NATURAL BACKGROUND LEVELS FOR GROUNDWATER IN THE UPPER RHINE VALLEY

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1. Introduction

The Commission proposal of Groundwater Directive COM(2003)550 developed under Article 17 of the Water Framework Directive (WFD) sets out criteria for the assessment of the chemical status of groundwater, which is based on existing Community quality standards (nitrates, pesticides and biocides) and on the requirement for Member States to identify pollutants and threshold values (TVs) that are representative of groundwater bodies found as being at risk, in accordance with the analysis of pressures and impacts carried out under the WFD. In this context groundwater background values (NBLs) are required as a reference to quantitatively evaluate whether or not groundwater is significantly modified by anthropogenic influences (Nieto et al, 2005).

In the light of the above, in the framework of the EU-Specific Targeted Research Project BRIDGE (Background CRiteria for the IDentification of Groundwater thrEsholds) a scientifically based and generally applicable approach to derive natural background levels for the groundwater and groundwater threshold values was derived. The applicability and validity of this approach is checked in 14 case study areas at the level of aquifer typologies throughout Europe (Wendland et al., 2008), including the Upper Rhine Valley as a transboundary French-German-Suisse case study.

2. General applicable approach for deriving natural background values (NBLs) and threshold values for groundwater (TVs)

In particular groundwater quality in aquifers taking part in the active water cycle (surface-near aquifers) is influenced by anthropogenic inputs, e.g. from agriculture and atmosphere (Campell et al, 2004). Whereas some of these inputs (e.g. pesticides) are a direct indicator of human impacts, most inorganic contents occurring in the groundwater originate both from natural and anthropogenic sources (Plant et al, 2001). This makes it difficult to decide whether an observed groundwater concentration pattern in a certain area is influenced by pollution intakes or still represents an (almost) natural state.

An evaluation of existing approaches for NBL assessment (Kunkel et al., 2004; Chery, 2006; HLUG, 1998; Wendland et al., 2005; Christensen et al, 2000) has shown that preselection methods are appropriate to derive natural background levels on the level of aquifer typologies as defined by Wendland et al., 2008 on the basis of petrographic characteristics.

The basic idea of preselection methods is that there is a correlation between the concentration of certain indicator substances and the presence of anthropogenic influences. The following criteria to preselect the groundwater samples were chosen based on the experiences in several French and German studies on NBL assessment (Kunkel et al., 2004; Chery, 2006; HLUG, 1998; Wendland et al., 2005), where they proofed to be appropriate:

Exclusion of groundwater samples displaying purely anthropogenic substances,
Exclusion of samples displaying concentrations of indicator substances exceeding:
NO3 > 10 mg/ l in oxidized aquifers (O2 > 2 mg/l and Fe (II) < 0.2 mg/l) or
NH4 > 0.5 mg /l in reduced aquifers (O2 < 2 mg/l and Fe (II) > 0.2 mg/l).

The NBLs are defined subsequently for all groundwater parameters as the 90th percentiles (P90) of the concentration distributions from the remaining samples. For substances that are purely synthetic with no natural sources (for example, TCE), NBLs are set to zero.
The threshold values (TVs) get established with reference to the NBLs and a chosen reference standard (REF). The latter may either be a drinking water standard value (DWS), an environmental quality standard or ecotoxicological value (EQS or EToxV). The calculation of threshold values is presented for 3 cases (see figure 3).

Case 1: NBL ≤ REF: If the NBL of a certain substance is below the REF value the TV is set as the concentration in the middle between the NBL and the REF values: TV = (REF + NBL) / 2.

Case 2: NBL<one third of REF: In case the NBL is considerably below the REF-value, the TV is limited to twice the NBL: TV = 2 NBL.

Case 3: NBL ≥ REF: In case the NBL is larger than the REF value, the TV is set equal to REF itself: TV=NBL.

The TV for purely synthetic substances with no natural sources (e.g. TCE) is defined as the detection limit.

