Technical report No 39

Pilot implementation EUROWATERNET – groundwater

State of groundwater in selected groundwater bodies with reference to nitrogen

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Preface

This pilot study was undertaken to demonstrate the potential benefits from using EUROWATERNET for assessing nitrogen contamination of groundwater and thus assist in further implementation of the groundwater part of the network by the countries. Information and data for the pilot study were provided by national experts of twelve countries and do not intend to provide a representative overview of the groundwater quality situation across Europe or in any of the participating countries. It should be stressed that measured data (not model outputs) were used to test data collection and analysis as proposed in Technical Report No 7: EUROWATERNET – The European Environment Agency's Monitoring and Information Network for Inland Water Resources (EEA, 1998).

Executive summary

This pilot study was carried out to demonstrate how EUROWATERNET can enable the European Environment Agency (EEA) to answer general as well as more specific questions on the condition of groundwater bodies, and to give an overview of the quality status and trends at the European scale. The pilot study on implementation of EUROWATERNET – groundwater focused on the nitrogen status of groundwater in Europe. The pilot study was carried out by the European Topic Centre on Inland Waters (ETC/IW) and had the following objectives:

- to test the proposed draft Guidelines for a European Groundwater Monitoring Network Design (see Appendix A) with readily available data provided by volunteer partners;
- to demonstrate the state of groundwater in selected groundwater bodies with reference to nitrogen (nitrate, nitrite, ammonium and dissolved oxygen), and
- to recommend a way forward of extending the technical scope and geographic spread of the network in parallel with the efforts on surface waters over the next years.

Experts from 12 countries (Austria, Czech Republic, Denmark, Finland[1], France, Germany, Hungary, the Netherlands, Norway[2], Slovenia, Spain and United Kingdom) delivered information on 34 groundwater bodies. The information requested comprised a general characterisation of the groundwater body and quality data on nitrogen compounds. In general, information was delivered within five weeks and the quality of the answers was high.

Results of this pilot study show that the proposed draft EUROWATERNET guidelines allow for the inclusion of a broad variety of groundwater bodies with regard to size as well as to the intensity of monitoring or groundwater quality. The size of the reported groundwater bodies varies between 1.25 km^2 and 7 754 km^2, most of them fall into the area class 100-1 000 km^2. Sampling site density varies between 1 313 and 1.2 km^2/site. However, at two thirds of the groundwater bodies the sampling site density is below 25 km^2/site. Provided maps show a more or less even distribution of sampling sites within the respective groundwater bodies.

In the draft guidelines for EUROWATERNET – groundwater it is proposed to present data for a particular groundwater body in a standardised aggregated form (percentiles, mean values, summary frequencies, frequency distributions etc.). This pilot study shows that for nitrate such aggregated data provide sufficient information for assessing the state of groundwater at the European scale.

To improve the assessment of nitrogen problems in groundwater the study recommends not to focus on nitrate only but to pay attention also to nitrite, ammonium and dissolved oxygen. Results show that some groundwater bodies have serious groundwater problems. In most cases nitrate is the compound exceeding the limit values for drinking water, but there are groundwater bodies exceeding the limit values for ammonium without exceeding the nitrate limits.

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[1] Data were not included since due to late delivery some inconsistencies could not be clarified

[2] Insufficient data were provided

Furthermore, the pilot study showed that a scientific assessment of cause-effect relationships can hardly be carried out at the European level. Such an assessment is currently more feasible at the regional level since the detailed information required is not available on the European scale.

As a further step data collection in EEA member countries and database development in accordance with the draft EUROWATERNET guidelines should be initiated. In parallel it is necessary to develop EUROWATERNET – groundwater to meet the requirements for groundwater monitoring and reporting laid down in the proposed Water Framework Directive. Furthermore, it is necessary to develop an update mechanism for EUROWATERNET – groundwater to be a tool for day-to-day work and for informing the users of groundwater information.

1. Introduction

1.1. EUROWATERNET – groundwater

The main objective of the European Environment Agency (Council Regulation 1210/90, Article 1)) is to provide the European Union and EEA member countries with:

> 'objective, reliable and comparable information at a European level enabling them to take the requisite measure to protect the environment, to assess the results of such measures and to ensure that the public is properly informed about the state of the environment.'

In order to achieve this goal the European Topic Centre on Inland Waters (ETC/IW) working under contract to the EEA has prepared groundwater monitoring strategies. The first draft of the monitoring network design (for surface and groundwater) as well as the results of a pilot study carried out for an existing network in one country were presented to EEA National Focal Points (NFP) at the first European Information and Observation Network (EIONET) workshop on water held in Madrid in June 1996. In the light of the recent development of water policy in Europe (in particular the elaboration of the draft Groundwater Action Programme (GWAP) and the draft Water Framework Directive) together with the further development and implementation of EUROWATERNET it became evident that it will be necessary to adapt the EEA groundwater monitoring network design since monitoring needs and strategies at the European level should be in line to avoid duplication.

As a consequence it was decided to establish an expert group to prepare a revised version of the guidelines for a European groundwater monitoring network and to test these guidelines for groundwater bodies in twelve different European countries. Countries participated at expert level on a voluntary basis.

The key concepts of EUROWATERNET are (EEA, 1998):

- It samples existing national monitoring networks and information databases;
- It compares like with like;
- It has a statistically stratified design 'tailor-made' for specific issues and questions;
- It has a known power and precision.

1.2. Guidelines for a European groundwater monitoring network design

As agreed by ETC/IW partners at a meeting in December 1997, an expert group under the leadership of the Austrian Working Group on Water (AWW) adapted the technical specifications for EUROWATERNET – groundwater – the draft guidelines for a European groundwater monitoring network – in early 1998.

These draft guidelines were set up with regard to EEA information needs EEA. They are based on already available investigations carried out by the ETC/IW as well as on the experience of participating experts. Furthermore, the spirit of the draft Groundwater Action Programme as well as the current development and discussions on Annex II, III and V of the draft Water Framework Directive were considered.

1.3. Pilot study

The purpose of the second EIONET water workshop in October 1998 was to demonstrate how EUROWATERNET enables the EEA to answer general as well as more specific questions related to the condition of inland water bodies, and to give an overview of status and trends at the European scale. To achieve this objective with regard to groundwater, it is proposed to focus the first phase of implementation of EUROWATERNET – groundwater on the following question:

What is the nitrogen status of groundwater in Europe?

To support this objective a pilot study with the following aims was initiated:

- to test the proposed draft guidelines for a European groundwater monitoring network with readily available data provided by volunteer partners;
- to demonstrate the state of groundwater in selected groundwater bodies with reference to nitrogen and
- to recommend a way forward for extending the technical scope and geographic spread of the network in parallel with developments on surface waters over the next years.

2. Pilot study – requested information

Based on the goals of the workshop in October 1998 and derived from the draft guidelines for a European groundwater monitoring network a questionnaire was prepared and distributed to volunteer partners.

In the questionnaire, information was requested on (at least) three groundwater bodies including a general characterisation of each groundwater body and groundwater quality data (see Annex B).

2.1. General characterisation

In order to make groundwater quality and quantity information comparable it is essential to characterise each groundwater body by its local, geological, hydro(geo)logical and pressure situation. Furthermore, general information on a groundwater body allows for a better understanding of quality data.

In the draft guidelines for a European groundwater monitoring network a general characterisation of all important groundwater bodies is requested. In Annex II of the Water Framework Directive a two-step characterisation of all groundwater bodies is required, which is structured into an initial and a further characterisation.

For the present study only selected parts of the general information required by the draft guidelines for a European groundwater monitoring network as well as by the Framework Water Directive were asked for. The primary aim of the study is to demonstrate that characteristics of groundwater bodies vary widely, to show which data sets are already available and to test which data are available in the short term.

For identifying the location and the boundaries of a groundwater body the following maps were requested: one map of the country indicating the investigated groundwater bodies and one map for each groundwater body indicating the boundaries and sampling sites. If possible, the types of sampling sites should have been indicated in the second map.

2.2. Groundwater quality

One of the main items on the agenda at the workshop in October 1998, was to demonstrate the potential of EUROWATERNET – groundwater to assess 'What is the nitrogen status of groundwater in Europe?'. Therefore, the nitrogen determinands nitrate, nitrite and ammonium as well as dissolved oxygen (to have additional information on the redox-conditions) were selected for this study.

Quality data were to be based on readily available data and be provided as proposed in the draft guidelines for a European groundwater monitoring network.

In order to assure the comparability of data, the main purpose of the sampling sites had to be indicated distinguishing four categories: drinking water well, industrial well, wells with other uses and surveillance.

Quality data for each sampling site were to be aggregated to provide annual mean values. The annual statistics of individual sampling sites within a groundwater body were to be aggregated for the groundwater body as a whole and delivered in accordance with the draft guidelines.

3. Description of the requested information and results

3.1. Database

Experts of twelve countries (Austria, Czech Republic, Denmark, Finland[3], France, Germany, Hungary, the Netherlands, Norway[4], Slovenia, Spain and United Kingdom) delivered information on 34 groundwater bodies. For most of the groundwater bodies the delivery of information did not take longer than five weeks. Nearly all experts submitted information on at least three groundwater bodies.

The following Table 3.1 gives an overview of the groundwater bodies on which general information has been delivered and illustrates the heterogeneity of the different groundwater bodies by some general figures.

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[3] Due to the large number and small size of the groundwater bodies in Finland, appropriate data could not be compiled in the given timeframe. Hence no information concerning Finnish groundwater bodies is included in this study.

[4] Insufficient data were provided.

Table 3.1: General information on groundwater bodies in the pilot study

Code	Name of groundwater body (location)	Area (km²)	Length/ width (km)	Length/ width ratio	Thickness of the gw. body (m)	Depth to gw (unsaturated zone) (m)	Number of sample sites for (NO_3)	Site density (km²/ site)
AT01	Marchfeld (Niederösterreich)	1 030	45/35	1.3	**10**	**3–15**	76	13.6
AT02	Mattigtal (Oberösterreich)	347	35/25	1.4	**18–50**	**4–50**	19	18.3
AT03	Südliches Wiener Becken (Niederösterreich)	1 015	70/30	2.3	**up to 100**	**2–20**	106	9.6
AT04	Tullner Feld (Niederösterreich)	605	50/15	3.3	**45 % 4–8** **50 % > 8**	**60 % < 4** **40 % > 4**	77	7.9
CZ01	Velké Opatovice (Blansko)	26	4.8/8.4	1.8	**130–150**	**6**	1	26.0
CZ02	Ivanèice (Brno-Venkov)	6	3.8/4.0	1.1	**3–6,5**	**0.2–3.5**	5	1.2
CZ03	Vojkovice (Brno-Venkov)	1.25	1.5/1.3	1.2	**5.5–7.5**	**2–3.8**	1	1.3
DE01	Halterner Sande (Nordrhein-Westfalen)	540	30/21	1.4	**100**	**5–8**	22	24.5
DE02	Buntsandstein Odenwald (Baden-Württemberg)	984	80/20	4.0	**100**	**20–25.5**	42	23.4
DK01	Thisted limestone (Northwest Jutland)	400	20/20	1.0	**~100**	**0–5**	16	25.0
DK02	Grindsted sand (Middle Jutland)	380	20/19	1.1	**10–20**	**up to 50**	20	19.0
DK03	Skuldelev sand (Northern Zealand)	78	16/5	3.2	**~100**	**20–30**	18	4.3
ES01	Region de los Arenales - 02.17 (Duero)	7 754	120/80	1.5	**500**	**10**	30	258.5
ES02	Madrid-Talavera - 03.05 (Tagus)	6 300	130/60	2.2	**1 500**		57	110.5
ES03	Plana de Valencia Norte - 08.25 (Jucar)	260	60/35	1.7	**100–150**		11	23.6
FR01	Nappe phréatique de la plaine d'Alsace (Alsace)	3 240	165/27	6.1	**78–220**	**1–15**	720	4.5
FR02	Nappe de la Craie-Colnines de L'Artois (Pas de Calais)		60/20	3.0	**15–30**		16	
FR03	Villafranchien of Vistrenque (Gard) (South of France)	420	40/10	4.0	**6–7**		46	9.1
HU01	Bankfiltered water (Csepel Island – Danube)	257	2 x 47 / 1-2	31.3	**7.5–10**		3	85.7
HU02	Deep groundwater (Nyírség)	3 940	60/50	1.2	**20–60**		197	20.0
HU03	Karstic water (Mecsek and Villányi Mountains)	740	50/20	2.5	**300–2 000**		37	20.0
HU04	Shallow groundwater (Nyírség)	3 940	60/50	1.2	**7.5–10**		3	1 313
NL01	Northern sand area	5 123	110/90	1.2			75	68.3
NL02	Eastern sand area	3 228	80/40	2.0			46	70.2
NL03	Southern sand area	5 452	120/40	3.0			105	51.9
SI01	Celjska Kotlina (Central-Eastern)	125	29/10	2.9	**10–30**	**5.6–12.4**	11	11.4
SI02	Dravsko Polje (Eastern)	327	24/23	1.0	**30–40**	**12.1**	11	29.7
SI03	Ljubljansko Polje (Central)	95	18/8	2.3	**35–100**	**21.6**	9	10.6
UK01	Lincolnshire Chalk (Anglian Region)	1 087	65/20	3.3	**up to 25**	**up to 45**	15	72.4
UK02	Chalk of the Marlborough & Berkshire Downs and Kennet Valley (Thames Region)	1 534	75/35	2.1	**up to 220**		32	47.9
UK03	Lower Greensand (Thames Region)				**up to 80**		13	
UK04	Lincolnshire Limestone (Anglian Region)	2 510	150/20	7.5	**up to 36**		14	179.3
UK05	West Shropshire (Shropshire, England)	450	25/11 (L-shape)	2.3	**20 % < 100,** **35 % 100–500,** **45 % > 500**	**30 % < 15,** **60 % 15–50,** **10 % > 50**	19	23.7
UK06	Sherwood Sandstone Group (North Yorkshire, North East Region)	550	54/28	1.9	**up to 300**	**1–20**		

In general, the quality of answers was very high. Information on the characteristics of the groundwater bodies (location, area, length/width and groundwater horizon) is nearly complete as is information on the geological units and the thickness of the groundwater body.

Information on the type of the overlying strata and the depth to groundwater (unsaturated zone) is not available for all groundwater bodies but it is an important determinand describing the vulnerability of a groundwater body.

Information on hydrology (esp. climate and surface temperature) is only available for half of the groundwater bodies but could give important information on the renewal rate and water balance.

For detailed information on the completeness of information for each groundwater body see Table 3.2.

Time needed to answer the questionnaire

Seven experts provided information on the approximate amount of time spent on answering the questionnaire. The amount of time ranges from 1 to 15 man-days.

Table 3.2: Approximate amount of time for answering the questionnaire (in man-days)

	General information	Quality information	Remarks
AT	3	1	
CZ	5		
DK	1		Every year GEUS receives data from the National Monitoring Network by the 1st of June and data have already been stored in a database
ES	10		
FR	2–3		A large part of the data for the general characterisation of the aquifer is already available from a study established for a river basin management plan. Sorting the data by frequency required a lot of time, which can be reduced through automation
HU	5		
SI	5	10	Data had to be collected at the library and processed into digital form first

Main problems of data collection

Experts have been asked to provide information about the main problems encountered in the data collection for this study. In general, information and data were available in sufficient quantity and serious problems did not arise. In some countries groundwater quality data have to be collected from different institutions (sometimes difficulties due to standardisation problems) and in some cases data are not stored in the required structure. Thus, additional time had to be spent on data selection and preparation for the specific use. The expert from the Czech Republic mentioned payment claims of operators of groundwater sources as a serious problem.

Table 3.3: General characterisation of groundwater bodies – completeness of information (x … information delivered)

	AT 01	AT 02	AT 03	AT 04	CZ 01	CZ 02	CZ 03	DE 01	DE 02	DK01	DK02	DK03	ES 01	ES 02	ES 03	FR 01	FR 02	FR 03	HU 01	HU 02	HU 03	HU 04	NL01	NL02	NL03	SI 01	SI 02	SI 03	UK 01	UK 02	UK 03	UK 04	UK 05	UK 06		Completeness %
Location / region	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		100
Area (km²)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		94
Max. length/width (km)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		97
No. of horizon (top=1st,…)	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x		91
Geology																																				
Geological units	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x		91
Thickness of the groundwater body (m)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x		91
Overlying strata (type) and thickness above the main groundwater body (m)	x	x	x	x	x	x	x	x	x	x	x	x	x			x										x	x	x	x	x	x	x	x	x		68
Hydrology																																				
Diagram of climate (long-term average monthly precipitation and temperature) or data (prec./temp/month)	x	x	x	x	x	x	x		x				x	x	x				x	x	x	x				x	x	x	x	x		x				62
Surface temperature (mean)	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x			x	x	x	x				x	x	x		x						68
Mean annual precipitation (mm) and max. mean monthly precipitation (mm, month)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x				x	x	x	x	x		x				79
Hydrogeology																																				
Aquifer type	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x	x		91
Average hydraulic conductivity of the groundwater body (kf)	x	x	x	x				x	x	x	x	x	x	x	x	x										x	x	x	x	x	x	x	x	x		65
Recharge due to: (e.g. precipitation, surface waters, groundwater, etc.)	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x			85
Mean annual groundwater level amplitude	x	x	x				x	x		x	x	x				x	x					x				x	x	x	x			x	x	x		53
Pressures																																				
Land use (% of agriculture, arable, pasture, forest, urban.)	x			x	x	x	x	x	x	x	x	x	x		x		x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x		79
Water abstractions (yes/no and purpose)	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x			x	x	x		82
Artificial recharge (yes/no and purpose)	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x					x			71
Main infrastructures influencing the groundwater dynamics		x		x	x	x	x		x				x		x	x	x		x	x	x	x					x	x		x	x		x			56
ssociated aquatic ecosystems	x	x			x	x	x						x		x	x			x	x		x				x	x	x	x			x	x	x		53

Locality, criteria for the boundaries and selection of groundwater bodies

The groundwater body is identified by its name, its location in a (administrative) region, its area and its extension characterised by maximum length and maximum width. The vertical position of the groundwater body is given by the hierarchy of the groundwater horizon.

Groundwater bodies situated below other groundwater bodies are better protected and thus information on the hierarchy of the groundwater horizon is important with regard to the comparability of data.

Six experts delivered information on the criteria for the boundaries of a groundwater body. In general the groundwater bodies are based on (hydro)geological units (for Slovenia additionally on the morphological characteristics). In one country groundwater bodies are defined by the catchment area of the groundwater body. One groundwater body can contain several aquifers.

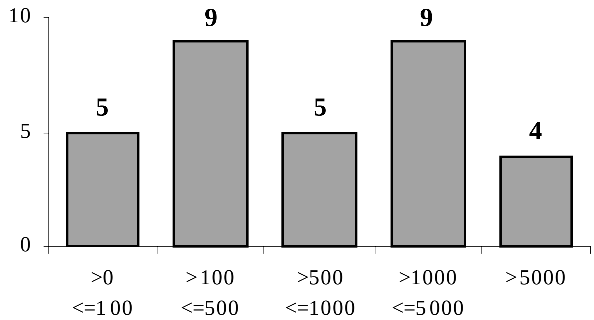
Eight of the 32 groundwater bodies on which information was delivered are ≤ 300 km². The draft guidelines for a European groundwater monitoring network require to provide information on important groundwater bodies which meet one of the following three requirements:

- > 300 km²;
- regional, socio-economic or environmental importance in terms of quantity and quality;
- exposure to severe or major impacts.

As information was received on smaller groundwater bodies (≤ 300 km²), too, they must be of regional importance or be exposed to severe or major impacts. As outlined in Table 3.8 water abstractions take place in nearly all reported groundwater bodies. Hence, it seems to be important that area size is not the only selection criterion. Table 3.4 illustrates the distribution of the groundwater bodies on which information has been submitted in area classes.

Table 3.4: Distribution of the groundwater bodies on which information has been submitted in area classes

Area (km²)	Number of groundwater bodies
> 0 to ≤ 100	5
> 100 to ≤ 300	3
> 300 to ≤ 500	6
> 500 to ≤ 1 000	5
> 1 000 to ≤ 5 000	9
> 5 000	4



Geology

The *geological characteristics* of the groundwater body determine to a high degree the chemical properties of groundwater. They give information on geogenically-induced components of groundwater, vulnerability, renewal rate etc.

Overlying strata may act as a buffering system and influence both moisture transport and characteristics of seepage water.

