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Baseline groundwater quality: a European approach

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Abstract

One need of the European Union Water Framework Directive (WFD) as applied to groundwater is to have a clear understanding of the groundwater background quality reference, or baseline, in order for it to be compared to the current situation. As a scientific approach to this issue, the research project ''BaSeLiNe'' has been carried out by institutions from 12 European countries. Among the different work packages, an applied element was included in the project to involve groundwater managers, end-users and regulators as stakeholders in the groundwater baseline quality issue. This was done through a questionnaire which was distributed to selected high-level people from each participating country. The main subject of this paper is the results obtained from the 69 questionnaires retrieved and the related discussions originating from them. Most answers refer to water supply issues, but not exclusively. It comes out that groundwater in many cases is the main or the only available water source for human and agricultural supply. Generally, it is of good quality, although a progressive deterioration and the excessive content of some components is becoming noticeable. Groundwater protection is a long-term key issue which needs regulation, management and planning, and should be a subject of public information. However, at high management and policy-making levels often just a small sensitive awareness to the use of groundwater and its protection has been recognized. Groundwater quality improvements are expected from a combination of factors that mainly include changes in land use and better farming practices. The costs involved must be supported by users, but they are often not very prone to pay for quality improvements, and therefore ask for subsidies. The effective participation of river basin districts, groundwater user associations and stakeholders in groundwater management is considered to be positive, although experience is lacking and there may be some drawbacks if there are no adequate institutions.

Keywords: Baseline groundwater quality; European Water Framework Directive; Groundwater Directive; Aquifer protection; Groundwater management

1. Introduction

The project ''*Natural Baseline Quality in European Aquifers*: *a basis for aquifer management*'' (BaSeLiNe) has been financed by the European Union (EU) as project EVK1-1999/0006, which was later extended (EVK1-2002/40527) to admit new participants (BaSeLiNe, 1999). The main objective was to establish criteria for defining natural groundwater background quality and to develop a standardized European-wide assessment approach which could be used in the implementation of the recently enacted European Union Water Framework Directive (WFD, 2000; AIH-GE, 2003; Manzano et al., 2003a,b), and on the drafting of the Groundwater Daughter Directive, now well advanced. Such a baseline reference, based on geochemical criteria, is needed to be able to quantitatively assess whether or not anthropogenic contamination is taking place in groundwater.

Research groups from the United Kingdom, Belgium, Denmark, Estonia, France, Poland, Portugal, Spain and Switzerland have participated in this project from the beginning, and new groups from Czechia, Bulgaria and Malta were included during the third year. The project focused on the following aspects: the time-scales influencing groundwater natural processes and the rates at which these processes occur; the variation of major and trace inorganic quality in representative reference aquifers; the naturally occurring dissolved organic carbon in these aquifers; the reactive transport modeling to provide quantitative understanding of the evolution of groundwater quality and of how to predict future changes; the selection and application of tracers that fit the involved time-scales; the interpretation of

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trends in groundwater quality; the selection of optimum indicators for monitoring natural waters.

Another somewhat different work domain considered in BaSeLiNe was policy and end-users, looking for a discussion forum comprised of scientists, policy-makers, regulators and water industry managers. The aim was to provide them with a European-wide scientific approach to the concept of groundwater *baseline quality* and also with ways to handle data for policy decisions. The objective is to find a common approach for the needs of the community with regard to groundwater baseline quality and the ways in which the scientific and technical studies can address these problems. This involves defining optimum strategies for data use and dissemination, and also for providing advice on data required to meet problems at local and regional scales.

Joint work between scientists/experts and stakeholders was required to carry out these objectives, integrating their own particular domains (scientific research and policy decisions) and complementing each other with their different viewpoints concerning these issues. *A strategic advisory group* was also set up, comprised of experienced high-level end-users and policy-makers from each of the countries participating in the BaSeLiNe project. Water supply issues were dominating since they are the most organized group and represent a main concern in Central and Northern Europe. However, agriculture consume up to 90% of freshwater resources in Mediterranean regions, but its voice is far less organized.

Below is a summary of the meaning of *groundwater baseline quality* taken from selected European water managers and scientists, as well as a brief description of the steps followed to carry out this task within the BaSeLiNe project. Additionally, some relevant issues are proposed aimed at assessing a correct application of the WFD to groundwater.

2. Approach to end-user involvement

The involvement of end-users and policy-makers in the project was set up consecutively in different steps. First, a personal approximation was carried out through several contacts and meetings held at local and national scales within each country involved. Later, on a European scale, a meeting took place by gathering one or two representatives from each country group (during the BaSeLiNe workshop held in Madeira, Portugal, in October 2002), who were appointed by the national group to represent it.

