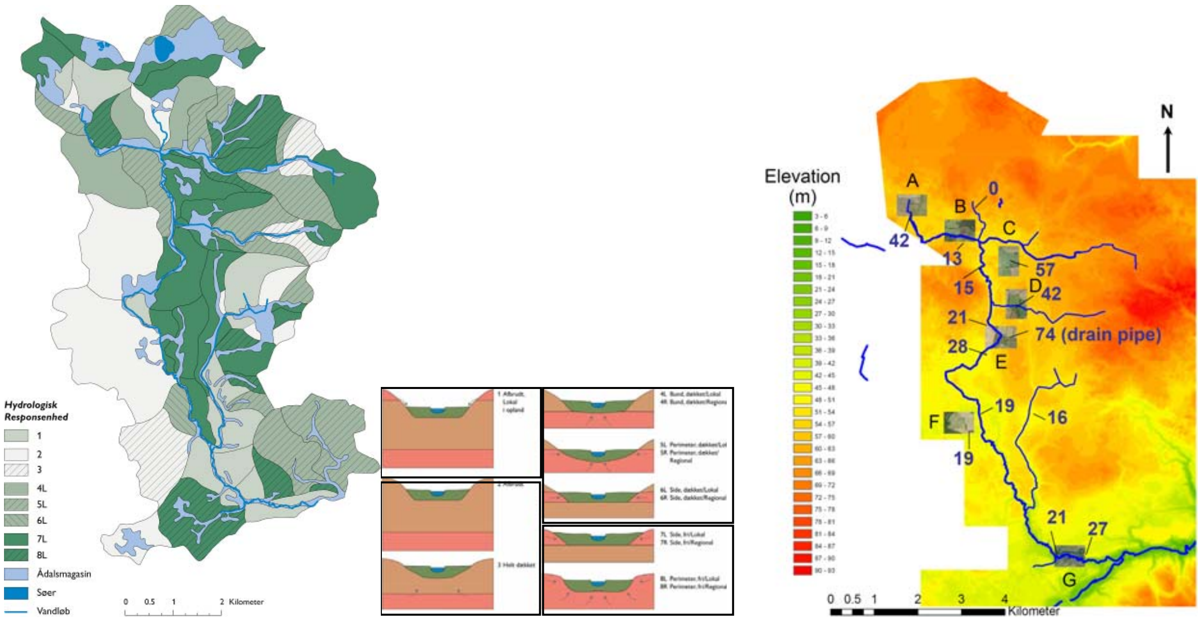
4. Lillebælt coastal water body / Åkær stream basin case study in Denmark

As part of a management plan to achieve good ecological status of a coastal water body, Lillebælt, in which a Natura 2000 area with many protected habitat types is situated, a survey of groundwater – surface water interaction was conducted in the contributing Åkær stream basin applying the GSI typology for Kolding Municipality (Figure 5). Åkær stream is recharged by a nitrate polluted Local Groundwater Body of poor status. scale.

The aim of the survey was to gain a detailed knowledge of groundwater - surface water interaction within the basin and to guide restoration projects to reduce nitrate load from the basin to the coastal water body.

Åkær stream basin is situated in a moraine landscape in Eastern Jutland in Denmark (Figure 5). During the case study Riparian Hydrogeological Types were extended from originally characterizing only the hydrogeological setting adjacent to the riparian area aquifer, till characterizing the setting all the way to the water divide of the contributing groundwater body (Dahl, 2008). This enlargement encompassed a setting with a contributing Local Groundwater Body above a confining layer in the upland, and settings with a confining layer above the contributing groundwater body in the upland (Figure 6). The enlargement was necessary to support assessment of groundwater nitrate contribution to riparian area aquifers. Riparian Hydrogeological Types were mapped based on geological cross sections, surface lithological maps and elevation contours. Finally, Riparian Flow Path Types were assessed in the field in restoration sites pointed out by the municipality (Figure 6). A screening of nitrate concentrations in the stream (Figure 6) as well as in groundwater, drains and ditches recharging and passing through riparian area aquifers of restoration sites (Figure 7) were conducted in December 2007 to support identification of important flow paths and areas with high N export to the stream (Hinsby *et al*., 2008a). The combined use of a sound hydrological and hydrochemical conceptual model of the system enhance the possibility of proper planning of relevant measures and location of restoration sites.

Figure 6: Riparian Hydrogeological Types in Åkær stream basin (left and middle). Location of restoration sites (A to G picture insets) and nitrate concentrations (mg/l) in streams and drains in December 2007 (right).

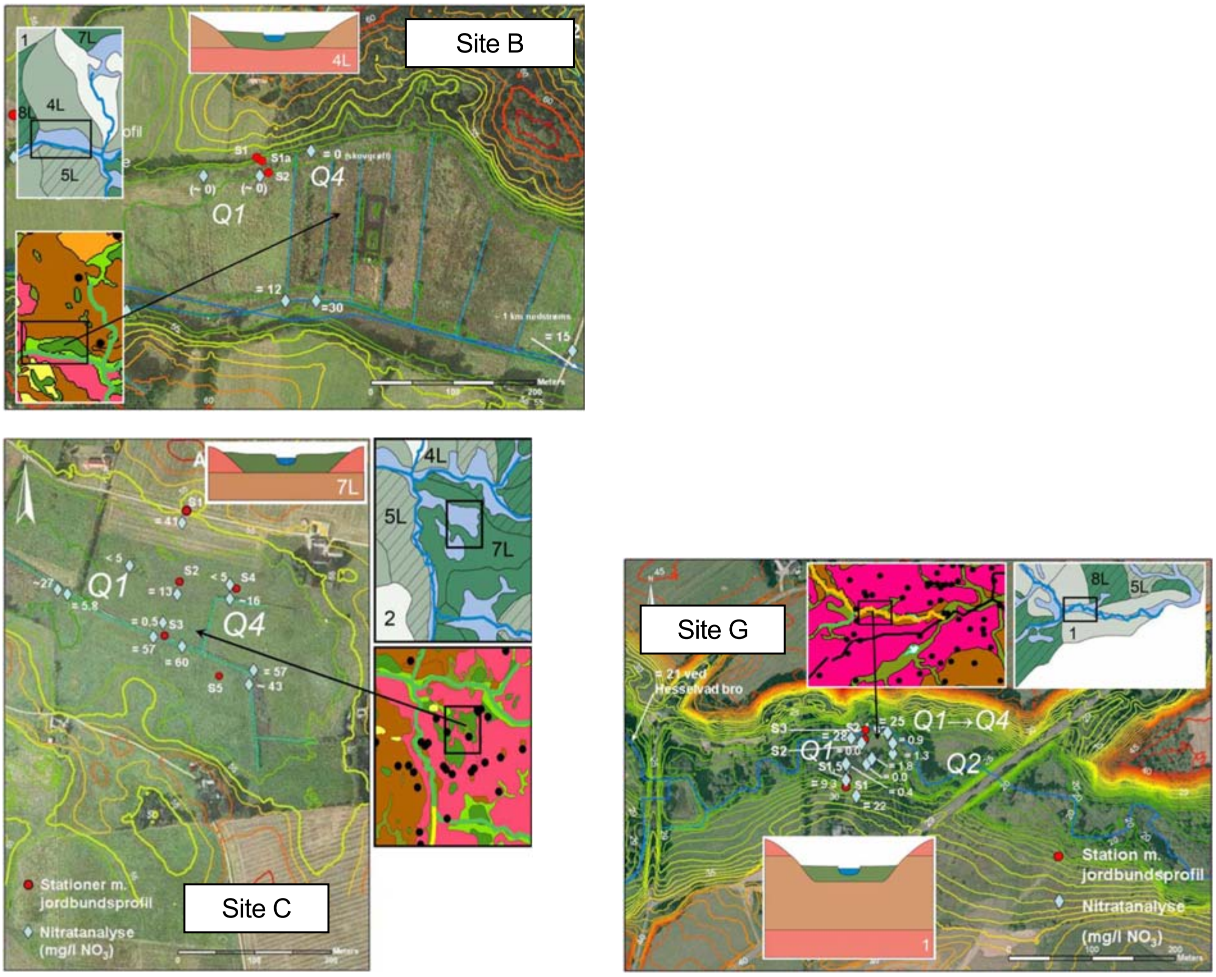


Proposed protection strategies against nitrate load to Åkær stream in restoration sites are based on an attempt to primarily restore the natural Diffuse Flow path (Q1) with the highest nitrate attenuation capacity through the riparian area aquifer, or where this is not possible, to reduce the nitrate contribution from the upland area, rather than flooding the valley terrestrial ecosystem from the stream. Information on Riparian Hydrogeological Type, upland land use and nitrate concentrations in the recharging groundwater and drainage water is combined with information on nitrate concentrations in present flow paths through the riparian area aquifer and general path-specific nitrate attenuation capacities, to propose a protection strategy for each site. Three examples with different settings are illustrated in Figure 7.

At site B (Figure 6) the contributing sandy Local Groundwater Body is covered by a thick confining layer of clayey till (Riparian Hydrogeological Type 4L). An upland ditch draining a forested area into the riparian area is nitrate-free. Small amounts of groundwater recharging the riparian area through the clayey till is probably also nitrate-free. Because of the thick confining layer overlying the contributing groundwater body, groundwater recharging the riparian area aquifer from below is also assumed to be nitrate-free. The dominant flow path through the riparian area is Drainage Flow (Q4) but Diffuse Flow (Q1) is also present. Both ditch water and groundwater within the riparian area are nitrate-free. In this area it is not necessary to implement any measures to reduce nitrate load to the stream.

At site C the contributing sandy Local Groundwater Body is placed on top of a confining layer of clayey till (Riparian Hydrogeological Type 7L). The upland land use is agriculture. The recharging groundwater has a high nitrate concentration of at least 41 mg/l. The riparian area aquifer is dominated by Drainage Flow (Q4) but Diffuse Flow (Q1) is also present here. The nitrate concentration in drainage water is as high as 60 mg/l, whereas the concentration in the Diffuse Flow is less than 6 mg/l. To reduce nitrate load to the stream the riparian ditches could be de-activated to allow groundwater to pass the area af Diffuse Flow (Q1) or Overland Flow (Q2) instead.

Figure 7: Information in restoration sites B, C and G applied to guide protection strategies against nitrate load to Åkær stream. Nitrate concentrations in mg/l in December 2007.



At site G the stream has cut a deep valley into a thick confining layer of clayey till. On top of the till a gravelly Local Groundwater Body is recharging the riparian area aquifer. A Regional Groundwater Body is situated below the confining layer, but it is not discharging groundwater to the riparian area aquifer at this site. The Riparian Hydrogeological Type is classified as 1. The upland land use is agriculture. Probably, the main part of the groundwater discharge from the upper nitrate polluted Local Groundwater Body to the riparian area takes place in small seepage areas and springs in the hillslope and through rivulets passing the riparian area overland into the stream (Q2) with very little contact to the riparian area aquifer. Consequently, very little nitrate attenuation is expected during this passage. Hence, a measure til reduce nitrate load to the stream at this site could be to reduce upland nitrate input to the gravelly Local Groundwater Body.

In the restoration areas there seems to be a good agreement between upland surface lithology and nitrate concentration levels in the recharging groundwater. If the riparian area aquifer is in contact with a groundwater body reaching terrain the recharging groundwater is nitrate polluted. If the riparian area aquifer, on the contrary, is in contact with a thick confining layer reaching terrain the recharging groundwater is nitrate-poor or nitrate-free. Drainage recharge always shows high nitrate concentrations of 57-77 mg/l. Åkær stream concentrations are 15-30 mg/l, whereas concentrations of Diffuse Flow and Overland Flow through riparian areas are 0-10 mg/l.

5. Conclusion

In relation to the WFD the GSI typology may be applied to group interacting groundwater bodies, riparian areas and streams in a functional way to support effective groundwater risk and status assessments, and to establish programmes of monitoring and measures. As such it may act as a framework for comparison between sites, an approach for regionalisation of features, and a tool to point out data and research needs.

The Riparian Hydrogeological Types support delineation of riparian areas receiving nitrate free or nitrate polluted groundwater. The Riparian Flow Path Types, on the other hand, assist assessment of nitrate attenuation in riparian areas. This knowledge may be applied in management plans to protect and enhance the chemical and ecological status of associated surface water systems, which is a main purpose of the WFD.

In an eco-hydrological context the GSI typology may also provide an important interlock framework overcoming difficulties in dealing with different time and space frames within the two fields. Hense, Riparian Hydro-geological Types may be applied to evaluate a number of aspects such as physical and temporal contact, stability, flux, and water quality in the exchange between a groundwater body, a riparian area aquifer and a stream. These aspects to a large extent control abiotic site factors such as hydrological regime and water quality determining riparian terrestrial habitat distributions. They also affect stream habitats through sustaining baseflow, moderating surface water levels and temperatures, and supplying nutrients and inorganic ions. Consequently, Riparian Hydrogeological Types may form basis for evaluation of eco-hydrological interaction and assist in assessing habitat vulnerability to water requirements.

In regional hydrological models Riparian Hydrogeological Types may form basis for distributing leakage properties between aquifers and surface water. However, if the modelling purpose is to simulate consequences of groundwater withdrawal or contaminant transport and attenuation the controlling processes on various scales point to the need of applying flexible models to simultaneously estimate regional-scale groundwater body and local-scale riparian area aquifer processes.