The *thickness* of the overlying strata determines the passage of seepage water in the aerated zone. Therefore, it also determines possible complex interactions between solid, gaseous and liquid phase. It is also a determining factor of the renewal regime, as even in humid climatic zones at a thickness of less than 1–1.5 m the evaporation rate exceeds the renewal rate (Voigt, 1990).

Table 3.5 gives an overview of the geological information provided for each groundwater body. Two thirds of the reported groundwater bodies are situated in porous media (23 of 31 groundwater bodies), six in fractured rock and one in karst. Most of the countries reported on groundwater bodies which are situated at the top groundwater horizon. The thickness of the groundwater bodies reaches up to 2 000 m and groundwater bodies are situated up to about 50 m below the surface.

Table 3.5: Geological information (? XXX ? … information missing)

Code	Name of groundwater body	Area (km²)	Gw-horizon (top=1st)	Aquifer type	Geological units - Stratigraphy (petrographic description)	Thickness of the ground-water body (m)	Overlying strata (type), soil	Depth to groundwater (m)
AT01	Marchfeld	1 030	1	**porous** media	- Quaternary (gravel and sand)	10 (max: 65)		**3–15**
AT02	Mattigtal	347	1	**porous** media	- Quaternary (gravel and sands)	18–50		**4–50**
AT03	Südliches Wiener Becken	1 015	1	**porous** media	- Quaternary (gravel)	up to 100		**2–20**
AT04	Tullner Feld	605	1	**porous** media	- Quaternary (gravel and sand)	5 % < 4 m, 45 % 4–8 m, 50 % > 8 m		**60 % < 4** **40 % > 4**
CZ01	Velké Opatovice	26	1, 2	**fractured** media	- Cenomanian, Turonian, Middle Turonian (chalk sediments), 3 groundwater bodies	130–150		**6**
CZ02	Ivanèice	6	1	**porous** media	- Upper quaternary Boskovice furrow (gravel-sand deposits and bars of the Jihlava and Rokytná Rivers	3–6.5		**0.2–3.5**
CZ03	Vojkovice	1.25	1	**porous** media	- Quaternary sediments (gravel - sand deposits)	5.5–7.5		**2–3.8**
DE01	Halterner Sande	540	1	**porous** media (solid rock)	- Upper cretaceous (unconsolidated fine grained to coarse grained sands, partly silty) - pore volume 19-40 % (average: 30 %)	100 (max: 300)	Quarternary sediments (mainly till and loess)	**5–8**
DE02	Buntsandstein Odenwald	984	1, 2	solid rock		up to > 100		**20–25.5**

DK01	Thisted limestone	400	1	**fractured** media (water table aquifer with small areas of artesian conditions)	- Cretaceous (chalk), - Danian (limestone), - Quaternary (tills and sand)	~100	Clayey and sandy tills with minor sandbeds	**up to 5**
DK02	Grindsted sand	380	2	**porous** media (Main aquifer: artesian. Sec. aquifer: water table aquifer)	- (Miocene (quartz sand and mica clays), - Quaternary (outwash plain sand and gravel)	Main aquifer: 10–20 m Sec. Aquifer: Upper sand and gravel, up to 50 m.		**up to 50**
DK03	Skuldelev sand	78	2	**fractured** media dominated limestone aquifers, artesian and water table	- Danian (limestone), - Paleocene (glauconitic limestone) - Quaternary (tills and meltwater sand and gravel)	Lower main limestone aquifer: approx. 100 m Upper sec. sand aquifer: 2–3 m.	Quarternary deposits above main limestone aquifer	**20–30**
ES01	Region de los Arenales (02.17)	7 754	2	**porous** media	- Tertiary and Quaternary (detritic)	500	Sands	**10**
ES02	Madrid-Talavera (03.05)	6 300		**porous** media	- Tertiary (detritic)	1 500	Conglomerate, sand, clay	
ES03	Plana de Valencia Norte (08.25)	260	2	**porous** media	- Miocene (detritic)	100–150	Gravel, sand, clay	
FR01	Nappe phréatique de la plaine d'Alsace	3 240	1	**porous** media	- Quaternary (pliocene sands)	78 (max: 220)	Soils and sediments	**1–15**
FR02	Nappe de la Craie-Colnines de L'Artois		1	**porous** media	- Cretaceous (chalk)	15-30		
FR03	Villafranchien of Vistrenque (Gard)	420	1	**porous** media	- Quaternary (sediments)	6–7		
HU01	*? name ?* (Bankfiltered water)	257	top is not rele-vant	**porous** media	- Upper Pannonian (gravel, sand)	7.5–10		
HU02	*? name ?* (Deep groundwater)	3 940	top is not rele-vant	**porous** media	- Upper Pannonian (sediment)	20–60		
HU03	*? name ?* (Karstic water)	740	top is not rele-vant	**karst**	- Upper triassic *? petrographic description?*	300–2 000, changeable		
HU04	*? name ?* (Shallow groundwater)	3 940	1	**porous** media	- Quaternary (sand)	7.5–10		
SI01	Celjska Kotlina	125	1	**porous** media	- *? Stratigraphy ?* (Argil, clay, gravel, marl, carbonatic alluvium - clay, sand)	10–30	SP. Savinjska Dolina (sempeter); Dolina Bolske (Latkova vas)	**5.6–12.4**
SI02	Dravsko Polje	327	1	**porous** media	- Alluvium (gravel, sands, clays)	30–40	Brunsvik	**12.1**
SI03	Ljubljansko Polje	95	1	**porous** media	- Alluvium (gravel and sands)	35–100	Klece	**21.6**
UK01	Lincolnshire Chalk	1 087	1	**fractured** media	- Cretaceous (chalk)	up to 25 at outcrop	Superficial Drift deposits	**up to 45**

UK02	Chalk of the Marlborough & Berkshire Downs and Kennet Valley	1 534		**fractured** media (fissured media)	- Chalk undifferentiated	up to 220	(Part confining) Reading Beds & London Clay	
UK03	Lower Greensand			**porous** media (sandstone intergranular flow)	- *? Stratigraphy ?* (Lower Greensand Hythe & Folkestone Beds, Bargate and Sandgate Beds)	up to 80	Gault clay, chalk, tertiary beds	
UK04	Lincolnshire Limestone	2 510	1	**fractured** media *(?karst?)*	- Jurassic (limestone)	up to 36	Upper estuarine sands and clays	
UK05	West Shropshire	450	1	**porous** media (intergranular with some areas of fissuring	- Triassic (Sherwood Sandstone)	20 % <100, 35 % 100-500, 45 % >500	10 % sand and gravel 70 % boulder clay	**30 % < 15, 60 % 15-50, 10 % > 50**
UK06	Sherwood Sandstone Group	550	1	**porous** media (intergranular flow with significant proportion of fissure flow often fault controlled)	- Permo-Triassic (poorly cemented sandstone with marl bands)	up to 300	Glacial drift of Boulder clay and or sand and gravel with areas of alluvium	**1-20**

Hydrology

Precipitation is a basic causal factor determining the qualitative (chemical) and quantitative balance of seepage water and groundwater.

The spatial and temporal distribution of precipitation, its intensity and quantity can vary widely between different climatic zones. In humid areas a period of accumulation of certain determinands in the soil during dry seasons is followed by an intensive period of leaching in winter and spring.

Additionally, a variable chemical composition of seepage water is to be expected due to the varying availability of substances and a varying evapotranspiration ratio. (Voigt, 1990).

Microbial activity determines the transformation of nitrogen compounds in soil and water. In addition to humidity, evapo(transpi)ration and other factors microbial activity depends on temperature. Under certain circumstances the microbial production of nitrogen in the soil peaks after the harvest of the main crops and without fixing and removing nitrate from the soil by cultivating catch crops it will be leached into the groundwater.

Table 3.6 illustrates the different hydrological conditions of the reported groundwater bodies. The mean annual surface temperatures range between 7.1°C and 17.0°C and mean annual precipitation ranges between 377 mm and 1 394 mm.

Table 3.6: Hydrological characterisation

Code	C[1]	Surface temp.[2]	Mean ann. prec.[3]	Max mean monthly precipitation		Code	C[1]	Surface temp.[2]	Mean ann. prec.[3]	Max mean monthly precipitation	
		(°C)	(mm)	(mm)	(month)			(°C)	(mm)	(mm)	(month)
AT01	H	9.6	480–600	70	VI, VII	FR03					
AT02	H	8.0	850–1 360	115–180	VII	HU01	A	11.7	490	189	VI
AT03	H	9.5	500–650	66–94	VI, VII	HU02	A	10.6	377	79	X
AT04	H	9.2	520–610	77	VI	HU03	A	12.6	693	146	X
CZ01	H	7.1	620	90	VII	HU04	A	10.6	377	79	X
CZ02	H	8.6	500–550	80	VII	NL01					
CZ03	H	9.0	500–550	80	VII	NL02					
DE01	H	9.3	750–800			NL03					
DE02			986	108	XII	SI01	H	9.1	1 146	137	VI
DK01		7.9	750			SI02	H	9.7	1 046	129	VIII
DK02		8.1	825			SI03	H	9.8	1 394	155	VI
DK03		8.3	625			UK01			668	66.5	VIII
ES01	A	11.3	425	50	XI	UK02	H	8.7	540–790	71	XII
ES02	A	14.0	485	60	XII	UK03					
ES03	A	17.0	465	96	X	UK04			629	62.5	VIII
FR01		10.0	650			UK05					
FR02			680–1 000	68–140	XII	UK06					

[1] C…climate (H…humid, A…arid), [2] mean surface temperature, [3] mean annual precipitation

Hydrogeology

Vulnerability of an aquifer, its flow characteristics, dilution characteristics, dynamics and contamination risk are influenced by the aquifer type (porous media, karstic or fractured rock).

The average hydraulic conductivity (k_f) of a groundwater body corresponds to the average velocity of water in the groundwater body and provides information on: yield, potential renewal rate and the short-term variability of the groundwater level respectively on how quick contaminants disperse in the groundwater. The mean annual groundwater level amplitude is the average range between the lowest and highest groundwater level. The main sources of groundwater renewal were requested, to know whether groundwater renewal is mainly due to precipitation, surface waters, groundwater etc. and to get an idea of a possible accumulation or dilution of contaminants in the groundwater body.

The aquifer type of most of the submitted groundwater bodies is porous media. For 21 groundwater bodies the average hydraulic conductivity (and transmissivity) was delivered and ranges between 10^{-2} and 10^{-6} m/s (and 0.25–10 000 m^2/d). The mean annual groundwater level amplitude has a maximum of 30 m (UK06) but is commonly lower than 3.8 m.

Information on the recharge situation was delivered for nearly all (28 of 34) groundwater bodies. The primary source is precipitation, which was mentioned for all groundwater bodies on which information has been delivered. Recharge due to surface water has been reported for 14 groundwater bodies and recharge due to groundwater for nine. Recharge due to irrigation was mentioned for two groundwater bodies.

Table 3.7: Hydrogeological characterisation of the groundwater bodies

GW-body	Aquifer type*	Average hydraulic conductivity; transmissivity (k_f = m/s), (m²/d)	Mean annual groundwater level amplitude (m)	Recharge due to: Precipitation	Surface water	Groundwater	Springs	Irrigation
AT01	P	1–20 10^{-3}	0.3–2	●	●	●	●	
AT02	P	10^{-5}–10^{-2}	1–6	●				
AT03	P	4 10^{-3}	0–7.5	●	●	●		
AT04	P	5–8 10^{-6}		●				
CZ01	F			●				
CZ02	P			●	●			
CZ03	P			●	●			
DE01	P	10^{-5}–10^{-3}	1.2	●		●		
DE02		10^{-6}–5 10^{-5}						
DK01	F	10^{-3}	5	●				
DK02	P	10^{-4}	1	●				
DK03	F	21 10^{-4}	0.5	●				
ES01	P	0.25 m^2/d		●	●			●
ES02	P	15 m^2/d		●				
ES03	P	20 m^2/d		●				●
FR01	P	2.5 10^{-3}	2	●	●			
FR02	P		2–12	●				
FR03	P			●	●	●		
HU01	P			●	●			
HU02	P			●				
HU03	K			●		●		
HU04	P		3.8	●				
NL01								
NL02								
NL03								
SI01	P	5 10^{-3}	1.5–2.2	●	●			
SI02	P	6 10^{-3}	1.8	●	●	●		
SI03	P	1 10^{-2}	3.6	●	●	●		
UK01	F	60–10 000 m²/d 25 % < 1 024 and 75 % < 6 075 m²/d	3	●	●	●		
UK02	F	0.5–8 000 m²/d 25 % < 380 and 75 % < 1 500 m²/d						
UK03	P	150–3 000 m²/d		●	●			
UK04	F	100–10 000 m²/d 25 % < 259 and 75 % < 2 265 m²/d	3	●	●	●		
UK05	P	1.1x10^{-7}–1.8x10^{-4}	0.5 (0.3–1+)	●				
UK06	P	500 m²/d	20–30					

*) P … porous media; F … fractured rock; K … karst

[grey cell] no information

Pressures

It is a main objective of the EEA to describe the pressure and status situation in order to derive cause/effect relationships. Hence, it was attempted to select determinands which can be considered as pressures and for which data is likely to be available in the short-term.

Nitrogen in groundwater originates from diffuse sources as well as from point sources – e.g. from the leaching of agriculturally cultivated and (over) fertilised areas and to a lesser degree from the leaking of septic tanks and leaking sewer systems. This is why the type and the share of different land use activities within the area of a groundwater body can give an idea of the potential contamination risk.

Artificial groundwater recharge can directly import pollutants into the groundwater body whereas changes in the hydraulic regime and the groundwater dynamics due to hydrological engineering, land sealing etc. and heavy water abstractions may indirectly cause groundwater contamination.

Information on water abstractions and associated wetlands indicates the importance of a groundwater body for man and environment.

For each groundwater body information (yes/no) on water abstractions and their purpose, artificial recharge, main infrastructures influencing the groundwater dynamics and associated aquatic ecosystems was as requested. Table 3.8 gives an overview of the pressures in each groundwater body.

Water abstractions were reported for nearly all groundwater bodies, with drinking water supply as the main purpose. Artificial recharge is mentioned for four groundwater bodies but it is not clear if it happens on purpose (e.g. groundwater recharge in AT01) or if it is a side effect of a measure with another primary aim (e.g. flood protection in AT02).

The main infrastructures influencing groundwater dynamics are related to surface waters and have been reported for nine of 19 groundwater bodies. At six groundwater bodies no such pressure is evident.

Information on associated aquatic ecosystems is available for 18 groundwater bodies, 12 of which are connected to such ecosystems.

Table 3.9 gives information on the land use situation which was delivered for 27 groundwater bodies. At 22 groundwater bodies the share of agricultural land use is at least 50 %, at 15 of these groundwater bodies the share exceeds 75 %.

Table 3.8: Pressure situation

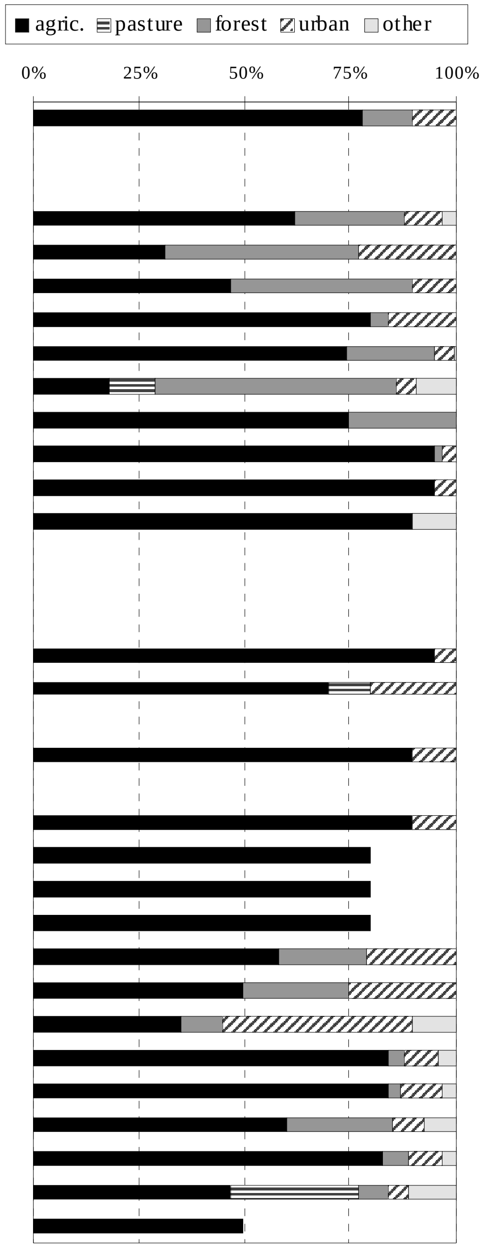
GW-body	Water abstraction: annual figures and purpose	Artificial recharge (yes/no, purpose)	Main infrastructures influencing ground-water dynamics	Associated aquatic ecosystems
AT01	25 mio m^3 irrigation, 12 mio m^3 industry, 1.5-2 mio m^3 drinking water	7.9 mio m^3 ground-water recharge (Marchfeldkanal)	**no**	March-Danube-floodplains (national park), Danube
AT02	16 mio m^3 drinking water and industry	**yes**	**no**	**no**
AT03	28.4 mio m^3 drinking water and irrigation	**no**	**no**	**no**
AT04	52 water abstractions	**no**	2 hydropower plants	Danube-floodplains
CZ01	water supply	**no**	**no**	**no**
CZ02	water supply	**no**	manipulation of the Dalešice Reservoir	**no**
CZ03	water supply	**no**	manipulation of the Brno Reservoir	**no**
DE01				
DE02	public water supply	**no**	water supply, damming of the Neckar	
DK01	irrigation, livestock, households	**no**		
DK02	irrigation, livestock, households	**no**		
DK03	irrigation, livestock, households	**no**		
ES01	210 mio m^3	**no**	**no**	**no**
ES02	100 mio m^3 irrigation; 50 mio m^3 urban and industry	**no**		
ES03	17 mio m^3 urban; 9 mio m^3 agriculture	**no**	**no**	**no**
FR01	agriculture, industry, drinking water	infiltration of surface water	Rhine river, Rhine channel, pumping	Rhine Forest, diffe-rent humid zones
FR02	drinking water, industry	**no**	**no**	
FR03	60 % potable water, 20 % industrial, 20 % agriculture	**yes**		
HU01	water supply	**no**	water supply	water level in the Danube
HU02	irrigation, water supply	**no**	agriculture, arable	water level of rivers
HU03	water supply	**no**	mining	
HU04	irrigation, water supply	**no**	agriculture, arable	water level of rivers and irrigation canals
NL01				
NL02				
NL03				
SI01	drinking water, industry	**no**		Savinja river
SI02	drinking water, industry	**no**	4 hydropower plants derivation channel	Drava river, derivation channel
SI03	drinking water, industry	**no**	2 hydropower plants	Sava river
UK01	144.5 TCMD * public water supply 35.5 industry 10 TCMD private, industry-mineral, cooling, agriculture, irrigation			Rivers (e.g. Waithe Beck), wetlands (e.g. Shacklewell Hollows)
UK02			flow towards River Kennet, parallel with M4	
UK03			Rivers, Mole and Wey	
UK04	130.1 TCMD public water supply 17.8 industry, private, irrigation, agriculture			Rivers (e.g. River Glen), wetlands
UK05	water supply, agriculture, industry, small domestic	**no**	**no**	Rivers Roden, Perry and Severn
UK06	heavy			little

*… TCMD = thousands of cubic metres per day

[grey box] … no information

Table 3.9: Total area of the groundwater body and percentage of land use considered to be agricultural, pasture, forest, urban and other.

		land use in %				
	area (km²)	agric.	pasture	forest	urban	other
AT01	1 030	78		12	10	
AT02	347					
AT03	1 015					
AT04	605	62		26	9	3
CZ01	26	31		46	23	
CZ02	6	47		43	10	
CZ03	1.25	80		4	16	
DE01	540	74		21	4,5	0,5
DE02	984	18	11	57	5	9
DK01	400	75		25		
DK02	380	95		2	3	
DK03	78	95			5	
ES 01	7 754	90				10
ES 02	6 300					
ES 03	260					
FR01	3 240					
FR02		95			5	
FR03	420	70	10		20	
HU01	257					
HU02	3 940	90			10	
HU03	740					
HU04	3 940	90			10	
NL01	5 123	80				
NL02	3 228	80				
NL03	5 452	80				
SI01	125	58		21	21	
SI02	327	50		25	25	
SI03	95	35		10	45	10
UK01	1 087	84		4	8	4
UK02	1 534	84		3	10	3
UK03		60		25	8	7
UK04	2 510	83		6	8	3
UK05	450	47	30	7	5	11
UK06	550	50				



3.2. Quality data

Information on groundwater quality was submitted for 33 groundwater bodies. For quality determinands the requested investigation period was limited to the ten most recent years. Nitrate data for at least 10 years was delivered for only eight groundwater bodies. Hence, it is to be supposed that for most of the groundwater bodies the total monitoring period is identical with the submitted time series (see Table 3.10).