In order to get comparable information and to draft a document for discussion, a questionnaire was drawn up by those responsible for the work package (the Spanish team). The questionnaire was discussed and finally agreed upon by the BaSeLiNe national teams. The objective was to know what the selected stakeholders understood groundwater quality and particularly the baseline component to be, and what the current and future application (within the WFD) of the baseline concept was. The questionnaire was sent to about 150 people selected from the consortium countries, and its distribution within each country was made by the respective BaSeLiNe national teams, who contacted the people and sometimes helped them fill in the forms. On the whole, 69 questionnaires were filled out and recovered. One of them contained interesting general comments on the matter from an experienced professor. The good percentage of response, about 45%, reflects the partners' interest in this matter. This was also highlighted during the national scale meetings. Most of the people who replied are from water supply companies and environment agencies/organizations with regional responsibilities.

2.1. The questionnaire

A formal inquiry analysis approach was discarded, even if this procedure is known to yield very good results for expert groups (Miller, 1984), and particularly, the Delphi method, if adequately oriented (Taylor and Ryder, 2003; Ono, 1994; Rowe et al., 1991; Sackman, 1975). However, the time and economic resources required were not available, and the sample was relatively small and conditioned by the scarce number of representative water institutions in a given territory. There was also some bias due to social and political constrains, or simply the respondents were not used for these inquiries, or some sectors were not adequately represented, such as the agricultural one.

Consequently, the questionnaire was drafted in a rather informal way and no specialists were involved in the preparation of the inquiries. From the beginning, it was clear that the people who would be asked to fill in the document covered a wide spectrum of orientations, such as suppliers, policy-makers, regulatory agencies, water association representatives, hydrogeologists and groundwater experts. Due to this, they would only be institutionally concerned for a part of the issues at stake, and also they would contribute both corporative thinking and their own personal ideas. The content had to be directed toward BaSeLiNe objectives and toward the application of the WFD to groundwater, but restricting the field in order to get comparable answers. For instance, this meant avoiding some bias from the Spanish team who prepared it, both personal and related to the geographic water resource environment, influenced to some extent by problems in semi-arid areas where intensive aquifer development for irrigation is a dominant issue (Custodio, 2002; Llamas and Custodio, 2002, 2003) when compared with other temperate areas where irrigation is less important and pollution is a more serious threat due to thin unsaturated areas. There was also a BaSeLiNe project bias towards large, deep aquifers, but this aspect was corrected to some extent by considering shallow aquifers as well, which are often used for town supply. It was agreed that technical, economic, social and administrative aspects should be considered as equally important issues (Custodio, 2001, 2003), and that some hydrogeological background on the person/entity filling in the questionnaire was needed. Although monitoring for aquifer

Table 1
Index of the questionnaire on Groundwater Baseline Management

1 Introductory aspects
- 1.1 Relevance of groundwater quality for human supply in your organization/company [4]
- 1.2 Main groundwater quality problems [3]
- 1.3 Assessment of public attitude [4]
- 1.4 Influence of groundwater quality standards/directives [4]

2 Groundwater quality management issues relative to baseline
- 2.1 Groundwater abstraction works [well construction, operation and maintenance] [4]
- 2.2 Aquifer protection and land use [4]
- 2.3 Adequate knowledge/understanding of the aquifer system [4]
- 2.4 Attitude towards original groundwater quality problems [4]
- 2.5 Environmental issues and public attitude [4]
- 2.6 Groundwater baseline quality sustainability [short-term issues vs. long-term issues] [4]

3 Economic issues
- 3.1 Cost of groundwater quality [4]
- 3.2 Pollution and opportunity cost [4]
- 3.3 Elasticity of demand to groundwater quality [3]
- 3.4 Origin of funds [3]

4 Administrative and policy issues
- 4.1 Groundwater quality regulations and laws [4]
- 4.2 Main legal/administrative problems [4]
- 4.3 Social appraisal of groundwater quality [4]
- 4.4 Solution to conflicts [4]
- 4.5 Role of users' associations/citizen groups [5]
- 4.6 Role of the water/environmental authority [4]
- 4.7 What is expected needed from the EU Water Framework Directive? [5]

5 Groundwater quality monitoring
- 5.1 Groundwater monitoring [5]
- 5.2 Groundwater quality monitoring [4]
- 5.3 Well monitoring for groundwater quality [4]
- 5.4 Study of aquifers, specially coastal ones [4]

[·] Indicates the number of questions in each sub-item.

baseline quality characterization was the subject of a separate work package within the project, it was also decided to use the questionnaire opportunity to address, together with the Portuguese team, monitoring aspects, which are closely related with end-users.