Finally, a combined use of a sound typology for description of the physical/hydrological system and the biogeo- and hydrochemical system decrease uncertainties in estimation of quantitative as well as chemical groundwater- surface water interaction.

Acknowledgements

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Keywords: Water Framework and Groundwater Directives, typology, groundwater – surface water interaction, multi-scale.

Knowing the transfer time of solutes to manage better the groundwater bodies. Example of the Loire-Bretagne river district

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Posing the problem and state-of-the-art conditions

Groundwater quality is increasingly monitored in Europe and especially in France. This has shown a contamination to varying degrees with nitrates and pesticides (EEA, 1999; Barbash *et al*., 2001; IFEN, 2004). The main objective of the European Water Framework Directive (2000/60/CE) is that by 2015 all ground- and surface waters should present good quantitative and qualitative conditions. The Directive thus imposes on the Member States the obligation of not only characterizing the level of contamination of groundwaters, but also of studying evolution trends in pollutant concentrations. The Member States also must set up action programmes for attaining satisfactory conditions. In case of failure of this last objective, the Member States must be able to explain the reasons for such failure, and well-documented requests for extending the deadline are to be presented. After completing a characterization of groundwaters in France, it appears that nitrates and pesticides cause 99% of the risks that such satisfactory conditions will not be reached within the deadline (Normand and Gravier, 2005). The 2004 inventory of the Loire-Brittany river district has shown that 53% of the groundwater masses risk not attaining the objectives for the nitrates parameter and 36% for the pesticides one. In all, almost half of the groundwater volume runs the risk of not reaching the set objectives by 2015.

In parallel to the Water Framework Directive, the Nitrates Directive (91/676/EEC) aims at controlling nitrogen pollution and requires Member States to identify groundwaters that contain more than 50 $mg.L^{-1}$ nitrate or could exceed this limit if preventive measures are not taken. According to a 2003 European Commission report, 20% of EU stations had concentrations higher than the allowable concentration and 40% were in excess of the guide value of 25 $mg.L^{-1}$. France and Sweden are the European countries showing an overall increase in nitrate concentrations in groundwater (Nixon *et al.,* 2003).

Nitrogen is an essential nutrient for crop growth, largely used for fertilization in agriculture. To reduce the potential for NO_3-N leaching toward groundwater, a wide range of management practices is recommended and applied, including changes in crop rotation, improved accounting for residual N in soil, and better timing and methods of fertilization (McLenaghen *et al*., 1996; Webster *et al.*, 1999; Li *et al*., 2005). Despite a generalization of these measures over the past decade, the improvement of groundwater quality is not or little perceptible in many cases.

The existence of a nitrate stock in soil and the unsaturated zone, after fertilizer spreading over several years, has been demonstrated repeatedly in varied geological materials (Baran *et al*., 2006; 2007). In some cases it was possible to estimate the water-transfer velocity in parallel with an identification of the stock, indicating that nitrate transfer probably occurs at the same speed as the water velocity. This shows clearly that where the unsaturated zone is thick and/or has an infiltration velocity causing long transfer times, the impact of the start of good practices will not be immediate, but may take several years or even a decade to become apparent.

Tritium and CFCs can successfully be used as hydrological tracers for estimating the water-transfer velocity and residence time. However, most applications of such tests until now have been localized, mostly concerning small catchments of a few square kilometres, or even just a vertical profile. Moreover, comparisons of the results obtained for different basins of the same type are rare. In addition, such hydrological-tracer studies are seldom compared in detail with other, hydrogeological, data, or they are not necessarily used for modelling, whether global or discretized. The point is that such complementary approaches can validate the use of such tracers in other hydrogeological settings.

In the Loire-Brittany river basin, hydrogeological contexts are quite varied, ranging from sedimentary aquifers to basement ones, with a few volcanic-rock aquifers. The expected times and types of response to a modification of agricultural practice thus very probably will vary in terms of the type of aquifer, its size, its rate of water renewal, etc. Today in France very little information is available on response time and type, except for a few sites that were studied for instance for a doctoral thesis, and the Loire-Brittany River Basin Agency does not dispose over a global overview of these parameters for the basin as a whole.

In 2007, monitoring and operational-control networks as defined by the Framework Directive were installed by the Agency, leading to a reorganization of the former network. At the same time, new observation points were set up on the basis of pressure by Man-made activities, aquifer-type, and infiltration-index criteria. The study presented hereafter was initiated to obtain a better knowledge of these observation points, to evaluate their true significance, and to define water and solute transfers. The main objective of the study was to provide a typology of the existing aquifers for the entire basin; this typology was not to be based on only geological criteria, as is usual, but also and especially on their hydrodynamic functioning as this latter point influences solute transfer. This typology identification, which is ongoing, is in particular based on the comparison of data on the age of waters, on the type of water table level response of the system to climatic variations, and on the type of quality response (for nitrates) to Man-made pressures.

Dating of groundwaters

Principles of the method

The age of water is the time span between the moment a water drop enters the system and the moment it is collected for analysis. Residence time is the time it takes this water drop to travel from the recharge zone to the discharge zone of an aquifer. The age of the water in the discharge zone is equal to its residence time, whereas in any other point of the aquifer the two notions are different. Here, we generally use the term "apparent age" as the existing dating methods define an average age for all water drops, rather than an exact age for a single drop. After a brief description of the dating methods for young waters, the limits are presented of the two methods presently used, i.e. tritium and dissolved gases (CFC and SF_6).

Tritium, ^3H, is a marker for contemporaneous water masses. The airborne thermonuclear tests between 1952 and 1963 added an artificial tritium source to the natural production. Water resulting from precipitation without nuclear ^3H (pre-1952) thus is distinguished from precipitation formed in an atmosphere containing nuclear ^3H (post-1952). The use of this radio isotope requires knowledge of the entrance signal corresponding to the chronicle of tritium contents of precipitations. In France, five measuring stations provide more-or-less regular monitoring (IAEA/WMO, 2003). The data used here are those from the Orléans and Brest-Plouzané stations in the basin. Because of radioactive decay, present tritium contents of rain are low and spatial variations because of emissions from certain industries and nuclear power plants are higher than seasonal variations. This means that the small number of stations and analytical limits in most cases conspire against a quantitative estimation of the age of groundwaters. Notwithstanding this, the analysis of tritium in water has the advantage of considering transport times in both the unsaturated and saturated zones. Tritium being intimately associated with the infiltrating water, this tracer allows a faithful reproduction of its behaviour in the hydrological system.

CFCs (chlorofluorocarbons comprising CFC11, CFC12, CFC113) do not occur in the natural atmosphere. They were first synthesized in 1928 and sales started around 1930. By considering the quantification limits of these gases, CFCs help in dating waters with ages younger than 1945 (CFC12), 1950 (CFC11) and 1957 (CFC113).

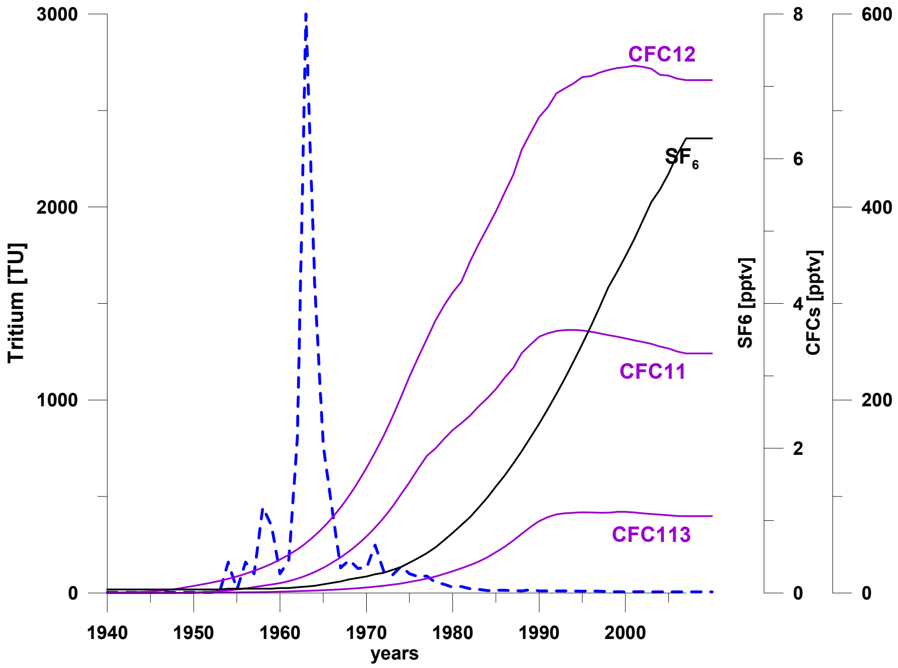
Industrially produced CFCs diffuse in the atmosphere and the hydrosphere. Such gases then pass through the unsaturated zone through diffusion before entering into the groundwater as dissolved gases. Dating of the waters requires a comparison between dissolved-gas contents in the groundwater and the contents of the same gases in the atmosphere. The latter are known as they are routinely measured by several stations (ALE/GAGE/AGAGE programmes and the National Oceanic and Atmospheric Administration, USA). Data on CFC concentrations discharged into the atmosphere before 1970 were estimated from production data for the same gases (McCarthy *et al*., 1977). The CFC data used are those provided for the northern hemisphere by the Climate Monitoring Diagnostics Laboratory of the National Oceanic and Atmospheric Administration (CMDL/NOAA; Figure 1).

Both tritium and CFC methods thus use a relatively well known input function (Figure 1). For tritium the concentration in groundwater directly derives from rainfall data, but for CFCs the dissolved-gas concentrations in water must be calculated with Henry's Law from concentrations in air. This law integrates parameters such as elevation and the average recharge temperature and salinity of the waters. Such parameters are in theory easily obtained, except where the conceptual hydrogeological model is poorly understood. Other factors that influence the estimation of apparent ages from CFC data include human input, the thickness of the unsaturated zone, excess air, sorption effects, microbial degradation, and local contamination during sampling. Contamination effects are easily detected but cannot be corrected for; however, the use of several tracers and careful sampling allow limiting this problem. In an anoxic environment, where dissolved oxygen contents are low, some gases are sensitive to degradation phenomena, but others, like CFC113, are less affected. The excess-air phenomenon, i.e. where the dissolved-gas concentration is higher than expected (Heaton and Vogel, 1981), can strongly affect some CFCs, but is almost negligible for CFC11 because of its high solubility (IAEA, 2006).

Transfer in the unsaturated zone can cause different estimated apparent ages, thus being the main difference between the tritium and dissolved-gas tools. Tritium follows the movement of the liquid and gaseous phases in the unsaturated zone, whereas CFCs follow the, more rapid, movement of only the gaseous phase (Cook and Salomon, 1997). Several such effects can be calculated from additional measurements, such as of dissolved N_2, O_2, and Ar, or they can be estimated with the help of field measurements of the depth of the unsaturated zone, the Redox potential, or the dissolved organic carbon concentration. It is also important to dispose over several tracers with different properties (*e.g.* CFC and tritium) in order to evaluate estimation errors of the apparent CFC ages.

Evaluation of the residence time to describe the hydrodynamic functioning requires, regardless of the tracer used, the use of empirical models of the piston type and exponential type and of binary mixing models with two poles.

Figure 1: Time series of input data for tritium in precipitation, and CFC and SF_6 in the atmosphere (data from IAEA and CMDL/NOAA).

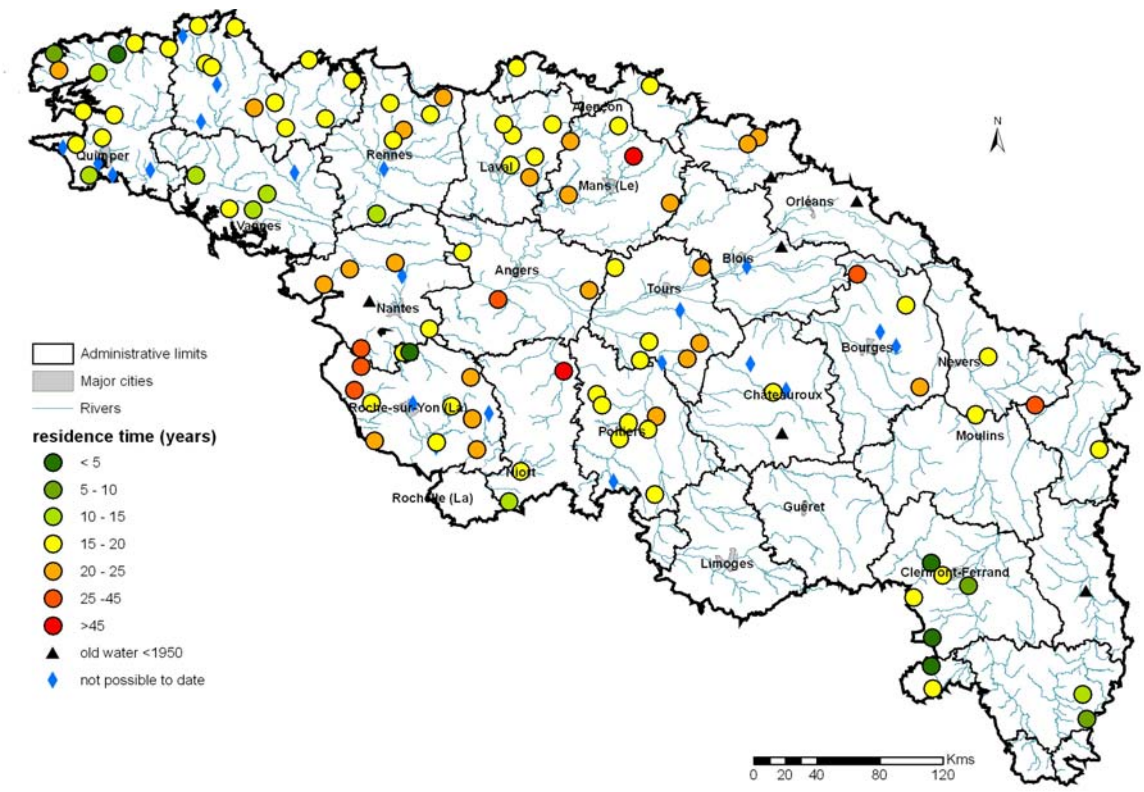


For the present study, it was opted to work with both tritium and CFCs (11, 12 and 113). A total of 153 samples was taken in April 2007; another 34 samples were taken in April 2008 to fill data gaps or to reconsider sampling points for which a first dating was impossible. The samples were taken during field-measuring campaigns covering the monitoring network, excluding captive or alluvial aquifers for which such dating tools seemed less relevant, as well as privileging areas of high importance, such as drinking-water supply areas and major aquifers.

