European Commission

DG Environment

Economic assessment of groundwater protection

Impact of diffuse pollution of the upper Rhine valley aquifer

Case study report No. 2

A project financed by the European Commission

ENV.A.1/2002/ 0019

May 2003

BRGM/RC-52325-FR

European Commission

DG Environment

Economic assessment of groundwater protection

Impact of groundwater diffuse pollution of the upper Rhine valley aquifer

Case study report No. 2

A project financed by the European Commission

ENV.A.1/2002/0019

Jean-Daniel RINAUDO

May 2003

BRGM/RC-52325-FR

Géosciences pour une Terre durable

brgm

Keywords : Economics. Environmental costs. France. Groundwater directive. Nitrate. Pesticides. Pollution.

This report will be quoted as follow :

> Rinaudo, J-D. (2003) – Economic assessment of Groundwater Protection : impact of groundwater diffuse pollution of the upper Rhine valley aquifer. Case study No. 2. Report number BRGM/RC-52325-FR, Orléans: BRGM.

Abstract

This report presents the results of a case study conducted in trans-boundary alluvial aquifer located between Germany and France and which is severely affected by diffuse nitrate and pesticide pollution. The increasing nitrate and pesticide concentrations have generated significant costs for economic sectors using groundwater. The objective of this case study is to describe the economic damages due to diffuse pollution and to assess the related cost in monetary terms.

The report presents the results of a survey conducted in the French part of the aquifer (the Alsace Region) to identify drinking water utilities (DWUs) which have been affected by nitrate and/or pesticide pollution during the last 15 years. Three different sources of information were used : (i) a review of the press coverage by the local newspaper; (ii) a consultation of the archives of the major public institutions which finance the development of the drinking water sector and (iii) face to face interviews conducted with 22 drinking water utilities (in April 2003).

The survey has lead to the identification of 28 DWUs which have been severely affected by pollution and compelled to undertake investment programmes to achieve quality standards of the Drinking Water Directive. Different type of strategies implemented by DWUs are identified; the total investment cost is estimated at € 26.4 million over the last 15 years. Other costs born by the industry are also identified and illustrated though the case of a very large brewery which has to treat groundwater before using it at a very high cost.

We then assess the potential future costs of pollution, assuming that the pollution trend be continued for an additional 20 years. The scenario shows that 37 DWU (out of 89 using water from the alluvial aquifer) could be affected by diffuse pollution by 2020, generating an additional costs estimated at € 5.9 million per year.

Table of content

1. INTRODUCTION...6

2. CONTEXT, OBJECTIVE AND METHODOLOGY...6

2.1. AGRICULTURAL PRESSURES AND IMPACT ON GROUNDWATER... 6
2.2. OBJECTIVES OF THE CASE STUDY 8
2.3. METHODOLOGY 9

3. SENSITIVITY AND RESPONSES OF WATER USERS TO NITRATE AND PESTICIDES ..9

3.1. DRINKING WATER SECTOR 9
3.2. URBAN WATER USERS.. 12
3.3. INDUSTRIES.. 12

4. SOCIO-ECONOMIC IMPACT OF DIFFUSE POLLUTION ON THE DRINKING WATER SECTOR OVER THE LAST 15 YEARS...13

4.1. IMPACT ON DRINKING WATER UTILITIES.. 13
4.2. IMPACT ON HOUSEHOLDS.. 15
4.3. IMPACT ON INDUSTRIES... 16
4.4. SENSITIVITY THRESHOLDS... 16
4.5. LOOKING TOWARDS THE FUTURE 17

5. CONCLUSION 18

6. REFERENCES 18

List of Maps and Tables

Map 1 : Nitrate concentration in the upper Rhine valley alluvial aquifer in 1997 (source : Région Alsace, France) and location of DWUs and drinking water wells (Source BRGM).____ 8

Table 1: Number of DWUs severely affected by nitrate and/or pesticide pollution over the last 15 years and population concerned.____ 13

Table 2: Type of solutions adopted by DWUs in response to the pollution by nitrates and/or pesticides.____ 14

Table 3 : Total investment generated by non point source pollution per type of pollution (period 1988-2002). Source : Région Alsace____ 15

Table 4 : Total investment generated by non point source pollution per type measure implemented (period 1988-2002). Source : Région Alsace____ 15

1. Introduction

This report presents the results of a case study conducted in the upper Rhine valley aquifer, a trans-boundary alluvial aquifer located between Germany and France. This aquifer extends over 4200 square kilometres. With a reserve of approximately 45 billions cubic meters of water, that is approximately half of the volume of the Lake Geneva, this aquifer is one of the largest fresh water reserves in Europe. Groundwater from the Rhine alluvial valley fulfils 75% of the drinking water needs and about half of the industrial water needs. More than three millions inhabitants of the Alsace Region (France) and the Land of Baden-Württemberg (Germany) directly depend on this resource for their water supply.

