Hidrogeologija • Hydrogeology • Ãèäðî ãåî ëî ãèÿ

Assessment of natural groundwater concentrations of hydrogeological structures in Germany

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On 23 October 2000, the European Parliament and the Council adopted the Water Framework Directive (Directive 2000/60/EC – *WFD*), which constitutes the basic legislation for management and protection of the aquatic environment in Europe.

An Expert Advisory Forum on Groundwater based on Article 17 of the WFD" (*EAF*) was established to propose measures of groundwater control and protection. These measures should be designed to achieve the objective of a good groundwater chemical status in accordance with Article 4(1)(b) of the WFD. On their session in October 2002, EAF found that "the option to set out a list of quality standards that would be uniformly applied to all groundwater bodies throughout Europe in relation to the definition of good chemical status was withdrawn, owing to the natural variability of groundwater chemical composition and the lack of present monitoring data and knowledge". But the EAF recommends that the member states characterise the good (natural) chemical status of groundwater bodies (hydrogeological structures) in their respective countries independently.

INTRODUCTION

On 23 October 2000, the European Parliament and the Council adopted the Water Framework Directive (Directive 2000/60/EC – *WFD*), which constitutes the basic legislation for management and protection of the aquatic environment in Europe.

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status of groundwater bodies (hydrogeological structures) in their respective countries independently.

Data base of hydrogeological information in Germany

According to the Expert Advisory Forum on Groundwater (EAF), the data bases for regional hydrogeological information are on very different levels, not only in various countries of Europe but also within Germany. There are two important reasons for that situation in Germany.

Firstly, laws and directives on water are the responsibility of the individual states in the Federal Republic. Regional evaluation and measures for control and protection depend on the local state organisations.

Secondly, there are different pragmatic and scientific approaches to groundwater studies in the old and new federal states of Germany. In the former GDR, groundwater was treated as a resource. For an exploitation of groundwater, regional exploration of a watershed was necessary. Groundwater exploitation by waterworks was permitted only on the basis of estimated groundwater resources. In old states of Germany, permission was already given on the basis of pumping test only, without exploration.
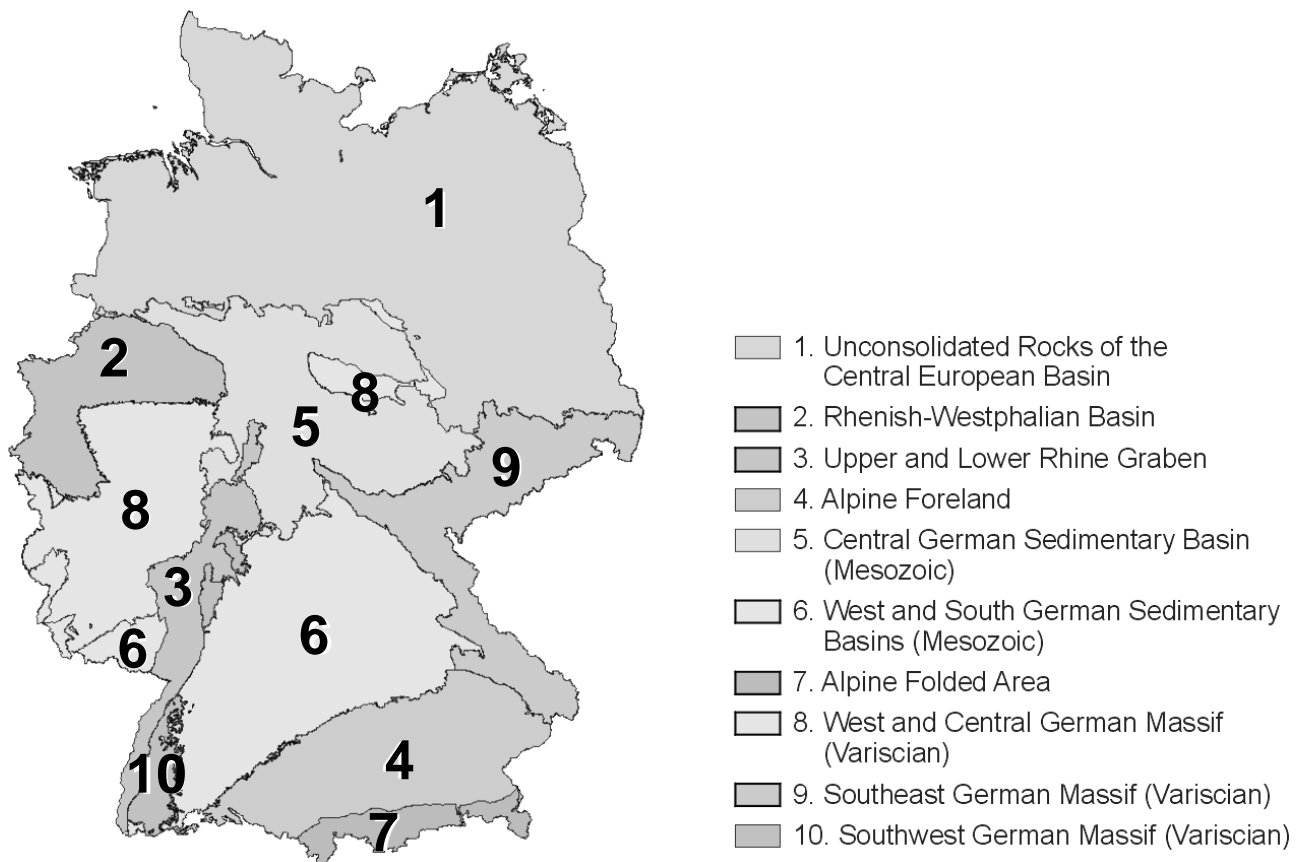
As a consequence of these two reasons, there exists no unified hydrogeological map for the whole country (only for the territory of the former GDR a hydrogeological map to a scale of 1:50000 is available).

No regionalisation of hydrogeological structures and their vertical profiling in the form of a hydrogeological stratification had been done, so there was no possibility of correlation of hydrogeological information across the borders of separate states.

There are no adequate systems for monitoring the level and quality of groundwater in different states.

A solution of these problems is necessary not only for the characterisation of natural chemical groundwater conditions, but also in order to be able to deliver Germany's report to the EU, as required by other articles of the Water Framework Directive (WFD).

This is the reason why a method for hydrogeological mapping was prepared for the first subsurface aquifer for the whole territory of Germany (Hannappel et al., 2001). Work will be finished by the end of this year.

1. Unconsolidated Rocks of the Central European Basin
2. Rhenish-Westphalian Basin
3. Upper and Lower Rhine Graben
4. Alpine Foreland
5. Central German Sedimentary Basin (Mesozoic)
6. West and South German Sedimentary Basins (Mesozoic)
7. Alpine Folded Area
8. West and Central German Massif (Variscian)
9. Southeast German Massif (Variscian)
10. Southwest German Massif (Variscian)

1 pav. Svarbiausios Vokietijos hidrogeologinės struktūros: *1* – Centrinio Europos baseino nekonsoliduotos uolienos, *2* – Reino-Vestfalijos baseinas, *3* – viršutinio ir apatinio Reino grabenas, *4* – Alpiø priekalnė, *5* ir *7* – Centrinës ir Pietvakariø Vokietijos mezozojiniai sedimentacijos baseinai, *7* – Alpiø raukðlëtoji sritis, *8* – Vakarø ir Centrinës Vokietijos hercininis masyvas, *9* ir *10* – Pietryèiø ir Pietvakariø Vokietijos hercininiai masyvai

Fig. 1. Major hydrogeological structure units of Germany

A group of hydrologists was assembled from all State Geological Surveys for the realisation of the tasks connected to the report required by the WFD. As the first step, the hydrogeological regionalisation of entire Germany was carried out by this group (Fig. 1) Ten main hydrogeological structures on the German territory were distinguished. The first group of hydrogeological structures includes unconsolidated aquifers of the Cenozoic age:

1. Unconsolidated Rocks of the Central European Basin
2. Rhenish-Westphalian Basin
3. Upper and Lower Rhine Graben
4. Alpine Foreland.