Results obtained at basin scale

This study, carried out over a huge basin, includes one or two data points for each groundwater mass, which is a low density of sampling points with an average of 1 point per 800 km^2. It was not possible to consider local hydrogeological data when estimating the apparent ages of the water, as for instance the catchment area of each well is not necessarily well defined. Characteristic hydrochemical data of sampled wells were used as an aid in interpretation. The temperature- and average-elevation data of the recharge are those of the sampling points. This approximation is possible as the study area does not contain areas of strong relief. The difference between the temperature data used for evaluating the age of the waters, *i.e.* those measured during sampling, and the average temperatures measured at the same point (ADES data), is at most 3.4 degrees. For 83% of the points this difference is less than 1°C. The maximum errors induced by such temperature differences when evaluating CFC ages, are one year for a piston-type model and 5% for the mixing-type model. As only level-1 aquifers were considered for this study and as alluvial aquifers were not sampled, only a few groundwater points show reducing conditions. For these points, degradation indices of the CFC11 were noted. Age determinations were thus preferentially based on CFC12, which is little or not affected by microbial degradation problems (Horneman *et al*., 2008). Several samples showed a contamination with one or more gaseous tracers. In those cases, data from unaffected tracers can be used as complements of tritium data. In some cases, however, no dates could be obtained because of a strong contamination by several CFCs.

Figure 2: Results of water dating in the Loire-Brittany basin with piston and exponential models, also showing old (pre-1950) waters and the points where dates could not be obtained (sampling in April 2007 and 2008).



The three empirical models were applied to the waters sampled in the Loire-Brittany basin by integrating the CFC and tritium data. For each case, the most appropriate model was retained. It should be noted that the models give slightly different information, as the piston and exponential models give a residence time or apparent age in the aquifer, and the mixing model indicates the percentage of young (>1990) and old (fixed at 1950) water within the aquifer at the measuring point. The data are presented in classes of five years and in percentage slices of 15% for the mixtures. This approximation is justified because no corrections were made for the effects of the unsaturated zone, of sorption, or of excess air, and because estimating the average temperatures and elevations can cause a maximum error of two years or 10% in the age calculations. For six points, the age of the water was older than 1950, as neither CFCs nor tritium were found.

The piston model dominates with 88 of the 161 analysed water points in the Loire-Brittany basin. The spatial distribution of average residence times indicates that the oldest water mainly occurs west of Nantes and La Roche-sur-Yon, and that the most recent (<15 years) waters occur on the point of Brittany and in the Massif Central (water masses contained in fractured basement and volcanic rock). Waters with residence times from 15 to 25 years dominate over the basin as a whole. The binary mixing model was used for 52 water samples. The young-water component represents between 2 and 90% of the recharge.

Photographic-type sampling in April 2007 made it possible to distinguish between groundwater with slow circulation and that with a more rapid renewal in the Loire-Brittany basin. Water in the basement areas is relatively young, but shows an average recharge time of 10 to 20 years. These results confirm the first more detailed studies using CFCs and SF6 in Brittany (Vergnaud-Ayraud *et al*., 2008). Such data at the scale of the entire Loire-Brittany river basin are the first elements to be used in a study of aquifer behaviour considering the residence time of groundwater.

Moreover, it is possible to correlate water chemistry and estimated age. The first tests show a good correlation between young waters and nitrate concentrations. This simple relationship, which needs further refining as it does not consider the various pressures on the water resource at the scale of the basin as a whole, shows that, at a small scale, a simple relationship may exist between groundwater residence times and resource vulnerability.

Typical responses of aquifers to the climatic context and man-made pressures

Water table level variations

The French ADES database (http://www.ades.eaufrance.fr/) was consulted and all available potentiometric data for the basin until March 2008 were downloaded. Only data noted as “correct” by the supplier were retained, which represents 1,371,655 measurements from 511 observation wells. A geostatistical approach was used to arrive at an objective and automated comparison of the water table level behaviour.

A geostatistical analysis of the temporal behaviour of an aquifer allows to compare, for a given observation well and for different values of Δt, a measurement at time t and another at time $t + \Delta t$, using a time variogram. Once this time variogram has been defined from observed data, a theoretical variogram model can be adjusted. Creating a theoretical model for each observation well, allows, for a whole range of time intervals, to make a systematic comparison of the different variograms obtained and to group them into families. In other words, notwithstanding the heterogeneous nature of the data (length of time series, different monitoring periods, different measuring frequencies), a comparison of water table level time series becomes possible.

A time variogram of the water table level was calculated for each observation well. As most wells show an annual cycle and as some were not measured for long periods, it was decided to calculate the variogram up to a maximum Δt of two years. Observation wells with time series shorter than four years, or twice this Δt, were eliminated as their measuring period was too short for calculating a representative variogram. Other time series showing obvious anomalies, such as the influence of pumping, were eliminated as well. In the end, 414 time series of the initial 511 could be processed, leading to the determination of an experimental variogram. After this, an automated procedure was used for fitting a theoretical variogram model to the experimental ones, using the least-squares method. This was done by combining four components: a nugget effect, a “spherical” component with a six-month range (short-term component), an annual component (cosine model), and a linear component for describing the longer-term behaviour (multi-year and drift components).

Using a hierarchical ascendant classification (HAC) of the last three components (the nugget effect was discarded as it had a tendency to affect the results with noise), four main classes were discriminated:

- Class A: weak short-term and annual components, dominant multi-year drift (15 individuals);
- Class B: non-negligible short-term and annual components, dominant multi-year drift (159 individuals);
- Class C: non-negligible short-term component, predominant annual component, low or nil multi-year drift (112 individuals);
- Class D: strong short-term and annual components, low or nil multi-year drift (128 individuals).

Geographic examination of these four classes shows areas with homogeneous water table level behaviour. For instance, Brittany and the Beauce plain correspond to two different families: an annual component with strong amplitude in Brittany; moderate annual and short-term components with multi-year drift in the Beauce. Though this result was obviously expected for these two large regions, the proposed method made it possible to rank the points in an objective manner in less well-known areas. Automated data processing made it possible to handle the large number of observation wells in the basin, but especially to envisage easy updating of the measurements as and when new data become available. Finally, the same method forms the basis of the geostatistical processing of nitrate-concentration time series.

Nitrate concentration time series

A similar geostatistical approach to that for the water table level time series was applied to the 238 available time series for nitrate concentrations in the basin. This allows disregarding absolute concentration values that are due to human pressure and especially agriculture, as this is very uneven at the scale of the basin, with areas under intensive crop growing or animal husbandry.

Principal component analysis of the variogram components identified five classes:

- Class 1: Strong short- and long-term variability of the concentrations; observation of a pure nugget effect in statistical terms (99 individuals);
- Class 2: Dominant multi-year drift, continuous increasing or decreasing phase of the concentration with in some cases a stabilization of the concentration over time (35 individuals);
- Class 3: Non-negligible multi-year drift associated with a notable periodicity in concentration fluctuations over long periods, with alternating increase and decrease phases of the nitrate concentration (24 individuals);
- Class 4: Strong multi-year drift and a great regularity over time of the phenomenon. Dominant phase of concentration increase or decrease (74 individuals);
- Class 5: Dominant nugget effect caused by a strong short-term variability in the concentration and in many cases coupled with non-negligible fluctuations of the concentrations over long periods, with alternating phases of increase and decrease of the nitrate concentration (6 individuals).

Unfortunately, the nitrate results are less convincing than those obtained for the water levels, not because the method is unsuitable, but in particular because of the small number of available and exploitable time series. Either the monitoring periods were too short, or the measuring frequency was unsuitable for establishing a representative experimental variogram for the measuring point. For instance, annual cyclical variations cannot be shown if only two measurements are made each year. Still, this approach has shown the existence of several typical cases.

Preliminary conclusions and next stages of the project

The study presented here is ongoing and, obviously, far from complete. However, some lessons and conclusions have already become clear.

Concerning the methodologies used, it is clear that an apparent age in most cases can be estimated by using CFCs coupled with tritium. Still, where abnormal concentrations exist for at least two of the three CFCs studied, it was impossible to obtain an age. This may be local contamination, such as the proximity of a rubbish tip, or it may be due to the sampling itself. It became clear, however, that the simplified technique used, such as no data on the elevation of recharge, or on the different geological settings, is valid and provides a clear view at the scale of a very large area, such as the Loire-Brittany river basin in this case.

Concerning the evolution of water quality in terms of nitrates, when assuming that nitrates move at the same velocity as groundwater and that the flow model is a piston one, any modification in surface practices will have significant consequences on groundwater quality beyond the time limit corresponding to the age. However, it is possible that the impact on the quality of recent infiltrating water will be noticed more rapidly in the level of contamination, especially where the ratio of young water to old water is high. Obviously, such information is essential in terms of resource management. The dating results also help in explaining why in some sites where efforts were made to reduce contamination levels, such as in the "Ferti-Mieux" areas of optimum fertilization, changing the practice is accompanied by an increase or stabilization of nitrate levels, which can be quite discouraging. The answers provided here show that the situation as observed today is the result of old practices rather than actual ones. However, the data presented above show the importance of highlighting any perceptible signs of change as soon as a new practice is introduced, such as a decrease in recharge. However, no spatialized information is available for the basin as a whole on changes in agricultural practices over the past years or decades, and such data cannot be acquired as part of this study. For that reason, the determination of apparent ages in each point does not allow predicting a point-by-point water-quality evolution.

Predicting changes in water quality is even more difficult because of the different hydrodynamic behaviour of aquifers. This was illustrated by the geostatistical approach with an intra- or multi-annual cyclicity of the water table level, showing a variable inertia of the aquifer. In terms of water quality, changes in the nitrate concentration can also follow different patterns, such as linear, step-wise, or cyclic changes.

Combining different data further helps in defining case types, such as points with marked seasonal water-level changes, whether or not with overall nitrate-level increases, or points without seasonal changes, but with a linear or step-wise increase in nitrate levels, etc. The difficulty of combining such data lies in the fact that water quality an water levels are not always monitored in the same points. The first step is thus the definition of points where coherent quality and water-level couples are found, such as those concerning the same aquifer. The next step is then to couple water-dating information, generally found at a third point, to this first set.

When the case types are defined, three sites will be selected and studied in more detail. Monitoring water quality coupled with water dating at frequent time steps, such as once a month, will show if short-term nitrate-level fluctuations during a year can be explained by the inflow of water of apparent different ages, or if, on the contrary, the determined apparent age shows little fluctuation over several months. This type of information will help in qualifying, if necessary, the results obtained from apparent ages determined from a single sampling campaign throughout the basin. Finally, in parallel with the above and so as to advance more rapidly in terms of water-quality change predictions, BRGM developed the global Biche model that will be applied to these sites. The overall coherence of data obtained by these various approaches will obviously be evaluated. Recommendations will thus be possible concerning the use of these different tools, outlining the advantages and drawbacks of each.

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Keywords: Groundwater, nitrate, transfer time, CFC, hydrodynamics.

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Occurrence of sulfonamide antibiotics in two groundwater bodies of Catalonia (Spain)

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Introduction

The occurrence of antibiotics in the environment has become a subject of major concern among scientists due to the potential spread and maintenance of bacterial resistance (Halling-Sorensen *et al.*, 1998). Amongst them, the family of sulfonamides is one of the most widely used in human and especially in veterinary medicine. They have been detected in all kind of water matrices (Díaz-Cruz *et al*., 2008), not only because of their high consumption rates, but also to their amphoteric properties, rather poor chelating ability and low sorption to soils tendency. Other reasons for greater occurrence may be due to their relatively low elimination efficiency during sewage treatment procedures and to the increase in the number of confined animal feeding operations, which often lack proper waste management practices. Furthermore, the extensive use of manure as fertilizer on agriculture can be a significant source of diffuse contamination of ground waters by these compounds.