Table 1 shows the questionnaire index. It contains five chapters with four to seven sections each, and each section has five to six questions. Both oriented and non-oriented answers were possible. Oriented answers were a closed list of four to six possible choices; some were provocative, or an indefinite alternative to indicate some doubt about the answer. In some cases, choices were restricted to just one, and in others, more than one alternative could be selected. Non-oriented answers consisted in introducing free comments to produce nuances, but this possibility was rarely used by respondents. The final questionnaire included 30 pages with 125 questions (BaSeLiNe, 1999).

The first chapter deals with introductory aspects and the following three chapters address groundwater policy affairs, groundwater quality and baseline quality understanding, as well as the regulations and norms affecting groundwater resources development and use. The last chapter is devoted to the monitoring of groundwater baseline quality. Some comments prior to filling in the questionnaire stated that not all the questions are appropriated for all participants, and that some could be skipped, in accordance with previous remarks about the diversity of respondents.

2.2. The sample

The entities selected to fill out the questionnaire and to participate in the meetings shared many characteristics but they also presented large differences. Table 2 shows the distribution of the entities by country and activity. All of them were deeply involved in groundwater and play a relevant role in the (ground)water domain at their respective scale. They were public, private or mixed organizations, and their scope was municipal, regional or national. Also, people who filled out the questionnaires had different backgrounds, such as hydrogeology, engineering, chemistry, law and management. Geographical differences between the diverse countries involved in this consultation were also significant whenever climatic conditions, population, surface area, importance of agriculture, animal rising and irrigation, human activities and/or economic characteristics were considered. Besides this, each organization had its physical

Table 2
Characteristics of the entities which answered the questionnaire

Country	Status			Activity					Scope			Number of questionnaires
	Public	Private	Mixed	Supply	Regul./manag.	Consultant	Research	Other	Nat./intern	Regional	Local	
Belgium	7	0	0	6	1	0	0	0	0	6	1	7
Bulgaria	1	0	1	1	1	0	0	0	1	1	0	2
Czechia	2	0	1	2	1	0	0	0	1	1	1	3
Denmark	5	0	0	0	3	1	1	0	2	2	1	5
France	3	0	0	0	2	0	0	1	0	3	0	3
Poland	10	0	0	5	5	0	0	0	2	5	3	10
Portugal	6	1	1	3	4	0	0	1	2	4	2	8
Spain	10	3	3	3	12	0	1	0	1	13	2	16
Switzerland	5	0	0	3	2	0	0	0	1	2	2	5
UK	4	6	0	4	4	1	1	0	2	8	0	10

Note: Two countries were not able to get answers.

and human particularities. All these aspects make each aquifer management unique. Sometimes there are strong differences, for instance, between a small-size coastal aquifer in semi-arid Southern Europe and a large continental aquifer in a temperate industrialized area. However, some group communalities can be found and this was one of the objectives of the Groundwater (Daughter) Directive, to facilitate the real application of the WFD within a reasonable timeframe and with reasonable effort.

2.3. Methodology used

First, the collected data were handled and treated country by country. A table was prepared with all the original results listed straight from the questionnaires plus some elementary rates calculated using these data to single out particularities from the whole. As an example, the first page of the results for Spain is shown in Table 3 (Nieto et al., 2003).

As already mentioned, the results were presented and discussed with the partners involved at national meetings. Then, as some of the primary conclusions on the matter began to emerge, these were taken into account to prepare the corresponding "National Summary" draft. Later, the same calculations were applied with the same purpose in mind to the complete dataset from all the BaSeLiNe teams as a whole. The first page of these results is shown as an example in Table 4. Selecting extreme rate values may easily single out some relevant results. Some of them are gathered in Table 5.

Table 3
Example of results from the Spanish questionnaires

Questionnaire on Groundwater Baseline Management : SPAIN

Number of questionnaires — **sent** : S = 30; **answered** : A = 16 — **A / S = 53 %**