Information on nitrate in groundwater is available for all reported groundwater bodies but for the determinands ammonium, nitrite and dissolved oxygen the database is incomplete. Information is missing for ammonium, nitrate and dissolved oxygen at seven, 10 and 14 groundwater bodies respectively.

Frequency distributions are available for all determinands on which information has been submitted. Information on the type of sampling sites, summary frequency and monitoring frequency is incomplete, probably due to the short time limit of the request.

Table 3.10: Information on delivered quality data

GW-body Code	latest year for NO3	Ammonium (years)	Nitrite (years)	Nitrate (years)	Dissolved oxygen (years)	Type of samp-ling sites	Monit oring frequ ency	Sum mary frequ ency	Frequ ency distrib ution
AT01	1997	6	6	6	6	■	■	■	■
AT02	1997	6	6	6	6	■	■	■	■
AT03	1997	6	6	6	6	■	■	■	■
AT04	1997	6	6	6	6	■	■	■	■
CZ01	1997	4	4	4	4	■	■		■
CZ02	1997	8	5	8	–	■	■		■
CZ03	1995	6	6	6	2	■	■		■
DE01	1997	10	10	10	10	■	■	■	■
DE02	1997	10	10	10	10	■		■	■
DK01	1996	7	7	7	6	■	■	■	■
DK02	1996	17	8	17	8	■	■	■	■
DK03	1996	8	8	8	7	■	■	■	■
ES01	1995	–	–	5	–	■	■		■
ES02	1995	–	–	5	–	■	■		■
ES03	1995	–	–	4	–	■	■		■
FR01	1997	15	15	15	1	■	■	■	■
FR02	1996	9	9	9	5	■	■	■	■
FR03	1997	6	6	6	6	■	■	■	■
HU01	1992	–	–	1	–	■			■
HU02	1992	–	–	1	–	■			■
HU03	1992	–	–	1	–	■			■
HU04	1992	–	–	1	–	■			■
NL01	1997	10	–	10	–	■		■	■
NL02	1997	9	–	10	–	■		■	■
NL03	1997	10	–	10	–	■		■	■
SI01	1997	6	6	6	6	■	■	■	■
SI02	1997	6	6	6	6	■	■	■	■
SI03	1997	6	6	6	6	■	■	■	■
UK01	1998	12	3	12	–			■	■
UK02	1998	10	10	9	–			■	■
UK03	1998	9	9	8	5			■	■
UK04	1996	12	10	6	8			■	■
UK05	1998	3	4	4	–			■	■
UK06	no quality information delivered								

■ Information delivered

Characteristics of sampling sites

It is important to recognise that the different types of sampling sites provide different status information. The intended supply purpose of a well (with its different quality demands) determines the choice of an aquifer and the location of a well (EEA, 1998). A monitoring network dominated by a specific type of sampling site could provide results which are not representative for the region (e.g. drinking water wells are generally located in areas where groundwater quality is high) (Annex A).

The monitoring network should be based on a balanced spatial distribution as well as a balanced mixture of different types of sampling sites in order to provide representative information on the average quality of a groundwater body (Annex A). Therefore, in the pilot study the main purpose of the sampling sites had to be indicated by one of the four categories: drinking water well, industrial well, wells with other uses and surveillance.

Sampling site density

The optimum density of observed sampling sites depends primarily on the size of the groundwater body, the geological and hydro(geo)logical characteristics and the complexity of the aquifer as well as the intensity of impacts. Site density is an important figure when comparing aggregated results of different groundwater bodies.

Sampling site density is calculated in km²/site and shown in Table 3.1 and Figure 3.1 for each groundwater body with reference to nitrate and the latest year of investigation. At 19 groundwater bodies sampling site density is below 25 km²/site (see Table 3.11). Figure 3.1 shows the relationship between the size of the groundwater bodies and the site density (which is proportional to the area of the circle). Most of the groundwater bodies fall into the area class 100–1 000 km². Within this area class the sampling site density is lower than 30 km²/site except for HU01.

Table 3.11: Distribution of sampling site density (with regard to nitrate)

Sampling site density (km²/site)	Number of groundwater bodies
> 0 to ≤ 25	19
> 25 to ≤ 100	8
> 100 to ≤ 500	3
> 500 to ≤ 1 000	0
> 1 000	1

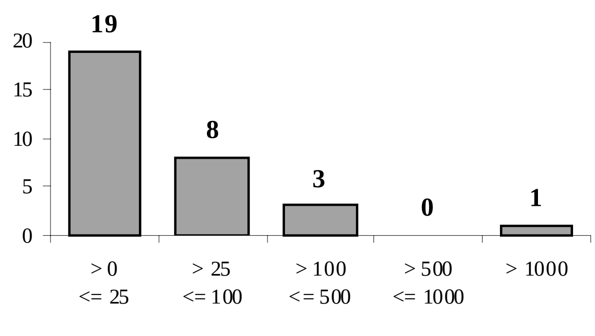
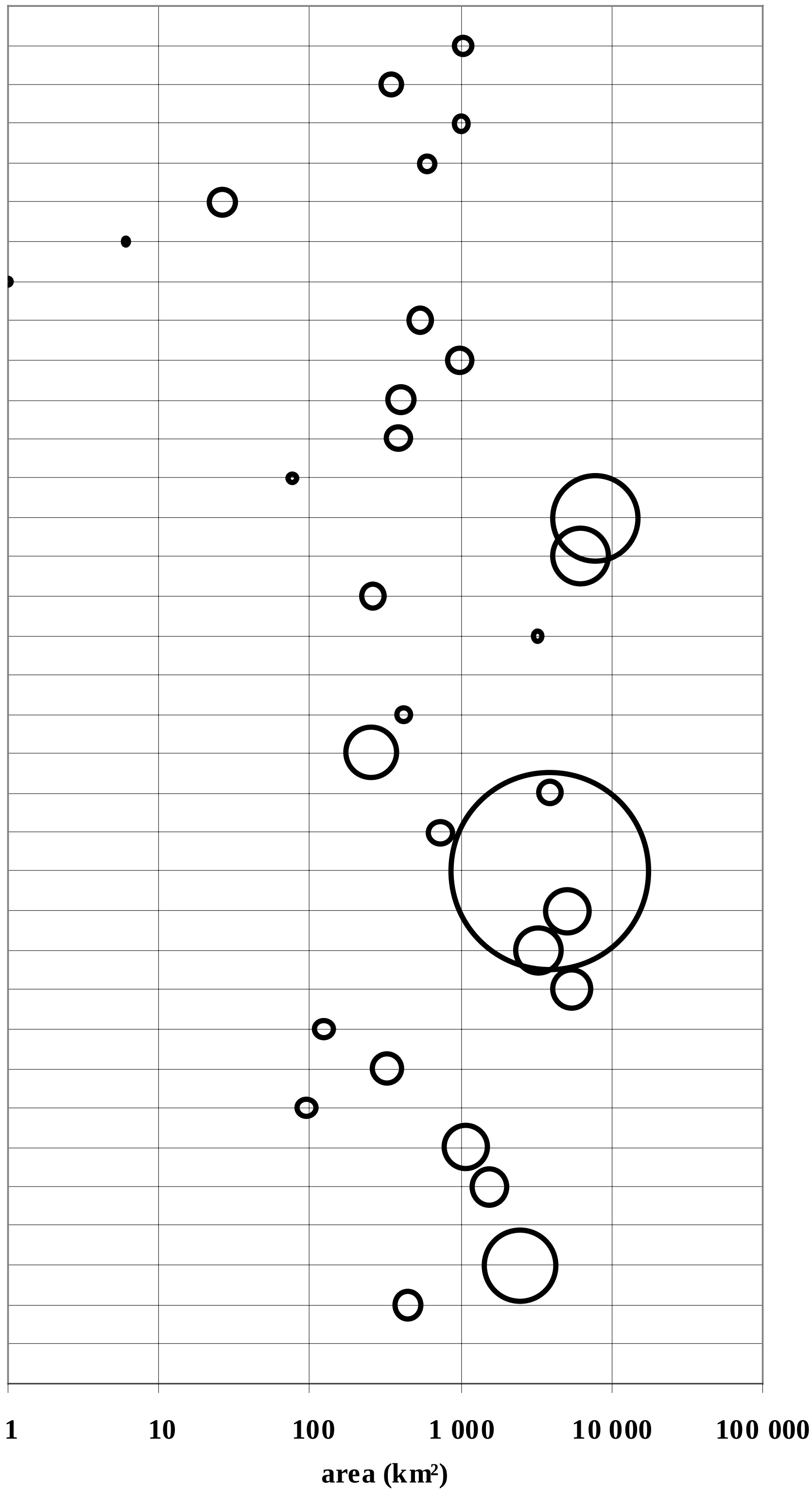


Figure 3.1: Area and site density (as circles) with reference to nitrate

Code	Area (km²)	Site density (km²/site)
AT01	1 030	13.6
AT02	347	18.3
AT03	1 015	9.6
AT04	605	7.9
CZ01	26	26.0
CZ02	6	1.2
CZ03	1	1.3
DE01	540	23.5
DE02	984	23.4
DK01	400	25.0
DK02	380	19.0
DK03	78	4.3
ES01	7 754	258.5
ES02	6 300	3.0
ES03	260	23.6
FR01	3 240	4.5
FR02		
FR03	420	9.1
HU01	257	85.7
HU02	3 940	20.0
HU03	740	20.0
HU04	3 940	1 313.3
NL01	5 123	68.3
NL02	3 228	70.2
NL03	5 452	51.9
SI01	125	11.4
SI02	327	29.7
SI03	95	10.6
UK01	1 086	72.4
UK02	1 534	47.9
UK03		
UK04	2 510	179.3
UK05	450	23.7
UK06	550	



Spatial distribution of sampling sites

The spatial distribution of sampling sites at a groundwater body gives an impression of how representative data are with regard to the whole groundwater body. Table 3.12 gives an overview of the availability of country maps and maps of the groundwater bodies. Austria, Czech Republic, France, Germany, Hungary, the Netherlands, Slovenia and United Kingdom provided maps which indicate the location of sampling sites showing that sampling sites are more or less evenly distributed within the respective groundwater bodies. For FR02 the type of sampling sites is given in addition to the location of the sampling sites, in the map of the Hungarian groundwater bodies additional information on groundwater quality (nitrate) is indicated.

Table 3.12: Information on the delivery of maps

Maps of	AT	CZ	DE	DK	ES	FR	HU	NL	SI	UK
Country	✔	✘	✔	✘	✔	✔	✔	✔	✔	✔
Groundwater body	**4** of 4	**2** of 3	**1** of 2	✘	✘	**2** of 3	**4** of 4	**3** of 3	**3** of 3	**6** of 6

✔…delivered, ✘…not delivered

Requested and presented statistics

For each year and determinand the number of sampling sites assigned to the proposed types of wells was requested and is presented by percentages in bar charts in figures 3.2, 3.4, 3.7, 3.8, 3.11 and 3.13.

For each year and determinand the number of sampling sites and sampling frequency was requested and is presented in a table (only for nitrate).

In order to present summary frequencies of each year and determinand data had to be aggregated for each groundwater body. The requested information comprised the reference year, number of sampling sites, mean value, minimum, maximum and percentiles (10, 20, 25, 30, 40, 50, 60, 70, 75, 80 and 90 %). Summary frequencies are presented in figures (only for nitrate).

The temporal development of quartiles, median and mean value (for nitrate only) over the investigation period is presented in figures. But it has to be born in mind that this type of analysis should be carried out from a consistent database (consistent number of sampling sites).

In order to present frequency distributions for each year and determinand, data had to be aggregated for each groundwater body. Then sampling sites were classified according to their annual mean values using given ranges for each determinand. Summary frequencies are presented in bar charts

Monitoring frequency

The monitoring frequency should take into account seasonal variations and aquifer characteristics and the sampling schedule should be adapted to the infiltration or recharge regime of the groundwater body and to seasonal variations in the use of substances causing groundwater pollution (Annex A).

Monitoring frequency with reference to nitrate and the most recent year varies between once a year to twelve times per year. The average weighted sampling frequency lies between 1.0 and 4.0 times per year – with exception of FR03 (see Table 3.13). For ten groundwater bodies information on monitoring frequency is not available. Considering the whole database with reference to nitrate the average weighted sampling frequency is 2.5 times per year.

Table 3.13: Monitoring frequency per year for the latest year available (for nitrate as an example)

Code	Year	Sites	ASF	Number of sites and sampling frequency per year				
				1	2	3	4	12
AT01	1997	**76**	4.0			76		
AT02	1997	**19**	2.0		19			
AT03	1997	**106**	4.0			106		
AT04	1997	**77**	4.0			77		
CZ01	1997	**1**	1.0	1				
CZ02	1997	**5**	1.0	5				
CZ03	1995	**1**	2.0		1			
DE01	1997	**22**	2.0	1	20	1		
DE02	1997	**42**	-					
DK01	1996	**16**	2.0	3	11	1	1	
DK02	1996	**20**	3.5		5		15	
DK03	1996	**18**	2.7	1	10		7	
ES01	1995	**30**	2.0		30			
ES02	1995	**57**	2.0		57			
ES03	1995	**11**	2.0		11			
FR01	1997	**720**	1.0	720				
FR02	1996	**16**	1.1	15	1			
FR03	1997	**46**	12.0					46
HU01	1992	**3**	-					
HU02	1992	**197**	-					
HU03	1992	**37**	-					
HU04	1992	**3**	-					
NL01	1997	**75**	-					
NL02	1997	**46**	-					
NL03	1997	**105**	-					
SI01	1997	**11**	2.0		11			
SI02	1997	**11**	2.0		11			
SI03	1997	**9**	1.0	9				
UK01	1998	**15**	-					
UK02	1998	**32**	-					
UK03	1998	**13**	-					
UK04	1996	**4**	-					
UK05	1998	**19**	-					

ASF … Average Sampling Frequency (weighted)

Determinands

As already mentioned, the scope of the pilot study is limited to nitrogen in groundwater and therefore the determinands ammonium, nitrite, nitrate and dissolved oxygen are investigated.

The main part of nitrogen occurs in the atmosphere as nitrogen gas (N_2). In the soil a main part is nitrogen gas and the inorganic ions ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) as well as organically bound nitrogen in the soil humus. (Fresenius and Schneider, 1994). The relative concentrations of each compound depend on redox conditions, pH and the presence and activity of denitrifying bacteria.

Nitrogen compounds are transformed by biological processes. In the presence of oxygen organically fixed nitrogen is transformed via amino acids, ammonium and nitrite into nitrate. Some organisms reduce nitrate into elementary nitrogen or into ammonium (Mathess, 1990).

Ammonium

Unimpacted groundwater is nearly free of ammonium. The ammonium content of precipitation ranges between 0.001 and 1 mg/l (commonly around 0.1 and 0.2 mg/l) (Mathess, 1990).

Ammonium ions may occur naturally in so-called reduced groundwaters but they may also be an indicator of anthropogenic influences. Whether their presence is 'natural' and harmless or secondary can only be assessed if a number of factors (e.g. geological conditions, redox potential, iron ions) are taken into account (Fresenius and Schneider, 1994).

The limits of the concentration classes were set at 0.1, 0.3 and 0.5 mg NH_4/l. These limits were selected because a maximum admissible concentration (MAC) of 0.5 mg/l for water intended for human consumption is specified in the Drinking Water Directive (80/778/EEC).

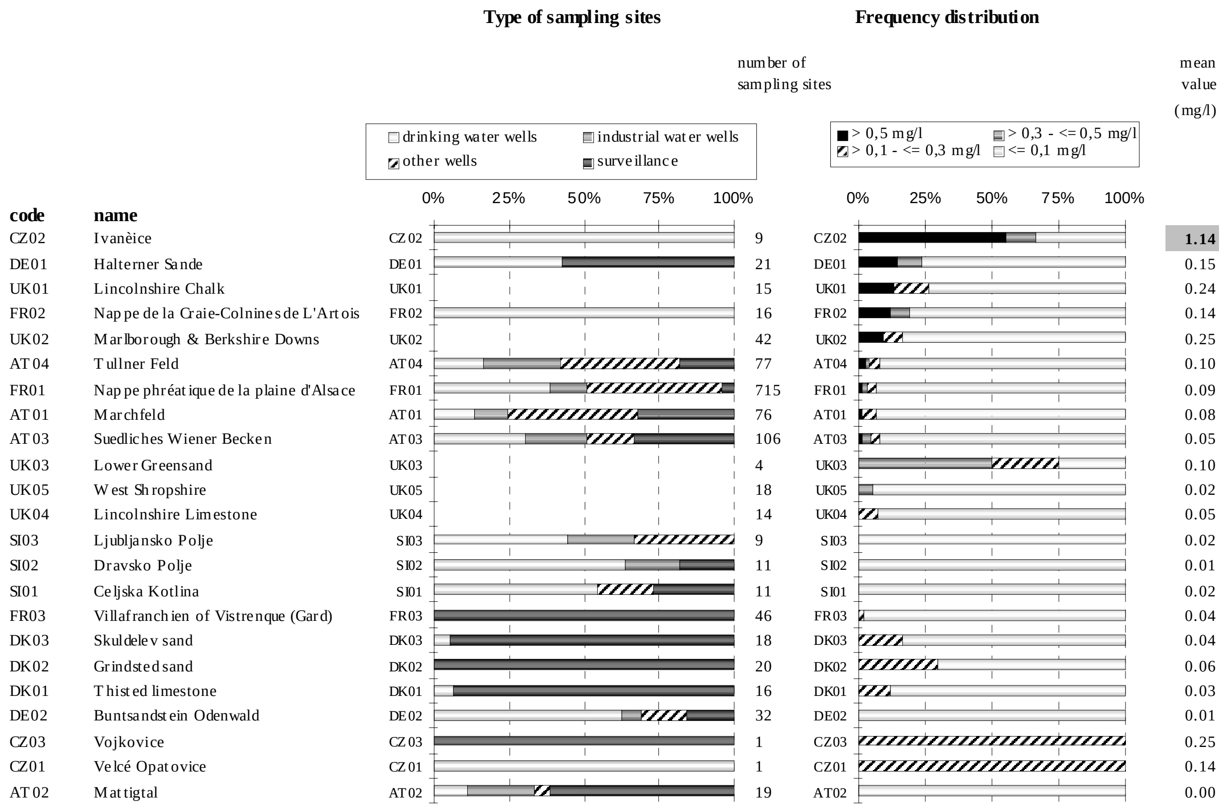
Information on ammonium was provided for 23 groundwater bodies. The number of sampling sites varies between 1 and 715.

In nine groundwater bodies the limit value of 0.5 mg/l is exceeded at at least one sampling site and in one groundwater body the level of 0.5 mg/l is exceeded at more than 50 % of sampling sites. In the latter groundwater body the mean value exceeds the limit value of 0.5 mg/l. In CZ02 and FR02 sampling sites with ammonium problems are located at drinking water wells.

Figure 3.2 illustrates the number of sampling sites and their distribution according to type as well as the mean value and the frequency distribution of ammonium in groundwater. The distribution in the upper figure is ranked by the percentage of wells showing ammonium values > 0.5 mg/l, the bottom figure is ranked by the percentage of drinking water wells.

Figure 3.3 shows the temporal development of the quartiles and the median of annual average ammonium concentration for each groundwater body. A downward trend over the investigation period can only be seen in FR03.