Sulfonamides are metabolized to a considerable and varying extent in the organism (*i.e*. by acetylation and hydroxilation) and these metabolites, together with the not assimilated parent substances, are excreted mainly via urine and faeces. Therefore, very small amounts of these substances are being continuously introduced in the aquatic environment, and concentrations that had previously been considered as harmless are leading to the emergence of antibiotic resistant bacteria strains. The application of manure from treated animals in crop soils can also constitute a main entrance pathway for these antibiotics in the natural media.

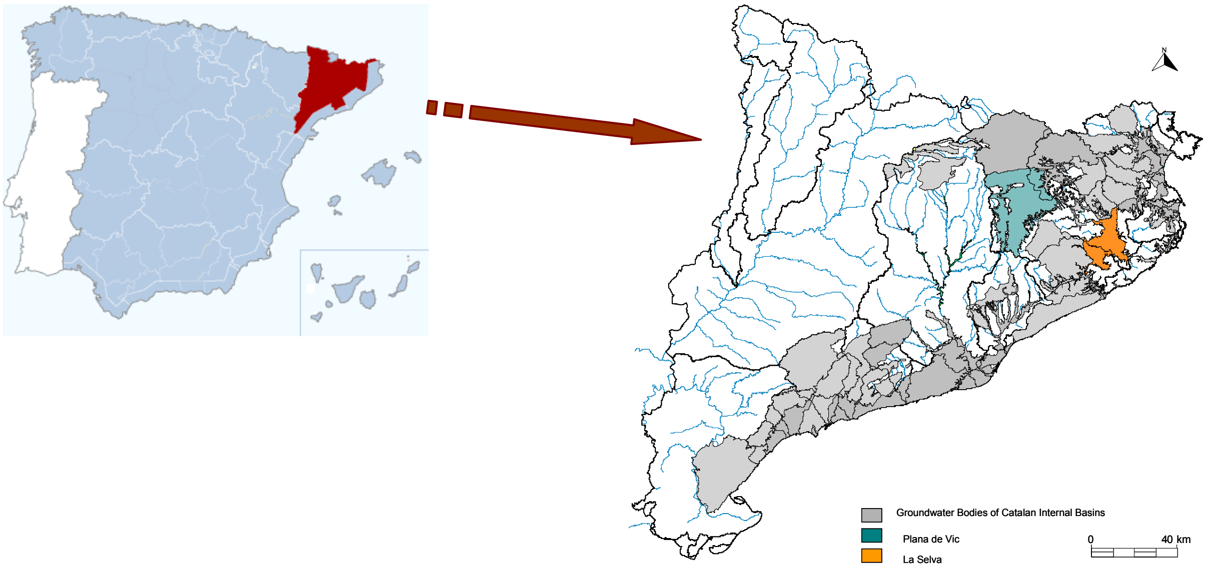
In the present work the occurrence of 20 selected sulfonamides, including some of their metabolites, were investigated in groundwater samples taken from surveillance and operational monitoring networks located in two groundwater bodies, Plana de Vic and La Selva, in Catalonia (Spain) (see Figure 1). Both of them include areas designated as nitrate vulnerable zones under the provisions of Directive 91/676/CEE ("nitrate directive") and are at risk of not reaching WFD environmental objectives in 2015. In the case of Plana de Vic groundwater, elevated concentrations of nitrate have been documented during the period 1996-2007, with average nitrate concentrations ranging from 39.5 mg/L to 99.7 mg/L. In La Selva, concentrations between 12.1 and 78.5 mg/L have been reported from 1998 to 2007.

Sampling sites

The groundwater body Plana de Vic is located in the north of Barcelona, between Prelitoral and Pyrenees mountain ranges, and encompasses an area of 740 Km^2. The geology is diverse, consisting mainly of Eocene sandstones, limestone and marls and Quaternary sands that form a complex sequence of alternating sedimentary continental deposits and marine facies. Unconfined detritic (non alluvial) aquifers are the most common in this area, although alluvial and carbonate aquifers are also present. Most of the aquifers are used for groundwater abstraction for water supply: drinking water accounts for the 74.3% of the total abstractions, 6.9% for agriculture use and 18.8 of industrial use.

The groundwater body of La Selva is located in the Northwest of Catalonia. It´s bounded on the North by the Transversal range and the Ter river, on the East by the Prelitoral range, on the South by the Litoral range and on the West by the Gavarres range, which surrounds the Selva basin. The total area comprises 291 Km^2. Geology is also diverse with igneous (granite) and metamorphic rocks, Neogene alluvial deposits filling the Selva basin and Quaternary alluvial and piedmonts materials. Like in Plana de Vic, unconfined detritic aquifers predominate, but granite and alluvial are also relevant. The most significant percentage of groundwater abstraction is used for agriculture practice (68.9%); drinking water production represents the 19.5% and industrial use the 11.6%.

Figure 1. Geographical location of the two groundwater bodies under study.



Water from 42 monitoring wells and a natural spring was sampled. In Plana de Vic 28 wells were assesssed. Waters analysed were sampled at different depths, ranging from 3 to 200 meters. Water from a natural spring was also sampled in this area. In La Selva, 13 wells were studied and water was sampled from 10 to 206 meters depth.

Analysis and results

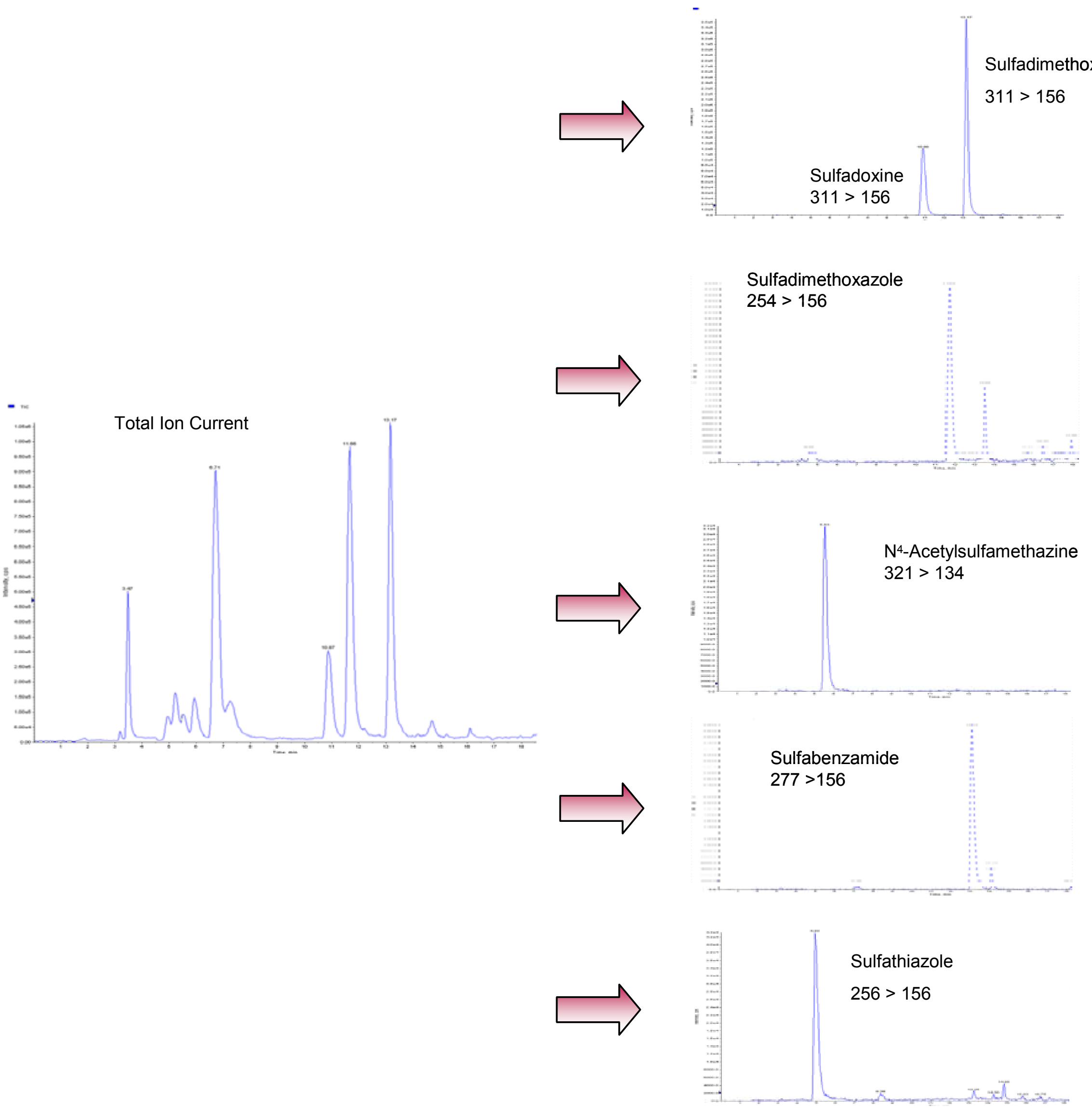
The samples were analyzed by a highly selective and sensitive analytical method based on on-line solid phase extraction-liquid chromatography-tandem mass spectrometry (SPE-LC-MS/MS). This new analytical method developed is fully automated and, in addition, requires smaller sample volumes, only 40 mL, compared to conventional off-line SPE methods that require between 100 and 500 mL of ground water for each analysis.

Identification of the target analytes was accomplished by comparing the LC retention time and the MS/MS signals of the target compounds in the samples with those of standards analyzed under identical conditions. For a positive identification, the following criteria had to be met: i) LC retention time agreement within 2%; ii) relative abundance of the two selected precursor ion-product ion transitions within a margin of ± 20%. The requirements set by the EU regulation regarding the identification and confirmation of organic pollutants in the environment (Commission Decision 93/256/EEC) (≥ 3 IP) was accomplished.

For quantitative analysis, and in order to get enough IPs to achieve analyte confirmation, data acquisition was performed in selected reaction monitoring (SRM) mode, recording the transitions between the precursor ion and the two most abundant product ions for each target analyte. Quantification, based on peak areas, was done by the internal standard (IS) method, using a deuterated sulfonamide. The performance of the method was evaluated through estimation of the linearity, sensitivity, repeatability, recovery, and matrix effects of the method. Five to seven point-calibration curves were built (matrix matched) with a concentration ranging from 0.01 to 1,000 ng/L.The developed method allowed detecting concentration values as low as 0.02 ng/L.

Results indicated that sulfadimethoxine, sulfamethazine and the N4-acetylated metabolite of sulfamethazine were the three sulfonamides more frequently detected and at the highest concentrations in both sampling areas, with concentrations in the range 0.1 - 228 ng/L. Nearly all the target sulfonamides could be detected in most of the samples as well, although at lower concentrations.

Figure 2. Total ion current (TIC) and single ion chromatograms showing the most abundant transitions of five of the sulfonamides studied in a matrix-matched standard solution of 1 ng/L.



The relationship between the occurrence of the sulfonamides and nitrates coming from organic fertilizers is also being investigated, in order to assess their common origin.

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Keywords: Water Framework Directive, emerging contaminants, antibiotics, sulfonamides, groundwater.

Poster session

WISE-RTD: Transfer of science results, technologies and practices into water policy implementation.

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Implementation of Policy Strategies such as the European Water Framework Directive (WFD) requires knowledge of best available methodologies, practices, technologies, tools, etc. Bringing science results into policy implementation is not a straight forward activity (Quevauvillier *et al*., 2005). Within Europe, the implementation of the WFD occurs at different countries under different circumstances, but is aiming to accomplish the same tasks and milestones defined in the WFD. *e.g.* definition of ground water bodies occurred at the same time in all Member States of the EU. Exchange of knowledge -as described above- at a relevant and adequate level is not easy even though an enormous amount of information is available on the internet.

The WISE-RTD web portal (www.wise-rtd.info) enables to select relevant information on the basis of keywords that are defined in the context of the WFD (Willems and De Lange, 2007). In support of water policy implementation, it guides to find information related to the subsequent tasks and milestones of the WFD. WISE-RTD is focussed around documents (on technologies, tools, experiences and guidances) in support of the implementation of the WFD and related directives such as the Groundwater Directive. However, data, GIS, and national reports for the WFD can be found in the other branches of WISE, the Water Information System for Europa (www.water.europe.eu)

The WISE-RTD web portal has been tested and evaluated by users providing and searching for information ever since its first prototype in 2004. In the recent workshops held within the project SPI-Water (funded by the European Commission), river basin managers were positive on what they found. Especially, in the workshop in Fes (Marocco) water managers from the Meditaranean countries have been searching for groundwater related information and found several relevant items (SPI-Water WP3, 2008).

After several years of development, the system now provides accurate information and is loaded with information from virtually all research projects funded by the European Commission (FP5/6/7, LIFE, etc.) In response to the recent extensive evaluations by river basin managers and their staff, the user entry undergoes a significant change (summer 2008) to enable users to find their information in 3 selection steps. The renewed user entry will be shown at the conference. User comments will remain welcome to improve the system in the future.

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Keywords: Water Framework Directive, implementation support, web portal, information selection.

Constraining the residence time of groundwaters using short-lived U isotopes: the Trias aquifer (Paris Basin, France) and the Mid-Eocene aquifer (Aquitanian Basin, France).