The second group contains Mesozoic fissured and porous deposits:

5. Central German Sedimentary Basin
6. West and South German Sedimentary Basin
7. Alpine Folded Area.

The third group comprises fissured aquifers of hydrogeological massifs:

8. West and Central German Massifs (Rhine Mountains, Harz, Pfalz Forest, and others)
9. Southeast German Massifs (Ore Mountains, Thuringian Forest, Bavarian Forest, and others)
10. Southwest German Massifs (Black Forest, Odenwald, and others).

Correlation schemes of regional aquifers and aquicludes were prepared for those major hydrogeological structures. Table 1 describes, as an example, the hydrostratigraphic units of the unconsolidated rocks of the Central European Basin, which contain natural groundwater (Manhenke et al., 2001).

By this, the foundations for a correlation of existing hydrogeological data of monitoring and exploration wells were created.

Table 1. **Hydrostratigraphical units of Cenozoic deposits of the Central European Basin**
1 lentelė. **Centrinës Europos baseino kainozojaus uolienø hidrogeologinës stratigrafijos vienetø schema**

| Hydrostratigraphical unit	Lithological specification (dominant)	Lithological / lithogenetic unit	Stratigraphy
C1	Peat, silt, loam	Upland and low-moor peat, turfy moulder, meadow loam, ooze	Holocene
F1	Sand, gravel	Flood-plain sand, dune sand, drifting sand, river gravel, lowland sand, melt-water deposits, spring lime	Holocene, Pleistocene (Vistulian)
C2	Till, loess	Vistulian basal moraines, periflacial deposits	Pleistocene (Vistulian)
F2	Sand, gravel	Melt-water deposits of the Saalian detrital subsequent stage to foreset phase of the Visualian, including spring lime	Pleistocene (Saalian to Vistulian)
C3	Till, silt, clay	Saalian basal moraines, basin deposits	Pleistocene (Saalian)
F3	Sand, gravel	Melt-water deposits of the Elsterian detrital subsequent stage to Saalian foreset phase, river gravel (middle terraces), spring lime	Pleistocene (Elsterian to Saalian)
C4	Silt, clay, till	Lauenburg Clay, Elsterian basal moraines, basin deposits	Pleistocene (Elsterian)
F4.1	Sand, gravel	Melt-water deposits, river gravel, high terraces, younger and older main terraces, upper terraces, decomposed coarse gravel	Pleistocene (Lower Pleistocene to elsterian)
F4.2	Sand, gravel	Melt-water deposits in deep channels	Pleistocene (Elsterian)
F4.3	Sand	Kaolin sands, micaceous fine sands of the Pliocene and Upper Miocene, sands of the Rauno strata	Tertiary (Pliocene, Miocene)
C5	Clay, silt, lignite	Upper micaceous clay, 1st and 2nd Lusatian lignite seam horizon, silts of the Rauno strata	Tertiary (Miocene)
F5	Sand	Upper lignite sands / marine sands, sands of the Oxlund strata, lower Brieske sands	Tertiary (Miocene)
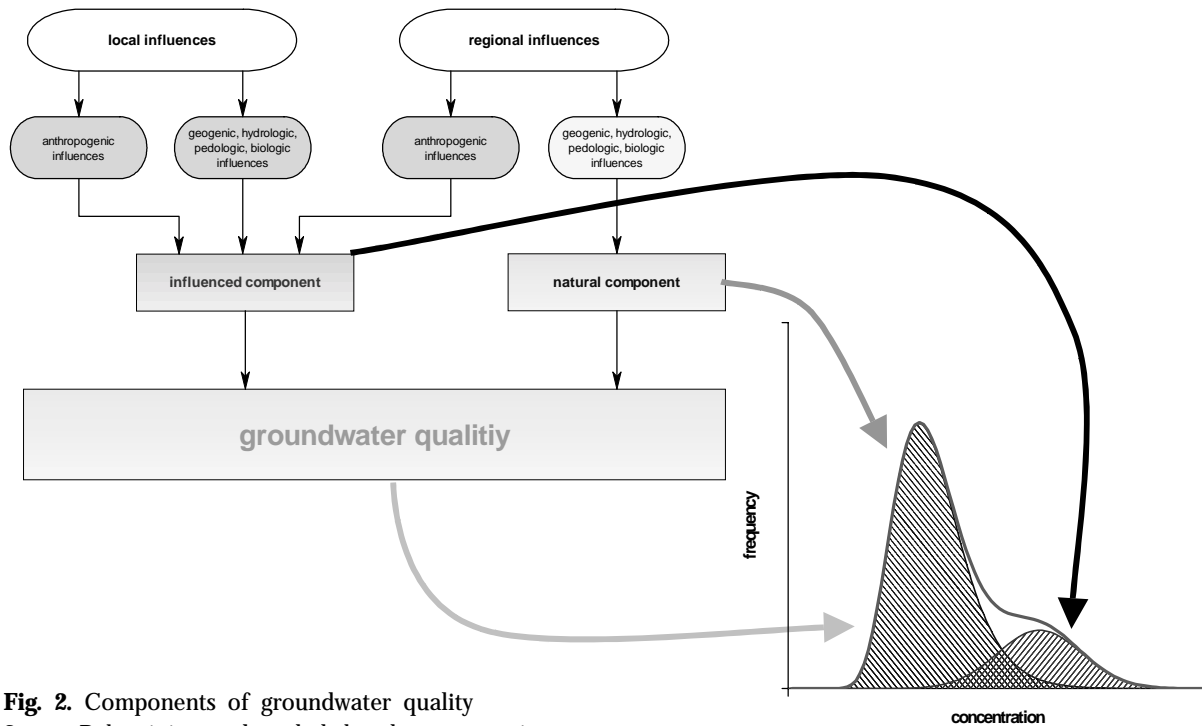
Fig. 2. Components of groundwater quality
2 pav. Poþeminio vandens kokybës komponentai

Methical approach

The solution content of groundwater is determined by a variety of factors, such as the properties of the vadose zone and groundwater-bearing rocks, as well as the hydrological and hydrodynamic conditions (Fig. 2). In addition to these "natural" factors, groundwater quality is affected by anthropogenic influences, *e.g.*, land cover changes, diffuse input from agriculture and the atmosphere, and point source input (Appelo & Postma, 1996; LFU, 1996, Matthess, 1994; Domenico & Schwartz, 1990; Voigt, 1990). Whereas the occurrence of some groundwater parameters (*e.g.*, pesticides) is a direct indicator of human impact, most inorganic constituents may originate both from natural and anthropogenic sources. This renders it difficult to decide whether the observed groundwater condition is reflecting the "good groundwater chemical status" according to the requirements of the WFD or not, the latter implying that measures to decontaminate groundwater have to be taken.