NA = Sections with no answer
T = Total of answers

		Set of answers : 1 to 16															T	NA	T / S T		T / A	
1.- Introductory aspects																						
1.1.- Relevance of groundwater quality for human supply in your organization/company																						
a.- The majority of water quality problems you face are:	long-term			1		1	1	1		1				1	1		1	8		8/23	35%	8/16	50%
	medium-term	1			1		1			1	1	1	1	1		1		9		9/23	39%	9/16	56%
	short-term		1				1				1				1			4		4/23	17%	4/16	25%
	just the present										1				1			2		2/23	9%	2/16	13%
	no problems																	0		0/23	0%	0/16	0%
	other																	0		0/23	0%	0/16	0%
Nº of answers in this section		1	1	1	1	1	3	1	0	2	3	1	1	2	3	1	1	23	2				
b.- Is groundwater quality related to operation / management options?	yes		1	1	1		1	1					1	1	1		1	9		9/16	56%	9/16	56%
	sometimes					1	1			1	1	1				1		6		6/16	38%	6/16	38%
	no	1																1		1/16	6%	1/16	6%
	other																	0		0/16	0%	0/16	0%
Nº of answers in this section		1	1	1	1	1	2	1	0	1	1	1	1	1	1	1	1	16	2				
c.- Groundwater abstraction / use is:	continuous	1		1	1	1	1	1		1	1		1	1	1			11		11/20	55%	11/16	69%
	seasonal										1		1	1	1	1	1	6		6/20	30%	6/16	38%
	back up											1						1		1/20	5%	1/16	6%
	other		1										1					2		2/20	10%	2/16	13%
Nº of answers in this section		1	1	1	1	1	1	1	0	1	2	1	3	2	2	1	1	20	2				
d.- Groundwater use:	urban purposes	1	1	1	1	1	1	1		1	1				1	1		11		11/49	22%	11/16	69%
	drinking water						1	1			1			1		1	1	6		6/49	12%	6/16	38%
	industrial supply			1	1	1	1	1		1	1				1	1	1	10		10/49	20%	10/16	63%
	cooling						1				1				1	1		4		4/49	8%	4/16	25%
	irrigation			1	1	1	1			1	1			1	1	1	1	10		10/49	20%	10/16	63%
	animal use						1				1							2		2/49	4%	2/16	13%
	other			1		1	1			1				1		1		6		6/49	12%	6/16	38%
Nº of answers in this section		1	1	4	3	4	7	3	0	4	6	0	0	3	4	6	3	49	4				
1.2.- Main groundwater quality problems																						
a.- Do you have groundwater quality problems?	no relevant problems		1						1			1						3		3/19	16%	3/16	19%
	in the past				1										1			2		2/19	11%	2/16	13%
	they are appearing				1	1	1			1	1			1	1		1	8		8/19	42%	8/16	50%
	not known																	0		0/19	0%	0/16	0%
	other	1		1			1	1					1			1		6		6/19	32%	6/16	38%
Nº of answers in this section		1	1	1	2	1	2	1	1	1	1	1	1	1	2	1	1	19	1				

Table 4
Example showing the first page of the summary results obtained for all countries

Questionnaire on Groundwater Baseline Management : ALL COUNTRIES

Number of questionnaires answered : **A = 68** **T** = total of answers

	COUNTRY											Main Values Obtained			
	E	**P**	**B**	**DK**	**F**	**GB**	**PL**	**CH**	**BU**	**CZ**	**T**	**T / S T**		**T / A**	
1.- Introductory aspects															
1.1.- Relevance of groundwater quality for human supply in your organisation / company															
a.- The majority of water quality problems you face are:															
long-term	8	5	5	5	2	8	5	3	0	2	43	43/97	44%	43/68	63%
medium-term	9	1	2	3	1	3	3	2	0	1	25	25/97	26%	25/68	37%
short-term	4	2	2	0	1	3	2	4	0	0	18	18/97	19%	18/68	26%
just the present	2	0	0	0	0	0	3	0	1	0	6	6/97	6%	6/68	9%
no problems	0	0	1	0	0	0	0	1	0	0	2	2/97	2%	2/68	3%
other	0	1	0	0	0	1	1	0	0	0	3	3/97	3%	3/68	4%
Nº of answers in this section	*23*	*9*	*10*	*8*	*4*	*15*	*14*	*10*	*1*	*3*	*97*				
b.- Is groundwater quality related to operatio / management options?															
yes	9	1	6	0	2	4	3	1	1	3	30	30/61	49%	30/68	44%
sometimes	6	3	1	4	0	3	3	2	0	0	22	22/61	36%	22/68	32%
no	1	1	0	1	1	0	2	2	0	0	8	8/61	13%	8/68	12%
other	0	1	0	0	0	0	0	0	0	0	1	1/61	2%	1/68	1%
Nº of answers in this section	*16*	*6*	*7*	*5*	*3*	*7*	*8*	*5*	*1*	*3*	*61*				
c.- Groundwater abstraction / use is :															
continuous	11	2	5	5	0	5	8	5	1	3	45	45/62	73%	45/68	66%
seasonal	6	0	1	0	0	0	1	1	0	0	9	9/62	15%	9/68	13%
back up	1	2	0	0	0	0	1	0	0	0	4	4/62	6%	4/68	6%
other	2	0	0	0	0	2	0	0	0	0	4	4/62	6%	4/68	6%
Nº of answers in this section	*20*	*4*	*6*	*5*	*0*	*7*	*10*	*6*	*1*	*3*	*62*				
d.- Groundwater use:															
urban purposes	11	1	0	1	0	0	3	3	1	1	21	21/102	21%	21/68	31%
drinking water	6	2	5	2	0	0	3	3	1	2	24	24/102	24%	24/68	35%
industrial supply	10	1	1	2	0	0	4	3	1	1	23	23/102	23%	23/68	34%
cooling	4	0	0	1	0	0	1	2	0	0	8	8/102	8%	8/68	12%
irrigation	10	0	0	1	0	0	0	2	0	0	13	13/102	13%	13/68	19%
animal use	2	0	0	0	0	0	0	1	0	0	3	3/102	3%	3/68	4%
other	6	0	1	1	0	0	0	2	0	0	10	10/102	10%	10/68	15%
Nº of answers in this section	*49*	*4*	*7*	*8*	*0*	*0*	*11*	*16*	*3*	*4*	*102*				