Figure 3.2: Ammonium – number and type of sampling sites, frequency distribution and mean values (bold type: mean values exceeding limit value)



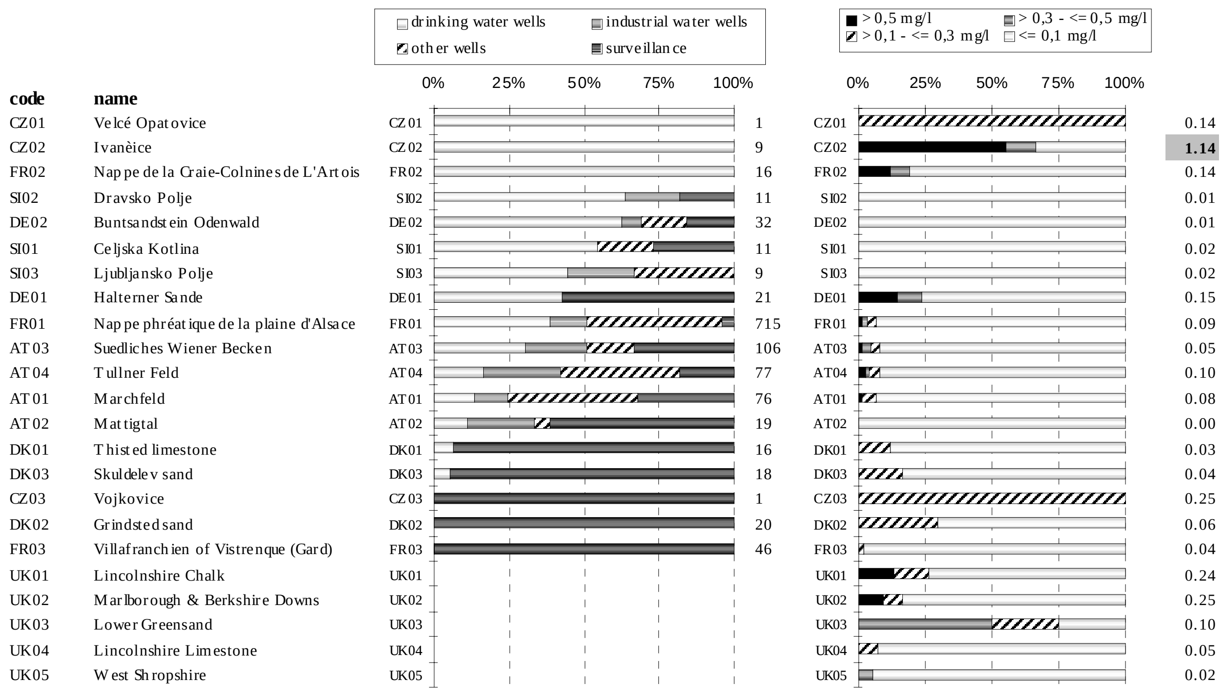
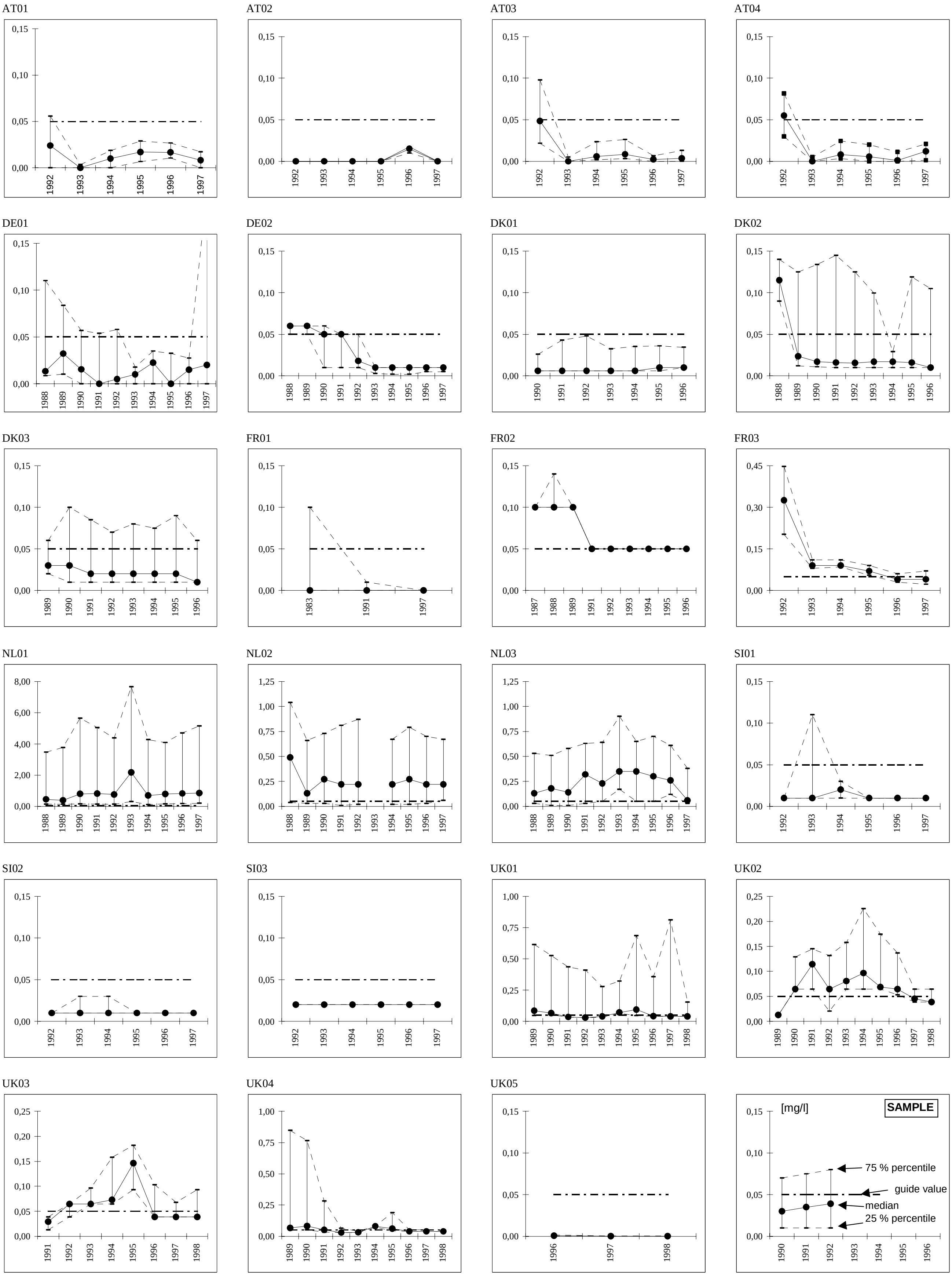


Figure 3.3: Ammonium (in mg/l) – Annual time series



guide level according to 80/778/EEC

Nitrite

Nitrite does not usually occur in anthropogenically unimpacted groundwaters. A concentration of 0.01 mg/l is usually not exceeded. Low concentrations can appear in reduced groundwaters where nitrite is not being oxidised into nitrate.

The main cause for increased nitrite values is faecal contamination. Together with ammonium, nitrite is a very important indicator for such contamination. In contaminated groundwater nitrite values range between 0.1 and 2.0 mg/l and commonly the values of nitrate, ammonium and organic substances are increased as well. Another reason for nitrite in groundwater is a low oxygen concentration which limits oxidation processes.

The limits of the concentration classes were set at 0.01, 0.03, 0.06 and 0.1 mg NO_2/l. These limits were selected because the natural content of groundwater is up to 0.01 mg/l and because a maximum admissible concentration (MAC) of 0.1 mg/l is specified in the Drinking Water Directive (80/778/EEC).

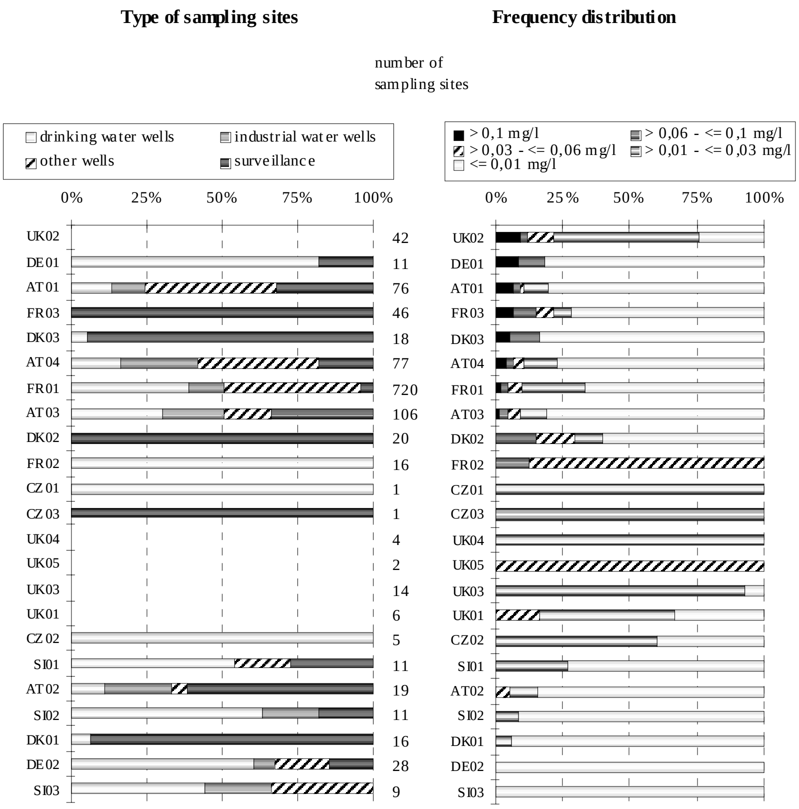
Information on nitrite was provided for 23 groundwater bodies. The number of sampling sites per groundwater body varies between 1 and 720.

In seven groundwater bodies the MAC is exceeded at less than 10 % of sampling sites. In two groundwater bodies (AT01 and FR03) the mean value exceeds the MAC.

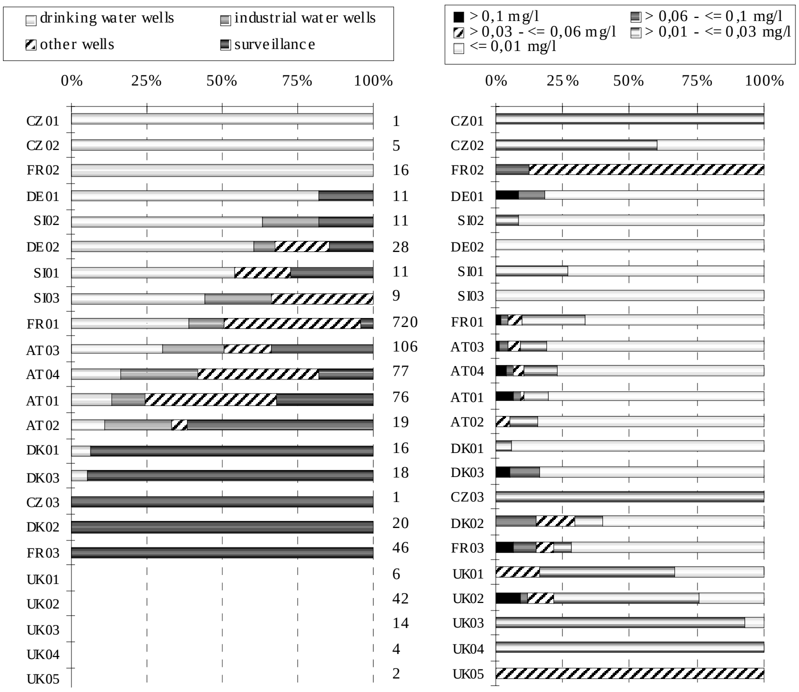
Figure 3.4 illustrates the number of sampling sites and their distribution according to type as well as the mean value and the frequency distribution of nitrite in groundwater. The distribution in the upper figure is ranked by the percentage of wells showing nitrite values > 0.1 mg/l, the bottom figure is ranked by the percentage of drinking water wells.

Figure 3.5 shows the temporal development of the quartiles and the median of annual average nitrite concentration for each groundwater body. A reduction of nitrite concentrations over the investigation period can only be seen at DE02.

Figure 3.4: Nitrite – number and type of sampling sites, frequency distribution and mean values (in mg/l) (bold type: mean values exceeding limit value)

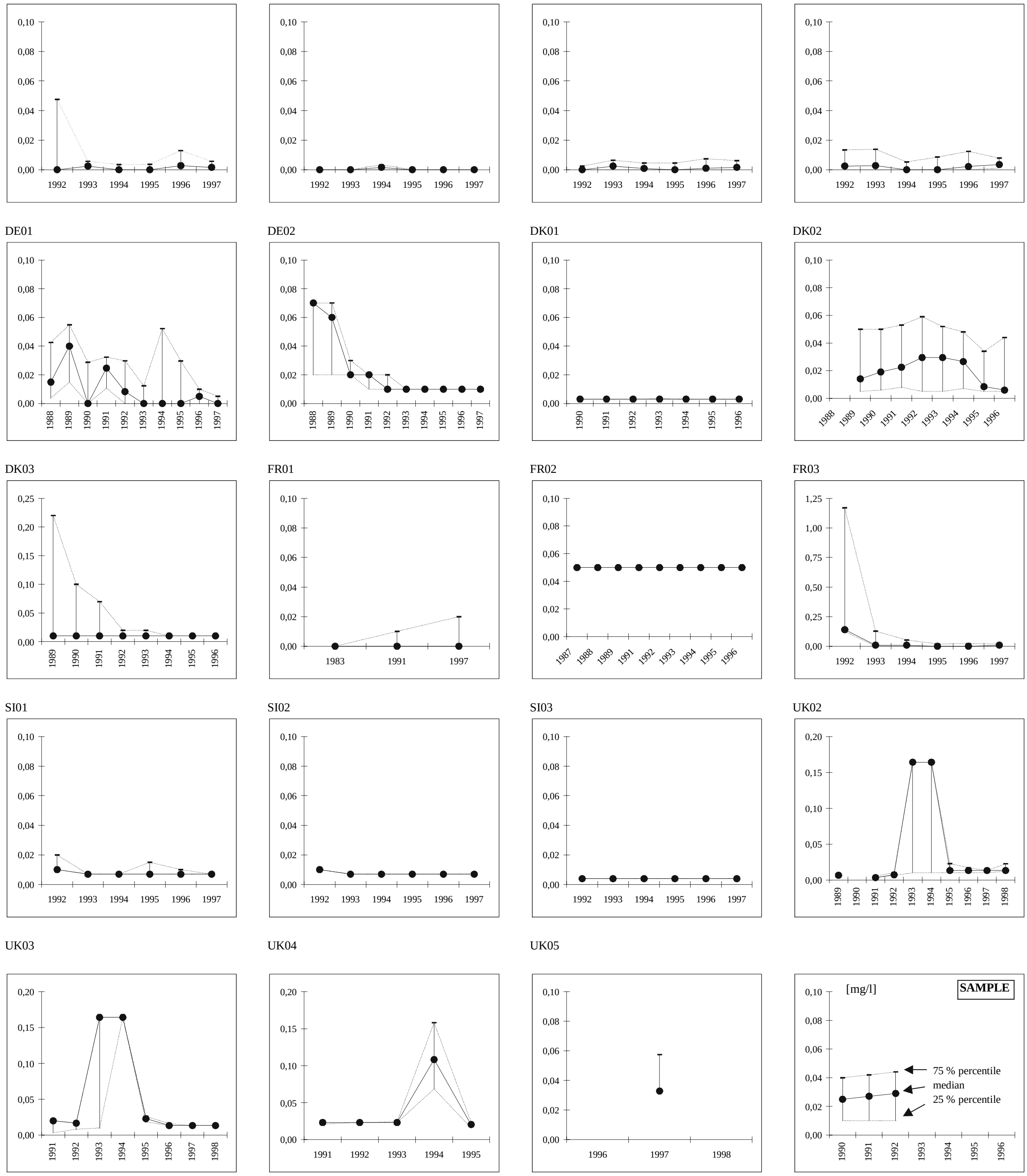


code	name	number of sampling sites	mean value
UK02	Marlborough & Berkshire Downs	42	0.03
DE01	Halterner Sande	11	0.03
AT01	Marchfeld	76	**0.28**
FR03	Villafranchien of Vistrenque (Gard)	46	**0.11**
DK03	Skuldelev sand	18	0.04
AT04	Tullner Feld	77	0.02
FR01	Nappe phréatique de la plaine d'Alsace	720	0.02
AT03	Suedliches Wiener Becken	106	0.01
DK02	Grindsted sand	20	0.02
FR02	Nappe de la Craie-Colnines de L'Artois	16	0.06
CZ01	Velcé Opatovice	1	0.01
CZ03	Vojkovice	1	0.03
UK04	Lincolnshire Limestone	4	0.01
UK05	West Shropshire	2	0.03
UK03	Lower Greensand	14	0.01
UK01	Lincolnshire Chalk	6	0.01
CZ02	Ivanèice	5	0.01
SI01	Celjska Kotlina	11	0.01
AT02	Mattigtal	19	0.01
SI02	Dravsko Polje	11	0.01
DK01	Thisted limestone	16	0.01
DE02	Buntsandstein Odenwald	28	0.01
SI03	Ljubljansko Polje	9	0.00



code	name	number of sampling sites	mean value
CZ01	Velcé Opatovice	1	0.01
CZ02	Ivanèice	5	0.01
FR02	Nappe de la Craie-Colnines de L'Artois	16	0.06
DE01	Halterner Sande	11	0.03
SI02	Dravsko Polje	11	0.01
DE02	Buntsandstein Odenwald	28	0.01
SI01	Celjska Kotlina	11	0.01
SI03	Ljubljansko Polje	9	0.00
FR01	Nappe phréatique de la plaine d'Alsace	720	0.02
AT03	Suedliches Wiener Becken	106	0.01
AT04	Tullner Feld	77	0.02
AT01	Marchfeld	76	**0.28**
AT02	Mattigtal	19	0.01
DK01	Thisted limestone	16	0.01
DK03	Skuldelev sand	18	0.04
CZ03	Vojkovice	1	0.03
DK02	Grindsted sand	20	0.02
FR03	Villafranchien of Vistrenque (Gard)	46	**0.11**
UK01	Lincolnshire Chalk	6	0.01
UK02	Marlborough & Berkshire Downs	42	0.03
UK03	Lower Greensand	14	0.01
UK04	Lincolnshire Limestone	4	0.01
UK05	West Shropshire	2	0.03

Figure 3.5: Nitrite (in mg/l) – Time series



Nitrate

Natural nitrate levels in groundwater are generally very low (typically less than 10 mg/l NO_3). Elevated nitrate levels are caused by human activities, such as agriculture, industry, domestic effluents and emissions from combustion engines.

The limits of the concentration classes were set at 10, 25 and 50 mg NO_3/l. These limits were selected because the natural content of groundwater is up to 10 mg/l and because a guide level (GL) of 25 mg/l and a maximum admissible concentration (MAC) of 50 mg/l are specified in the Drinking Water Directive (80/778/EEC).

Information on nitrate was reported for 33 groundwater bodies. For UK01 data refer to total oxidised nitrogen. The number of sampling sites per groundwater body varies between 1 and 720.

In 24 groundwater bodies the mean value of at least one sampling site exceeds the MAC. In eleven groundwater bodies more than 25 % of the sampling sites show nitrate values higher than the MAC and in four of these groundwater bodies the MAC is exceeded at more than 50 % of the sampling sites (even up to 75 %). In six groundwater bodies (AT01, SI01, SI02, FR03, NL03 and UK04) the mean values for the whole groundwater body exceed the MAC. In seven groundwater bodies all sampling sites are drinking water wells and the nitrate concentrations are comparatively low. Due to the type of sampling site, information on the actual contamination situation in these groundwater bodies is probably not representative.

Correlation between mean values and the frequency class > 50 mg/l for the whole data set on nitrate is shown in Figure 3.6. The upper figure includes information for all years delivered. The bottom figure illustrates data of the latest year available. Correlation coefficients of nitrate mean values and the frequency class > 50 mg/l are very similar for the whole data set and data of the latest year available. The correlation coefficient of nitrate for both the whole data set and the latest year available is 0.90.

Figure 3.6 shows that for groundwater bodies in which more than 25 percent of sampling sites exceed the MAC the mean value for the whole groundwater body is at least 30 to 40 mg NO_3/l or even higher. If the mean value exceeds the limit value, more than 40 % of sampling sites exceed the limit value.