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The Water Framework Directive (WFD, 2000/60/EC) aims at achieving in 2015 the objective of good groundwater status from both a quantitative and a qualitative point of view. In this context, it is critical to put constraints on the residence time of a groundwater within its aquifer (in other words, to give "ages" of groundwaters). U-series may constitute a powerful tool for such investigations. The naturally occurring ^{238}U disintegrates with time due to its natural radioactivity, producing built-up ^{234}U, a nuclide that is also radioactive, and disintegrates itself, etc., thus producing a so-called decay chain, until a stable atom is built up (^{206}Pb in the case of the ^{238}U). In a closed system, the decay chain is at secular equilibrium: the activities of both ^{238}U and ^{234}U are equal. On the other hand, natural processes may fractionate ^{238}U and ^{234}U, leading to a disequilibrium between the two nuclides. In case of a ^{234}U/^{238}U higher than 1 (equilibrium value), there is ^{234}U in excess or "excess ^{234}U". Then, after the fractionation event, the decay chain tends to return to the secular equilibrium. For ^{238}U and ^{234}U, this time is typically in the order of 1 My, the time range usually investigated by the ^{234}U/^{238}U disequilibrium. This approach has been applied to two french large aquifer systems having very different characteristics.

The deep aquifer of Lower Triassic sandstones age extends over the whole Paris Basin, ~600 km wide in diameter. Groundwaters are slightly reducing fresh waters close to the recharge areas, whereas they are salt waters in the central part of the aquifer, with occurrences of crude oil fields (East of Paris, near the centre of the aquifer). ^{234}U/^{238}U activity ratio is very high in the water sampled at the recharge area (~ 9), and decreases gradually until activity ratios slightly higher than 1 in groundwaters recovered from the oil fields. These characteristics allow us to try to apply a simple model of downflow radioactive decay of excess ^{234}U (Osmond and Cowart, 1976). Such a model fits almost perfectly the data, giving a long-term (1 My scale) flow rate of 0.25 m y^{-1}. An "age" of approximately 1 My can be derived from waters associated with oil fields.

The Eocene sands aquifer of Aquitanian Basin (Adour–Garonne district) extends North and South of the Garonne River. The district is divided into two distinct water bodies, North (NWB) and South (SWB) of a major faulting system. Both aquifers are made of sands with occurrences of dolomitic limestones and evaporites. Unlike the Triassic sandstones aquifer, groundwaters are oxidizing. ^{14}C dates are available in a number of waters from the SWB (André *et al.,* 2005), ranging from 14 ka BP to 38 ka BP. U activity ratios higher than 10 are observed in some groundwaters from both water bodies. In the SWB, high ^{23}4U/^{238}U activity ratios are found in the area of "old" groundwaters (André *et al*., 2005), while recharge areas are characterized by much lower activity ratios, close to the equilibrium value (Innocent and Négrel, 2008). ^{14}C dates correlate perfectly with ^{234}U/^{238}U activity ratios in the groundwaters from the SWB for which both data are available (with only one exception). This precludes the application of a simple model similar to that utilized for the Triassic sandstones aquifer. An open-system model is proposed, involving gain and loss of U concomitant with radioactive disintegration, in which the incoming U displays a very high activity ratio (15). For most groundwaters of the SWB, "ages" are constrained by ^{14}C data, and U gain and loss per time unit may be estimated. For SWB groundwaters for which there is no a priori time constraint, model parameters together with hydrological data infer "ages" that are in the same range (between 30 ky and 40 ky). For groundwaters from the NWB, no ^{14}C date is available. The same model has been applied to these waters, giving "ages" that are comparable (~ from 15 ky to 35 ky) than SWB, as a function of model parameters.

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Keywords: Eocene - Groundwater – Residence time – Triassic sandstones – U-series.

Characterisation of groundwater systems: How to choose the isotope tool to answer a question? Application to the Eocene sands aquifer water body (SW France); CARISMEAU project

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The main objective of the Water Framework Directive (WFD, 2000/60/EC) is to prevent further deterioration and protect and enhance the status of aquatic ecosystems. Within this framework, and especially according to Annex II, aims of CARISMEAU are to provide further characterization of groundwater bodies or groups of bodies which have been identified as being of primary importance and/or at risk in the Adour-Garonne district (SW France). The demonstrative water body is the Eocene sands aquifer water body which constitutes a major aquifer used for drinking water, agriculture irrigation, gas storage and thermo-mineral water resource and extends over the Adour-Garonne district, being an artesian system to the west of the district and confined with piezometric levels around 250 m to the east of the district.

For that purpose, especially to reinforce the knowledge with regards to heterogeneities and interconnections between the aquifers, combined geochemical analysis (major and trace elements), common isotopic methods with $\delta^{18}O$ and $\delta^{2}H$ of the water molecule and $\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$; innovative isotopic method with strontium isotopes ($^{87}Sr/^{86}Sr$) and potential isotopic methods with boron ($\delta^{11}B$) and lithium ($\delta^{7}Li$) isotopes as well as U series were applied.

Select the appropriate isotopic tool to answer a question

The *stable isotopes of the water molecule* ($\delta^{18}O$, $\delta^{2}H$) allowed to trace the origin of the aquifer recharge, either in space (defining the recharge zone) and time as well as to highlight spatial heterogeneities between aquifers and inside one aquifer. Even though stable isotopes are not a tracer of the water ages, they can be used to constraint the recharge time, particularly in the context of deep sedimentary confined aquifers. They thus showed a recharge in some part of the aquifers under a colder climate (*i.e.* > 10,000 y).

The *strontium* ($^{87}Sr/^{86}Sr$) and *sulfur isotopes* ($\delta^{34}S_{SO4}$-$\delta^{18}O_{SO4}$) are able to trace the origin of dissolved Sr and SO_4, either from natural origin (rainwater, water rock interaction) or from anthropogenic ones (mainly fertilizers). Thus they help in answering to the question "from where originate dissolved Sr and SO_4 in groundwater? is there spatial and/or temporal variation in the source(s) of the dissolved elements". We observed contrasted signature in the groundwater according to the weathered lithologies in the aquifer systems and/or the anthropogenic inputs. Mixing between different waters (*i.e.* end-members) with $^{87}Sr/^{86}Sr$ and $\delta^{34}S_{SO4}$- $\delta^{18}O_{SO4}$ isotopes signatures that differ, led to a final signature that depends on the respective contribution of each end-member and thus $^{87}Sr/^{86}Sr$ and $\delta^{34}S_{SO4}$-$\delta^{18}O_{SO4}$ isotopes allows the proportions of the mixing to be calculated. Therefore, they help in answering to the question "where the groundwater came from? How the groundwater being recharged? What are the relationship between the different aquifer levels?". A better estimate of the groundwater circulation results from their investigation.

The *sulfur isotopes* also allow to trace the bacterial reduction processes of dissolved sulfates. Thus they allow to answer the questions "Is there any sulfate loss through bacterial reduction processes? Is the media anaerobic?". For a similar initial isotopic signature, reflecting the sources of dissolved sulfates, the bacterial reduction may yield to contrasted isotope signature in the groundwater. On one hand, this process may allow to identify mixing between aquifers with different signature but on the other hand, this processes hides the initial signature of the dissolved sulphate and thus may also make difficult to identify mixing between different aquifers.

The *boron isotopes* ($\delta^{11}B$) allowed to identify mixing between groundwater that have interacted with various lithologies and to confirm this mixing by coupling with the observed lithologies in the boreholes. Contrary to the strontium isotopes for which the seawater signal has been variable over geologic time that of boron remained identical. Thus the isotope signature of the evaporite and carbonate lithologies are well constrained and numerous groundwater in the district are explained, with regard to B isotopes, by a mixing of boron originating from the weathering of these two rock types. Similarly, the $\delta^{11}B$ of water interacting with a silicate is less variable than that of strontium isotopes. Here again, $\delta^{11}B$ highlight mixing between the carbonate and silicate end-members. Lastly, $\delta^{11}B$ illustrated the impact of the recharge zone, in complement to stable isotopes of the water molecule and the role of some specific part of the district (clayey rich deposits) on the water signature, allowing a precise characterisation of these very specific zones.

Groundwater vulnerability assessment in carbonate aquifers of semi-mountainous areas, case study from the French Western Pyrenees

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Carbonate aquifers of the French Western Pyrenees are able to produce important amounts of high quality groundwater (Rey, 2007). These resources are of strategic importance especially in the very competitive context of south-western France where conflicts of interest over water resources are occurring between water supply, agriculture and industry. In order to ensure on the long term the quality of the resources it is now of major importance to proceed to the evaluation of the intrinsic vulnerability of these aquifers to be able to forecast and even prevent any limitation of the resources (Muet *et al*., 2006). Two carbonated aquifers - Orbe and Ourtau - presenting both well developed karstic features were selected. These systems are very representative of semi-mountainous aquifers within the area and are characterised by very limited areal extension (2.4 and 3.8 km^2). The method used to evaluate the intrinsic vulnerability is adapted from the RISKE method (Petelet-Giraud, 2000) and includes new improvements proposed by Plagnes *et al.* (2005) and Pranville *et al.* (2008a and b). PaPRIKa characterizes the vulnerability of the aquifer system during the infiltration processes that is to say the possibility for a pollutant to reach more or less easily the saturated zone of the aquifer. The PaPRIKa method is a parametric weight and rating method. The name PaPRIKa means "Protection of the aquifers by Protection, Reservoir, Infiltration and Karstification criteria". Each of these parameters is assigned a weight value between 0 and 4, according to its relative importance in the evaluation of vulnerability. The degree of vulnerability is quantified by an index that is the sum of the products of each parameter weight in this rating. The distribution of the vulnerability index within five intervals of the same magnitude allows us to specify the different vulnerability classes of the PaPRIKa method (Dörfliger *et al*., 2007). The use of the PaPRIKa method is well adapted to large carbonated systems, but the adequacy of the method to small aquifers needs some adaptations to take into account the diversity and the huge variability of semi mountainous reliefs. One of the difficulties encountered is linked to the minimal resolution of the grid which is of 25m at minimum. In most cases this size is too large to guaranty the consideration of the heterogeneity of parameters such as soil nature or epikarst development. It is then necessary to attribute the least favourable parameter to the whole cell which can results in a worsening of the vulnerability evaluation. Another very specific problem to mountainous areas is also illustrated by the importance to consider the dip of geological formations. This parameter is of great importance on the runoff conditions and thus on infiltration processes. Thanks to adaptations of the method to the specific situation of the Western Pyrenees, a set of about 17 vulnerability maps has been generated for each test site. Amongst these results very good agreement between field conditions/observations and generated maps is observed showing the good fit of the PaPRIKa methodology to vulnerability evaluation even in the hydrogeological conditions of semi-mountainous areas.

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Keywords: Carbonate aquifer, groundwater, vulnerability, semi-mountainous area, PaPRIKa, Pyrenees.

How isotopic monitoring can improve management of nitrate pollution in water: ISONITRATE Life Demonstration Project

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ISONITRATE is a Life Demonstration Project which aims at demonstrating, to policy makers, the technical/economical feasibility of integrating the isotope approach as an integral part of the characterisation of water bodies and pressure and impact analysis of nitrate pollution, for a more effective implementation of environmental management measures in river basins.

Why using isotopes?

Current approach to environmental management and control of water quality regarding nitrate is generally based on the sole monitoring of NO_3 concentrations. Chemical data alone do not permit to establish unambiguously the type, location and contribution of its different sources in a river basin. In particular, differentiating urban and agricultural origin is impossible (even by increasing the number of monitoring stations or samples). Thus, design and application of specifically targeted management plans for nitrate control is improbable. Research showed the great added value of using isotopes to precisely distinguish nitrate sources, trace them in water and quantify their respective contributions. This new isotope approach inherently provides more information, but is yet to be fully demonstrated through a suitable long-term integrated pilot project; this is the objective of ISONITRATE.

Isonitrate Tools

Nitrate (NO_3) is found naturally at moderate concentrations in many aquatic environments, but is often enriched to high levels by anthropogenic activities involving nitrogenous compounds such as mineral fertilizer and by-products of organic compounds from agriculture, septic systems, and poultry, hog or cattle manure. In spite of the increasing efforts at national and European (EC Directive 91/976/EEC) levels to reduce NO_3 inputs from intensive agriculture, NO_3 is still one of the major contaminants of groundwater resources.

The isotopic composition of the dissolved nitrogen ($\delta^{15}N_{NO3}$) species has been used extensively to better constrain the sources and fate of N in groundwater. Nitrogen is not conservative because it is biologically modified through nitrification/denitrification reactions, both during infiltration and in the groundwater body, causing isotopic fractionation that modifies the $\delta^{15}N$ signatures. Because of the complexity of the biogeochemical nitrogen, $\delta^{15}N$ are combined to oxygen isotopic signature of NO_3 ($\delta^{18}O_{NO3}$) to trace natural and anthropogenic sources of nitrate and to identify potential microbial denitrification, nitrification and biological fixation processes in order to constrain the nitrogen budget in groundwater.