The study of all this information gave rise to a partial report. This sort of general pre-synthesis was discussed by the country participants (39 people) attending the work package discussion during the project meeting held in 2002 in Funchal, Madeira (Portugal). The topics involved were thoroughly discussed. Valuable suggestions emerged, which gave rise to the final report which is summarized below. Nevertheless, some explanations about the questionnaire and the method applied for interpretation will be required in order to have an appropriate understanding of the results already presented. These are important, derived from the complexity of the matter, and do in fact lead to the final results.

In a first stage, the different particularities of the respondents were overlooked and were not taken into account when analyzing the results, but indeed they were behind each answer. Accordingly, simple (unweighted) averages were calculated by summing up all answers to each question. But the relatively large sample set is assumed to support the results, since their diversity in many important aspects gives an interesting conceptual representation. Furthermore, this sort of dispersed data makes this information difficult for traditional statistical treatment. This could be clearly improved through an approach with a broader scope, if a similar future consultation involving more countries, sectors and institutions were considered.

Table 5
Questions with the highest scores

Questionnaire on Groundwater Baseline Management : ALL COUNTRIES

Number of questionnaires answered : 68 **T** = Total of answers **S T** = Total of answers in the section

	COUNTRY											Main Values Obtained			
Question	**E**	**P**	**B**	**DK**	**F**	**GB**	**PL**	**CH**	**BU**	**CZ**	**T**	**T / S T**		**T / A**	
1. 1. c	11	2	5	5	0	5	8	5	1	3	45	45 / 62	**73%**	45 / 68	66%
1. 3. c	15	8	5	5	3	6	7	4	1	3	57	57 / 69	**83%**	57/ 68	84%
2. 3. d	13	5	4	2	2	7	1	3	1	2	40	40 / 57	**70%**	40 / 68	59%
2. 6. a	13	8	6	4	2	8	6	5	0	2	54	54 / 64	**84%**	54 / 68	79%
2. 6. c	10	7	4	4	1	4	5	5	1	2	43	43 / 63	**68%**	43 / 68	63%
2. 6. d	11	7	4	4	2	8	10	2	1	2	51	51 / 62	**82%**	51 / 68	75%
4. 3. c	15	7	4	4	2	8	5	3	2	1	51	51 / 65	**78%**	51 / 68	75%
5. 1. a	9	7	5	3	1	7	5	5	2	1	45	45 / 64	**70%**	45 / 68	66%
5. 2. b	10	5	6	5	3	7	4	4	0	2	46	46 / 68	**68%**	46 / 68	68%
5. 2. c	16	8	6	5	2	8	7	4	2	3	61	61 / 64	**95%**	61 / 68	90%

Question	***Content***	***Selection***
1. 1. c	*Groundwater abstraction use is*	**continuous**
1. 3. c	*What do you think about providing information on groundwater quality to users ?*	**beneficial**
2. 3. d	*Are some of your technical staff capable of dealing themselves with groundwater quality problems that may appear ?*	**yes**
2. 6. a	*Does long-term groundwater quality sustainability concern you ?*	**it is a key issue**
2. 6. c	*Must groundwater baseline quality sustainability be the subject of strict planning and regulation ?*	**yes**
2. 6. d	*Are you in favour of keeping and protecting good quality palæowater primarily for drinking purposes ?*	**yes**
4. 3. c	*Is groundwater quality a serious matter ?*	**very serious**
5. 1. a	*Do you operate a groundwater monitoring network ?*	**yes**
5. 2. b	*Early warning of groundwater quality changes is :*	**essential**
5. 2. c	*Investment in monitoring for early warning of water quality changes is :*	**important**

A specific column in the data list shows the answer frequency (how many answers are missing).

All the answers have been treated in the same way, as indicated below.