Since the 1970's, the regular monitoring of groundwater quality has revealed that the aquifer is increasingly affected by diffuse nitrate and pesticide pollution. The increasing nitrate and pesticide concentrations have generated significant costs for economic sectors using groundwater. The objective of this case study is to describe the economic damage due to diffuse pollution and to assess the related cost in monetary terms.

The report presents the results of a survey conducted in the French part of the aquifer (the Alsace Region). It identifies 28 drinking water utilities (DWUs) which have been affected by nitrate and/or pesticide pollution during the last 15 years and describes the responses adopted by these DWUs. The total cost generated by non point source pollution is also assessed. Other costs borne by other economic agents are also identified and described qualitatively.

The first section of the report presents the pollution problem (agricultural pressures and their impact on groundwater quality) and the methodology adopted. The second section describes the sensitivity and observed responses of water users to rising pesticide and nitrate concentration. The third section estimates the costs of non point source pollution borne by DWUs during the last 15 years. A concluding section then highlights the implication of the case study for the groundwater directive.

2. Context, objective and methodology

2.1. AGRICULTURAL PRESSURES AND IMPACT ON GROUNDWATER

- **Intense agricultural pressure**

Intensive agriculture is mainly responsible for non point source pollution of the upper Rhine valley alluvial aquifer.

On the French side of the aquifer in particular, agriculture is one of the pillars of the regional economy. With more than 15000 farms, out of which more than half are classified as "professional farms" (i.e. more operating more than 12 hectares and employing at least ¾ full time person), the farming sector of Alsace generates a total turn over of € 894 millions and a total added value estimated at € 722 million (Source : Agreste – Agricultural Statistics). It also supplies raw material to a well developed food and beverage industry, which is producing high added value products and represents a flagship of the regional industry.

Vine and cereals and the two major crops cultivated in the Alsace region. Overall, cereals occupy more than 182,000 km², comprising 134 000 ha of maize out of which

48 000 are irrigated. Wheat only represents 40 000 ha. Vines cover an area of 15 000 ha but it is the main production for 30% of the farms.

The two major crops (maize and vines) are using high levels of inputs (fertilisers and pesticides) and thus represent a significant (although not the sole) source of diffuse pollution of groundwater. This is illustrated by the fact that areas where groundwater shows high nitrate concentration levels correspond to areas where mostly maize or vine are grown.

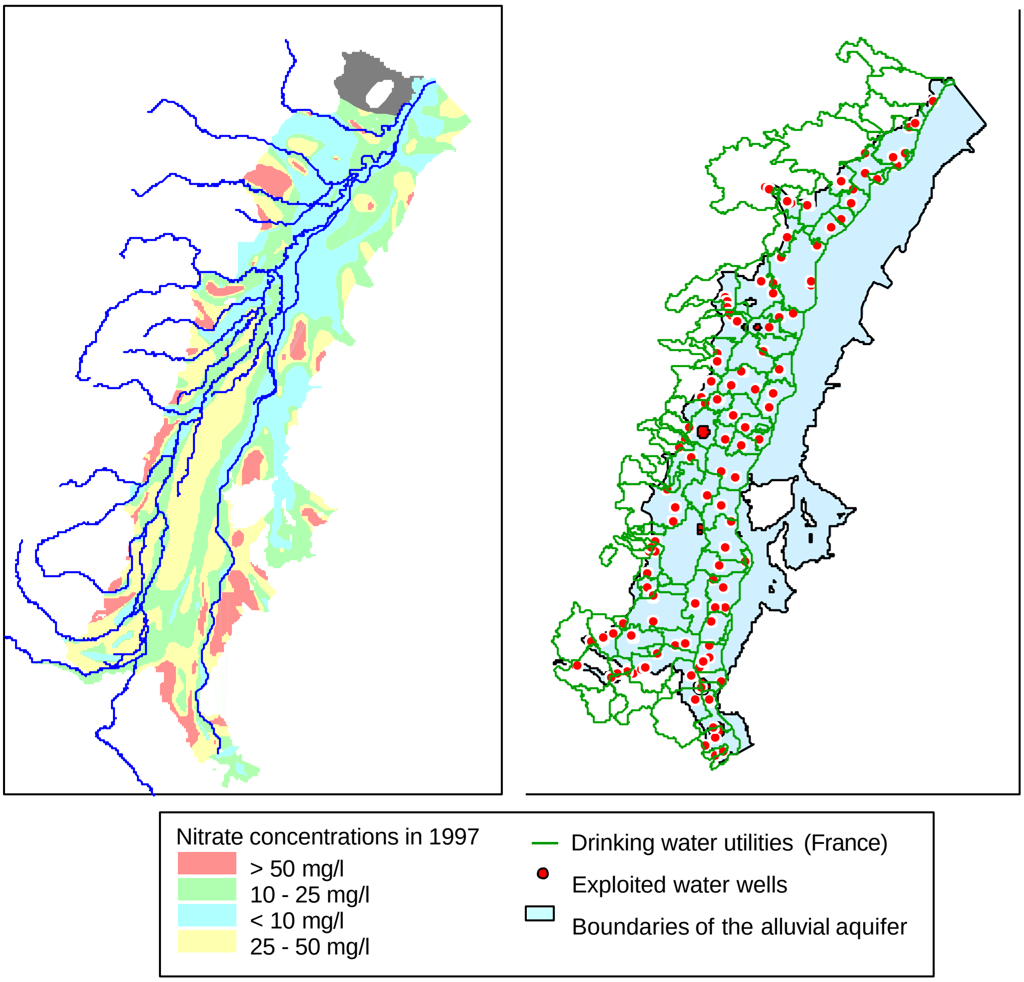
The pressure exerted by agriculture on the water resources is likely to continue increasing, in spite of significant efforts made by the farming lobby to adopt more environmentally friendly practices. The analysis of recent trends shows that the cropping intensity is on the rise whereas the area occupied by grassland systematically declines. The comparison of the two last agricultural census (1988 and 2000) shows that the area under vine has increased by 13%, the area under maize by 60% whereas area under wheat and grassland decreased by respectively 25% and 13%.

