The influence of diffuse pollution on groundwater content patterns for the groundwater bodies of Germany

1. Research Centre Jülich (FZJ)
Agrosphere, ICG IV,
D-52425 Jülich, Germany

2. Brandenburg University
of Technology, Chair of
Environmental Geology
D-03013 Cottbus, Germany

3. HYDOR Consult GmbH
Am Borsigturm 40
D-13507 Berlin, Germany

4. Federal Environmental Agency
D-14191 Dessau, Germany

Ralf Kunkel[1],

Frank Wendland[1],

Stephan Hannappel[3],

Hans-Jürgen Voigt[2],

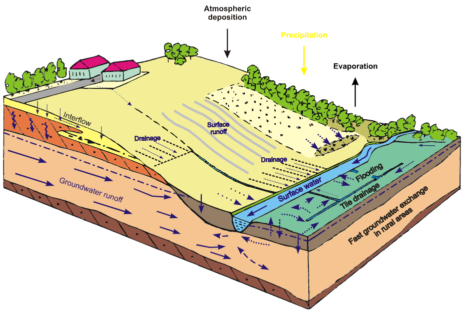
Rüdiger Wolter[4]

Background

1. **EU water framework directive (article 17)**
   - Prevent and control groundwater pollution
   - Measures to achieve or restore a „good groundwater chemical status“
     - Criteria for assessing good groundwater chemical status
     - Criteria for the identification of significant and sustained upward trends and for the definition of starting points for trend reversals
   - A complementary Groundwater Directive has just been accepted by the parliament
2. **Research Contract commissioned by the Working Group of the Federal States of Germany on Water problems (LAWA)**
   - Development of a method to identify the natural background values for groundwater
   - Application to hydrogeological units in Germany

According to the EU - Water Framework Directive, Natural Background Levels (NBLs) and Threshold Values (TVs) for the groundwater should be established taking into account natural influences as well as human impacts

Solution contents of groundwater depend on…



Natural influences

- Groundwater covering layers
- Petrographical aquifer properties
- Hydrodynamical aquifer properties

Human impact

- Landcover (changes)
- Water regulations
- Mining
- Point source pollution
- Diffuse intakes from agriculture and atmosphere

→ A strictly "natural" groundwater may be found at best in regionally restricted areas, with mostly minor importance for water supply

Methodological aspects for the derivation of natural background levels

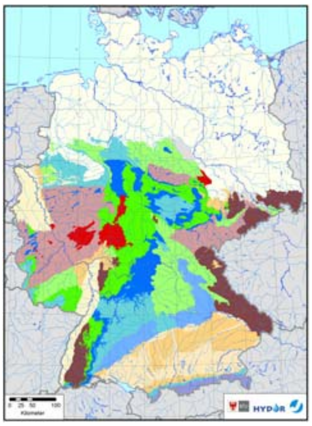
1. **Hydrochemical simulation of solution processes in aquifers**
   - Only for well monitored small areas and time-consuming
2. **Evaluation of groundwater samples free from human impact**
   - Only samples from deeper aquifers or from natural reservates
3. **Evaluation of groundwater samples by separation methods**
   - Preselection methods: Exclusion of samples with
     - purely anthropogenic substances (e.g. PAC, pesticides)
     - concentrations of indicator substances above a certain value (e.g. NO_3 > 10 mg/l)
   - Separation of natural / anthropogenic components from concentration distributions
     - all available groundwater samples and parameters can be used

Hydrogeological differentiation

17 hydrogeological units differentiated according to petrography, stratigraphy, hydrodynamics, hydrology

- Pleistocene gravels and sands
- Sand and gravel Lower Rhine Bay
- Sand and gravel Upper Rhine Valley
- Moraine deposits of the Alps foreland
- Tertiary sediments
- Jurassic limestones
- Mixed-layered silicatic rocks
- Mixed-layered carbonatic rocks
- Triassic limestones
- Triassic sandstones
- Limestones of the Alps
- Paleozoic sediments
- Paleozoic limestones
- Basic vulcanites
- Magmatites and metamorphic rocks

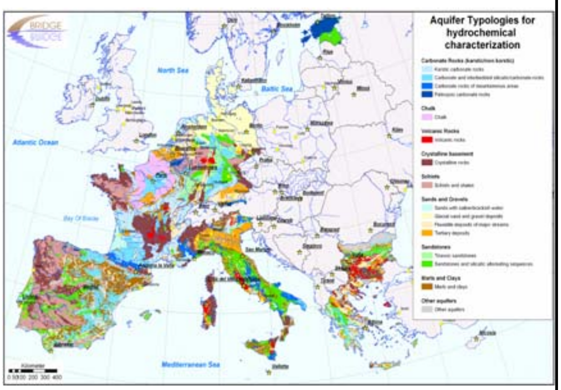
Allocation to hydroeological units from monitoring station master data (depth, stratigraphy, etc.) and maps (isolated cases)