Since in many cases several of the suggested options have been selected simultaneously for each question, *T* represents how many times each one of these options has been selected. Two simple arithmetic ratios are calculated with *T* to obtain a sort of average result for each option:

(a) The *particular* or *internal* average, calculated by dividing *T* by the total amount of *the options selected* in this question, i.e. summing up all the individual *T*'s. The addition of all these particular averages gives 100 (%).
(b) The *general* or *external* average, calculated by dividing the same number *T* by the *total amount of questionnaires*, which is 68. The 69th questionnaire received consisted of interesting comments and could not be treated on this manner. The addition of these ratios for each question may give a number exceeding 100 (%), even though sometimes it is less than 100. This ratio gives a more general or simple idea about the option preferred for each question.

The greater the number of questionnaires containing no answer for a given question and the number of different options selected at a time on many questionnaires (which is the most frequent case), the difference between the two ratios will be greater. The analysis performed focused only on the *general* or *external* ratio because it was considered to be more interesting for BaSeLiNe goals. In certain cases, the *internal* ratio was also taken into account if it helped in the interpretation. Examples are shown in Tables 3 and 4.

Quantitative and qualitative results were derived from both what was said and what was not said throughout the

consecutive questions. Relevant particularities may be picked up straight from the calculations mentioned, such as items with the highest percentage values of their average (Table 5). This gives a sort of ''wide agreement'' from the participants on these particular issues. A similar *outcome* can be obtained from answers with the lowest percentages, although in this case the meaning is not as direct as before and must be considered with care.

As mentioned before, all the results and their interpretation were discussed at the different national and European meetings. The comments and suggestions put forward and received complemented and improved the interpretation and allowed improvements and nuances to be made to the draft reports. This method required consecutive feedback and a deep involved commitment from all the partners throughout the project. Even though this was an unusual procedure, it ran well, probably because the entire BaSeLiNe team had several years experience of working as a group. In fact, many of those involved had been engaged in another previous European project called ''Palæeaux'' (ENV4-CT 95/0156).

3. Main results

3.1. General comments

In what refers to the questionnaire itself, the main conclusion is that any future similar inquiry should improve the wording of the questions. It must always be clear whether the question refers to *what has already been done* or to *what is being considered* that *should be done*. It should also be made clear who is intended to answer when it says *you*: the person filling in the questionnaire, his organization/company, his national legislation or common people. Also, a ''yes/no'' answer should be added to the questions dealing with very technical aspects, besides the specific items looked for.

Some results seem obvious and were derived from questions that every entity would normally point out or would never single out. Their interest may consist of enlightening possible deviations, inciting additional comments, offering their selection together with other alternatives, or forcing the trial of other questions.

Scores alone are too cold for obtaining and showing results and they may be distorted by an unclear understanding of the question, which is sometimes difficult to avoid. Comments and suggestions received from country teams and consulted experts also added new nuances that could not be numerically expressed. This is the reason why the main results are presented as comments, without figures or without reference to the size of the agreement.

As an example, something that was not included in the questionnaire, but did appear in later meetings, is the importance of small and of shallow aquifers for human supply. This contrasted with the mostly large and deep aquifers considered in BaSeLiNe to study the natural reference quality. While the large, deep aquifers may still contain palæowater ($>$10,000 years old) or at least pre-industrial water, due to the low ratio abstraction/reserves, in the small aquifers groundwater is essentially young (a few to some tens of years) and reflects recent rain or surface water recharge, including irrigation return flows. The baseline concept becomes more difficult to establish in quickly renovated aquifers and can be defined to two ways: (1) it refers to pre-industrial development quality under close-to-natural conditions; often there is no data to check this and it has to be deduced by means of assumptions and (2) it refers to good groundwater quality resulting from actual recharge in areas with low anthropic pressure or from only slightly polluted surface water.

It is important to take into account that quoted results are derived mostly from entities, or from people related with them, but rarely do they represent the groundwater user and other stakeholders since it is difficult to know and obtain their collective opinion. This also applies for irrigated agriculture with groundwater. To resolve this, different, more detailed and extensive enquiries are needed.

3.2. Main results related to general groundwater issues

Groundwater is used as a continuous water supply source for all types of human demands, and sometimes as the only water resource. Its good quality is generally acknowledged, but not always. Protection of supply wells and springs is a paramount regulatory and managerial objective to address the diverse problems faced by water supply.

It has been pointed out that in many cases there is observed a slow but continuous deterioration of groundwater quality, hardly any improvement. This may be real or a consequence of paying more attention to quality or a better and more accurate monitoring, accompanied by improved analytical capabilities. Diffuse contamination by agrochemicals (and also from solute evaporative concentration in southern areas) is probably the most common cause of negative trends (deterioration).

Occasional high concentrations of some natural components in groundwater may sometimes make surface water preferred for human supply, despite greater vulnerability to pollution and more rapid degradation.

Suitable information concerning groundwater and its baseline quality will be acknowledged by users and will help them to interpret existing information correctly and be aware of commercial interests, such as the promotion of water purifiers or bottled water advertising.