Because of the omnipresence of human influences, truly "natural" groundwater occurs at regionally limited locations at best. Especially groundwater from aquifers that are part of the active water cycle (aquifers close to the surface) have been influenced since decades and centuries by human activities, *e.g.*, agriculture, which changed soil types or soil cover, which in turn induced changes in percolation water quality. This situation is true for more than 99% of the area of Germany. Consequently, the present solution content of groundwater samples from aquifers close to

the surface rarely reflects true "natural" groundwater concentrations.

Against this background, a more pragmatic understanding of the term *"natural groundwater condition"*, which considers human impact to a certain degree as inevitable, is suggested. In this paper this is done by assuming natural groundwater concentrations to be present *if the concentrations of the most important cations and anions originate from anthropogenically not significantly influenced (by fertilizers) soils and rocks of a watershed, including groundwater from areas under agricultural use or from areas where land cover changes occurred over the last centuries* (Schenk, 2003).

This definition of natural groundwater quality was the starting point for this research project, which has been commissioned by the Working Group of the Federal States of Germany on Water Problems (LAWA). The aim of this project was to provide data for the definition of "good groundwater chemical status" from existing data of groundwater monitoring networks provided by the federal states. As a reference, four groups of aquifers, each with comparable petrographical and hydrodynamic properties (groundwater typologies) were investigated. The selected hydrostratigraphical units,

• aquifers in Triassic limestones (Muschelkalk),
• aquifers in Triassic sandstones (Buntsandstein),
• aquifers of unconsolidated sediments of the Saalian glaciations, and
• aquifers in Jurassic limestones (Malm),

occur throughout Germany (see Fig. 3) and are of high importance for water supply. For these typologies, 10 different data sets from 8 federal states (50000

groundwater samples from 19500 monitoring stations) were provided by the involved State authorities.

Before assessing natural groundwater concentrations, it was necessary to merge the individual heterogeneous data sets into one data base with a unified structure and reference to the groundwater typologies. In addition, a number of consistency checks (DVWK, 1994), *e.g.*, the elimination of analyses with incorrect ion balances, salt-effected stations, and elimination of temporal trends by median averaging had to be performed. In the end, a total of 7920 monitoring stations in the investigated groundwater typologies, with one representative groundwater analysis each, were used for further analysis (see Fig. 4).

The 15 evaluated groundwater parameters include environmental parameters (O_2, pH), summary parameters (electrical conductivity, DOC), major components (Na, K, Ca, Mg, Cl, HCO_3, SO_4), and trace substances (Fe, Mn, NH_4, NO_3). Table 2 lists the total number of observations available for each parameter in the individual groundwater typologies. The number of evaluated observations for each parameter in each typology is in a range between 200 and about 4900, allowing for a statistically sound analysis.

METHODS AND RESULTS

Two statistical methods for the assessment of natural chemical conditions of groundwater, the so-called separation method and the selection (ranking) method were developed.

The separation method

The basic steps of this method are illustrated in Fig. 5. The starting point of the method is the frequency distribution of the observed concentrations of a groundwater parameter (represented by black dots in Fig. 5). It is assumed that this concentration profile can be expressed by the superimposition of two components representing the natural and the influenced contributions. In this case the observed concentration distribution may be described by the sum of two statistical distribution functions which represent the natural and the influenced components.

The mathematical forms of the two distribution functions are not known a priori. But it can be expected that the concentration patterns, which are predominantly resulting from interactions with the soil or groundwater-bearing rocks, may be represented by lognormal distributions, whereas the concentration patterns originating from direct inputs from the soil are more or less proportional to the inputs into the soil and may be represented by normal distributions. Therefore, the natural component should follow a lognormal distribution, while the anthropogenic component should usually follow a normal distribution.
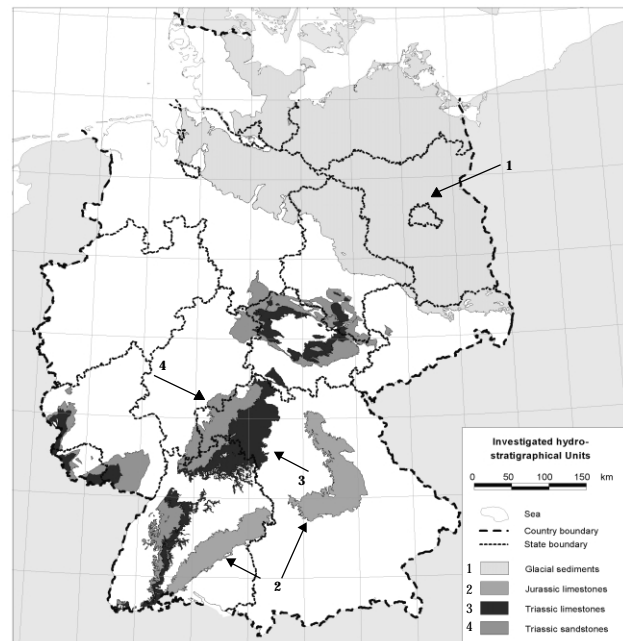

Fig. 3. Investigated groundwater units. *Orange:* Pleistocene sands and gravel. *Light grey:* Jurassic limestones. *Green:* Triassic sandstones. *Dark grey:* Triassic limestones
3 pav. Iðtirti hidrogeologinës stratifikacijos vienetai: *1* – ledyninës nuogulos; *2* – juros klintis, *3* – triaso klintis, *4* – triaso smiltainis
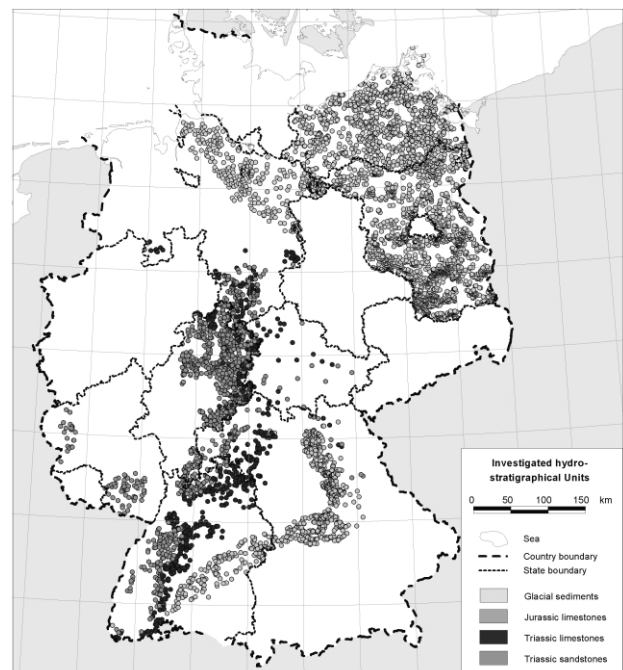

Fig. 4. Groundwater sampling locations
4 pav. Poþeminio vandens mëginiø imties vietos