♦ **Increasing nitrate and pesticide concentration**

The development of an intensive agriculture described above has resulted in increasing nitrate and pesticide concentration in the underlying alluvial aquifer which represents one of the largest fresh water resources in Europe.

The nitrate pollution problem is particularly acute an the two countries are equally concerned. While the nitrate concentrations were lower than the drinking water standard in the entire aquifer in the early 1970s, values now exceed 50mg/l in 8% of the aquifer area on the French side and 10% on the German side (Map 1). Overall, approximately 15% of the 1100 monitored points show nitrate concentration exceeding 50 mg/l (13% of the 740 monitored points on the French side and 22 of the 315 points on the German side). And the European guide value of 25 mg/l is exceeded in 36% of the monitored points. The largest pollution plume, extending in the central plain of Alsace (from South to North), corresponds to the most intensive agricultural area where almost only maize is grown. Nitrate concentrations are also high in vine areas where the aquifer is relatively thin: in such areas, pollution tends to concentrate as the dilution rate is small.

Pollution by pesticides (in particular herbicides) is another very significant source of concern (Région Alace, 2000). The presence of herbicides in groundwater is mainly due to agricultural practices (intensive use for maize and vine crops) but the pollution also originates from other sectors using herbicides, and in particular road and railway maintenance services and households (gardens). On the French side of the aquifer, atrazine and its metabolite (desethyl-atrazine) are the most frequently encountered molecules: the presence of these substances is detected in respectively 59% and 63% of the monitored points (in 1996-97). Concentrations exceed the drinking quality thresholds (0.1 µg/l) in 13% and 17% of the samples for respectively atrazine and desethyl-atrazine. The pollution is less severe on the German side. However, although the use of atrazine has been banned since 1991, this substance is still found in 40% of the monitored points, with concentration exceeding the drinking water thresholds in 4% of the samples. Desethyl-atrazine is found in 43% of the samples, with concentration exceeding the drinking water threshold in 8% of the samples. The presence simazine, desisopropyl-atrazine and diuron is also reported in respectively 21%, 13% and 6% of the samples (France and Germany), with concentrations exceeding the drinking water thresholds in respectively 2%, 3% and 2% f the samples.



Map 1 : Nitrate concentration in the upper Rhine valley alluvial aquifer in 1997 (source : **Région Alsace**, France) and location of DWUs and drinking water wells (Source BRGM).

2.2. OBJECTIVES OF THE CASE STUDY

Since the water supply of more than three million inhabitants depend on this aquifer, the degradation of its quality has generated significant costs. The objectives of this case study consist in:

(i) characterising the nature of these costs;

(ii) assessing the total expenditures generated by diffuse agricultural pollution during the last 5 years; identifying costs borne by other water users (industrial users, households);

(iii) characterising the sensitivity of water users, that is identifying the threshold values above which additional costs are generated by pollution;

(iv) assessing what could be the future costs if the pollution trend is continued over the next 20 years.

For data availability constraints, the case study only focuses on the French part of the aquifer. All the information reported below therefore only refers to the French Alsace Region.

2.3. METHODOLOGY

The following methodology, consisting of four major steps, was developed and implemented.