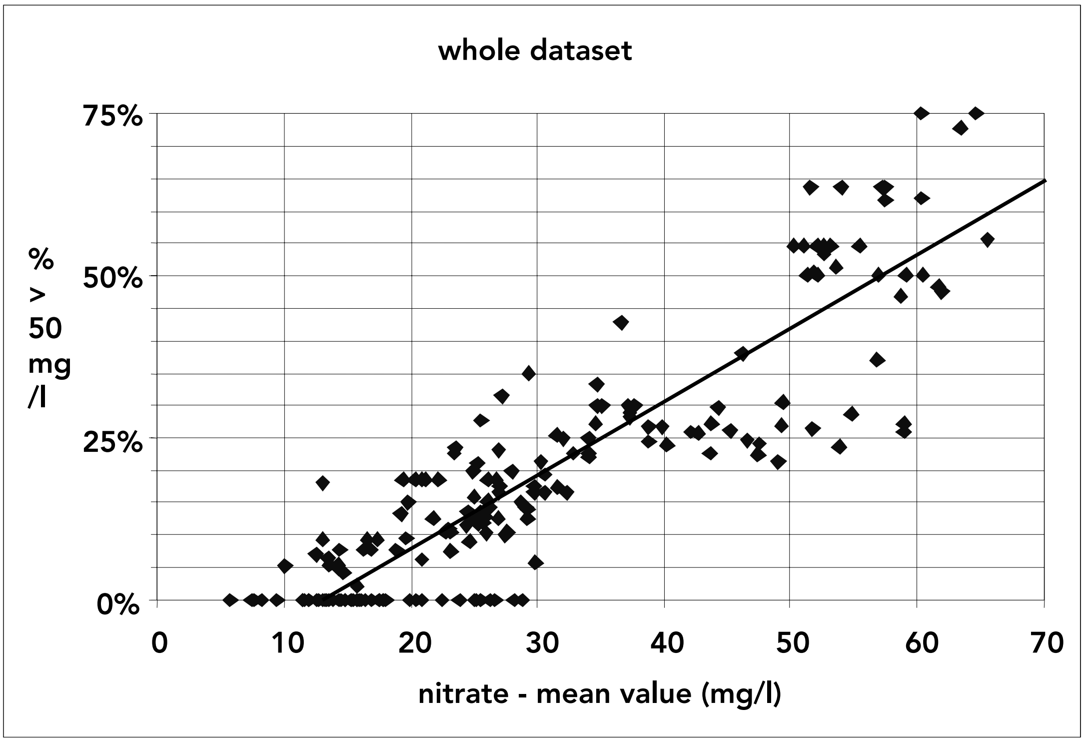
If more than 25 % of sampling sites exceed the limit value in certain sub-areas of a groundwater body serious nitrate problems might exist. Therefore, it should be investigated whether such problem sub-areas exist.

Figure 3.7 and Figure 3.8 illustrate the number of sampling sites and their distribution according to type as well as the mean value and the frequency distribution of nitrate in groundwater. The distribution in Figure 3.7 is ranked by the percentage of wells with nitrate values > 50 mg/l, the distribution in Figure 3.9 is ranked by the percentage of drinking water wells.

Figure 3.9 shows the temporal development of the quartiles and the median of annual average nitrate concentration for each groundwater body. Additionally the mean value is added as a bold dotted line. Except for SI01, SI02, UK02 and UK04, mean values are higher than medians. There seems to be a slight upward trend over the investigation period at AT01, AT04, DK03 and UK02 with regard to mean values. At SI01 there seems to be a slight downward trend.

Figure 3.10 illustrates the cumulative (summary) frequency of nitrate by the quartiles for each groundwater body and for all years delivered.

Figure 3.6: Correlation between nitrate mean values and the frequency class > 50 mg/l. Upper figure: data for all years delivered. Bottom figure: data for the latest year available



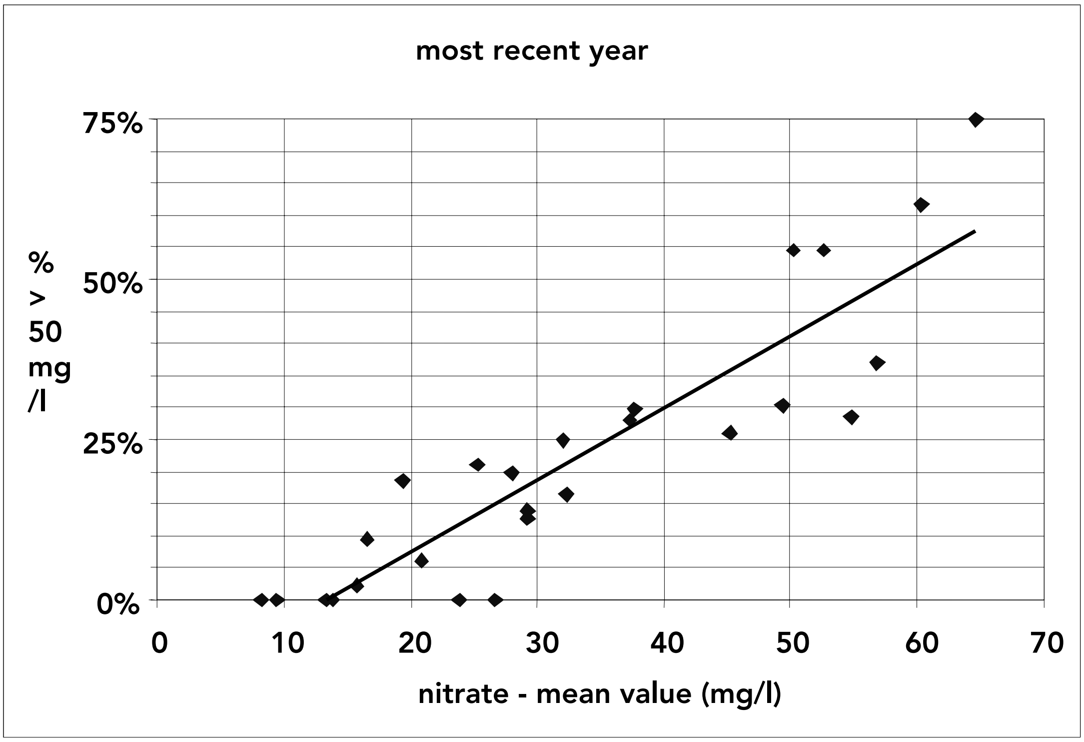
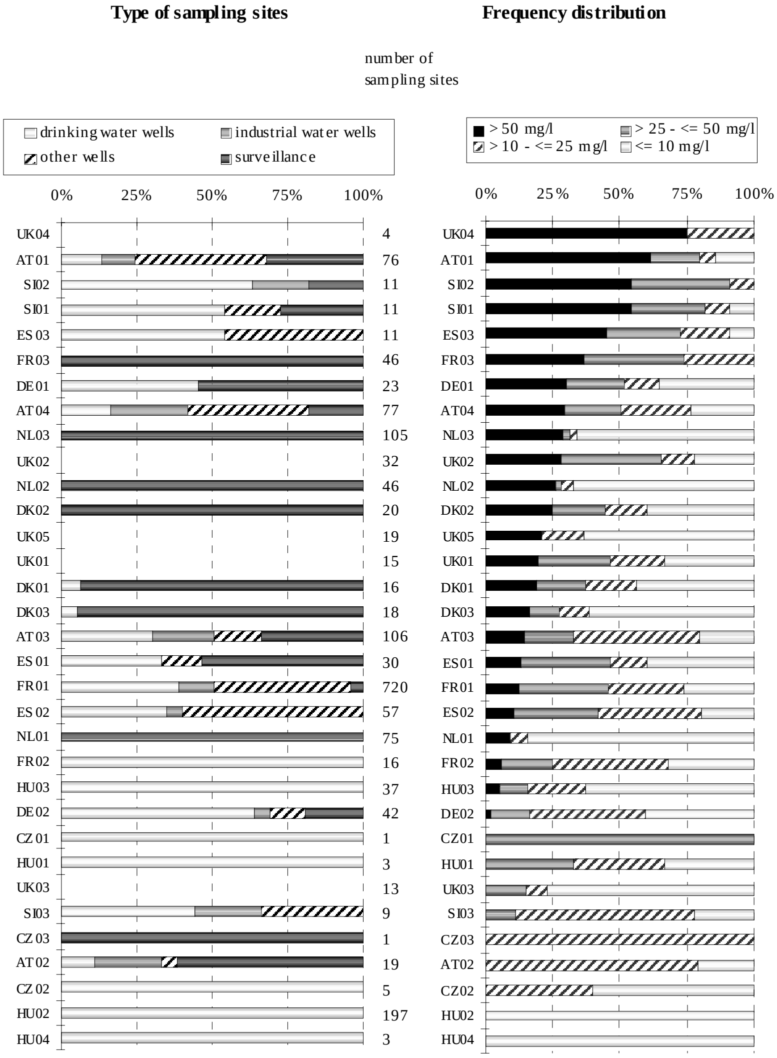
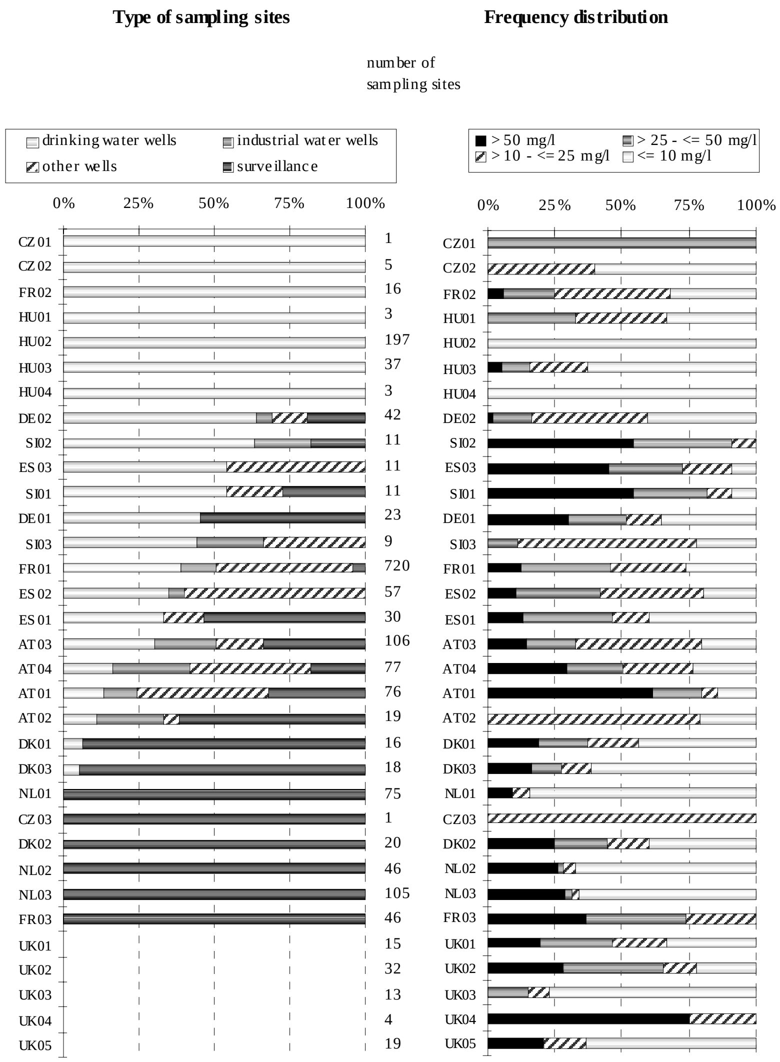


Figure 3.7: Nitrate – number and type of sampling sites, frequency distribution and mean values (bold type: mean values exceeding limit value)



code	name	number of sampling sites	mean value (mg/l)
UK04	Lincolnshire Limestone	4	**64.6**
AT01	Marchfeld	76	**60.4**
SI02	Dravsko Polje	11	**52.7**
SI01	Celjska Kotlina	11	**50.2**
ES03	Plana de Valencia Norte (08.25)	11	
FR03	Villafranchien of Vistrenque (Gard)	46	**56.8**
DE01	Halterner Sande	23	49.4
AT04	Tullner Feld	77	37.7
NL03	Southern sand area	105	**54.7**
UK02	Marlborough & Berkshire Downs	32	37.3
NL02	Eastern sand area	46	45.2
DK02	Grindsted sand	20	32.1
UK05	West Shropshire	19	25.3
UK01	Lincolnshire Chalk	15	28.0
DK01	Thisted limestone	16	19.4
DK03	Skuldelev sand	18	32.3
AT03	Suedliches Wiener Becken	106	29.2
ES01	Region de los Arenales (02.17)	30	
FR01	Nappe phréatique de la plaine d'Alsace	720	29.2
ES02	Madrid-Talavera (03.05)	57	
NL01	Northern sand area	75	16.7
FR02	Nappe de la Craie-Colnines de L'Artois	16	20.9
HU03	karstic water	37	
DE02	Buntsandstein Odenwald	42	15.8
CZ01	Velcé Opatovice	1	26.7
HU01	bankfiltered water	3	
UK03	Lower Greensand	13	8.2
SI03	Ljubljansko Polje	9	13.3
CZ03	Vojkovice	1	23.8
AT02	Mattigtal	19	13.8
CZ02	Ivanèice	5	9.5
HU02	deep groundwater	197	
HU04	shallow groundwater	3	

Figure 3.8: Nitrate – number and type of sampling sites, frequency distribution and mean values (bold type: mean values exceeding limit value)



code	name	number of sampling sites	mean value (mg/l)
CZ01	Velcé Opatovice	1	26.7
CZ02	Ivanèice	5	9.5
FR02	Nappe de la Craie-Colnines de L'Artois	16	20.9
HU01	bankfiltered water	3	
HU02	deep groundwater	197	
HU03	karstic water	37	
HU04	shallow groundwater	3	
DE02	Buntsandstein Odenwald	42	15.8
SI02	Dravsko Polje	11	**52.7**
ES03	Plana de Valencia Norte (08.25)	11	
SI01	Celjska Kotlina	11	**50.2**
DE01	Halterner Sande	23	49.4
SI03	Ljubljansko Polje	9	13.3
FR01	Nappe phréatique de la plaine d'Alsace	720	29.2
ES02	Madrid-Talavera (03.05)	57	
ES01	Region de los Arenales (02.17)	30	
AT03	Suedliches Wiener Becken	106	29.2
AT04	Tullner Feld	77	37.7
AT01	Marchfeld	76	**60.4**
AT02	Mattigtal	19	13.8
DK01	Thisted limestone	16	19.4
DK03	Skuldelev sand	18	32.3
NL01	Northern sand area	75	16.7
CZ03	Vojkovice	1	23.8
DK02	Grindsted sand	20	32.1
NL02	Eastern sand area	46	45.2
NL03	Southern sand area	105	**54.7**
FR03	Villafranchien of Vistrenque (Gard)	46	**56.8**
UK01	Lincolnshire Chalk	15	28.0
UK02	Marlborough & Berkshire Downs	32	37.3
UK03	Lower Greensand	13	8.2
UK04	Lincolnshire Limestone	4	**64.6**
UK05	West Shropshire	19	25.3

Figure 3.9: Nitrate (in mg/l) – Time series

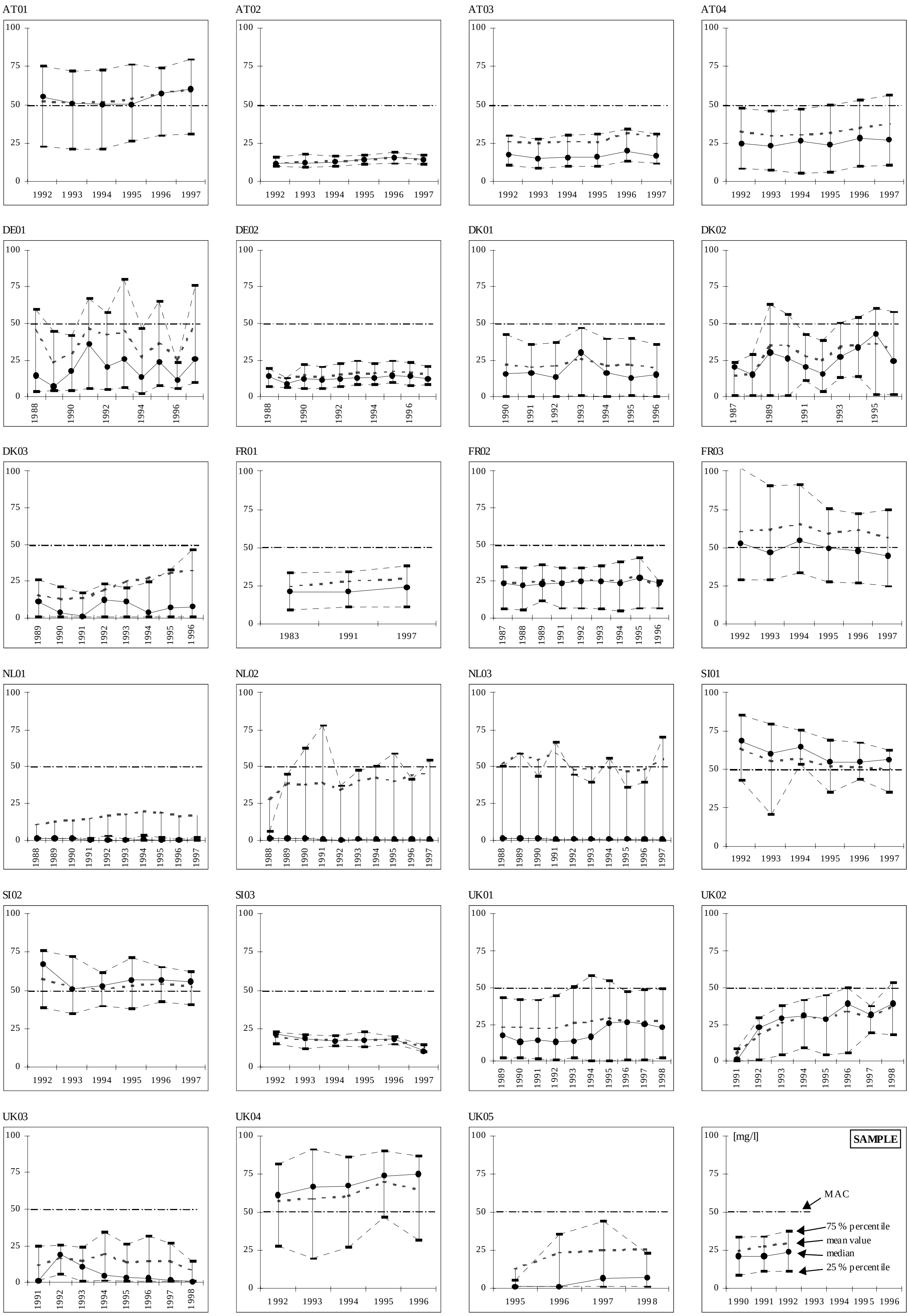
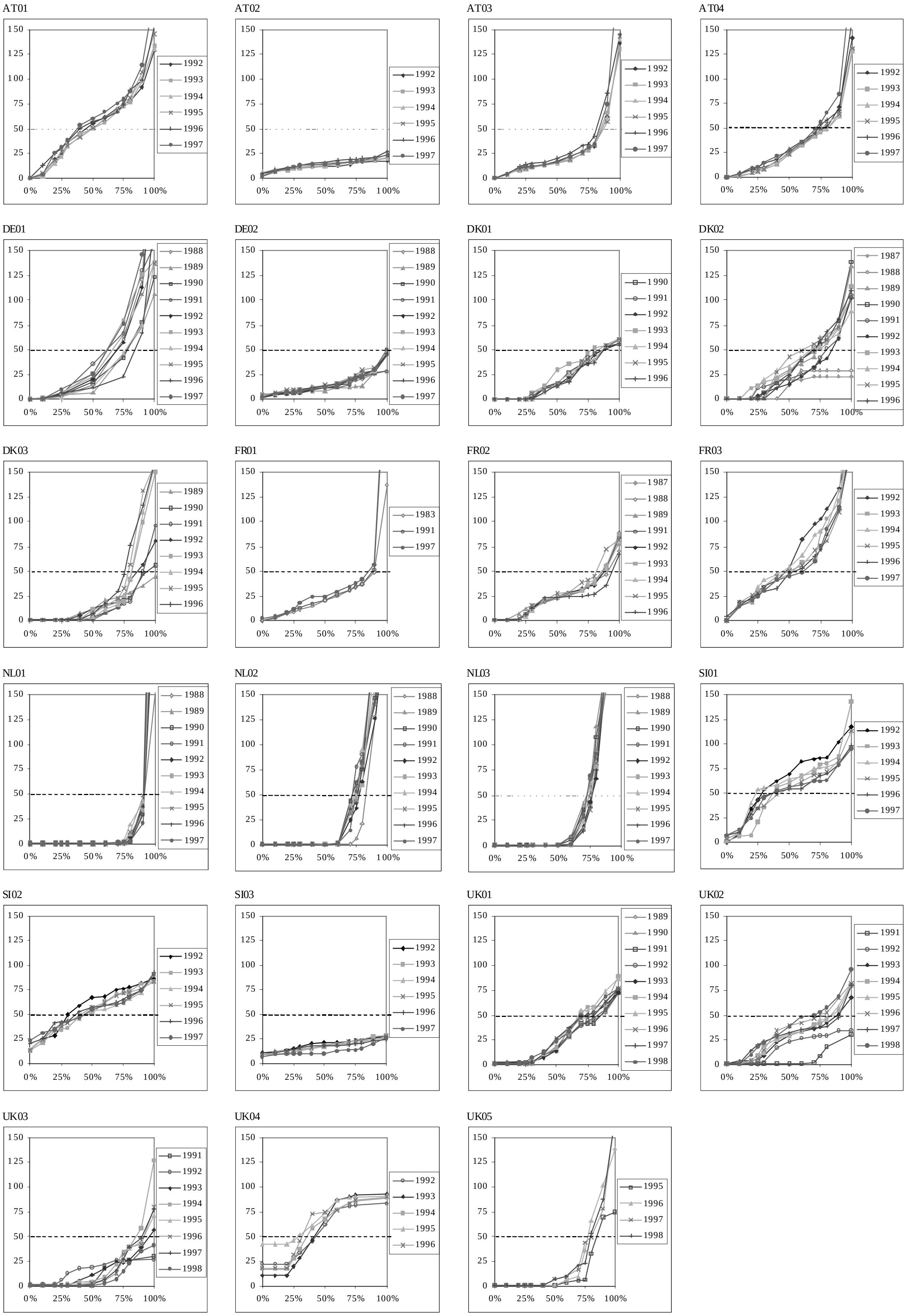


Figure 3.10: Nitrate (in mg/l) – Summary (cumulative) frequency



Dissolved oxygen

In groundwater the presence or absence of oxygen determines whether oxidising or reducing conditions exist. Especially for the transformation of nitrogen compounds oxygen plays a major role. Frequently observed dissolved oxygen concentrations range between 6–12 mg/l and, considering the temperature of groundwater, correspond to the maximum concentration in balance with the oxygen concentration of the atmosphere respectively the soil air (Matthess, 1990).