The isotopic composition of Boron ($\delta^{11}B$), as a NO_3 co-migrant, is not affected by denitrification and can therefore be used as a tracer of mixing processes. Boron commonly exists in groundwater as a minor constituent. Previous studies, focused on the characterisation of waste water and sewage dominated by synthetic B products, demonstrated that boron isotopes are suitable to trace anthropogenic inputs in surface and groundwater. The $\delta^{11}B$ of inputs related to agriculture (*e.g.* manure, synthetic fertilizers…) and combines N and B isotopes in the aim of distinguishing NO_3 anthropogenic inputs to ground- and surface water were used at the first time in 1997. The B isotopes, because they are not affected by denitrification, will bear the signature of the solute sources, but may nevertheless fractionate through processes such as adsorption on clay minerals.

The isotopic tools are used in addition to the more classical chemical analysis (major and selected trace elements) as well as the field parameters (T°, pH, Eh, EC, dissolved O_2) measured on site.

ISONITRATE, promoting isotopic approach to identify nitrate pollution sources, allowing the water quality assessment and tracing pollution origins, will (1) Show the economical advantage of isotopic approach based on a cost/benefit analysis; (2) Provide a transferable methodology to different catchments; (3) Help water managers and policy makers to adapt their measures to targeted sources of pollution; (4) Address guidelines explaining how to select catchments or river sections for isotopic measurements; (5) Demonstrate how operational Water Framework Directive monitoring programs would benefit from integrating the isotope analysis.

Improving the management of nitrate pollution in water in the Alsace Plain (France/Germany) through isotopic monitoring: ISONITRATE Life Demonstration Project

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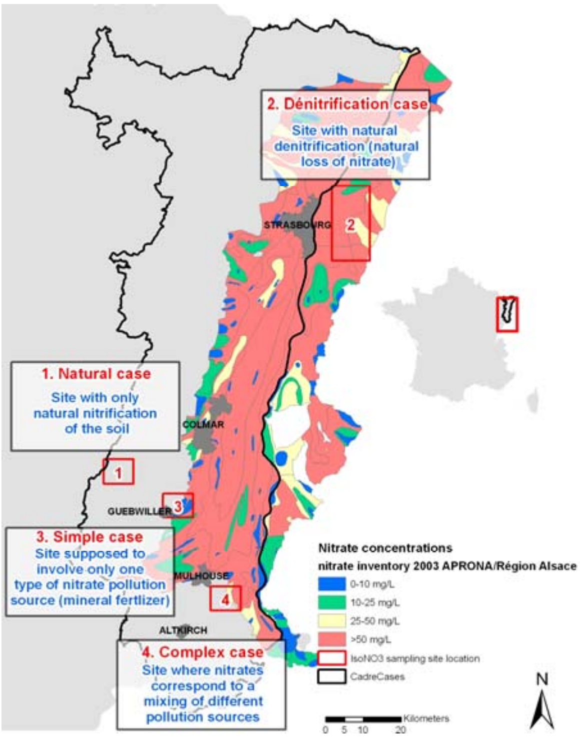
ISONITRATE is a Life Demonstration Project which aims at demonstrating, to policy makers, the technical/economical feasibility of integrating the isotope approach as an integral part of characterising water bodies and analysing pressure and impact of nitrate pollution, for a more effective implementation of environmental management measures in river basins.

Application to the Alsace Plain

Figure 1: Nitrate content in the Alsace Plain and location of the 4 studied cases.



Nitrate is a major source of pollution in water. The monitoring of NO_3 concentration allows to assess the spatial variability and temporal trends, but cannot identify the pollution sources responsible for the contamination. This step is crucial to build relevant management programs to reach a good water quality status. Isotopes of the NO_3 molecule ($\delta^{15}N$, $\delta^{18}O$) have demonstrated their capacity to decipher the main NO_3 pollution sources: mineral fertilizers, manures, domestic effluents… Nevertheless, the potential natural denitrification induces an isotopic fractionation of both $\delta^{15}N$ and $\delta^{18}O$ that modify the initial signature of the pollution source. Boron is a co-migrant of NO_3. Its isotopic signature ($\delta^{11}B$) is not modified by denitrification, B and can thus be used as a co-tracer.

4 different representative scenarios were chosen within the pilot site (the Alsace Plain): 1) Natural soil nitrification, 2) Natural denitrification, 3) Simple case: single source of nitrate, 4) Complex case: involving inputs from several different types of pollution. Surface and ground-waters are sampled during 12 sampling campaigns over a 18 months period.

The main potential contamination sources were also sampled in each considered catchments: various mineral fertilizers used for the different type of crops, organic fertilizers and also sewage effluents.

The Natural Case samples (surface and groundwater) have typical characteristics of a natural site: low NO_3 content corresponding to the natural soil nitrification, low B reflecting no anthropogenic influence; isotopic signature ($\delta^{11}B$, $\delta^{15}N$ and $\delta^{18}O$) are also in good agreement with natural values. This studied case constitutes the natural reference for the South part of the Alsace Plain. The Simple Case should be impacted only by mineral fertilizers as it is mainly covered by vineyards. It appears that surface waters (period October to April) have very low NO_3 contents compared to groundwaters (NO_3 up to 95 mg/l); one groundwater sample presents an high NO_3 coupled with a low B content, whereas another one presents high concentrations for both elements, reflecting probably more than one pollution source. Isotopes also plead in favour of at least two pollution sources. The Complex case should be impacted by various kinds of pollutions sources, resulting in very heterogeneous NO_3 and B contents in surface and groundwater samples; N and O isotopes plead in favour of the implication of natural denitrification for one sample. The Denitrification Case should be affected by natural denitrification of the NO_3 input from a single pollution source. While chemistry confirms the expected loss of NO_3 through the denitrification gradient, isotopes suggest that at least 2 anthropogenic sources are involved.

Keywords: Water Framework Directive, Nitrate, Boron, isotopes, groundwater.

Statistical procedures for trend analysis. Application to small data sets

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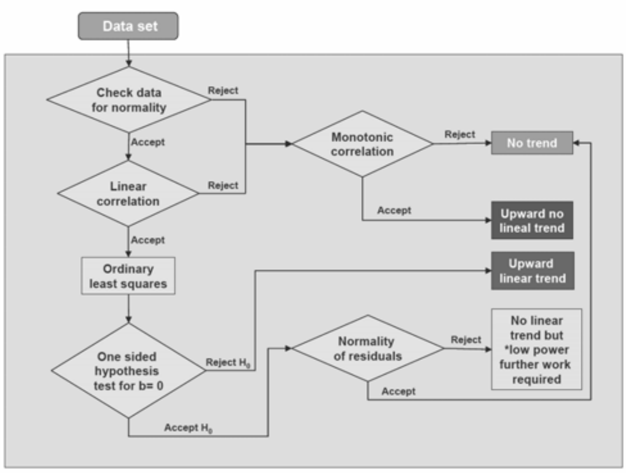
Trend analysis consists of the application of statistical techniques for making statements about the behaviour of a data set. In particular, it is of interest the detection of statistically significant upward or downward trends in a number of measurements. When investigating the increase in concentration of a given pollutant in a groundwater body, the relationship between the response or dependent variable (concentration) and time must be investigated. If such a relationship exists, its pattern may be linear or not. Because of that reason, the application of simple linear regression techniques with no previous check can produce erroneous results.



If concentration shows an increase or decrease with an increase in time it is said that there is a monotonous relationship between both variables. There are several procedures for checking correlations, like Kendall's Tau. Due to the fact that it is based on ranks, it is resistant to outliers and values below the detection limit can be handled. For number of measurements below ten, an exact test should be performed.

In case that variation in time of concentration follows a linear pattern, a linear relationship between both variables exists. The most widely used measure of correlation is the Pearson's r.

Normality of data is assumed. Statistical analysis can be done by means of linear regression. The relationship between concentration and time is modelled by a least squares function. This function is a linear combination of a number of parameters, called regression coefficients.

The model equation is the following:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \ldots,$$

where Xi are the n explicative or independent variables and Y is the dependent or response variable.

In the particular case that there is only one dependent variable, the model equation represents a straight line, defined by the first and the second coefficients, β0 y β1. The former is the point at which the line intercepts with or cross the y axis and the latter is the slope of that line. Finally, the linear regression model must be evaluated for checking adherence to assumptions. Normality of residuals is required when making hypothesis tests about the slope coefficient.

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Keywords: Trends, correlation, linear regression, hypothesis tests, residuals.

Influence of climatic cycles in the trend of the time series

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Cycles ranging from hours to decades have been observed in data from monitoring networks. Thus, phenomena such as El Niño South Oscillation (ENSO), North Atlantic Oscillation (NAO) or solar cycles, have been detected in different hydraulic head time series (Luque-Espinar *et al*., 2008a; Luque-Espinar *et al*., 2008b). In this context, any treatment of hydrogeological information for assessing trends should take into account these cycles. Therefore, a difference must be made among natural evolution and trend due to human activity. However, many aquifers have some sort of anthropogenic influence that can significantly disrupt natural cycles and that must also be taken into consideration.

Below, evolution of piezometric level with time in a well is displayed. In the figure it is possible to appreciate such cycles clearly (Fig. 1). A case study is presented in which series of cycles of 1 and 10 years are observed (Luque-Espinar *et al.,* 2008a). A smoothing has been performed by moving averages to soften the cycles (Fig. 1). In both cases the linear trend remained virtually unchanged. However, a significant change was observed when the selected data were part of a downward segment of a decadal cycle.

Moreover, in Figure 2 several chemical parameters of the same aquifer are presented. Quality of information in hydrochemistry is usually poorer than that obtained from piezometric networks. Therefore annual cycles are not seen with equal clarity. However, the decadal cycles can be seen with broad strokes. In Figure 2 it can be seen that the fastest increases of displayed parameters coincide with piezometric level raise periods.

Figure 1: Time evolution head.

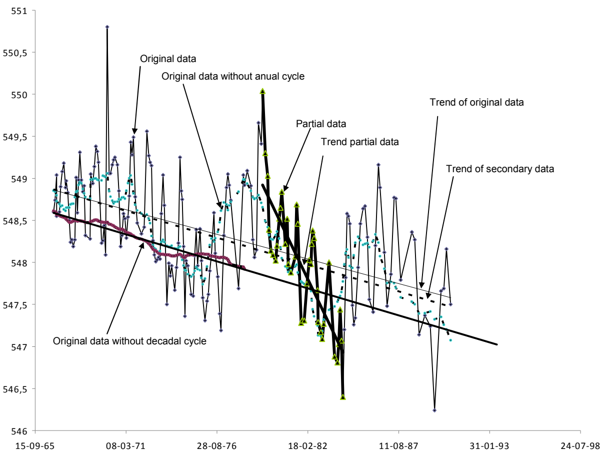
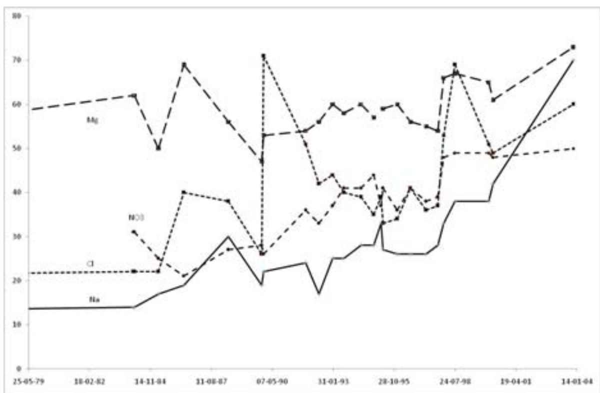


Figure 2: Time evolution of hydrochemical parameters.



Therefore, it is conceivable that more dense chemical information could allow cycles of the same period as described in the piezometric networks to be seen (Luque-Espinar *et al*., 2008).

Finally, it is considered necessary to take into account the existing climate cycles to perform a proper assessment of trends of both the level of groundwater and chemical parameters of interest. In this framework it is more appropriate to choose for this type of analysis time series with more than ten years length.

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Keywords: Cycles, groundwater, data series, trends, Water Framework Directive.

Emerging substances in groundwater: detection and fate of manufactured nanoparticles

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With an expected market of 1,000 billions euros by 2015, the increasing use of manufactured nanomaterials for industrial and household purposes will inevitably lead to their introduction in environment and our ecosystems, including groundwater. Risk assessment of groundwater contamination by nanoparticles requires the development of both appropriate metrology for their detection in water and knowledge about processes driving their mobility and attenuation.

An approach moving from lab experiments toward field studies by keeping a particular attention to the representativeness of experimental conditions and by aiming at identifying the processes involved during the transfer of a selection of manufactured particles within groundwater is being developed. Organic (C60) as well as inorganic (CeO_2, TiO_2, ZnO) nanoparticles are considered in this investigation.

Transport and fate of nanoparticles in a water saturated porous media are described by mechanisms such as: (a) dissolution; (b) aggregation; (c) complexation with dissolved or particulate mater; (d) interception of the particles and aggregates by the media. Consequently, transport and fate of nanoparticles depend, on one hand, on their characteristics such as solubility, pH_{zpc}, which may vary with chemical composition, cristallinity, size, eventual coating, and on the other hand, on the overall chemical composition of groundwater, particularly pH, ionic strength - major element concentration, *e.g.* Ca or Na (counter ions of nanoparticles in solution).

Groundwater chemistry, which depends on water rock interaction processes and which may be impacted by human activities, as well as surface charge of solid matrix of aquifer favouring or inhibiting dispersion/aggregation are key parameters for nanoparticles dispersion. The scheme for an aquifer typology based on lithology and saline influences, which has proven to be comprehensive with respect to the chemical composition of most current groundwater (Wendland *et al*., 2007) appears to be particularly adapted to the investigation of the fate of nanoparticles in groundwater.