- Firstly, we consulted the archives of three major public institutions that partly finance the development of the drinking water sector. This work, conducted with the financial support of **Région Alsace**, enabled us to identify a number of public water utilities that have been affected by non-point source pollution by nitrate and pesticide in the recent past (last 15 years). The result of this census was then cross-checked with a review of the press coverage by the major local newspaper.
- Secondly, we conducted a series of interviews with staff from 22 public water utilities affected by nitrate and/or pesticide pollution. The interviews addressed the customers' sensitivity to nitrate and pesticide pollution, the pollution problems faced in the past and the solutions adopted, the avoidance strategies adopted by water users as a reaction to nitrate and pesticide pollution, and their "vision" of future groundwater quality.
- The third step consisted in assessing costs other than those born by public water utilities. Several food and beverage industries were interviewed and one was chosen for an in-depth case study to assess the cost generated by nitrate pollution for that specific industry. The costs borne by households who increasingly purchase bottled water (or install filtering devices) were also assessed and compared to those borne by the public water utilities.
- The fourth and last step consisted in developing a scenario. Assuming that the nitrate and pesticides concentration in groundwater would continue to rise (due to the inertia of groundwater systems), we estimated the possible future cost of pollution for the drinking water sector.

3. Sensitivity and responses of water users to nitrate and pesticides

3.1. DRINKING WATER SECTOR

The Drinking Water Utilities (DWUs) affected by pollution have developed different responses, depending on their constraints and objectives. The following sections presents a typology of the observed responses.

♦ **Desertion of the polluted water well without replacement**

The first observed response consist in reducing (or even stopping) the exploitation of the water well affected by the pollution and to increase the abstraction from other resources. This strategy is only feasible when the DWU has access to different resources (wells, springs) and when the total capacity of the wells exceeds the current water needs. It is generally adopted by DWUs which assume that the pollution of the concerned wells can be reversed. This is for instance the case of Mulhouse DWU which has temporarily stopped the exploitation of its boreholes located in the Hardt forest but keep operating them a few hours a week in order to maintain them operational.

The temporarily stopping of a well represent a cost for the DWU since the capital invested in the well is “frozen” (opportunity cost). Theoretically, this cost can be assessed by multiplying the residual value of the investment (water well) with an average interest rate. This strategy also increases the vulnerability of the DWU to accidental pollution because the drinking water supply, which was previously secured due to the presence of several independent wells, then become fully dependent on a single resource.

- **Replacement of polluted drinking water wells with a new well**

The second observed response consists in replacing the polluting well with a new resource. While some DWUs construct new well, others prefer to hook-up on a neighbouring DWU’s distribution network and purchase water from it. The polluted well can either be totally abandoned (pumps removed an well disconnected from the network) or be maintained operational in view of possible future use if an improvement of the situation is anticipated.

When the DWU decides to construct a new well, the total cost includes that of (i) the preliminary study to select a favourable site, (ii) the drilling of a reconnaissance borehole, (iii) the drilling, casing and equipment of the borehole, (iv) the connection of the well to the distribution network (possibly including the restructuring of the distribution network) and (v) the establishment of a perimeter (sfeguard zone) in the catchment area of the well. When the DWU decides to hook on a neighbouring DWU, the cost is mostly that of the pipes that have to be installed and the cost of a pumping station, if the topography imposes it. The choice of this strategy also implies to purchase water from the supplying DWU at a price that frequently exceeds what the DWU would have to pay if operating its own well. In fact, the connection to neighbouring DWU seems to be envisaged by many DWUs as a temporary solution waiting for the recovery of groundwater quality in the polluted well catchment area.

- **Dilution of water extracted from the polluted water well**

The third response consists in continuing exploiting the polluted well and mixing the water it produces with better quality resource, so that the blend meets the drinking water standards. When the concerned DWU has access to different water resources, the dilution of polluted water can be carried out within the DWU; this frequently requires that the distribution network be restructured so that water abstracted from the different sources can be mixed in a single tank before being distributed. When the DWU does not have access to other water resources, it has to import water from a neighbouring DWU to mix it with water abstracted from the polluted well. As mentioned above, this generates important investment costs (construction of a pipeline to connect the two DWUs) but also additional operational costs (pumping costs to import water, cost of water purchase).

The case of DWUs located in the Vosges foot-hills is a good example of that strategy. Most of the DWUs located in the foot hills rely both on one or several wells abstracting (frequently polluted) water from the alluvial aquifer and on springs located in the hills. Since groundwater abstracted from the alluvial aquifer is increasingly polluted (by nitrate in particular), these DWUs undertake significant investments to increase the volume of water recovered from the springs (in particular works to improve the catchment of the springs and to reduce leakage on the pipes that bring water from the spring to the municipalities). Water from the springs is then mixed with the polluted water abstracted from the wells. Since the discharge of the springs vary over time during the year, the average quality of the water which is distributed (blend) is also fluctuating.