The explicit shape of both distribution functions is determined by three independent parameters each (amplitude, median, and variance), which have to be fitted to the observed frequency distribution using standard algorithms. As a result, the observed distribution pattern is represented by two distribution func-
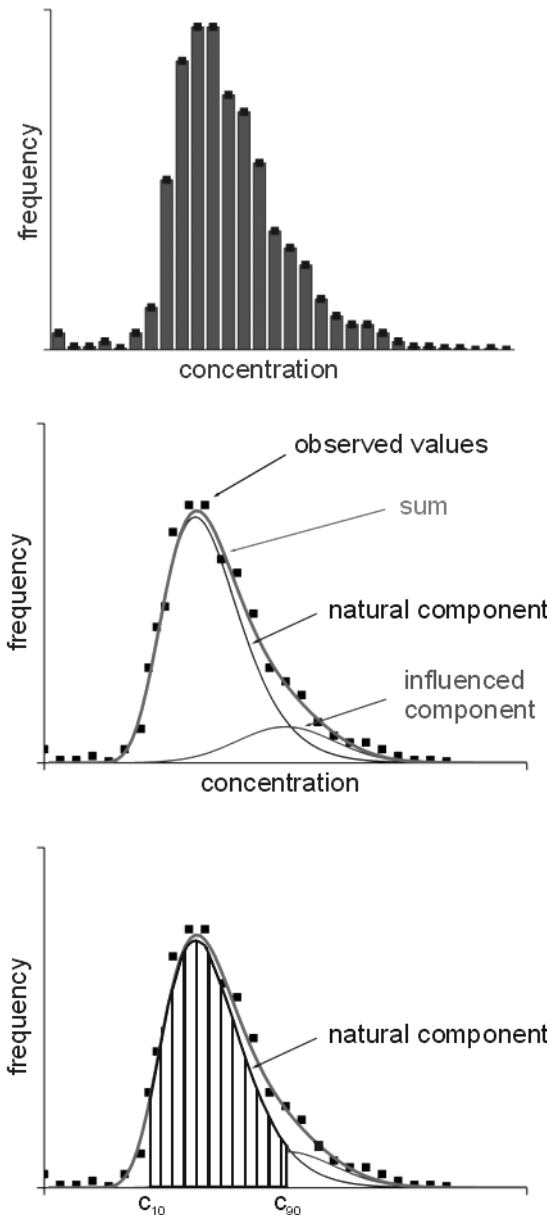
Fig. 5. Component separation analysis
5 pav. Poþeminio vandens cheminës sudëties komponentø pasiskirstymo analizë

tions of a known shape, which can be assigned to the natural and anthropogenic components.

The natural groundwater conditions could be described by several different sets of statistical parameters of the distribution function of the natural component. For normal and lognormal distributions, median and variance are commonly used. However, these values are not a very perspicuous measure to characterise typical groundwater conditions. Therefore, the natural concentration ranges are specified by the 10th and 90th percentiles of the distribution of the respective component.

Table 3 shows the results for natural groundwater parameters in the composition of the four investigated aquifers. As can be seen in the table, concentra-

tions in the aquifers significantly differ from each other, as well as the chosen distribution curves. Conclusions from electrical conductivity, magnesium and potassium should suffice as a brief example.

Electrical conductivity characterises the mineralisation of groundwater. From Table 3 and Fig. 6 it can clearly be seen that groundwater in carbonate rocks differs from that of sand and sandstone with increased mineralisation. The reason for this difference is the increased quantity of soluble minerals in the rocks (carbonates, sulphate, as wells as chloride).

The observed concentration distributions are represented very well by the sum of two statistical distribution functions. The distribution patterns of electrical conductivity representing the natural groundwater condition differ significantly:

limestone aquifer: 387…939 µs/cm
sandy aquifer: 186…521 µs/cm
sandstone aquifer: 50…256 µs/cm.

In all aquifers, the influenced component lies significantly above the natural component. The observed distribution curves of natural water in carbonate rocks correspond more or less to a normal distribution function, whereas sand and sandstone aquifers follow a typical lognormal distribution.

Distribution curves for magnesium are presented in Fig. 7. The figure shows that not only the shapes of the curves for natural water in sand and sandstone are similar, but the concentration as well:

sand 3…30 mg/l
sandstone 2…23 mg/l.

In comparison with these, water in Triassic carbonate rocks has an increased magnesium content of 17…50 mg/l.

Magnesium concentrations in Jurassic carbonate rocks exhibit an interesting distribution. There are two clearly distinguished maxima. The two statistical distribution functions reveal petrographical differences within the Jurassic limestone in Germany: the degree of dolomitisation of the Jurassic limestone increases from west to east. Accordingly, magnesium concentration rises. Therefore we suggest to distinguish two different types of natural groundwater for Jurassic carbonate aquifers in these two different parts of Germany.

The ranges of natural potassium concentration (Fig. 8) in the groundwater of carbonate aquifers are significantly narrower and lower than those in sandstone:

carbonate rocks: 0.3…2.1 mg/l
sandstone: 0.8…4.0 mg/l.

In all aquifers the influenced component lies significantly higher than the natural component. This can be explained by a diffuse input from fertilisation or sewage water.

Sodium, calcium, chloride, sulphate, and dissolved organic carbon exhibit similar distribution curves as those of potassium.

Table 2. **Evaluated hydrochemical parameters and the number of available analyses**
2 lentelë. **Ávertinti hidrogeocheminiai rodikliai ir panaudotø cheminiø analiziø skaièius**

	Sands and gravel of aquifer F2	Jurassic limestone (Malm)	Triassic limestone (Muschelkalk)	Triassic sandstone (Buntsandstein)
Conductivity	3012	921	541	533
O_2	824	902	622	1378
pH	4769	923	650	1469
DOC	4309	211	399	433
Ca	4699	809	649	1460
Mg	4683	810	648	1461
Na	2105	810	648	1459
K	2086	388	537	1409
NH4	4549	809	512	510
Fe	4615	806	626	1309
Mn	4260	808	570	1187
HCO_3	4741	807	649	1447
Cl	4846	810	649	1464
SO_4	4654	810	649	1461
NO_3	4521	810	650	1468

Table 3. **Results of component separation analysis**
3 lentelë. **Poþeminio vandens cheminës sudëties pasiskirstymo analizës rezultatai**

		Sands and gravel of Aquifer F2		Jurassic limestone (Malm)		Triassic limestone (Muschelkalk)		Triassic sandstone (Buntsandstein)	
		from	to	from	to	from	to	from	to
Conductivity	µS/cm	186	521	387	704	637	939	50	256
O_2	mg/l	0.2	4.6	6	11	3	10	5	11
pH	–	6.0	7.8	7.1	7.7	7.0	7.5	6.8	7.7
DOC	mg/l	0.8	5.0	0.3	1.3	0.4	1.2	0.3	1.6
Ca	mg/l	29	143	69	126	99	154	7	29
Mg	mg/l	3	30	4	37	17	50	2	23
Na	mg/l	6	24	1.3	6.3	3.0	9.2	2	16
K	mg/l	0.8	4.0	0.3	1.9	0.6	2.1	1.3	3.6
NH_4	mg/l	< 0.01	0.5	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Fe	mg/l	0.1	5.0	< 0.01	0.15	< 0.01	0.1	< 0.01	0.1
Mn	mg/l	0.04	0.64	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
HCO_3	mg/l	150	426	278	380	287	446	6	96
Cl	mg/l	9	43	5	37	9	49	4	17
SO_4	mg/l	4	68	13	32	30	147	5	58
NO_3	mg/l	< 0.01	0.1						

Selection analysis

At first sight, the statistical method of selection is a more pragmatic approach. It starts with the construction of a histogram for every measured parameter in the investigated aquifer.

The next step comprises exclusion of all analyses where the concentration of any parameter is higher than the 95th percentile of the frequency distribution. During the third step, all analyses are excluded where nitrate content exceeds 10 mg/l.