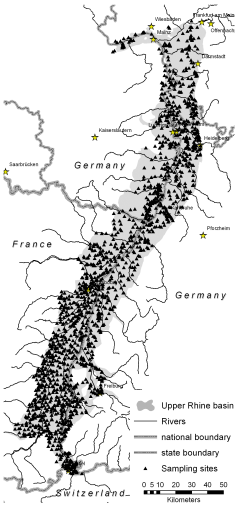
3. Application to the case study area Upper Rhine Valley

The case study area Upper Rhine Valley is a transboundary river basin located between France and Germany with smaller parts in Switzerland. It belongs as a whole to the aquifer typology "fluviatile deposits of major streams" (see figure 1, left part) and represents one of the biggest rift structures in Europe filled up with alternating layers of slit, clay, sand and gravel during the Pliocene and Quaternary period. The total area comprises 9.290 km2. Due to the high population density a variety of anthropogenic impacts on groundwater quality (intensive agriculture, industry, water withdrawal) are present.
In the last years a lot of joint German-French-Suisse projects dealing with the implementation of the EU – WFD have been carried out. In this framework BRGM (France) developed a joint groundwater quality data base, fed by different German, French and Suisse State authorities (BRGM Alsace, LUA Baden-Wurtemberg, LUA Rheinland-Pfalz, HLUG Hessen, Bâle Ville, Bâle Campagne). The access to this data base was guaranteed due to the participation of BRGM (France) and HLUG (Germany) in the BRIDGE - project. Only due to this fact, the data base could be used for evaluating NBL and threshold values and consists of almost 1700 groundwater samples for the years 2002 and 2003 from French, German and Suisse monitoring networks. For each of the monitoring stations one sample containing the solution contents for integral and chemical environment parameters, characteristic major and minor parameters and WFD pollutants was available. However, no information on heavy metals was contained in the data base.
Preselection according to Nitrate (NO3<10 mg/l) has lead to the exclusion of 1094 samples (64 %). Evaluation of the redox status of groundwater has shown that 188 samples indicate reduced aquifer conditions. 35 of those samples were excluded from the NBL derivation because of their high NH4-contents (NH4>0.5 mg/l). In the end 594 groundwater samples remained which are regarded as being appropriate for the NBL derivation in the Upper Rhine Valley.
The right part of figure 1 shows the derived NBL and TV for 14 substances, for which NBLs have been defined and REF values were available. As the last column in the table in figure 1 indicates, that case 1 is typical for TV derivation for most of the investigated parameters (Cl, K, Mg, SO4, LF, As, NH4), i.e. the TV was set to half of the difference between NBL and the REF. For B, Na, NO2, NO3 and PO4, however, parameters, for which the NBL is significantly below the REF value, case 2 was applied. Only for two parameters Mn(II) and Fe(II), the NBL is above the REF value, so that the NBL was regarded to be equal to the TV.

4. Discussion

After data preselection 594 samples have been used to derive the NBL and TV. However, it is essential to compare these values to the situation assessed on the basis of the total data set containing about 1700 groundwater samples. An analysis shows that about 90% to 95% of the 1700 available samples display concentrations below the derived threshold values. In these cases a good status of groundwater can be postulated and no further measures to improve groundwater quality are required.
However, 5 to 10% of the samples exceed the TV. For these cases the reasons for this exceedence need to be checked. The impacts of natural influences, like salinization, redox-conditions, hydrodynamics, which may lead to natural (geogenic) anomalies, as well as of

anthropogenic influences like diffuse and point source pollution must be assessed. If the reasons of exceeding the TV are due to natural influences, the "good status of groundwater" is achieved even in case the TV is exceeded as it can be explained by natural processes. Only in case the reasons are caused by anthropogenic influences, the "good status of groundwater" is failed and measures to improve the status have to be implemented.



Parameter	Unit	P_{90}	Ref	TV1	case	case	case	cas
B	mg/l	0,1	1	0,2	2	2		
Cl	mg/l	84	250	167	1	1		
Fe (II)	mg/l	3,6	0,2	3,6	3	3		
K	mg/l	7,2	10	8,6	1	3		
Mg	mg/l	25	50	37	1	1		
Mn (II)	mg/l	0,82	0,05	0,8	3	3		
Na	mg/l	41	200	83	2	1		
SO_4	mg/l	173	250	211	1	3		
LF	µS/cm	951	2500	1726	1	1		
As	µg/l	4	10	7	1	3		
NH_4	mg/l	0,39	0,5	0,45	1	3		
NO_2	mg/l	0,04	0,5	0,08	2	2		
NO_3	mg/l	8,2	50	16,4	2	2		
PO_4	mg/l	0,17	6,7	0,34	2	2		

Fig 1: Location of sampling sites in Upper Rhine Valley (left) and NBL- and TV- values (right)

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