- **Construction of treatment plants to remove pollutants**

The fourth response consists in treating water to remove nitrates (ion exchange resin technology), pesticides (active coal filters) or both (reverse osmosis, combined systems). This solution can be adopted when nitrate and/ or pesticide concentration regularly exceeds the drinking water thresholds and when no alternative resources can be substituted to the polluted well. Although this option is always considered in studies conducted by consultants, DWUs are reluctant to adopt it for three main reasons: firstly, the investment cannot be subsidised by financial institutions (whereas the construction of a new well or the connection with another DWU can be subsidised up to 80% of the total cost); secondly, the operation an maintenance costs are rather high (0.15 to 0.3 €/m3); thirdly, the technology available is not adapted to small DWUs. In the Alsace Region, we only found one DWU having adopted this solution (construction of a nitrate removal plant). Three other DWUs have, however, also decided to install active coal filters to remove pesticides (first three cases reported in 2002 and 2003).

- **Changes of agricultural practices in the well catchment area**

The fifth response to diffuse pollution consists in implementing measures aiming at reducing agricultural pollution at the source in order to avoid that expensive investments be undertaken (construction of a new well or of a water treatment unit, connection with another drinking water utility). These measures generally consist in changing agricultural practices in the catchment area of the well. Farmers are offered a financial compensation for reducing the level of organic and chemical fertiliser use. They a also sometimes financially incited to plant winter crops such as mustard seeds for instance to reduce the risk that nitrates remaining in the root zone after the summer crop be leached. These compensating measures are formalised through agreements signed between the farmers and the drinking water utility. The amount of the compensation for turning arable land into permanent grass land is ranging between 230 and 460€ per hectare and per year in the Alsace region. They are frequently supplemented by information and awareness campaigns that target not only farmers but also municipal employees (who frequently use herbicides) and the inhabitants (whose gardens also represent a significant source of nitrate and pesticide pollution).

DWU are encouraged to adopt this strategy by two factors. Firstly, the Social Affairs and Public Health administration authorise the DWU who attempt to recover groundwater quality to distribute drinking water which does not comply with the standards imposed by the Drinking Water Directive (as long as the WHO standards are met). Secondly, the financial institutions such as Agence de l'Eau and Region Alsace increasingly subsidise such programmes.

- **Purchase of the well catchment area**

Finally, the survey showed that two drinking water utilities have purchased part or all of the catchment area of their water wells which where affected by nitrate and/or pesticide pollution. The catchment area is then either turned into permanent grass land or forest. This strategy, however, presents some serious drawbacks. Firstly, it entails very high costs in a region where the price of agricultural land is very high. Secondly, it is not always effective as the pollution may come from areas located outside the protected area.

3.2. URBAN WATER USERS

A survey conducted by the University of Strasbourg for the Région Alsace between 1995 and 1997 has shown that citizens are increasingly aware of the pollution that threats the quality of the aquifer of the upper Rhine valley (Masson et al., 1999).

The results of the interviews conducted as part of the present study with staff of DWUs also reveal that a large percentage of the population is either drinking only bottled water and/or has installed filtering devices at home. The persons interviewed estimate that more than half of the population does not drink bottled water and that an additional 10 to 15% uses filtering devices at home. Most of the interviewees think that this change in household behaviour is mainly due the coverage, by local media, of the debate that has taken place during the last decade around the problem of diffuse pollution of the aquifer. They also attribute this change to other sources of pollution and in particular to chlorinated solvents that have caused problems to several large DWUs (Mulhouse, Strasbourg, Colmar, Erstein, Chatenois, etc.) and to the chloride by the potash mining field (see case study report No. 1).

It can therefore be considered that groundwater pollution by nitrates and pesticides has generated significant expenses for households (bottled water purchase, installation of filters at home). The amount of these expenditures is assessed in a following section.

3.3. INDUSTRIES

- **The case of industries having their own water supply**

The sensitivity of industries to nitrate and pesticide concentration varies depending on the role of water in the production process. For certain industrial branches, such as electronics, pharmacy or chemistry, the industrial process requires an extremely pure water. This imposes to treat water (reverse osmosis or distillation) whatever water quality might be. In such cases, the production cost is not affected by the presence of nitrates and/or pesticides since water has to be treated in any case.

The situation is very much different for other branches such as the food and beverage industry which use water as a basic ingredient and are therefore very sensitive to the presence of nitrates and pesticides (the drinking water standards apply to the food and beverage industries). For these industries, the pollution of groundwater generates costs as they either have to abandon their well or treat the water. In some very rare cases, the industry may decide to drill a new well; this however entails very high costs as the well must be drilled far away from the place where the industry is located. More frequently, the industries shift from their own well to the public water supply which generates investment costs for the industry but also for the drinking water company who might have to restructure entirely its distribution network depending on the total demand of the industry

- **Industries using public water supply**

Industries which rely on public drinking water supply may also suffer economic damage if water quality deteriorates. This is the case, for instance when the quality deteriorates from a very good status (e.g. nitrate concentration smaller than 25 mg/l) to a poor status (40 to 50 mg/l) : water remains drinkable and nothing prevents the DWU to distribute it but the quality is not sufficient for the industries which has more stringent quality standards. An example is breweries which cannot use water for beer production if the nitrate concentration exceeds 25 to 30 mg/l [1].