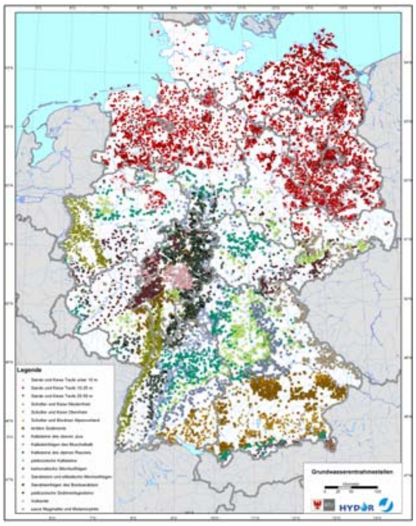
Aquifer typologies: a geographical reference for assessing Natural Back-ground Levels (NBLs) on a European scale

EU-STREPS project BRIDGE (Background criteria for the identification of Groundwater Thresholds)

27 partners from 19 countries involved

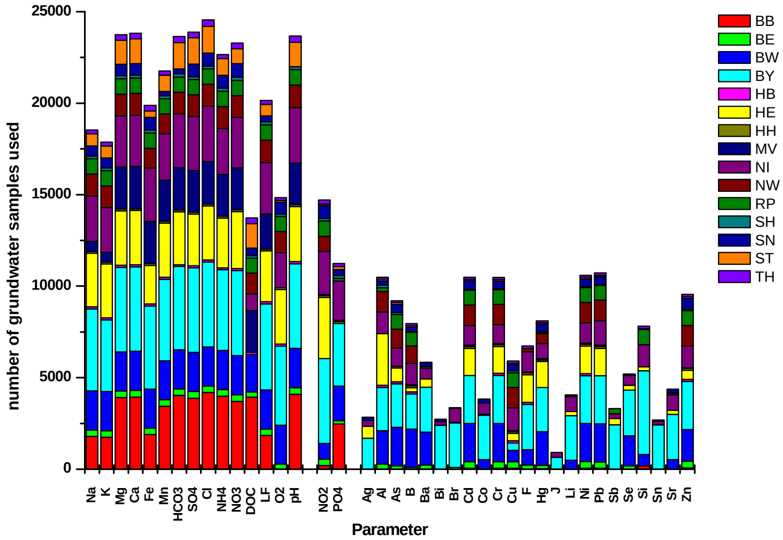


Evaluated groundwater monitoring data

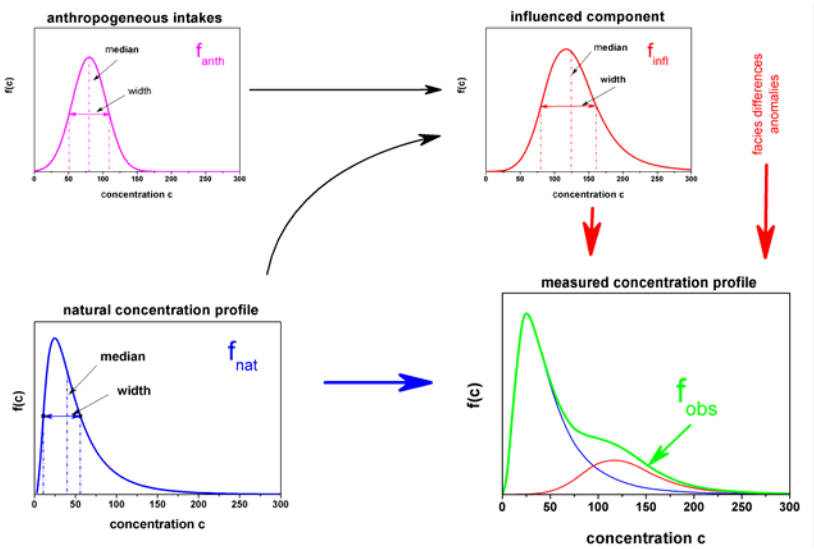


1. **Groundwater data from monitoring networks of 15 Federal States**
   - 160000 samples from 40000 stations
   - Different monitoring networks
   - Heterogeneous data structure
   - Differences in analyzed parameters
2. **Database creation**
   - Removing of samples with incorrect ion balance
   - Attachment of monitoring data to investigated hydrogeological units
   - Elimination of time series by median averaging
3. **25971 monitoring stations with one representative groundwater analysis each remained**

Parameter specific number of used stations



Components in concentration profiles



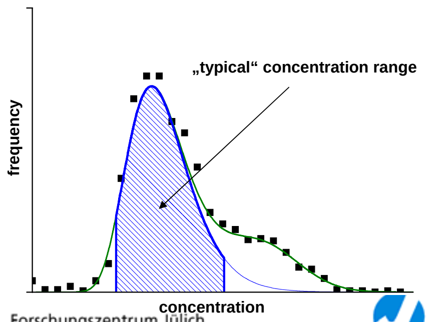
Procedure of component separation

Step1: Classification of data into concentration ranges and creation of frequency distributions of a groundwater parameter in a hydrogeological unit