The reaction of entities and people when limits/guidelines are exceeded refer mostly to financial considerations and technical conditions. If defensive monitoring (early warning) was employed within the well catchment areas, some problems could be redressed.

EU directives are generally welcomed and are considered as both adequate and essential to ensure stabilization and improvements in aquifers. But it would be better if they addressed more real problems and provided practical solutions to the actual situations.

Professional hydrogeologists are not numerous, and they are mostly employed in private consultancy and in some regulatory agencies rather than in water companies and groundwater developments. However, many well-qualified graduates in hydrogeology are looking for the opportunity to apply their knowledge.

3.3. Main results with respect to groundwater management issues related to baseline quality

Groundwater quality sustainability is a key issue and a long-term business. Both public and private entities are concerned that good quality groundwater is being impacted and that good quality groundwater reserves are too often used for purposes which do not need that kind of high quality. This matter should be the subject of public information and also of more studies, planning and regulation, with clear support for protecting and reserving high-quality water – including palæowater – for drinking purposes. This means that groundwater abstraction for different purposes should be managed, e.g. by water pricing.

The existing knowledge on hydrogeological and technical advantages and problems related to aquifer management are found to be adequate, but policy-makers, managers and large-scale water producers are not fully aware of them. This explains their preference for surface waters. A corporative lobbing for more widespread attention concerning groundwater resources is needed, supported by professional knowledge and expert hydrogeologists.

Threats to groundwater are well known to professionals and therefore there is a clear awareness of the risks. For instance, most water supply companies are working on well-headed protection zones, although progress from one to another may be very different, with variable support from water authorities. Groundwater quality can be improved by a combination of factors that include changes in land use as the broad solution, and better farming practices, in particular, which include improved use of agrochemicals and more efficient irrigation practices in areas with scarce water resources.

Employed professionals are well qualified on groundwater issues and related domains, but no compulsory scheme exists for training technicians, for example, in small drilling companies. Some environmental agencies are currently developing guidance in borehole design, construction and abandonment of wells, but economic criteria are always a very strong factor for companies. There is a need for water industry personnel to better understand on how groundwater occurs, behaves and evolves.

3.4. Main results related to economic issues

Aquifer pollution is considered to be a very important economic issue, but opinions differ on possible ways for financing remediation programs, especially for diffuse contamination cases.

Most drinking water companies are in favour of spending more on guarantying a good enough quality groundwater supply, provided this is recognized by the regulator and that costs are recoverable from end-users. However, the public would expect a lot from any increase in water costs, which often is systematically considered high. Companies doubt that the public is willing to pay more for a better water quality.

It is felt that local/regional regulators should likely be more pro-active in well catchment area protection to prevent the loss of supplies. Water quality regulations are stringent but the application often depends on real circumstances that point differently or lack support.

It was pointed out that groundwater quality should be subsidized partly by users and partly through general taxation, and that this must be put into practice by a Water Agency. The existing differences among the diverse European countries/regions might need a deeper specific study to find common available approaches on this topic. Likely, the common behavior on these aspects might be somewhat changed if fair and proper information were brought out to the final users.

3.5. Main results related to administration and policy issues

Current regulations already cover the main groundwater quality issues, although little evidence is available on how effective their implementation has been. Current regulations should be improved giving a greater weight to specific conditions and technical progress in monitoring and the link with health problems. In this sense, it is expected that the European WFD and the future Groundwater (Daughter) Directive will improve protection and management of aquifers and will highlight the areas in which rules are currently lacking, especially where toxicological data are sparse and where responsibilities are not clear.

The strong influence that some water authorities/regulators already have on groundwater management is sometimes perceived as helpful by public associations, domineering by private companies and even excessive by some irrigation groups. But they all agree that they do have a role in promoting groundwater sustainability. Their activity is often seen as primarily reactive and disrupted by insufficient resources. Water quality problems are on the increase and need intermediate-term action, while the staff mostly deals with daily problems and emerging issues. At the same time, increasing bureaucratic complexity tends to make decision-making a slow process, sometimes separated from real problems.

It is not well defined whether society is openly prepared for regulations that assign diverse groundwater resources to different uses according to its baseline quality, particularly on the practical aspects. Public awareness of water/environmental issues should be improved, including dialogue and involvement between the public served and the supply companies.

Diverse issues are specifically expected or needed from the European WFD. Enforcing the existing and the new regulations would lead to a better assessment of groundwater resources and their quality, maybe through the creation of a European Water Authority. A higher representation from the public seems to be felt. Also, river basin districts, with effective surface–groundwater integration, are considered to be another useful tool. A real, transparent and holistic view of costs and their application (who pays) is needed. The water price should reflect the true cost, and the European Union must be more involved in this. However, water companies from new country members are asking for substantial financial aid from the European Union. The same is for farmers.