4. Socio-economic impact of diffuse pollution on the drinking water sector over the last 15 years

4.1. IMPACT ON DRINKING WATER UTILITIES

♦ **Number of DWU and population concerned**

The research work conducted by BRGM for the Région Alsace, complemented b the interviews conducted for the European Commission as part of this study, have enabled to identify 28 drinking water utilities severely affected by nitrate and pesticide pollution during the last 15 years. By DWU severely affected by pollution, we refer to those who have been compelled to undertake at least one of the measures described in section 2 to cope with the raising nitrate and/or pesticides concentration. Knowing that only 89 DWU exploit the alluvial aquifer of Alsace, it means that more than 30% of the DWU are concerned[2].

As shown in the following figure, these 28 DWU supply water to 177 municipalities representing a total population of 432 000 habitants. Nitrates are the major cause of economic cost for DWUs, with 16 DWUs severely affected (over the 15 years period) whereas only 7 have been concerned by pesticide pollution, and 5 by both nitrates and pesticides.

		Nitrates	Pesticides	Nitrates + pesticides	Total
Alsace	DWUs	16	7	5	28
	Municipalities	75	80	22	177
	Inhabitants	141 026	82 346	208 731	432 103

Table 1: Number of DWUs severely affected by nitrate and/or pesticide pollution over the last 15 years and population concerned**.**

♦ **Solutions adopted by the DWUs**

The following table gives an overview of the solutions which have been adopted by the DWUS in response to nitrate and pesticide pollution.

[1] This is due to the fact that the biological activity of the yeast raises the nitrate concentration by 15 mg/l. If the water used contains 35 g/l, the final product will contain, at the end of the process close to 50 mg/l.

[2] Moreover, additional DWUs are affected by other types of pollution such as chlorinated solvants (from industrial point sources) and chloride (from the potash mining field).

Solution adopted	Total
New water wells	11
Changes of farming practices	11
Interconnection to another DWU	7
Renovating springs	2
Treatment	1

Table 2: Type of solutions adopted by DWUs in response to the pollution by nitrates and/or pesticides.

Among the strategies described above in section 2, constructing a new well to replace the polluted one is the most frequently adopted solution (11 cases). This solution is preferred to connecting the network to another DWU and purchasing water from this DWU (only 7 cases). One reason explaining this is that most DWUs, lead by local politicians, want to remain independent from their neighbours, in some cases for political reasons, in other cases by fear that the DWU supplying water could raise the price of water once the connection is made.

Measures that consist in changing farming practices in the well catchment area have also been widely adopted although all did not lead to positive results. In only 4 cases have they been implemented alone, whereas in all others (7 cases) , they have been combined with the construction of new well or the connection to another network. In such cases, the measures are implemented to recover groundwater quality in view of reusing the well in the future, once the problem has been solved. In two other cases, the DWU has purchased all the agricultural land lying within the catchment area and transformed them into safeguard areas (grassland and forest).

Only one DWU has installed a nitrate removal treatment unit in response to the pollution. This choice was probably made because all the alternatives were not viable : firstly, no area was found where to drill a new well (presence of roads and other point source pollution risks, intense diffuse pollution); secondly, all the neighbouring DWUs also has water quality problems. In other cases, the staff of DWUs that we interviewed stressed that nitrate removal equipment was not adapted for small municipalities, neither from an economic point of view nor from a technical point of view (complex maintenance). The interviews have also revealed that several DWUs affected by pesticide pollution were planning to invest in filtering devises (active coal filters) which are relatively cheaper and easier to operate and maintain.

- ♦ **Investment made in the water sector to cope with nitrate and pesticide pollution**

Nitrate and pesticide pollution has generated € 26.4 millions expenditures (constant 2001 €) for DWUs using the alluvial aquifer of the upper Rhine valley in France. More than three quarters (77%) of these expenditures are due to nitrates, 16% are linked to the presence of both nitrate and pesticides whereas 7% are due to pesticide only. The construction of new water wells and the interconnection of network represents respectively 54% and 25% of this amount. The cost of other measures only represents 16% of the total cost and studies 5%.