After that second selection, the 80% confidence interval is determined for the remaining analyses (by taking the interval from the 10th to the 90th percentile).

The determined confidential intervals for every groundwater component can be represented graphically using "box plots" (see Fig. 9). Table 4 shows the 10th and 90th percentile for each component of the investigated aquifers.

For the unconsolidated rocks of the Saalian Glaciation of Northern Germany, an improved selection method was tested using not only monitoring nets, but also exploratory and production wells. After preliminary selection, as described above (ionic balance, nitrate > 50 mg/l, etc.), about
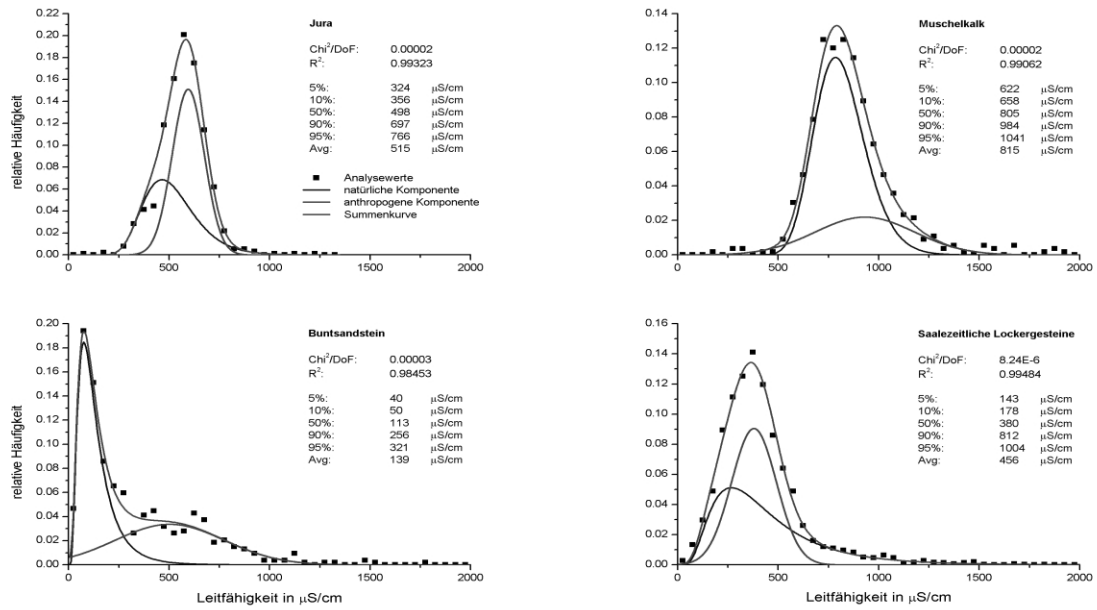
Fig. 6. Component separation for electrical conductivity
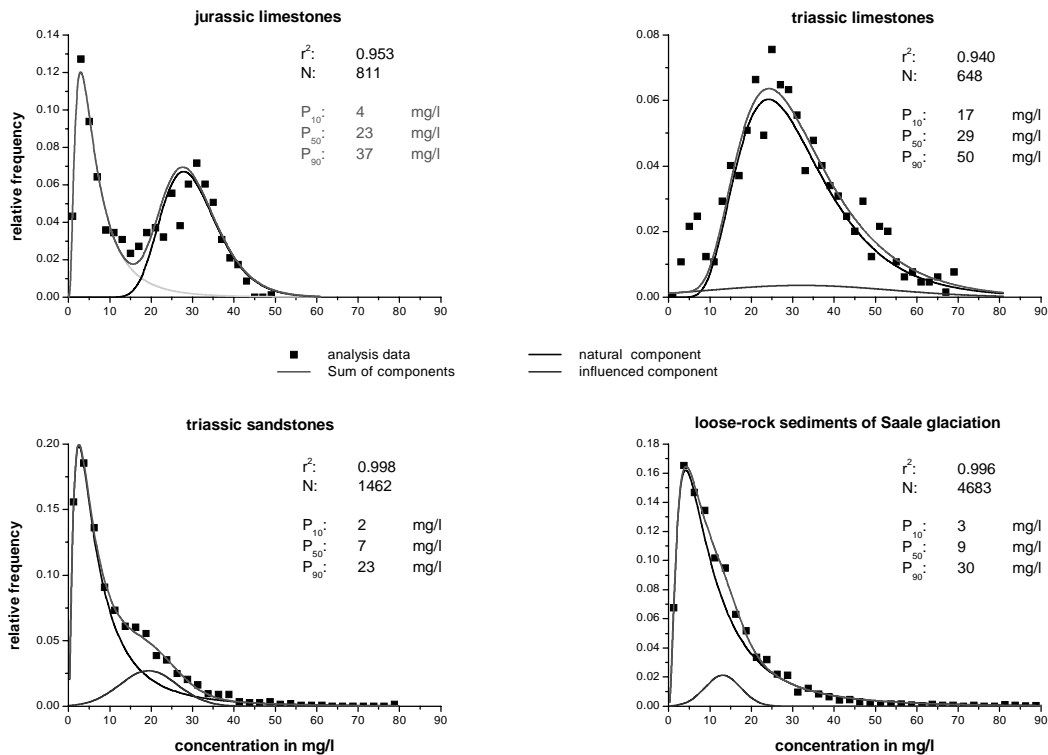**6 pav.** Elektros laidþio statistinio pasiskirstymo grafikai

Fig. 7. Component separation for magnesium
7 pav. Magnio jono statistinio pasiskirstymo grafikai

15000 analyses remained and were statistically analysed with regard to:

• the position of the well in the hydrodynamic system and

• depth interval of sampling.

Histograms for each component were constructed for different hydrodynamic positions:

• direct recharge areas

• indirect recharge areas
• transit areas
• discharge areas (lowlands).

After that, sequential selection of the so-called types of influence was carried out (Fig. 9). At first all analyses of mineralised water of discharging deep water were selected. They occur only in transit and discharge areas and are characterised by a
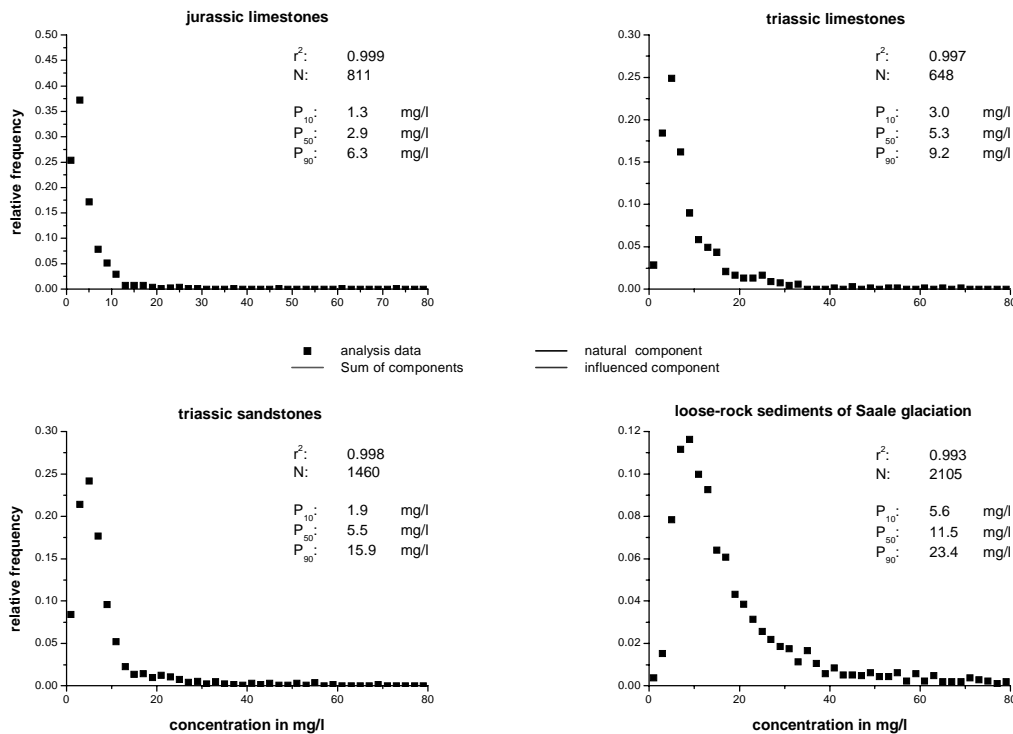
Fig. 8. Component separation for potassium
8 pav. Kalio jono statistiniai pasiskirstymo grafikai