Experiment of nanoparticles dispersion and ageing are being conducted in water, the composition of which being representative of major European groundwaters. Particles transport experiments will be shortly conducted at laboratory, pilot and field scale, allowing to take into account both chemical and hydrodynamic aspects. Transport along few centimeters will be investigated in lab conditions. These experiments will involve a wide variety of nanoparticles and will allow to select nanoparticles for large scale experiments: a) pilot-scale experiment for a 3D investigation of the transfer (1 m x 20 cm x 30 cm) in porous media; b) artificial tracer test between an injection and a pumping well along 10 to 20 m in a fissured aquifer.

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Keywords: Pollutants, nanoparticles, mobility and attenuation, aquifer typology.

Proficiency tests of Danish groundwater sampling

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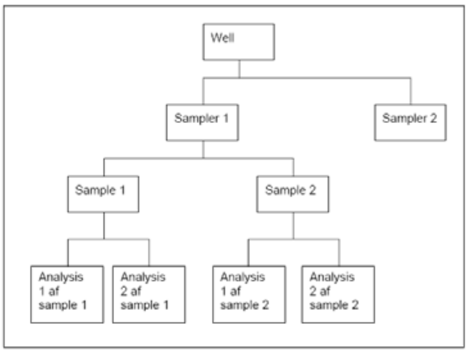
Introduction

Reliable and comparable methods for groundwater monitoring are crucial for assessment of the state of groundwater bodies and possible trends in the development of groundwater quality as demanded in the WFD. Investigations of groundwater quality have so far focused on obtaining high precision in the analytical results of the laboratories. In 2007 and 2008, a new development area of the Danish Environmental Monitoring Programme was initiated with the aim of reducing sampling uncertainty by introducing proficiency tests of groundwater sampling.

Statistical design

Double split design and range statistics (Grøn *et al*., 2007) were used to address the uncertainty associated with extant groundwater sampling (see Figure 1) performed by the 7 National Environmental Centres responsible for carrying out the field work under the monitoring programme. The same groundwater monitoring well was sampled under different conditions during the tests in 2007 and 2008 (see Figure 1). The choice of statistical sampling design allowed calculation of the following uncertainty parameters: 1) analytical precision, 2) sampling precision and 3) variability between samplers.

Figure 1: Statistical design of sampler proficiency test and conditions of tests in 2007 and 2008.

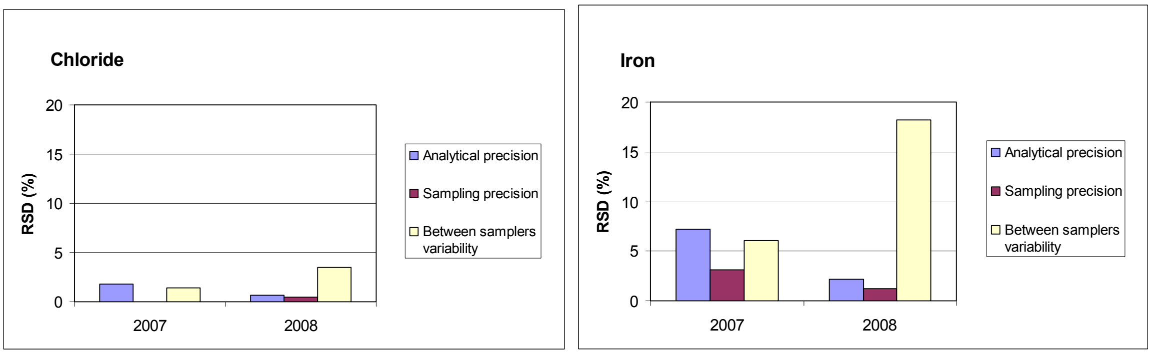


	Conditions
Test 2007	• Equal and constant pumping • Sampling during one day • Field measurements of oxygen, conductivity, pH, redoxotential and temperature • Cl and Fe
Test 2008	• Independent and individual pumping • Sampling during 1½ month • Field measurements of oxygen, conductivity, pH, redoxpotential and temperature • Cl, Fe, Ca, Mg and HCO_3.

High quality sampling

In general, the results from the tests showed that the Danish groundwater sampling has a high technical level. Surprisingly, the results from the tests showed that the sampling precision (RSD: 0 - 3.1%) outperformed the analytical precision (RSD: 0.7 - 7.2%) as regards chloride and iron groundwater analyses (see Figure 2). In 2008 the effect of pre-pumping of the groundwater well before sampling was investigated. A pre-pumping relative uncertainty of 2 – 9% on chloride and ion analyses was observed.

Figure 2: Selected statistical results from Danish groundwater sampling proficiency test in 2008.



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Keywords: Water Framework Directive, WFD, groundwater, sampling, monitoring, precision, uncertainty.

The groundwater flow simulation in the river Valin paleodelta

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The main objective of this work is the study of the effect of aquifer's internal architecture on the groundwater flow. The river Valin paleodelat, located in the Saguenay region in Quebec, was selected for this study. This paleodelta has been formed through the melting Laurentidian glacier. The digging bed of the Valin river has cut the delta into two parts thus forming two separate aquifers systems: one in Saint-Honore, and the other in Saint-Fulgence (Lasalle and Tremblay, 1978). The approach of investigation consisted of identifying the lithofacies on the walls of sand pits. The lithofacies corresponds to a portion of the deposit, which is characterized by a particular combination of lithology and physical structures (Walker, 1992).

So, 20 lithofacies have been identified. All identified lithofacies are characterized by the same granulometric class and granulometric fraction. They were grouped on one effective lithofacies. So, seven effective lithofacies have thus been determined. The second step consisted of estimating the hydraulic parameters for each identified lithofacies by using different methods. The hydraulic conductivity has been estimated in situ by a mini disc infiltrometer (Decagon, 2005) and tension infiltrometer (Reynolds and Elrick, 1991).

In the laboratory, this estimate is based on a grain-size distribution of the samples using the Hazen's, Beyer's and Slichter's empirical formulas (Vukovic and Soro, 1992). The porosity has been estimated in situ by a porosimeter manufactured at the University of Quebec at Chicoutimi. In the laboratory, it is estimated by Black's formula. A correspondence between the identified lithofacies and their hydraulic parameters values has been undertaken to determine the hydrofacies. The later can be defined as a homogenous but anisotropic unit, which is characterized by its size, geometry and hydrogeological properties, including hydraulic conductivity, when the value can vary by several orders of magnitude (Anderson, 1989). Thus, a hydrofacies can be represented by a range defining its hydraulic conductivity variation interval.

Therefore, each effective lithofacies was represented by its hydraulic conductivity value group as it has many values obtained from their lithofacies group of the same granulometric class and granulometric fraction. These groups are considered as hydraulic conductivity variation ranges. All effective lithofacies, with similar ranges of hydraulic conductivity variation, are grouped in one hydrofacies. Following this approach, four hydrofacies were thus determined. The aquifer system has been modeled by using Visual MODFLOW software. Let us note that, the modeling has been developed for only a part of the paleodelta system, where there were more sand pits and some wells and piezometers, which are well documented. This area has been considered as the modelling domain. So, two models have been developed following two different approaches. The first was named hydraulic model, because it has been developed relying on the hydraulic conductivity distribution. The second was named sedimentological model, because it has been developed relying on the sediments implementation mechanism.

The groundwater flow has been simulated by using the Visual MODFLOW software. So, new simulation elements have been incorporated in both developed models. The simulation in this study consisted of determining the well capture zone. This has enabled to characterize the groundwater flow, especially in the direction of a pumping well, and to appreciate its behaviour when the aquifer is composed of several hydrofacies. So, two well capture zones have been estimated. Thus, the determination of a capture zone has allowed assessing the behaviour of the groundwater flow when the aquifer is composed of several hydrofacies of different hydraulic conductivity.

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Keywords: Hydrofacies, lithofacies, internal architecture, hydraulic conductivity, porosity, model, capture zone, Groundwater flow.

About the impact of snowmelt as a source of hydromineral resources at a high mountain area (Serra da Estrela, Central Portugal)

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This study presents the results of geological, geomorphological, tectonic, geochemical, hydrogeological and isotopic techniques in hydromineral resources assessment at Serra da Estrela mountain region, the highest mountain in Portuguese mainland. A special emphasis is dedicated to the recharge and discharge processes and the role of snowmelt as a source of hydromineral resources. Mountain areas represent some of the blackest "black boxes" in the hydrological cycle (Chalise, 1994). The complex role of soils, geomorphology, geology, climate and land use on the hydrology of mountain areas, are rather difficult to model. Nevertheless, mountain river basins provide the finest opportunity to increase knowledge on the relationship between those variables as well as their impacts on the water quality at different altitude zones (Chalise, 1994). The relief of the study region consists mainly of two major plateaus (ca. 1,450-1,993 m a.s.l.), separated by the NNE-SSW valley of Zêzere River (Vieira, 2008). Late Pleistocene glacial landforms and deposits are a distinctive feature of the upper Zêzere catchment since the bulk plateau area was glaciated (Vieira, 2008). The ice sheet that covered most northern and central Europe 18,000 years BP did not reach the study region, where only mountain glaciers were present. Serra da Estrela Mountain is located in the so-called Central-Iberian Zone of the Iberian Massif (Ribeiro *et al.,* 1990), mainly composed by Variscan granitic rocks and Precambrian-Cambrian metasedimentary rocks, as well as alluvia and Quaternary glacial deposits. Most "normal" groundwaters belong to the Na-Cl and HCO_3-Na facies, with low TDS, considered as good signatures of local recharge and hydrolysis of Na-plagioclases, respectively. The high Na-Cl concentrations found in some of the waters of this group could be ascribed to the local use of NaCl to promote snowmelt in the roads during the winter season. Mineral waters from Caldas de Manteigas Spa are characterised by: high pH values (≈ 9), EC values around 300 µS/cm, the presence of reduced species of sulphur (HS- ≈ 1.7 mg/L), silica values (around 50 mg/L) and high F- concentrations (up to 7 mg/L), indicating that the reservoir rock should be mainly the granite. The most important isotopic signature is ascribed to the fact that no influence of a lighter isotope component in the groundwater samples from winter (April) campaigns was found. This isotopic signature can be explained by a high a mixing process between different groundwater bodies, with the tendency to the homogenisation of the isotopic composition. This process should occur mainly in the porous medium (dominated by alluvia and Quaternary glacial deposits) and the most weathered granitic rocks.

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Keywords: Geochemistry, isotopes, tectonics, high mountain areas hydrogeology, hydromineral resources, Portugal.

Groundwater reference framework for Italy in order to implement the European directives 2000/60/CE and 2006/118/CE - First results

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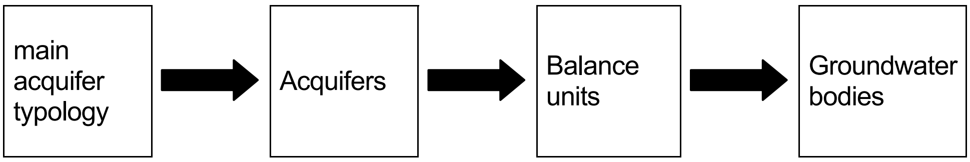
ISPRA has, in its institutional mandate, the role of technical coordination of the regional environmental protection agencies for the monitoring activities, this implying the standardization of the whole monitoring operational chain. The task is carried out through a partecipated process. ISPRA has, moreover, the function of building the national reference datasets for waters, in collaboration with regional and river basin authorities.

In order to support the implementation of European directives 2000/60/CE and 2006/118/CE, the Ministry of Environment has instituted a technical advisory board on groundwaters where different research institutes take active part, among which ISPRA and Tevere River Basin Authority.

After a first survey on available groundwater information, the need arose of a national groundwater reference framework, where decodification and upscale could be possible.

ISPRA carried out this task through a continuous dialogue with the regional authorities and in close collaboration with Tevere River Basin Authority, in the light of the mutual WFD – CIS experience.

The first two goals of the activity were: the systematization of existing information into a national scale and a guide to address actions in less surveyed areas according to the following conceptual schema:



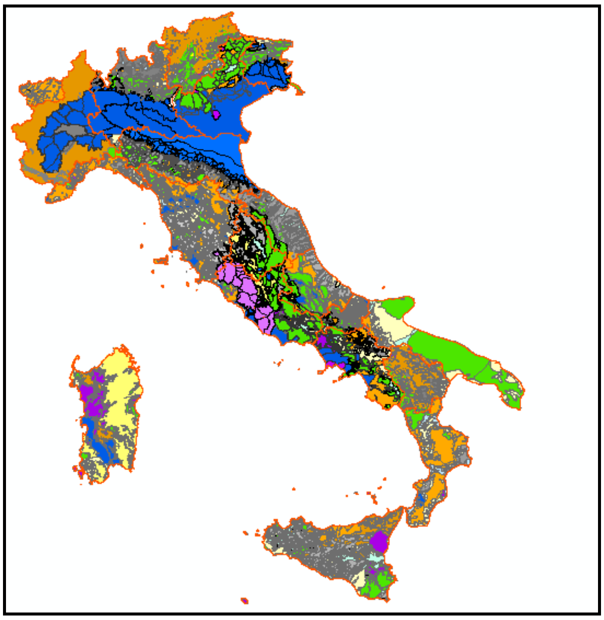
The initial layer to start from was identified in the 1993 Groundwater Resources Map (developed by SINA – the former National Environmental Information System – trough the revision and vectorialization of the 1982 Mouton's map). Seven acquifer macro-typologies were then identified and used for transcoding and upscaling information produced by territorial competent authorities (Regions, River Basin Authorities) into a national.