	Nitrates	Pesticides	Nitrates & pesticides	Total
Total cost in constant € (millions)	20.2	1.9	4.34	26.4
in % of total cost	77%	7%	16%	100 %

Table 3 : Total investment generated by non point source pollution per type of pollution (period 1988-2002). Source : Région Alsace

		Total (M€)
New well		14 .2
Interconnection		6.7
Changes in farming practices		2.5
Studies		1.4
Treatment plants		0.8
Renovating springs		0.7
Total	en € constants	26.4
	en % du total	

Table 4 : Total investment generated by non point source pollution per type measure implemented (period 1988-2002). Source : Région Alsace

4.2. IMPACT ON HOUSEHOLDS

In the previous section, we showed that nitrate and pesticide pollution was partly responsible for an increase in bottled water consumption by households. To assess the additional cost generated by households, we used the results of public opinion polls conducted at the national level (no existing information at the regional level).

The national public opinion polls conducted by several independent institutes all confirm that households trust in tap water has declined sharply during the last decade. Although 70% of the French households declare trusting their tap water (CIEAU, 2000), they are fewer to drink it. According to a CIEAU (2000), 64% of the French drink bottled water several times a week and 28% several times a day. Others install filtering devices at home (7% according to a public opinion poll by the institute PSOS for the Water Company Lyonnaise des Eaux). According to CIEAU (2000), only 12% of the households who declare using bottled water are explaining their choice by the fear of the presence of nitrates and / or pesticide in tap water.

Concerning the case of the Alsace Region, we made the following assumptions :

- Approximately 70% of the inhabitants receiving tap water pumped in the aquifer do consume bottled water (925 000 inhabitants) ;
- The fear of the presence of nitrates and pesticides in tap water only explains 12% of the consumption of bottled water;
- The “average” bottled water drinker purchase 1.5 litre per day; assuming only spring water is purchased at an average price of 0.5 €, the yearly expenditure is 280 € / person.

As a result of these assumptions, the total annual expenditure for the 925 000 inhabitants concerned is assessed at € 31 millions (en 2002). Moreover, assuming that the consumption of bottled water has linearly increase from 10% in 1970 to 70% in 2002, the total annual cost over 15 years is thus assessed at **266 M€** (in constant 2001 €).

4.3. IMPACT ON INDUSTRIES

Assessing the cost of pollution for the industrial sector is a real challenge as this would suppose to access to private accounting data. We here present one case study that should only be understood as an illustration of the type of costs born by the industry.

The case study focuses on a very big brewery established in the region for more than a century and producing approximately 40% of the volume traded on the French market. The brewery consumes (yearly) 3.5 millions cubic meters of water pumped in the alluvial aquifer through private wells. Since the end of 1980, the nitrate content of water has exceeded 35 mg/l which is the maximum concentration acceptable for the production of beer. This has compelled the industry to install a first nitrate removal plant in 1991 (ions exchange resin system) and a second one in 2002 (reverse osmosis). Since water extracted from the wells remains drinkable (less that 50 mg/l of nitrate) it continues to be used for washing, cooling and other uses; only 1.5 million m3 are treated every year.

The construction of these 2 treatment unit has required an investment of 7.19 million € (constant 2001 €). Also, the operation and maintenance of these units since 1991 has generated an additional cost estimated at 2.3 M€. Another 0.5 M€ has been spent to conduct studies aiming at finding new groundwater resources that could be exploited to avid the treatment.

Overall, nitrate pollution has already generated more than 10 millions € of damage for that industry and the ill could increase very soon since it is expected that a new water well will be drilled in the coming years at a cost of several millions €.

4.4. SENSITIVITY THRESHOLDS

Another important finding that emerged from the interviews was the identification of *sensitivity thresholds*, defined as *pollutant concentration values above which water users are forced to implement a strategy to mitigate the effect of the pollution*.

In the drinking water sector, two thresholds values were identified (through the 22 interviews): 25 and 40 mg/l. When the first threshold (25 m/l) is exceeded, DWUs start to pay attention to and carefully monitor the evolution of nitrates in the groundwater they pump. The second value represents a threshold beyond which the decision is generally taken to drill a new water well or hook up to a neighbouring DWU. From an economic point of view, this means that **the damage occurs before 50 mg/l are reached**. The attitude towards pesticides is slightly different because the government agency that monitors drinking water quality allows DWUs to distribute water even if its concentration in pesticides exceeds 0.1 µg/l (water is considered as safe up to 0.4 µg/l).

In the industrial sector, these threshold values vary significantly from one activity to another. For example, breweries need water containing less that 20 to 25 mg/l of nitrate to produce beer under optimal conditions because the other ingredients used to produce beer (namely malt and hops) are also a source of nitrate. Beer made with water containing 20 mg/l of nitrate will, therefore, contain around 30 mg/l of nitrate at the end of the process. Also, the biological activity of brewers' yeast is optimal for nitrate concentrations ranging between 10 and 25 mg/l. Above this threshold, brewers need to treat water. The sensitivity of the food and beverage industry to the presence of pesticides is even greater. Indeed, most companies have to prove to their customers (supermarkets and other integrated distribution companies) that there is **no**

trace of pesticides in the final product and sometimes even in the water used as an ingredient.