Table 4. **Results of selection analysis**
4 lentelė. **Požeminio vandens cheminės sudėties atrankinės analizės rezultatai**

		Sands and gravel of Aquifer F2		Jurassic limestone (Malm)		Triassic limestone (Muschelkalk)		Triassic sandstone (Buntsandstein)	
		from	to	from	to	from	to	from	to
Conductivity	µS/cm	187	490	360	578	486	581	47.7	354
O_2	mg/l	0.1	5.4	4.6	10.8	6.0	9.4	5.6	10.5
pH	–	6.7	7.9	7.2	7.7	7.2	7.7	5.6	7.4
DOC	mg/l	0.9	5.0	0.5	1.4	0.3	0.8	0.2	1.6
Ca	mg/l	28.0	99.2	62	112	35.3	107	5.8	48.1
Mg	mg/l	2.9	21.0	2.6	32	3.3	19.5	1.5	17.5
Na	mg/l	5.8	28.0	1.0	5.0	2.0	4.9	1.7	8.6
K	mg/l	0.8	4.6	0.3	2.3	0.4	1.3	1.2	3.1
NH_4	mg/l	0.01	0.7	0.0	0.01	0.01	0.01	0.00	0.03
Fe	mg/l	0.1	4.5	0.0	0.07	0.00	0.05	0.00	0.07
Mn	mg/l	0.01	0.4	0.0	0.01	0.00	0.01	0.00	0.04
HCO_3	mg/l	67.1	341	234	361	97	331	8.5	204
Cl	mg/l	9.4	46.0	2.5	11	2.9	13.3	3.1	12.5
SO_4	mg/l	6.3	99.1	10	35.1	11.7	51	3.4	36.1
NO_3	mg/l	0.1	1.0	1.2	9.5	3.3	8.1	1.8	8.9

chloride content of above 1452 mg/l (determined from the 95th percentile) and a ratio of equivalent sulphate and chloride concentrations of less than 1.

For the remaining analyses of those two areas, the histograms were constructed anew.

During the second step, analyses of water that indicate fertilisation influence on chemical com-ponents were selected. The 95th percentile served as a criterion for the respective hydrodynamic areas. These critical concentrations differ among different hydrodynamic conditions (Table 5). For example, the following concentrations of nitrate were identified as influenced:

• in recharge areas higher than 10 mg/l
• in transit areas higher than 1.7 mg/l

Table 5. **Classification of influence types**
5 lentelë. **Poþeminio vandens cheminës sudëties tipai pagal faktorinës analizës rezultatus**

		Recharge areas	Indirect recharge	Transit areas	Discharge areas
Geogenic chloride type					
Cl	mg/l			> 142	> 142
SO_4/Cl	–			< 1	< 1
Nutrient type					
NO_3	mg/l	> 10	> 12	> 1.7	> 4.1
NO_2	mg/l	> 0.20	> 0.34	> 0.30	> 0.22
NH_4	mg/l	> 1.0	> 1.2	> 1.5	> 2.6
o- PO_4	mg/l	> 0.35	> 0.50	> 0.60	> 0.54
K/Na	mg/l	> 0.35	> 0.38	> 0.24	> 0.37
Organogenic type					
COD (Mn)	mg O_2/l			> 7.8	> 14.6
NH_4	mg/l			< 1.2	< 1.6
Acidification type					
pH	–	< 6.1	< 6.4	< 6.6	< 6.2
SO_4	mg/l	> 138	> 207	> 143	> 225
Ca+Mg/Na+K	–	> 3	> 3	> 3	> 3
Diffusely affected type					
Evaporation Residue	mg/l	> 518	> 596	> 642	> 633
Total Hardness	ºdH	> 18	> 23	> 21	> 21
Cl	mg/l	> 58	> 77	> 99	> 85
SO_4	mg/l	> 120	> 167	> 117	> 176
NO_3	mg/l	2.4	> 2.5	> 0.5	> 1.2
NH_4	mg/l	> 0.7	> 0.7	> 1.0	> 1.4
Na	mg/l	> 34	> 48	> 96	> 61
K	mg/l	> 5.0	> 6.6	> 6.2	> 6.9

Table 6. **Results of simple and differentiated analyses**
6 lentelë. **Paprastos ir diferencijuotos poþeminio vandens sudëties analizës rezultatai**