Apart from the depletion or absence of oxygen another feature of reducing conditions in water is a significant occurrence of nitrite and ammonium and the absence of nitrate.

Information on dissolved oxygen was provided for 19 groundwater bodies. The number of sampling sites varies between 1 and 720.

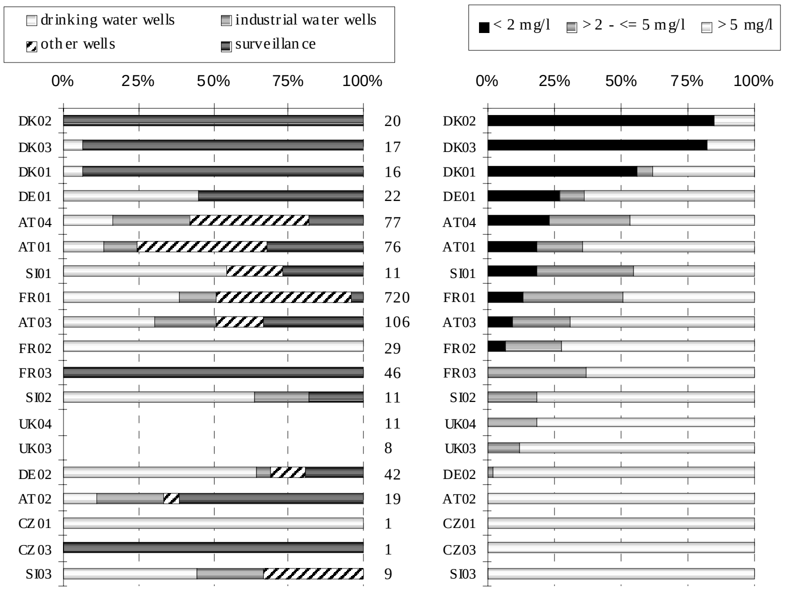
At 10 groundwater bodies the mean value of dissolved oxygen of at least one sampling site falls below 2 mg/l. Especially at the three Danish groundwater bodies the percentage of sampling sites with dissolved oxygen values ≤ 2 mg/l exceeds 50 %.

Figure 3.11 illustrates the number of sampling sites and their distribution according to type as well as the mean value and the frequency distribution of dissolved oxygen in groundwater. The distribution in the upper figure is ranked by the percentage of wells showing dissolved oxygen values ≤ 2 mg/l, the bottom figure is ranked by the percentage of drinking water wells.

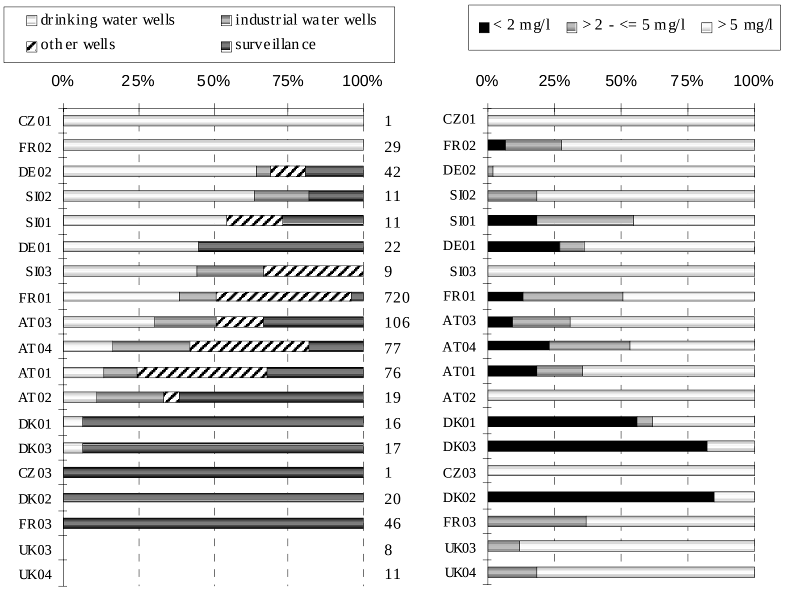
Figure 3.12 shows the temporal development of the quartiles and the median of annual average dissolved oxygen concentration for each groundwater body. At AT02 there seems to be a slight downward trend.

Figure 3.11: Dissolved oxygen – number and type of sampling sites, frequency distribution and mean values

Type of sampling sites **Frequency distribution**

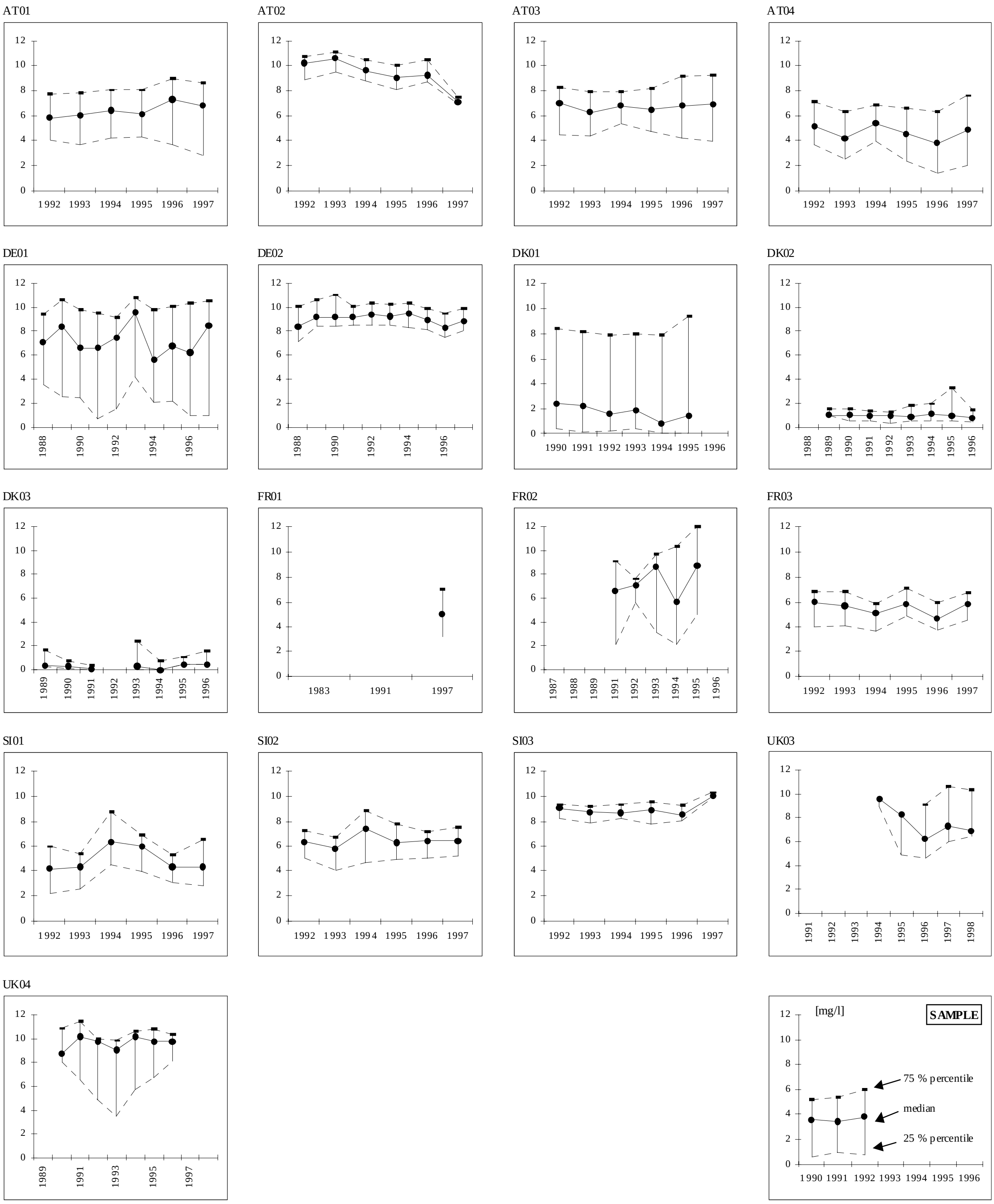


code	name	number of sampling sites	mean value (mg/l)
DK02	Grindsted sand	20	2.3
DK03	Skuldelev sand	17	1.8
DK01	Thisted limestone	16	4.3
DE01	Halterner Sande	22	6.3
AT04	Tullner Feld	77	4.9
AT01	Marchfeld	76	6.0
SI01	Celjska Kotlina	11	4.4
FR01	Nappe phréatique de la plaine d'Alsace	720	5.1
AT03	Suedliches Wiener Becken	106	6.5
FR02	Nappe de la Craie-Colnines de L'Artois	29	8.3
FR03	Villafranchien of Vistrenque (Gard)	46	5.4
SI02	Dravsko Polje	11	6.4
UK04	Lincolnshire Limestone	11	9.2
UK03	Lower Greensand	8	7.4
DE02	Buntsandstein Odenwald	42	8.8
AT02	Mattigtal	19	7.3
CZ01	Velcé Opatovice	1	8.5
CZ03	Vojkovice	1	
SI03	Ljubljansko Polje	9	10.1



code	name	number of sampling sites	mean value (mg/l)
CZ01	Velcé Opatovice	1	8.5
FR02	Nappe de la Craie-Colnines de L'Artois	29	8.3
DE02	Buntsandstein Odenwald	42	8.8
SI02	Dravsko Polje	11	6.4
SI01	Celjska Kotlina	11	4.4
DE01	Halterner Sande	22	6.3
SI03	Ljubljansko Polje	9	10.1
FR01	Nappe phréatique de la plaine d'Alsace	720	5.1
AT03	Suedliches Wiener Becken	106	6.5
AT04	Tullner Feld	77	4.9
AT01	Marchfeld	76	6.0
AT02	Mattigtal	19	7.3
DK01	Thisted limestone	16	4.3
DK03	Skuldelev sand	17	1.8
CZ03	Vojkovice	1	
DK02	Grindsted sand	20	2.3
FR03	Villafranchien of Vistrenque (Gard)	46	5.4
UK03	Lower Greensand	8	7.4
UK04	Lincolnshire Limestone	11	9.2

Figure 3.12: Dissolved oxygen (in mg/l) – Time series



Relationship between the investigated determinands

A comparison of the frequency distributions of ammonium, nitrite, nitrate and dissolved oxygen and the type of sampling sites is shown in Figure 3.14. At all groundwater bodies with ammonium or nitrite problems (except for CZ02), there are also sampling sites where mean values exceed the MAC for nitrate.

Groundwater body CZ02 shows that paying attention to nitrate only does not sufficiently describe groundwater status and contamination with nitrogen. At this groundwater body a serious ammonium problem exists but MACs for nitrite and nitrate are not exceeded.

At some groundwater bodies (AT01, AT03, AT04, DE01, FR01 and FR02) with sampling sites with dissolved oxygen values below 2 mg/l, nitrite and ammonium problems are evident. In contrast, for SI01 and for the Danish groundwater bodies (DK01, DK02 and DK03), which show a very high percentage of sampling sites with very low contents of dissolved oxygen, not one single sampling site exceeds the respective MACs for ammonium and nitrite.

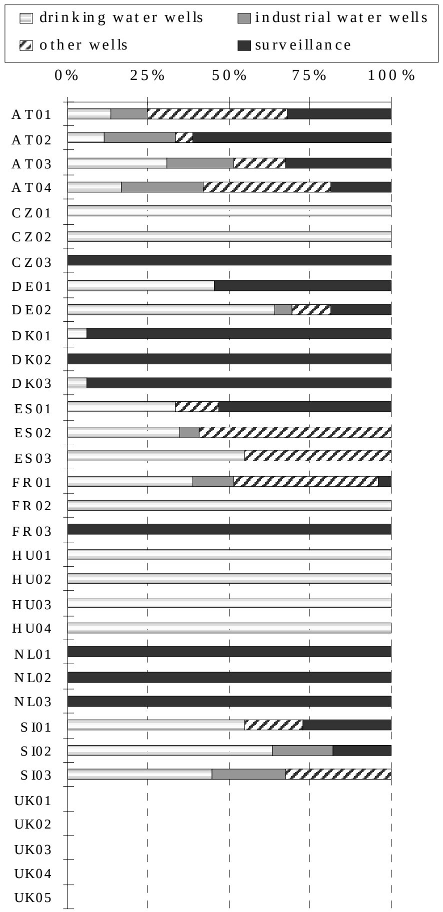
Table 3.14 summarises the information on the state of groundwater with regard to nitrogen for all groundwater bodies for which information has been submitted.

Table 3.14: Number of groundwater bodies where defined percentages of sampling sites exceed the given concentrations of selected determinands

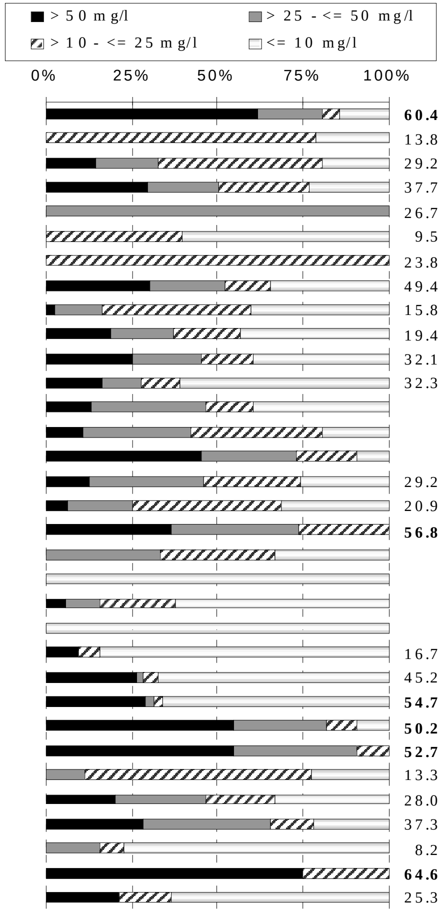
Determinand concentration (annual mean)	Total number of groundwater bodies	Number of groundwater bodies where			
		none	**> 0 % to < 25 %**	**≥ 25 % to < 50 %**	**≥ 50 %**
		of the sampling sites exceed the respective determinand concentration			
Ammonium					
> 0.5 mg/l	23	14	8		1
> 0.3 mg/l	23	12	9	1	1
Nitrite					
> 0.1 mg/l	23	16	7		
> 0.06 mg/l	23	13	10		
Nitrate					
> 50 mg/l	33	9	12	8	4
> 25 mg/l	33	5	6	12	10
Dissolved oxygen					
≤ 2 mg/l	19	9	6	1	3

Figure 3.13: Type and number of sampling sites and frequency distributions for nitrate, nitrite, ammonium and dissolved oxygen including mean values in mg/l

Type of sampling sites

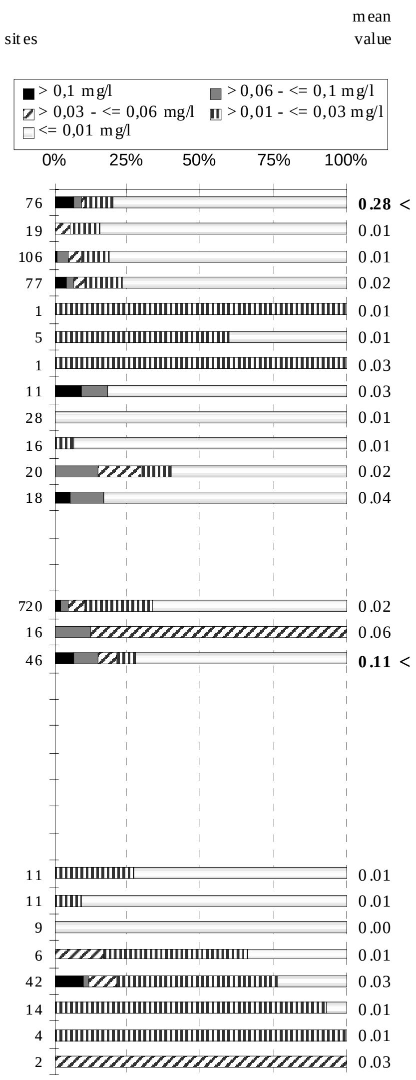


Nitrate

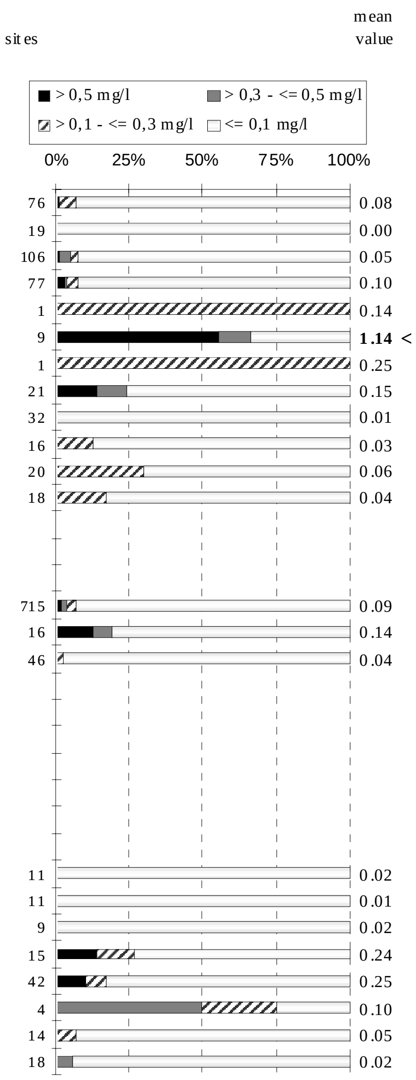


code	name	sampling sites	mean value
AT01	Marchfeld	76	**60.4** <
AT02	Mattigtal	19	13.8
AT03	Suedliches Wiener Becken	106	29.2
AT04	Tullner Feld	77	37.7
CZ01	Velcé Opatovice	1	26.7
CZ02	Ivanèice	5	9.5
CZ03	Vojkovice	1	23.8
DE01	Halterner Sande	23	49.4
DE02	Buntsandstein Odenwald	42	15.8
DK01	Thisted limestone	16	19.4
DK02	Grindsted sand	20	32.1
DK03	Skuldelev sand	18	32.3
ES01	Region de los Arenales (02.17)	30	
ES02	Madrid-Talavera (03.05)	57	
ES03	Plana de Valencia Norte (08.25)	11	
FR01	Nappe phréatique de la plaine d'Alsace	720	29.2
FR02	Nappe de la Craie-Colnines de L'Artois	16	20.9
FR03	Villafranchien of Vistrenque (Gard)	46	**56.8** <
HU01	Bankfiltered water	3	
HU02	Deep groundwater	197	
HU03	Karstic water	37	
HU04	Shallow groundwater	3	
NL01	Northern sand area	75	16.7
NL02	Eastern sand area	46	45.2
NL03	Southern sand area	105	**54.7** <
SI01	Celjska Kotlina	11	**50.2** <
SI02	Dravsko Polje	11	**52.7** <
SI03	Ljubljansko Polje	9	13.3
UK01	Lincolnshire Chalk	15	28.0
UK02	Marlborough & Berkshire Downs	32	37.3
UK03	Lower Greensand	13	8.2
UK04	Lincolnshire Limestone	4	**64.6** <
UK05	West Shropshire	19	25.3