Improved research and setting clear goals are pointed out as important, together with some other technical proposals, such as regulating laboratory capabilities.

3.6. Main results related to groundwater quality monitoring

Monitoring is considered an essential element of groundwater quality assessment programs. Several different organizations are commonly involved to some extent in this issue at national, regional and local levels. The multiplicity of aims and activities lead to several approaches, densities and protocols for network design and development, even for the same aquifer. But very little sensitivity toward groundwater in the high levels of public management is not unusual, failing to consider the uniqueness each aquifer features, which condition its effective use and protection. This complex situation leads to a certain confusion related to what should be monitored and how frequently, and this is an issue to be addressed within a national and/or European strategy.

Professional advice is needed on what should be monitored, because this may differ from aquifer to aquifer and basin to basin, depending on the local situation within each country/region. To understand changes in groundwater quality, the practice of monitoring with limits and thresholds adjusted to regulated values have to be substituted for more wide-scope practices. Modern analytical methods allow very low detection limits to be reached, providing an early warning of changes, not just the ''less than'' values set by drinking water standards. A series of indicators elements/species need to be agreed and prioritized to include major ions, key trace elements, microbiological components and some microorganics, to be monitored across the surveillance network with the same frequency. Particular attention should be given to specific techniques to know residence times, such as isotope techniques. This should be suitable for identifying both changes in baseline quality as well as pollution impacts.

Adequate operational procedures and the maintenance of high-quality monitoring programs, including early warning of groundwater changes, will require important financial resources. Their cost effectiveness depends more on the actual importance of aquifer use than on aquifer size.

Even though a wide range of tools and sampling devices are commonly applied, usually the simplest are used, and most are used to obtain water samples for common laboratory analyses. More elaborated devices are used only for special and research studies. Similarly, just simple technologies are applied for well construction and none for their abandonment, although actual practices depend greatly on the particular conditions of each borehole and aquifer.

4. Conclusion

To know the end-users point of view on baseline quality of groundwater, a specific questionnaire was drafted and sent to a necessarily reduced number of experts, institutions and companies. The answers contained in the 69 questionnaires finally retrieved were completed and extended when needed by means of direct contacts between the respondents and experts of the BaSeLiNe national teams, plus the results gathered at national meetings and finally in a conjoint workshop with end-users representatives. The direct treatment of data in the questionnaires was interpreted taking into account the abovementioned conditions to distil the main results. The varied background of the people participating in the enquiry allows for a range of viewpoints which make the exercise both interesting and useful.

Everybody agrees on the importance of having and obtaining good quality groundwater, especially for human consumption. But this is often not reflected in practice through effective groundwater management, especially in reference to its protection. This inconsistency is derived from the rather poor knowledge about aquifer properties, functioning and behavior, except for experts who are often not at the decision-making level. This results in poor performance of water authorities and regulatory agencies which lack the human and economic resources and whose hydrogeological mind is too limited. Also, the public, in a too resigned form, tends to accept that the solution to their present and future problems of water contamination is to use bottled water for drinking purposes, as may be deduced from some water advertising. A further factor that makes aquifer management difficult by untrained persons and under short-term goals is the slow reaction of groundwater to external actions implying abstraction and contamination. Decision-making pays more attention to ''urgent'' daily problems and on-the-spot pressure than to aspects that develop slowly, even when they are correctly explained by specialists. Hydrogeologic studies warn against the pervasive risks of groundwater contamination and provide well-documented case studies. But there are exceptions, either at local or national levels that show how to deal with current situations and risks as well as how to face future problems.

Long-term objectives for aquifer management are a desirable social goal but this contrasts with the short-term interests of most traditional water organizations.

Institutional aspects are not only one of the weaknesses of aquifer management but also the effective participation of water users. This participation is seen as positive but not all respondents are sure of the benefits. Public information is also seen as a possible contribution to correct groundwater management, but it is not unanimous.

Aquifer monitoring is considered a key tool for groundwater protection. It must be developed technically, paying attention to automatic equipment, making it more applicable and economically friendly for water companies, such as what took place years ago for surface water. But this equipment has to be purpose-designed, taking into account the very different circumstances of groundwater with respect surface water. The role of the European Union is in integration and standardization. On technical ground, this means the need to define the minimum requirements for aquifer monitoring by means of adequate guidelines. Financially, this entails devising some support to foster prompt application.

As a result from monitoring, the citizens should receive information that explains the state of the groundwater and how it evolves over time by means of objective approaches that avoid the bias that may be derived from commercial, corporate or other interests. Better and sound information from water authorities and water companies will probably, and hopefully, lead to increasing users' involvement in groundwater management affairs.

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