In particular, available groundwater bodies or balance units boundaries (or acquifers instead) have been transposed into the map and made topologically consistent. The information have been then uploaded into a specifically developed national geodatabase.

The layer so built (Fig. 1) not only represents a national reference layer, but also a guide to address the hydrogeological studies towards a more realistic definition of groundwater bodies and balance units boundaries.

* The Institute is a public body, under the vigilance of the Ministry of the Environment, Territory and Sea. It performs the functions, with the inherent tools, financial and human resources, of three former institutions: APAT (Agency for Environmental Protection and Technical Services), ICRAM (Central Institute for Applied Marine Research), INFS (National Institute for Wildlife).

Fig. 1. First draft of groundwater bodies layer: where information is missing, reclassified Mouton's map has been used.



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Keywords: Acquifer, water balance, balance unit, groundwater body.

Several cases of groundwater – surface water interaction in the Netherlands

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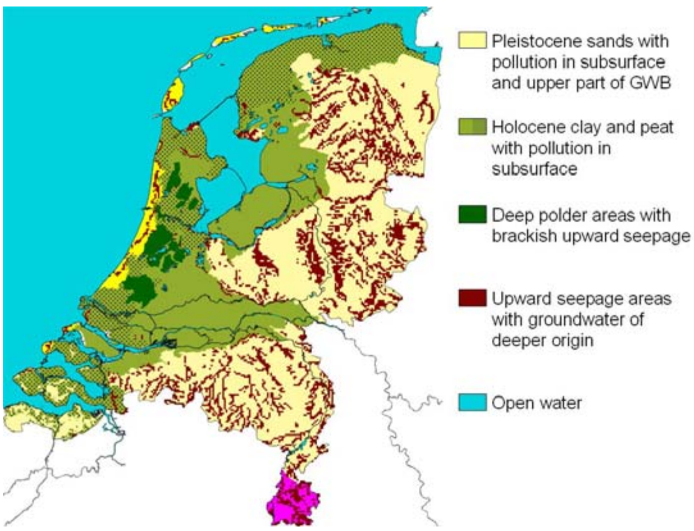
The Netherlands is a flat and wet country situated within the estuarine basin of the rivers Rhine, Meuse and Scheldt. In the northwest the country is bordered by the North Sea. Water is abundant, especially in the lower part of the country, which is covered by Holocene clay and peat. In this part, groundwater tables are mostly less than 1 m below the surface. Surface water is present in a dense network of ditches and small lakes. The higher eastern and southern part of the country is situated above sea level and is mainly covered by Pleistocene sand deposits. Here shallow groundwater tables are less abundant and mostly concentrated in landscape depressions (*e.g.* brook valleys). Since the 1950's intensive agricultural activities started and led to intensified drainage and wide spread pollution in the upper part of the subsurface and groundwater system. Due to a combination of a net surplus of rainfall, high groundwater levels, intensive drainage and polluted subsurface, transport of nutrients (N, P) and heavy metals (Ni, Zn, Cu) from the subsurface and upper part of groundwater bodies towards surface water bodies has become a dominant pathway for these substances in the rural areas of the Netherlands. The deeper part of the groundwater bodies in the Netherlands are mostly unpolluted and can be important for the chemical and ecological status of surface water bodies.

Due to groundwater abstraction and drainage the contribution of the deep groundwater component may have decreased, with negative consequences for the environmental flow needs of surface water bodies. A special situation in the Holocene part of the country is the presence of deep polder areas with upward seepage of brackish groundwater which leads to high input of chloride and phosphate towards the surface waters in these areas.

The groundwater – surface water interaction is considered to be a WFD knowledge gap. In 2008 an effort was made to locate the presence of different types of groundwater – surface water interactions in the Netherlands (figure 1), and to illustrate it through case studies. For three cases the relevance of the interaction in relation to the WFD is discussed.

Figure 1: An overview of the occurrence of regions with specific types of groundwater – surface water interaction in the Netherlands.



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Keywords: Water Framework Directive, groundwater – surface water relationships.

Groundwater age determination: a tool for understanding nitrate concentration in Brittany (western France)

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CFCs have been measured on several sites in the whole Brittany (France) for groundwater datation. Brittany is an agricultural area where high nitrate concentration limits water production for tap water. Since 1990/1995, agricultural practices have become more sustainable but only few and disparate effects have been observed on groundwater and river quality.

The studied sites have typical geology encountered in fractured aquifers elsewhere. Under a weathered zone of about 20 to 30 m depth, the highest flow rates are associated with large tectonic faults emphasizing local fracturation. Water is sampled by tubing sampler directly in front of main fractures and then analyzed for CFCs.

According to CFCs measurements, the groundwater age distribution seems to follow the geology compartimentation: recent groundwaters (0-5 years) in recharge areas and older ones (more than 25 years) in the fractured zone. In the intermediate zone, the CFCs concentration indicated that few groundwater is less than 15 years old. Moreover the results show old groundwaters (more than 10 years old) for a shallow depth (2-8m) which is surprising.

The influence of pumping on groundwater age patterns is clearly identified.

Nevertheless this study gives new clues on hydrogeological functioning comprehension and water management in hardrock aquifers. Although some uncertainty remains on groundwater residence time in the weathered area, some shallow groundwaters which participate to river flow are clearly older than 10 years old. This indicates that the efforts made for water protection could have been successful but that we must be patient to see clear effects on groundwater quality.

Groundwater age is a useful tool for calibrating ecosystem response time and more especially to know if the water mass could reach the good chemical status mentioned in the Water Framework Directive. Groundwater age is “the” new tool for water sustainable management.

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Keywords: Groundwater Age, CFC, nitrate, Water Framework Directive.

Environmental quality standards limitations towards immiscible organic compounds in groundwater: the case of organochlorine compounds

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Several organic compounds are weakly miscible, or even immiscible in water. This property is linked to their hydrophobic nature, which governs their aqueous solubility. Numerous organochlorine compounds belong to this type of substances, for which a little free-oil phase release in groundwater could lead to long lasting source of water pollution. In this communication, chlorinated solvents and their intermediates, which are common groundwater pollutants due to their massive industrial production during all the past century, were taken as a case study. New European regulations appeared recently to limit their impacts on environment and on human health, and are affecting different levels:

- Environmental regulation: The Water Framework Directive (WFD) requires reaching a good chemical status for natural water bodies, which is defined by Environmental Quality Standards (EQS).
- Industrial waste regulation: REACH European regulation defines persistence, bioaccumulation and toxicity criteria to recognize hazardous substances that must be eliminated from industrial processes. For example, Hexachlorobutadiene, a fortuitous intermediate of chlorinated solvent production, is a Persistant, Bioaccumulable and Toxic (PBT) substance in reference to this regulation. WFD defines also a list of priority substances which must be eliminated of industrial waste and concerns different organochlorine compounds (1,2-dichloroethane, Hexachlorobutadiene, Hexachlorobenzene, Chloroform, Hexachlorocyclohexane).

These new regulations are however raising different problems concerning the issue of contaminated groundwater by immiscible organochlorine compounds, two cases can be considered:

a) substances which solubility exceeds environmental quality standards:
   Remediation of such pollution generates important costs due to (i) difficulties of detection and characterization of pollution source and (ii) treatments of the pollution source and the dissolved plume (US EPA, 2004). In this case a question can be asked: “Does it worth removing the source rather than overcoming the impacts on water bodies?”
b) substances which solubility is close to environmental quality standards:
   Such immiscible compounds, are very difficult to detect in groundwater, and are therefore expected to reach aquatic ecosystems only to a very limited extent. However, despite their low solubility and low concentrations in water, these products can bioaccumulate in aquatic organisms. In this case, the concern pointed out by the new regulations would be: “How could we reach the good chemical and biological status in aquatic ecosystem interacting with groundwater bodies polluted in the past by PBT compounds?”.

Measurements performed on polluted sites where PBT compounds were released in soils and groundwater during the past century were used to study these issues. The potential of enhanced attenuation, considered as a complex but cost-effective method for groundwater remediation (Wiedmeier *et al*., 1999), is presented.

This works highlights the need of analytical development to determinate low-miscibility compounds in water, and to find natural or enhanced attenuation processes.

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Keywords: Groundwater, Contaminated lands, chlorinated solvents, PBT criteria, WFD, REACH, Industrial activity.

Antibiotics in groundwater

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Further to great environmental and health problems due to ecosystem exposure to anthropogenic chemicals in the 70's, attention has been raised about fate and persistence of human-made chemicals in the environment. In that context, water compartment and especially groundwaters as a supply of drinking water, are of particular concern.

In regard to the potential hazard presented by antibiotics in the environment and in accordance with the Water Framework Directive (WFD), recommending collection of data on emerging water contaminants such as antibiotics, these contaminants have been investigated in groundwater in few countries, in Europe: Germany (Sacher *et al*., 2001) and also in US (Batt *et al*., 2006). Results reported their findings in the ng L^{-1} range, which is low as compared to acute toxicity values published (in the mg L^{-1} range).

This work aims to discuss correspondence between level of contamination and toxicity potential of these compounds, and needs for implementation of the WFD.

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Keywords: Antibiotics, groundwater, contamination, risks, WFD.

Regional groundwater balance and submarine karstic springs. Examples in Southeastern France.

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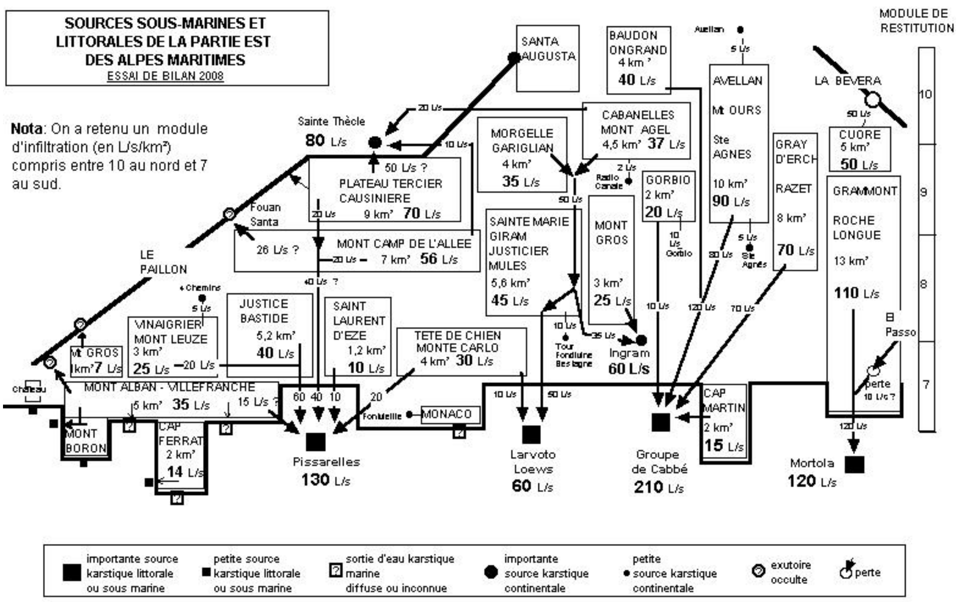
Presentation

Achieving an hydrogeological balance is difficult in coastal karstic areas due to the presence of important submarine springs. Many examples are known in Southeastern France and the absence of data do not make it possible to realize a satisfactory groundwater balance. Moreover, the mixing between sea and fresh water complicates the evaluation of the annual discharge.

Examples

The Port Miou-Bestouan group of springs (Marseille-Cassis, France) whose average flow is between 3 to 5 m^3/s, is the largest freshwater outlet between the Rhône and the Argens but it is not included in the french network of hydrological data. It is fed by a badly known aquifer that extends in the Basse Provence area (Gilli, 2001). This area is considered as a dry one but the values of rainfall and evapotranspiration do not explain the dryness. The absence of springs, or a too small discharge of the outlets, for several karstic units, tends to prove that only a part of the infiltrated water feeds the continental springs while the other part reaches a deep aquifer that is drained towards the sea. Data on discharge, temperature and salinity was collected in Port Miou. The correlation with rain fall gave indications to extend the basin up to 1,000 km^2 (Cavalera, 2007).

Figure 1: Groundwater balance of the karstic units between Nice and menton (France).



A same problem exists between Nice and Menton (Gilli, 2003) where several karstic springs have been studied for water supply. Their average annual discharge is 600 L/s. A global approach using different methods have been done to evaluate the importance of these emergences and to define the extension of their water basins (fig. 1). Dye tests, monitoring of springs, maps of surface salinity, bathymetric and palaeogeography analysis where conducted to define a more accurate ground water balance of this area (Mangan *et al.*, 2007).

Conclusion

Similar work of detection and monitoring should be done to characterize the european coastal karstic aquifers.

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Keywords: Coastal karst, submarine spring, groundwater balance, salinity, watershed, infiltration module.

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