Nitrite



Ammonium



Dissolved oxygen

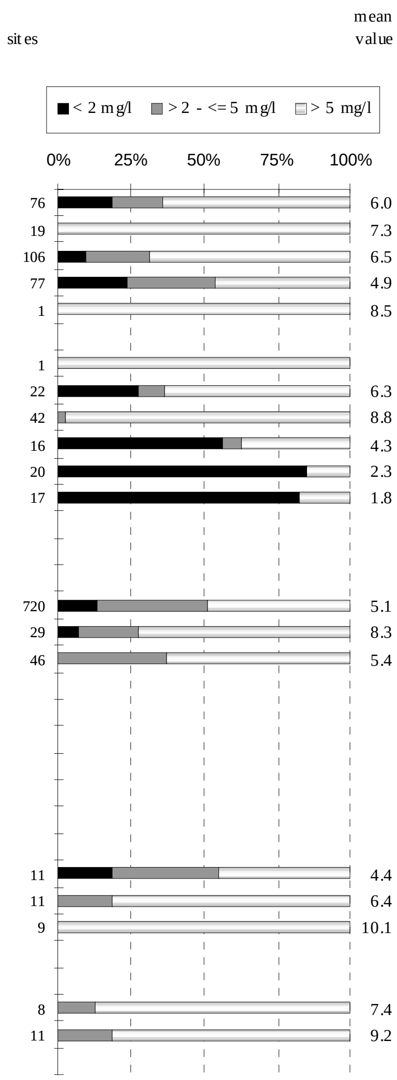


Table 3.15 gives an overview of the groundwater bodies where the mean values exceed drinking water limits for ammonium, nitrite or nitrate laid down in the Drinking Water Directive (80/778/EEC) or in the Nitrate Directive (91/676/EEC). With regard to nitrate only, the groundwater bodies AT01, FR03, NL03, SI01, SI02 and UK04 exceed the limit value in the Drinking Water Directive and the Nitrate Directive. Taking into account ammonium and nitrite as further nitrogen determinands, the groundwater bodies AT01 and FR03 additionally exceed drinking water limits for nitrite. Groundwater bodies CZ02, NL01 and NL02 exceed drinking water limits for ammonium but none of these sampling sites exceed the limit values for nitrate and nitrite.

Table 3.15: Groundwater bodies where the mean values exceed drinking water limits for ammonium, nitrite or nitrate specified in the Drinking Water Directive and the Nitrate Directive

Groundwater bodies	Ammonium	Nitrite	Nitrate
CZ02	●		
NL01	●		
NL02	●		
AT01		●	●
FR03		●	●
NL03			●
SI01			●
SI02			●
UK04			●

A comparison of the mean values and the bar charts shows that mean values of only a few groundwater bodies exceed limit values but obviously there are several groundwater bodies where probably at least parts of the groundwater body have to be classified as problem areas.

However, the results of such estimations depend very much on the type of sampling sites.

In order to identify these problem regions within a groundwater body the location of the sampling sites should be identified in a map indicating type of sampling sites as well as mean values according to defined classes.

3.3. Correlation between the general characteristics of a groundwater body and groundwater quality

In order to find cause-effect relationships between the general characteristics of a groundwater body and groundwater quality, groundwater quality data have been correlated with information on precipitation, thickness of the overlying strata, thickness of the groundwater body, average hydraulic conductivity of the groundwater body and the percentage of agricultural land use.

The amount of nitrogen in groundwater depends on a number of well-known as well as unknown factors which are more or less dependent on each other. Due to these complex interactions, the fact that information on known factors is not available in desirable detail and due to a wide range of different unknown factors, linkages among nitrogen balances and the occurrence of nitrate in water, for example, are not fully understood yet (LEI-DLO and IFF-ÖSTAT, 1998).

3.4. Agricultural land use: factors influencing the nitrate content of groundwater

Nitrogen surface balance

Agricultural nitrogen surface balances are set up to calculate nitrogen input and removal on the field, region and country level considering the following factors:

- total amount of applied nitrogen (by deposition, biological nitrogen fixation, sewage sludge, mineral and organic fertilisers) and
- the amount of nitrogen removed through the harvest (food and fodder).

It is recommended to quantify nutrient balances at regional level. The result of such a nitrogen balance reflects possible negative impacts of agriculture on the environment since high nitrogen surpluses indicate a potential nutrient contamination of associated ecosystems (groundwater, surface water, air).

Correlation between nitrogen balance and nitrogen in seepage water and groundwater

Müller et al. (1995) and Kerschberger & Hess (1997) found that for soils with a high site characteristic risk of leaching (sandy soils, high rate of seepage, small losses due to denitrification) nitrogen surplus correspond more or less with nitrogen leaching (see also Bouwer, 1995).

However, significant positive correlations between nitrogen surplus and nitrate concentrations in seepage water and groundwater cannot always be found (see Brouwer et al., 1995; Hege, 1997; OECD, 1997; Schüpbach, 1997) since the amount of nitrate leaching into groundwater depends on various other factors including:

- soil type,
- N-mineralisation processes in the soil, especially in autumn when plant cover is often missing,
- climatic conditions (amount, intensity and frequency of precipitation),
- weather conditions during and after fertilisation (precipitation after fertilisation causes higher losses of nitrate by seepage water, sunshine during and after fertilisation of organic fertiliser (esp. slurry) causes higher losses of ammonia),
- amount of gaseous nitrogen losses,
- kind of fertiliser applied: mineral, organic (liquid or solid manure, compost), timing of fertiliser application, fertilising techniques,
- fertiliser distribution: irregular application and seasonal differences in the applied amount,
- soil tillage activities (causing increased mineralisation of the nitrogen pool in the soil): timing and methods,
- groundwater level and groundwater renewal rate, volume of the groundwater body.

It should be stressed that fertiliser application per hectare provides little information on the linkage between agriculture and environment (OECD, 1997).

Under certain circumstances higher nitrate concentrations in soil and seepage water may occur in spite of a low nitrogen balance result due to various other factors. In this case the following additional measures should be applied:

- changes in crop rotation,
- conversion of arable land into grassland,
- catch cropping,
- cultivation of underseeds,
- timing of soil tillage and fertilising activities to suit requirement and weather conditions,
- changes in the kind of fertilisers applied and their distribution techniques.

Hege and Brandhuber (1990) proved a significant correlation between agricultural land use (special crops, vineyards, vegetables, hop, grassland, arable land) and the average nitrate concentration of seepage water below the root zone. However, a correlation between livestock density and nitrate concentrations in seepage water could not be detected (since gaseous losses of ammonia could not be quantified).

According to Wagner (1997; 1997a) the following factors influence nitrate concentrations in groundwater:

1. agricultural land use,
2. livestock farming,
3. farm type and size (cereal farms, diary farms, etc.),
4. other factors apart from agriculture: groundwater level, amount and distribution of precipitation, etc.

Wagner (1997) chose the following data sets for a discriminant analysis: shares of forest, grassland, risk crops, crops to cover soil in winter, density of settlements and the share of farms between 40 000 and 100 000 euro of total standard gross margin. A statistically significant correlation with nitrate in groundwater was found.

In the first place nitrogen balances are set up to assess nutrient management of single farms or in a certain region. They serve as a means to enhance the farmers' awareness in nutrient handling. However, a correlation between nitrogen surplus and the nitrate content of seepage water and groundwater cannot always be found. A balanced nitrogen balance does not necessarily imply an improvement of groundwater quality. On the other hand a high surplus in a nitrogen balance is an indicator that groundwater quality will not improve (Schüpbach, 1997).

At the European scale high surpluses in the nitrogen balances of some countries and regions indicate that this is the main cause of high nitrate concentrations in groundwater. The nitrogen balance is one important factor which has to be interpreted in combination with other information.

4. Conclusions

Type of sampling sites

It is important to provide background information on the type of sampling sites as different types of sampling sites provide different status information. The intended supply purpose of a well determines the choice of a groundwater body and the location of a well. Drinking water wells for example are generally located in areas where groundwater quality is high to minimise treatment. This matter of fact is well illustrated for nitrate (see Figure 3.7). In groundwater bodies where exclusively drinking water wells are investigated the contamination with nitrate is comparatively low.

In order to give a representative overview of the quality of a particular groundwater body a balanced mixture of different types of sampling sites is desirable.

Investigated groundwater bodies, sampling site density, site distribution

The maps provided show that in numerous countries the groundwater monitoring network within the investigated groundwater bodies consists of evenly distributed sampling sites.

The density of sampling sites at a groundwater body is relatively high and amounts to 25 – 30 km^2/site. The size of most of the groundwater bodies is between 100 and 1 000 km^2 but since Europe is very inhomogeneous there are also smaller and larger groundwater bodies.

Most groundwater bodies on which information was delivered are situated in porous media (23 of 31 groundwater bodies). Six groundwater bodies are fractured rock and one is karst. In most cases the boundaries are based on hydrogeological criteria (sometimes in combination with administrative borders).

Aggregated quality data – site related quality data

In the draft guidelines for EUROWATERNET – groundwater it is proposed to collect groundwater quality data for particular groundwater bodies in a standardised aggregated form. The pilot study shows that in general aggregated data provide sufficient information for the assessment of the state of groundwater on the European scale if the results are based on a representative monitoring network (with regard to site selection and site density).

If there is a need of further statistics e.g. to detect correlations between different determinands or to subsample specific sampling sites of different groundwater bodies it will be necessary to collect site-related data to answer these particular questions. For an interpretation of these detailed data local expertise will be essential.

State of groundwater with reference to nitrogen

In public discussion the question of the state of groundwater with reference to nitrogen usually focuses on nitrate. In this pilot study attention was also paid to ammonium and nitrite as other inorganic compounds of nitrogen in groundwater.

Results show that in some groundwater bodies on which information was provided nitrogen is a rather serious problem. In most cases, of course, nitrate is the compound which exceeds the limit values for drinking water but nevertheless there is also one groundwater body which shows an impact with reference to ammonium without exceeding nitrate limits.

Important for the assessment of the state of groundwater within a groundwater body is the applied criterion. In this pilot study the number of sampling sites within a groundwater body as well as mean values of selected determinands are presented for each groundwater body. The evaluation of nitrate shows that for groundwater bodies in which more than 25 percent of sampling sites exceed the maximum admissible concentration (MAC) for drinking water (50 mg NO_3/l) the mean value for the whole groundwater body is at least 30 to 40 mg NO_3/l. If the mean value exceeds the MAC, as a rule more than 40 % of sampling sites exceed the MAC.

Since groundwater bodies in porous media were the dominating group (23 of 31 bodies) no comparison of different aquifer types was carried out.

Cause/effect relationship

As described in section 3.4 in particular, the topic ‘nitrogen input into groundwater’ is complex and a scientific assessment of cause/effect relationships can hardly be carried out at the European level. Such an assessment is currently more feasible at regional level since the detailed information required (e.g. natural conditions like soil, climate, hydrology as well as agricultural practice etc.) is not available on the European scale.

At the European level an analysis of legal obligations, guidelines, etc. and their implementation seem to be more feasible. Furthermore, some key statistics on the use of organic and mineral fertiliser and nitrogen balances at national or regional level can indicate changes in agricultural practice.

The assessment of groundwater quality data will provide evidence if the measures identified in section 3.4 are suitable to improve groundwater quality (medium or long-term).

The way forward

The next step for the further implementation of EUROWATERNET – groundwater should be the development of a database for the storage and management of European data. In this database ‘general descriptions of groundwater bodies’ as well as groundwater quality and quantity data ought to be included. For the data transfer the necessary interfaces (exchange modules) should be elaborated.

As a further step data collection in accordance with the EUROWATERNET guidelines should be initiated.

In parallel it is necessary to develop an update mechanism for EUROWATERNET – groundwater. This is a crucial point if EUROWATERNET is intended to be a tool for day-to-day work under the proposed Framework Water Directive and for information purposes with regard to the European public.

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Appendix A: Guidelines for a European groundwater monitoring network design – draft proposal

A.1. Scope

The draft monitoring strategy outlined below has been developed based on

- the information needs of the EEA (objective, reliable and comparable data);
- the results which have been elaborated so far within the ETC/IW work programme (e.g. EEA Report 10/1996, Pilot study, Draft Groundwater Monograph, etc.) as well as on general principles of monitoring network design;
- the spirit of the Draft EU Groundwater Action Programme (COM(96) 315 final);
- the current discussion on Annex II, III and V of the draft Water Framework Directive;
- and last but not least on the principles of efficiency and saving costs.

Representative data in this proposal are seen as data which provide an overview of the state of groundwater quality and quantity in the EEA-area. Delivered information should allow to identify the status of groundwater bodies ranging from nearly 'natural' to 'heavily impacted'. Member countries should therefore deliver representative data based on their existing national programmes.

A.2. Objective EUROWATERNET for groundwater

Objective of EUROWATERNET for groundwater is to provide:

- objective, reliable and comparable information at the European level;
- a survey about important groundwater bodies in the EEA area;
- a description of the status of groundwater quantity and quality in the EEA area;
- information about trends in groundwater quantity and quality status;
- a long-term assessment of the impacts of measures.

A.3. Which aquifers are covered?

*[**Aquifer** means a subsurface layer or layers of rocks or other geological strata of sufficient porosity and permeability to allow a significant flow of groundwater and the abstraction of significant quantities of groundwater.]*

*[**Groundwater body** means a hydrogeologically distinct volume of groundwater within an aquifer or aquifers.]*

Monitoring of all important groundwater bodies (groundwater in porous media, karst groundwater and others), both shallow and deep aquifers.

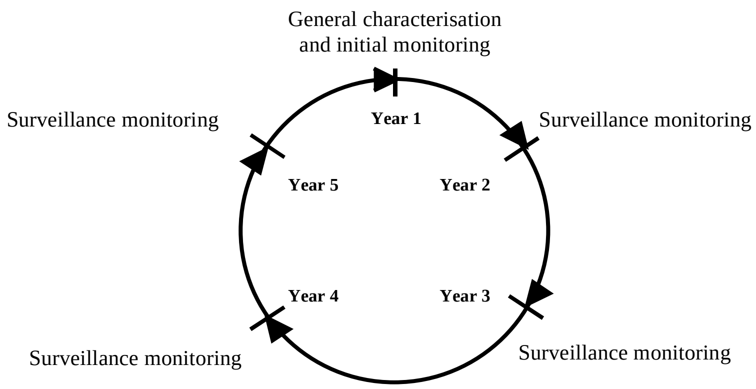
A groundwater body is defined as important when at least one of the three requirements are met:

- > 300 km²;
- of regional, socio-economic or environmental importance in terms of quantity and quality;
- exposed to severe or major impacts.

A.4. General characteristics of a representative monitoring programme

The proposed monitoring programme is cyclic with a period of five years. The monitoring specifications are illustrated in Figure A.1 and described as follows:

Figure A.1: Illustration of a representative monitoring programme



General characterisation and initial monitoring should provide a more comprehensive description of the groundwater body. Based on the knowledge of this programme, extent and characteristics of surveillance monitoring will be derived. Every five years the general characteristics should be updated (according to Table A.1) and the initial monitoring – based on the general characterisation – should be repeated. Monitoring results will then be the basis for the development of the new surveillance monitoring. This system should be a tool to adapt the monitoring strategy regularly in accordance with the change of conditions within the monitored region.

A.5. Characterisation of groundwater bodies

There should be a two-step approach:

- A general characterisation should be carried out for all important groundwater bodies.
- The general characterisation of the groundwater body should be reviewed and updated (especially the pressure situation) at least every five years.

The general characterisation of the groundwater body shall identify:

Table A.1: General characterisation

<table>
<tr><th>Groundwater quantity</th><th>Groundwater quality</th></tr>
<tr><td colspan="2">
• the location, area and boundaries of the groundwater body;
• geological characterisation of the groundwater body including: extent and type of geological units and the characterisation of the overlying strata in the catchment from which the groundwater body receives its recharge;
• hydrogeological characterisation of the groundwater body and the surface layer hydrological characterisation of the groundwater body including: climate (precipitation);
• stratification characteristics of the groundwater within the groundwater body;
• an inventory of associated surface systems including terrestrial ecosystems and surface water bodies, with which the groundwater body is dynamically linked;
• land use in the catchment or catchment from which the groundwater body receives its natural and artificial recharge; land use information shall include the percentage of: agricultural, arable, pasture land, forest, urbanisation or any other impacts of human intervention;
</td></tr>
<tr><td>• Assessment of the pressures to which each groundwater body is liable to be subject incl.: are there water abstractions or artificial recharges, associated aquatic or terrestrial ecosystems?</td><td>• Assessment of the pressures to which each groundwater body is liable to be subject incl.: are there diffuse sources or point sources of pollution, associated aquatic or terrestrial ecosystems?</td></tr>
</table>

A.6. Groundwater quantity monitoring

Two-step approach

- Periodical characterisation of the groundwater body (according to paragraphs A.4 and A.5);
- initial and continued surveillance monitoring of the groundwater quantity of all important groundwater bodies should be carried out.

Types of monitoring stations

- The monitoring network should be based on a balanced distribution of sampling sites in order to provide representative information on the quantitative aspects of a groundwater body;
- monitoring stations should be located away from abstraction or recharge stations.

Monitoring station density

The density of monitoring stations in a groundwater network shall depend on:

- The size of the groundwater body;
- the geological and hydro(geo)logical characteristic and complexity of the aquifer;

- the intensity of impacts (e.g. land use, population density, abstraction and recharge).

Vulnerability mapping will provide additional basic information for the selection of sampling sites and monitoring station distribution within the monitored area.

Monitoring frequency

Groundwater quantity shall be monitored according to the following monitoring programme which has been set up for a period of five years:

- In the first year of the monitoring period all important groundwater bodies have to go through an initial monitoring where groundwater bodies should be monitored at least four times in order to detect seasonal variations (depending on the hydrology and the dynamics of the aquifer system). More frequent monitoring may be necessary in more variable systems;
- in the following four years of the monitoring period all important groundwater bodies have to run through a surveillance monitoring where groundwater bodies shall be monitored at least twice a year in order to detect maximum and minimum groundwater levels (depending on their hydrology and dynamics).

Parameter

- Piezometric head of groundwater

No recommendation for karst aquifers can be made at this stage.

Interpretation and presentation of groundwater quantitative status

- Member countries should provide a map of all important groundwater bodies including the location of sampling sites;
- for each important groundwater body member countries should provide information on the characterisation of the groundwater body;
- the results for one sampling site should be aggregated as an annual mean value or twice-yearly mean value if appropriate. For each groundwater body monitoring these data should be aggregated per year and be compared with or related to the data of a reference year, the mean values for a reference period or to average long term values (e.g. for a 30 years period). The aggregation of yearly data could be done as percentiles, mean values and extremes for the groundwater area. Wherever possible trends should be calculated. Overviews should be provided by tables, figures and maps (further details will be given at a later date subject to the findings of pilot studies carried out by ETC/IW partners).

The following table (Table A.2) and figures show (by way of example) the difference of the mean groundwater levels of the current year to a reference year (mean value of a reference period).