|		Simple analysis		Differentiated separation analysis							
		Aquifer F2		Recharge areas		Indirect recharge areas		Transit areas		Discharge areas	
		from	to	from	to	from	to	from	to	from	to
pH	–	6.7	7.9	6.7	8.0	6.9	8.0	7.0	8.0	6.5	7.9
Ca	mg/l	28.0	99.2	24	92	36	113	35	101	35	103
Mg	mg/l	2.9	21.0	2.2	11	3	115	3	16	3	13
Na	mg/l	5.8	28.0	5	16	5	29	5	18	5.5	23
K	mg/l	0.8	4.6	0.7	2.5	0.9	3.0	0.8	2.7	0.8	3.8
NH_4	mg/l	0.01	0.7	0.1	0.4	0.1	0.3	0.1	0.5	<0.1	0.8
HCO_3	mg/l	67.1	341	47	246	85	286	97	334	61	270
Cl	mg/l	9.4	46.0	8	34	9	45	7.8	35	11	48
SO_4	mg/l	6.3	99.1	18	93	15	112	10	82	19	128
NO_3	mg/l	0.1	1.0	< 0.1	0.5	< 0.1	0.5	< 0.1	0.5	< 0.1	0.5
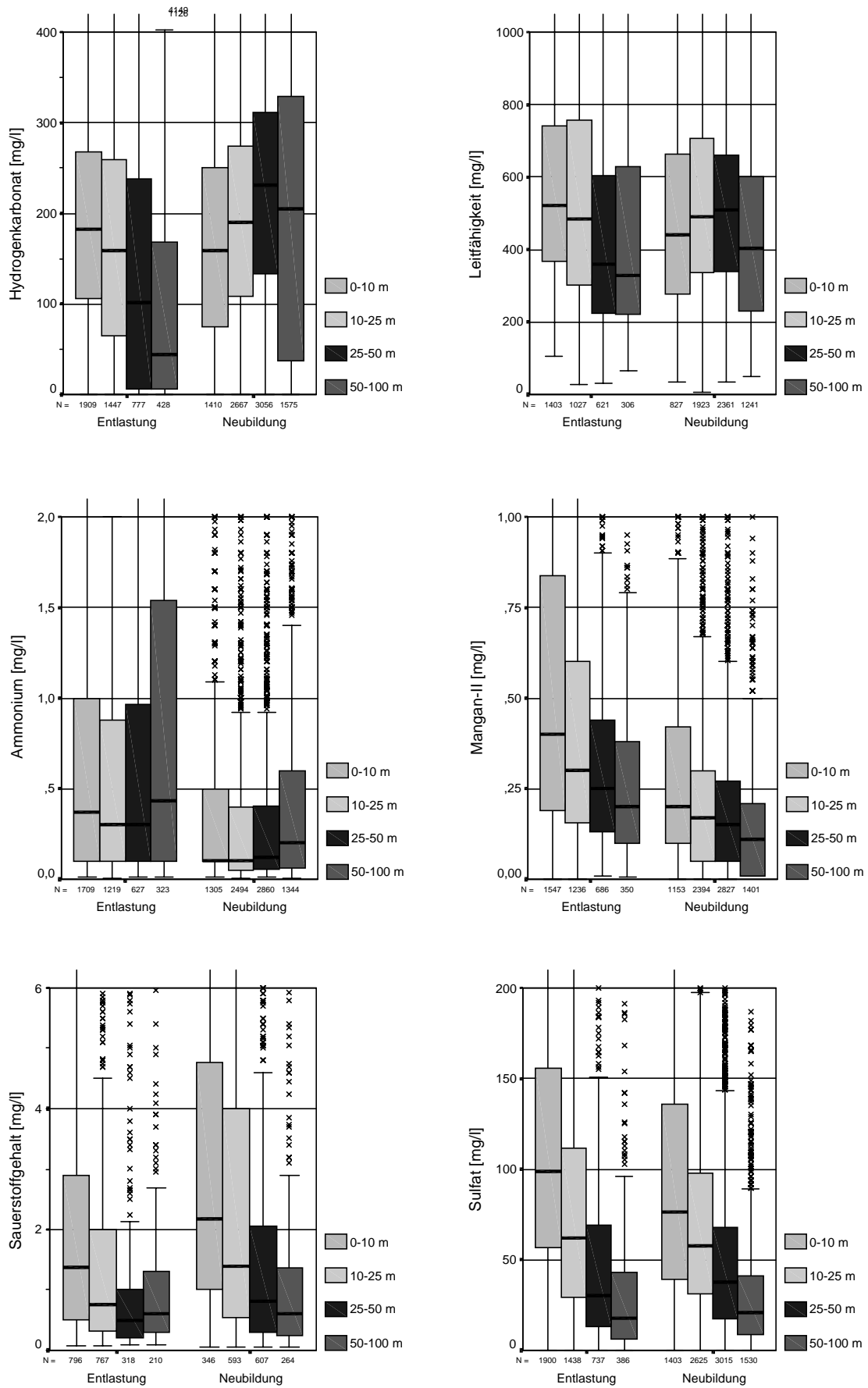
Fig. 9. Parameter values in regard to hydrodynamic position and depth
9 pav. Sprendiniø eiliðkumas tipizuojant poþeminá vandená pagal cheminæ sudëtá
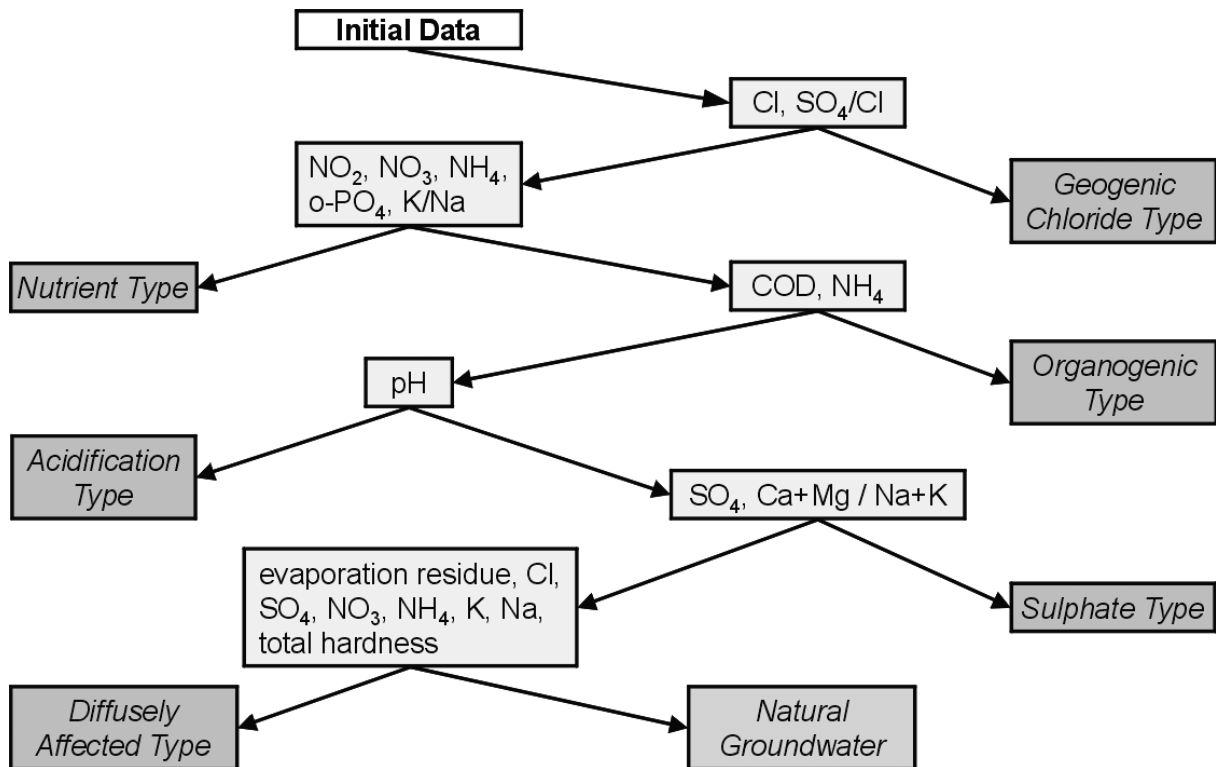
Fig. 10. Decision tree for groundwater influence types
10 pav. Hidrocheminiø rodikliø priklausomybë nuo poþeminio vandens hidrodinaminiø sàlygø: mitybos ir iðtakos srièiø iðsidëstymo, slûgsojimo gylio (nuo 0–10 iki 50–100 m), mëginiø skaièiaus (N)

• in discharge areas higher than 4.1 mg/l.

In the same way, other influence types are distinguished:

• organic type
• acidification influence on account of atmospheric precipitation
• sulphate type
• diffuse influence by anthropogenic factors.

After these selections, about 50% of the initial analyses remained as characteristic of natural groundwater, which is summarised in Table 6.

A comparison of the results shows that the differentiated and the simple analyses of the unconsolidated aquifers in the Central European Basin *do not differ significantly.*

Contrary to this conclusion, distinct sampling depth intervals show significant differences, as is illustrated by the box plots in Figure 9.