4.5. LOOKING TOWARDS THE FUTURE

The results presented above show that the current strategy adopted by DWUs to deal with nitrate and pesticide pollution consist in finding alternative groundwater resources when the water wells they exploit are contaminated. Water wells are abandoned and others drilled elsewhere in the same aquifer.

However, clear signs show that this strategy is not sustainable. Firstly, some DWUs have already encountered severe difficulties in finding alternative water resources and have been forced to buy water from another DWUs. Secondly, interviews of DWU employees and key policy makers and planners have shown that the siting of new wells is increasingly difficult because of:

(i) the extent of areas affected by nonpoint source pollution (nitrate, pesticides) and point source pollution (solvents, hydrocarbons, chloride from the potash mining field)

(ii) the extension of built-up areas, which are source of potential accidental pollution (roads, industrial areas, etc);

(iii) the presence of numerous domestic landfill sites, downstream of which wells cannot be sited.

In the future (2020), assuming that the economic development of the region (and the consequent increasing use of space) will continue at the same rate, it will soon be impossible to find suitable sites for new water wells. Consequently, if areas polluted by nitrate and pesticides continue to expand, the only option left to DWUs affected by non-point source pollution will be to treat groundwater in order to remove nitrate and/or pesticides.

To estimate the cost of this scenario, we made the following assumptions:

(i) In 2020, nitrate concentration will exceed 50 mg/l in all areas where the concentration of this pollutant currently exceeds 25 m/l. This assumption is justified by the fact that there is a long time lag between the emission of the pollutant and the effective contamination of groundwater (i.e., the pollution level of the aquifer in 2020 will reflect today's farming practices). We also assume that pesticides will be found in most places.

(iv) Technological innovation in the field of water treatment and the adoption of these technologies by a large number of DWUs will lead to a reduction of the treatment cost to 0.15 €/m^3 of distributed water (capital, operating and maintenance costs).

We identified 37 DWUs that will potentially be affected by nitrate and pesticide pollution in 2020. Assuming that the total volume pumped by these DWUs remains constant over time, we estimate that the total volume that might have to be treated in 2020 is **39 million m^3** per year, generating an additional cost of **€ 5.9 million per year**

5. Conclusion

The case study presented in this reports shows that groundwater pollution has already caused significant direct costs for water users. These costs are likely to continue increasing in the coming years because of the high inertia of groundwater systems and because of the continuation of intensive agricultural practices in the area. The trend is only likely to be reversed if economic incentives provided to farmers are altered. Such changes are needed at the European level (changes in subsidies to maize for instance) but also at the regional level where specific practices can be encouraged though well targeted financial compensation programs The fact that certain DWUs have already put in place such compensation programs demonstrate their feasibility.

As a result, more intensive groundwater protection policy seems socially desirable since it is likely to yield significant economic benefits. However, the fact that some of the benefits will be spread over a long period of time whereas costs will be felt immediately may reduce the political support base for the adoption of such a policy. This is particularly true in a region where the agricultural interests are well represented in the local political system. In the same time, evidences of citizens' concern about groundwater quality (Masson et al., 1999) shows that significant support can be expected from the public for a higher protection level of the Upper Rhine aquifer.

Concerning the definition of groundwater quality standards, the case study points out that economic damages can occur before drinking water quality thresholds are reached. For example, Drinking Water Utilities start investing in new infrastructures (new wells, treatment plants) before nitrate concentrations reach 50 mg/l. Similarly, the food and beverage industry suffers damages as soon as traces of pesticides are found in the water they use. "Groundwater quality standards" must, therefore, be lower than the current drinking water standard in order to void that the economic damage takes place.

6. References

Centre International de l'Eau – CIEAU (2000).

Région Alsace (2000). Inventaire de la qualité des eaux souterraines des eaux souterraines dans la vallée du Rhin supérieur. Synthèse et recommandations. Strasbourg: *Région Alsace*.

Masson, S. Verchere, A. Rozan, A. Stenger, A and Willinger, M. (1999) Vers une évaluation de la valeur patrimoniale de la nappe d'Alsace : recensement et mise au point d'une méthodologie. Strasbourg : Université Louis Pasteur and *Région Alsace*.

Rinaudo J-D. (2003). Evaluation du coût généré par la progression des teneurs en nitrates et pesticides dans la nappe d'Alsace sur la période 1988-2002. Report BRGM/RP-52316-FR. Strasbourg: BRGM and *Région Alsace*.

BRGM

WATER DEPARTMENT

Unité Evaluation des Ressources et Milieux Discontinus

BP 6009 – 45090 Orléans cedex 2 – France – Tél. : 33 (0)2 38 64 34 34