Table A.2: Differences of the mean groundwater levels of the current year to a reference year (mean value of a reference period) in cm. (All measured values were derived from one groundwater body)

1994	Summary frequency in % and extremes											
Groundwater body	mean	min	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	max
GW-1	0	-11	-9	-6	-5	-3	-2	-1	1	3	7	52
GW-2	6	-38	-12	-6	-2	2	6	8	12	16	20	74

Figure A.2: Summary frequency

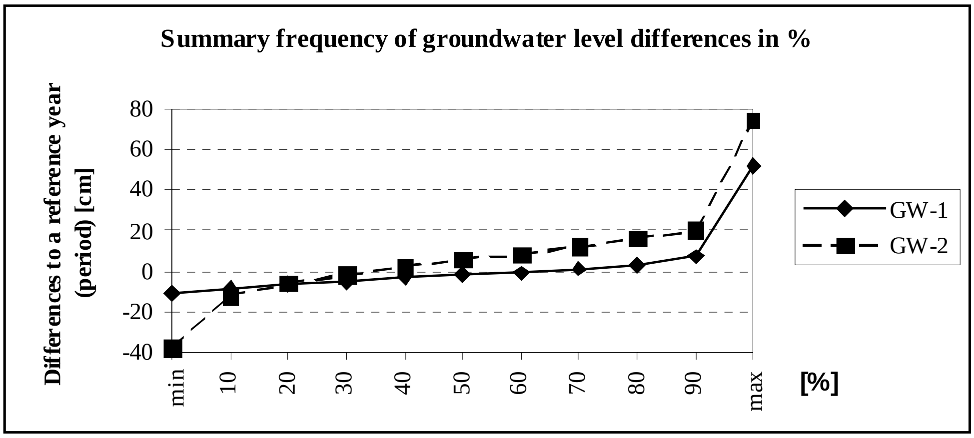
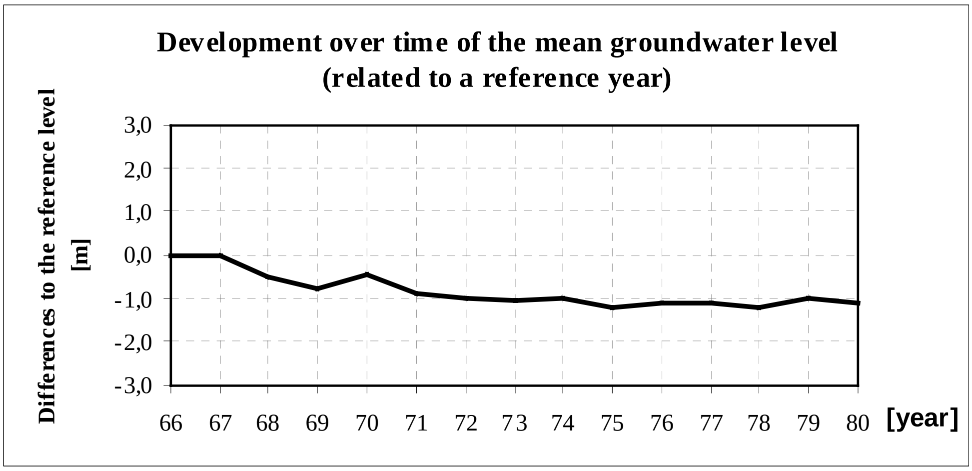


Figure A.3: Development over time of the mean groundwater level for a groundwater body related to a reference year



A.7. Groundwater quality monitoring

Two-step approach

- Periodical characterisation of each important groundwater body;
- initial and surveillance monitoring of the groundwater quality of each important groundwater body should be carried out.

Characteristics of sampling sites

The construction characteristics of the monitoring station must be provided when information is submitted (in particular the information on the aquifer (groundwater body being sampled or monitored). This is particularly important in multi-aquifer systems or where quality varies strongly with depth.

The monitoring network should be based on a balanced spatial distribution as well as a balanced mixture of different types of sampling sites in order to give representative information on the mean quality of a groundwater body. A monitoring network dominated by a specific type of sampling sites could provide results which are not representative for the region (e.g. drinking water wells are usually situated in unpolluted areas).

The purpose of a sampling site shall be indicated when information is submitted:

- Drinking water well;
- industrial;
- other uses (irrigation,…);
- surveillance.

Sampling site density

The density of observation wells should depend on:

- The size of the groundwater body;
- the geological and hydro(geo)logical characteristics and complexity of the aquifer;
- intensity of impacts (e.g. land use, population density, point and diffuse sources).

A pilot study in a heavily impacted area suggested that a sampling density of about 25 km^2/site would be appropriate. For regional surveillance of less-impacted areas a more appropriate sampling density could exceed 100 km^2/site. Further experience is essential.

For each important groundwater body for which vulnerability mapping exists monitoring density should be chosen also in accordance with the findings from the vulnerability mapping.

Monitoring frequency

Groundwater quality determinands should be monitored according to the following monitoring programme which has been set up for a period of five years:

- In the first year of the monitoring period all important groundwater bodies have to run through an initial monitoring where groundwater bodies should be monitored at least twice (initial monitoring). Seasonal variations and aquifer characteristics should be taken into account and might require higher monitoring frequency;
- during the following four years of the monitoring period all important groundwater bodies have to run through a surveillance monitoring

where groundwater bodies should be monitored at least once a year. Seasonal variations and aquifer characteristics should be taken into account and might require higher monitoring frequency;

- all important groundwater bodies for which the general characterisation did not detect significant anthropogenic pressures and the initial monitoring did not detect impacted groundwater quality, do not have to run through the surveillance monitoring;
- after the completion of the five-year monitoring programme it has to be started again with an initial monitoring.

The sampling schedule should relate to the infiltration or recharge regime of the groundwater body and to seasonal variations in the application of compounds (from land use) causing groundwater pollution.

Determinands

The initial monitoring should give a first overview and characterisation for all important groundwater bodies about the natural content of quality determinands and anthropogenically induced pollution. It shall contain at least determinands in bold of group 1 and all other determinands of group 1 and 2 which could be of relevance according to the anthropogenic pressures which were detected in the course of the general characterisation of the groundwater body.

Group		Determinands
1	Descriptive determinands	**pH**, **EC, DO** Temp.
	Major ions	**Ca, Mg, Na, K, Cl**, **NH_4**, **NO_3**, **NO_2**, **HCO_3**, **SO_4** PO_4, TOC
2	Heavy metals	As, Hg, Cd, Pb, Cr, Fe, Mn, Zn, Cu, Al, Ni, Choice depends partly on local pollution source as indicated by land-use framework
	Organic substances	Aromatic hydrocarbons, halogenated hydrocarbons, phenols, chlorophenols. Choice depends partly on local pollution source as indicated by land-use framework
	Pesticides	Choice depends in part on local usage, land-use framework and existing observed occurrences in groundwater.
	Additional determinands	Choice depends partly on results of pressure analysis (according to chapter 0)

The surveillance monitoring follows the initial monitoring and observes all group 1 determinands and all other determinands, where (significant) deviations from the natural background occur.

Interpretation and presentation of groundwater chemical status

- Member countries should provide a map of all important groundwater bodies including the location of sampling sites;
- for each important groundwater body member countries should provide information on the characterisation of the groundwater body.

The results from an individual sampling site should be aggregated as an annual mean value, and the results from individual sites within a groundwater body should be aggregated for the groundwater body as a whole.

- Sampling sites: Number of sampling sites for each type of sampling site.
- Quality data: For each groundwater body monitoring data should be aggregated per year. The aggregation of yearly data could be in the form of percentiles (10, 25, 50, 75, 90), mean values and extremes for the groundwater area. Wherever possible trends should be calculated. Overviews could be provided by tables, figures and maps.

This information should allow an assessment of groundwater quality with regard to limit values (e.g. Drinking Water), a comparison between unimpacted and impacted groundwater bodies and analysis of time series.

The information provided (maps, table, descriptions, statistical data) should allow the assessment of the status of the groundwater body and extent of the impacted areas.

Table A.3 to A.6 and Figures A.4 to A.6 show examples of presentation of quality data:

Table A.3: Example of summary frequency of nitrate (annual mean values in mg/l)

				percentile											
year	sampl. sites	mean value	min	10	20	25	30	40	50	60	70	75	80	90	max
1991	85	27,16	0,00	3,12	9,54	11,00	12,51	15,00	17,65	22,00	28,00	31,00	35,04	66,35	137,0
1992	85	24,95	0,00	3,08	7,90	9,30	10,20	12,90	15,60	19,36	23,60	26,50	31,84	63,68	138,0
1993	84	26,19	0,00	3,50	7,70	9,60	11,00	13,36	16,00	19,42	27,40	30,15	38,02	64,62	142,4
1994	83	25,02	0,00	2,51	7,32	9,00	10,26	12,50	14,95	18,10	24,80	29,65	34,14	61,92	243,0
1995	81	28,07	0,00	2,85	7,50	10,43	12,15	14,80	17,30	23,10	30,60	32,90	37,80	68,70	144,9
1996	94	30,51	0,00	2,71	9,61	11,28	12,20	14,60	17,55	22,20	29,10	32,43	42,60	83,10	251,0

Table A.4: Example of summary frequency of chloride (annual mean values in mg/l)

				percentile											
year	sampl. sites	mean value	min	10	20	25	30	40	50	60	70	75	80	90	max
1991	85	30,06	1,40	6,03	9,00	10,28	11,03	14,00	17,50	22,92	27,00	32,43	39,84	58,96	266,0
1992	85	30,97	1,40	6,28	7,98	9,20	10,38	14,02	16,60	22,50	27,56	31,60	38,26	54,64	548,0
1993	84	30,15	1,90	6,70	8,58	9,60	11,10	14,42	17,60	22,58	27,52	33,10	40,04	61,42	460,0
1994	83	38,31	1,70	6,41	8,70	9,28	11,03	14,70	17,50	23,18	28,24	33,53	39,32	60,95	947,1
1995	81	39,66	1,60	7,35	9,10	10,30	12,35	15,40	19,05	23,60	31,50	35,75	42,40	63,10	962,7
1996	94	35,82	1,94	7,57	9,68	10,78	13,30	16,40	21,30	28,30	39,70	44,75	53,00	71,95	468,0

Figure A.4: Example of 25 %, 50 % and 75 % percentiles for nitrate and chloride (1991–1996)

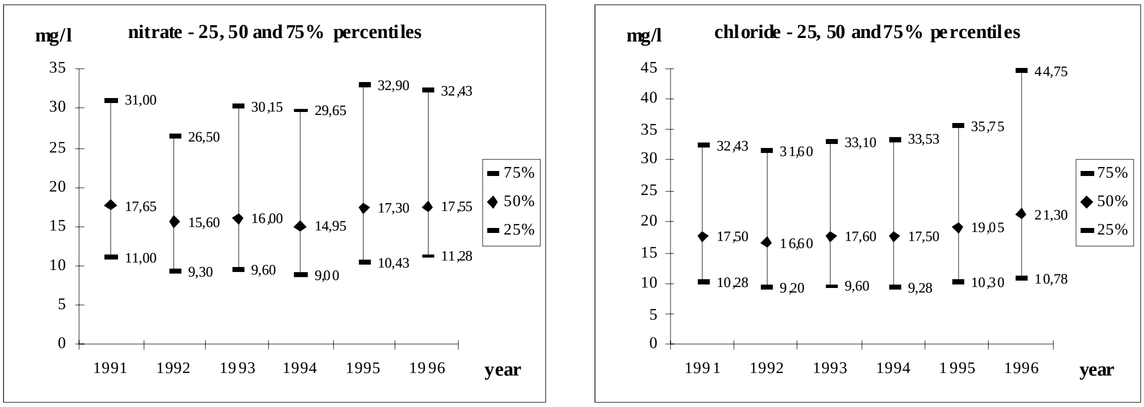


Table A.5 and Figure A.5: Example of summary frequency of nitrate and chloride in 1996

1996				percentile											
det.	sampl. sites	mean value	min	10	20	25	30	40	50	60	70	75	80	90	max
nitrate	94	30,51	0,00	2,71	9,61	11,28	12,20	14,60	17,55	22,20	29,10	32,43	42,60	83,10	251,0
chloride	94	35,82	1,94	7,57	9,68	10,78	13,30	16,40	21,30	28,30	39,70	44,75	53,00	71,95	468,0

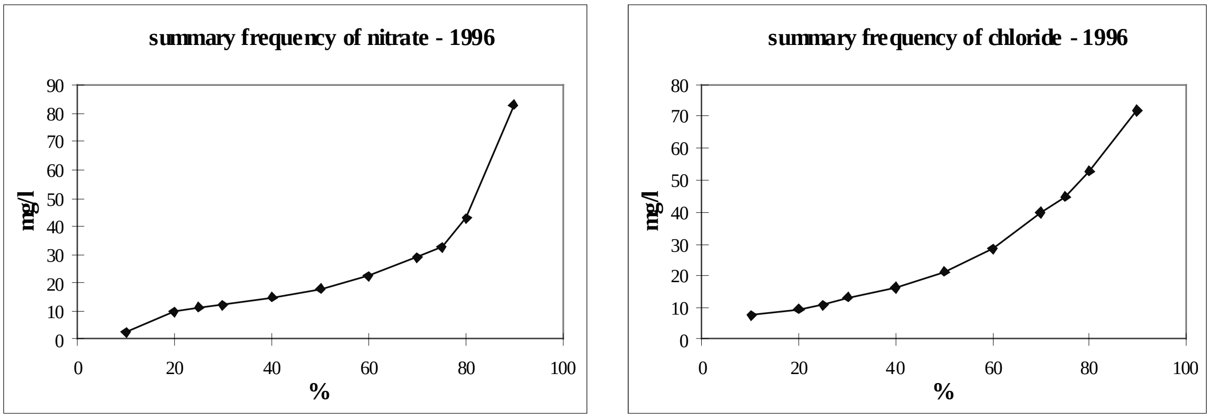
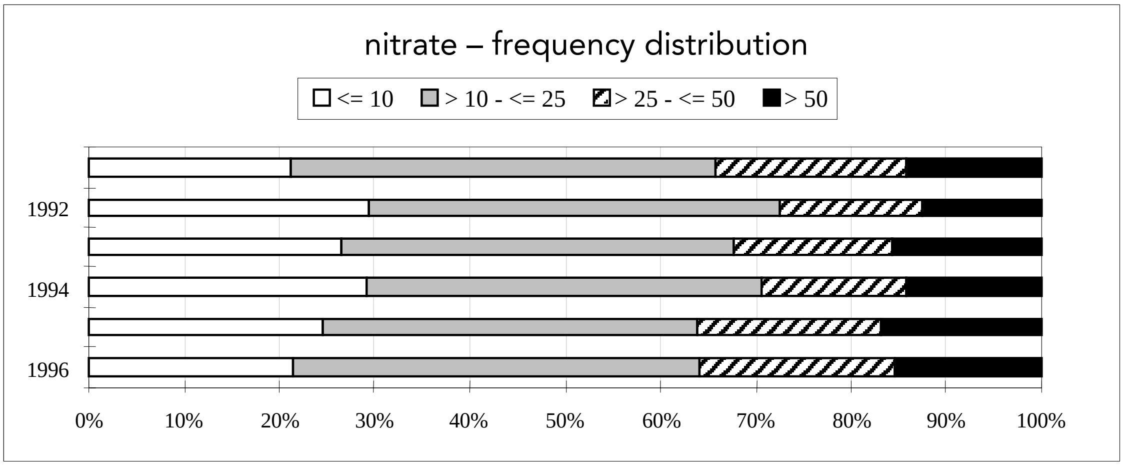


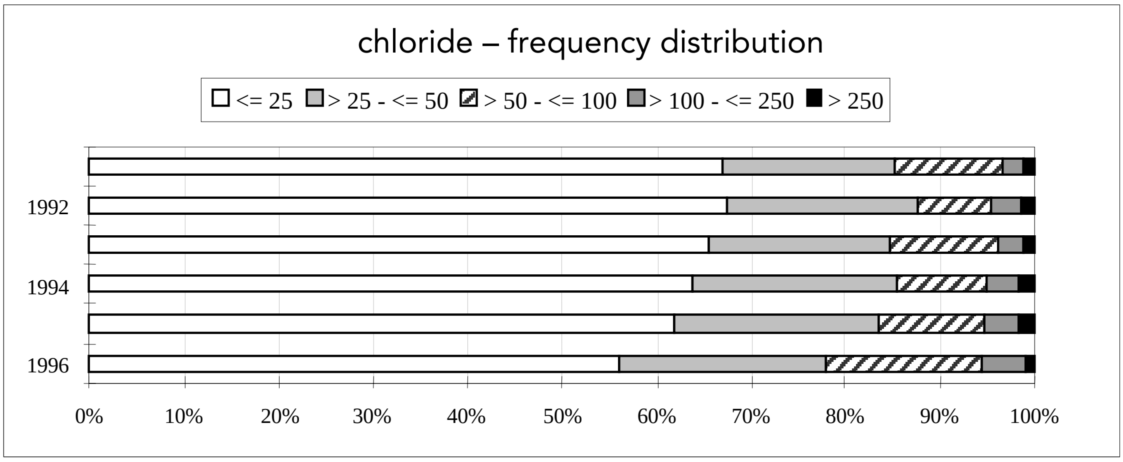
Table A.6 Example of frequency distribution of nitrate and chloride (annual mean values of sampling sites)

	frequency distribution in %				
nitrate	**<= 10**	**> 10 - <= 25**	**> 25 - <= 50**	**> 50**	**sampling sites**
1996	21%	43%	20%	16%	94
1995	25%	39%	19%	17%	81
1994	29%	42%	15%	14%	83
1993	26%	41%	17%	16%	84
1992	29%	43%	15%	12%	85
1991	21%	45%	20%	14%	85

	frequency distribution in %					
chloride	**<= 25**	**> 25 - <= 50**	**> 50 - <= 100**	**> 100 - <= 250**	**> 250**	**sampling sites**
1996	56%	22%	17%	5%	1%	94
1995	62%	22%	11%	3%	2%	81
1994	64%	22%	9%	3%	2%	83
1993	65%	19%	11%	3%	1%	84
1992	67%	20%	8%	3%	1%	85
1991	67%	18%	11%	2%	1%	85

Figure A.6: Example of frequency distribution of nitrate and chloride (annual mean values of sampling sites)





Appendix B: Questionnaire

B.1 General characterisation of the groundwater body

Name of groundwater body	
Location/region	
Area (km^2)	
Max. length/width (km)	
No. of horizon (top=1st…)	

Geology

Geological units	
Thickness of the groundwater body (m)	
Overlaying strata (type) and thickness above the main groundwater body (m)	

Hydrology

Attach diagram of climate (long-term average monthly precipitation and temperature) or give data (prec.(temp/month: e.g. 85/5.4/I;….;35/0.3/XII)	
Surface temperature (mean)	
Mean annual precipitation (mm) and max. mean monthly precipitation (mm, month)	

Hydrogeology

Aquifer type	
Average hydraulic conductivity of the groundwater body (kf)	
Recharge due to: (e.g. precipitation, surface waters, groundwater, etc.)	
Mean annual groundwater level amplitude	

Pressures

Land use (% of agriculture, arable, pasture, forest, urban)	
Water abstractions (yes/no and purpose)	
Artificial recharge (yes/no and purpose)	
Main infrastructures influencing the groundwater dynamics	
Associated aquatic ecosystems	

B.2 Groundwater quality with regard to ammonium, nitrite, nitrate and dissolved oxygen

DETERMINAND

Please give the most recent information of as many years as possible but not more than ten years.

name of the groundwater body	
country	

Type of sampling site

Please give the number and main purpose of the sampling sites monitoring the respective DETERMINAND
(only one nomination per sampling site!)

	year									
drinking water well										
industrial well										
wells with other uses										
surveillance										
total no. of sampling sites	0	0	0	0	0	0	0	0	0	0

Monitoring frequency

How many sampling sites with regard to the respective DETERMINAND are investigated for how many times per year?

	year									
number of sampling sites										
sampling frequency per year										
number of sampling sites										
sampling frequency per year										

Summary frequency

Please give the summary frequency of the respective DETERMINAND in mg/l.

				percentiles											
year	no. of sampl. sites	mean value	min	10%	20%	25%	30%	40%	50%	60%	70%	75%	80%	90%	max

Frequency distribution

Please give the number of sampling sites per class for each year (for the respective DETERMINAND)

				year									
ammonium	nitrite	nitrate	dissolved oxygen										
<= 0,1 mg/l	<= 0,01 mg/l	<= 10 mg/l	<= 2 mg/l										
> 0,1 - <= 0,3 mg/l	> 0,01 - <= 0,03 mg/l	> 10 - <= 25 mg/l	> 2 - <= 5 mg/l										
> 0,3 - <= 0,5 mg/l	> 0,03 - <= 0,06 mg/l	> 25 - <= 50 mg/l	> 5 mg/l										
> 0,5 mg/l	> 0,06 - <= 0,1 mg/l	> 50 mg/l											
	> 0,1 mg/l												
no. of sampling sites				0	0	0	0	0	0	0	0	0	0