For the majority of groundwater components, a change in depth is observed moreover, very often different in recharge and discharge areas. For example, hydrogen carbonate concentration and electrical conductivity decrease with depth in discharge areas, but increase in recharge areas.

Oxygen content and sulphate in both hydrodynamic structures decrease with depth, as does also manganese content, which is also significantly higher in discharge than in recharge areas, at comparable

depths. The latter effect is a result of reduction processes in discharge areas, which also characterises ammonium distribution.

Therefore, a conclusion was proposed that for a more detailed description of natural chemical groundwater composition in Central European aquifers, it is necessary to distinguish separate depth intervals for investigation:

• down to 10 m below surface
• 10…25 m
• 25…50 m
• deeper than 50 m.

CONCLUSIONS

• Identification of natural groundwater composition for four aquifers comprising a total of 7900 monitoring wells was carried out.

• Two methods were developed to separate the natural groundwater composition from modified.

• Typical intervals of natural groundwater components of the investigated aquifers were distinguished.

• The intervals found using those two methods correlate well (Table 6).

• For the unconsolidated aquifers of the Central European Basin, it is reasonable to establish natural groundwater quality ranges for different depth intervals.

The LAWA working group made a decision to determine natural groundwater composition for all regional aquifers in all hydrogeological structures by these two methods.

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VOKIETIJOS HIDROGEOLOGINIØ STRUKTÛRØ POÞEMINIO VANDENS GAMTINËS KONCENTRACIJOS ÁVERTINIMAS

S a n t r a u k a

Vienijantis Europos valstybëms á Sàjungà bûtina bendra daugelio ûkinës veiklos srièiø politika, tarp kuriø svarbià vietà uþima ir vienodø reikalavimø geriamojo vandens kokybei parengimas. Tam tikslui Europos Sàjunga (ES) yra parengusi atitinkamà direktyvà, nustatanèià Bendrijos veiksmø vandens politikos srityje pagrindus (Directive 2000/60EC… establishing a framework for Community action in the field of water policy). Joje iðskirtinis vaidmuo tenka poþeminiam vandeniui, kurio iðtekliai daþniausiai yra pagrindinis miestø ir kaimo gyvenvieèiø centralizuoto vandens tiekimo sistemø vandens ðaltinis.

Svarbiausias Direktyvos reikalavimas, kad geriamasis vanduo nebûtø terðiamas, kad jam formuojantis nebûtø esminio antropogeniniø veiksniø poveikio. Toks natûralioje aplinkoje susidarantis poþeminis vanduo direktyvoje ávardijamas kaip geros cheminës bûklës poþeminis vanduo, taèiau nenurodoma atskirø komponentø koncentracija vandenyje. Tai suprantama, nes Europos þemyno ir atskirø valstybiø hidrogeologinës sàlygos labai ávairios, todël kiekvienos ðalies specialistai turi patys suformuluoti geros kokybës poþeminio vandens sampratà remdamiesi jo cheminës sudëties gamtine kilme. Tai nëra paprasta, nes daugelis vandens komponentø gali atsirasti ir ið gamtiniø, ir ið antropogeniniø ðaltiniø.

Straipsnyje apibendrinta ekspertø grupës patirtis sprendþiant minëtà problemà Vokietijos gamtinëmis sàlygomis. Sukaupus daug hidrogeocheminës informacijos apie keturiø svarbiausiø Vokietijos teritorijoje hidrogeologiniø struktûrø poþeminio vandens cheminæ sudëtá ir panaudojus matematinës statistikos metodus, buvo parengta metodika, leidþianti atskirti „gamtinæ" ir „antropogeninæ" vandens komponentø sudedamàsias dalis. Kuriant metodikà buvo panaudoti duomenys ið 7920 poþeminio vandens monitoringo stoèiø, iðskirta 15 skirtingø hidrocheminiø geriamojo vandens rodikliø, taip pat nustatytos „gamtiniø" rodiklio veriø ribos kiekvienai hidrogeologinei sistemai. Tyrimø rezultatai bus siûlomi Europos Komisijai kaip „geros cheminës poþeminio vandens bûklës" ávertinimo pagrindas.

Ãàí ñ-Þ ðãåí Ôîèãò, Ñòåôàí Õàííàïïåëü, Ðàëüô Êóíêåëü, Ôðàíê Âåíäëàíä

Î ÖÅÍ ÊÀ ÅÑÒÅÑÒÂÅ Í Î É ÊÎ Í ÖÅ Í ÒÐÀÖÈÈ Ï Î ÄÇÅÌ Í ÛÕ ÂÎ Ä ÃÈÄÐÎ ÃÅÎ ËÎ ÃÈ×ÅÑÊÈÕ ÑÒÐÓÊÒÓÐ ÃÅÐÌ ÀÍ ÈÈ

Ð à ç þ ì å

Â Åâðîïåéñêîì Ñîþçà (ÅÑ) ðàçðàáàòûâàåòñÿ åäèíàÿ ñèñòåì à òðåáîâàíèé ê êà÷åñòâó âîäû. Ñ ýòîé öåëüþ ïîäãîòîâëåíà ñîîòâåòñòâóþùàÿ äèðåêòèâà (2000/60/ÅÑ), â êîòîðîé âàæíàÿ ðîëü îòâåäèòñÿ ïîäçåì í ûì âîäàì , øèðîê èñïîëüçóåì ûì äëÿ íóæä âîäîñí àáæåí èÿ.

Î ñí îâí à òðåáîâàíèå äèðåêòèâû ñàñäèòñÿ ê òîì ó, ÷òîáû âîäà, ïîäàí àçí à÷åí í àÿ ê óïîòðåáëåí èþ â êà÷åñòâå ïèòüåâîé, íå ïîääåðãàëàñü âîçäåéñòâèþ àíòðîïîãåí í ûõ ôàêòîðîâ. Î áðàçóþùàÿñÿ â åñòàñòâåí í ûõ óñëîâèÿõ ïîäçåì í àÿ âîäà í àçâàí à âîäîé õîðîøåé ïî ÷èñòåì ñîñòîÿíèè. Êàæäàÿ ñòðàí à îáÿçàí à óñòàí îâèòü êðèòåðèè, ïî êîòîðûì ïîäçåì íàÿ âîäà ì îãëà áûòü îòíåñåí û ê êàòåãîðèè «âîäû õîðîøåé õèì è÷åñêîì ñîñòîÿí èÿ».

Â ñòàòüå îáîáùåí îïûò ãðóïïû ýêñïåðòîâ, îïðåäåëÿþùèõ óñëîâèé êðèòåðèè äëÿ ïðîñòûõ ïîäçåì íûõ âîä ÷åòûðåõ âàæíåéøèõ ãèäðîãåîëîãè÷åñêèõ ñòðóêòóð Ãåðì àí èè. Ïðè ðàçðàáîòêà ì åòîäèêè áûëè èñïîëüçîâàíû äàí í ûå 7920 ñòàí öèé ì îí èòîðèíãà ïîäçåì í ûõ âîä, âûäåëåíî 15 ãèäðîõèì è÷åñêèõ ïîêàçàòåëåé êà÷åñòâà ïèòüåâîé âîäû. Ïîéó÷åí í ûå ðàçöëèòåòàòû óáóóò ïðåäñòàâëåí û â ÅÑ â êà÷åñòâå îñí îâû äëÿ ðàçðàáîòêè êðèòåðèåâ îöåí êè õîì è÷åñêîãî ñîñòîÿí èÿ ïîäçåì í ûõ âîä.