Step2: Selection of two statistical distribution functions representing the natural component and the influenced component

Step3: Finding those distribution parameters which get an optimal representation of the observed distribution by the sum of both components

Step4: Identification of natural groundwater concentration by the 80% confidence interval of natural component

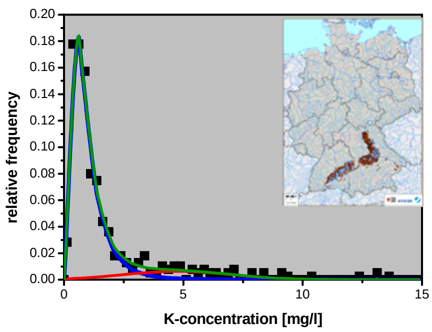


Derived background values

		Pleistocene sands and gravel		Jurassic limestones		Triassic limestones		Triassic sandstones	
		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	-	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	*	*	*	*	*	*

Significant different concentration ranges of natural groundwater concentrations between the groundwater units

Potassium in Jurassic Limestones



(dominant) natural component

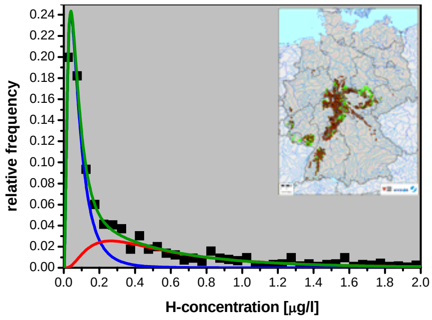
- at low concentrations
- indicates K-poor minerals in groundwater covering layers and aquifers of the jurassic limestones
- Natural concentration < 1,9 mg/l

influenced component

- in broad, high concentration range
- indicates the impact of potassium containing fertilizers

„Prototype“ distribution type for most parameters

Protons (pH) in Triassic Sandstones



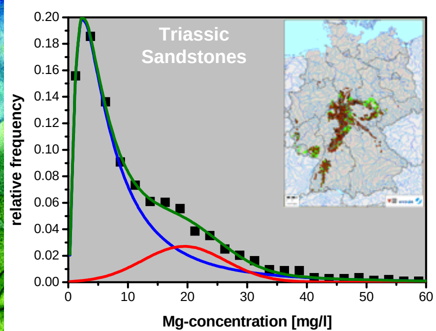
natural component

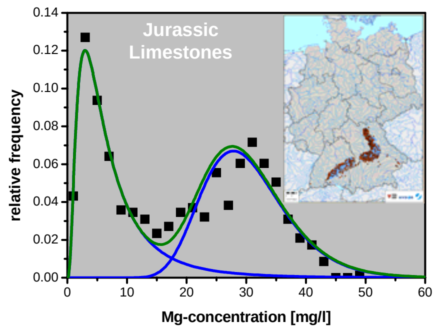
- pH: 6,7 – 7.6
  (high H+-concentration = low pH)

dominant influenced component

- pH <6,7
- indicates degree of acidification (vulnerability) of (buffer-poor) sandstone aquifers and their covering layers

Magnesium





dominant natural component

- < 22 mg Mg/l
- lack of Mg-containing minerals

influenced component

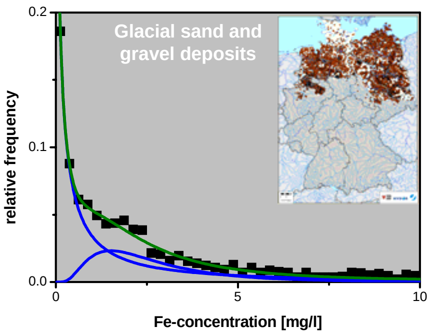
- impact of measures against soil acidification
- Mg-containing fertilizers

two natural components

- < 40 mg Mg/l
- rising degree of dolomitisation from SW to NE

No influenced component

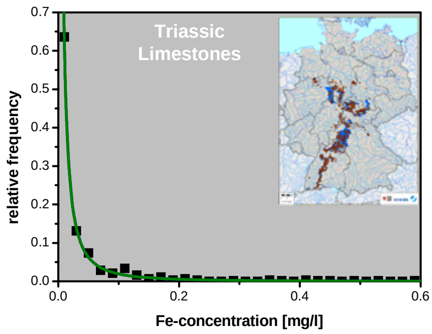
Iron (II): redox-sensitive parameter



Two natural components

- < 5 mg Fe/l
- indicates redox-stratification
- oxidized groundwater zone (below ca. 5 m)
- reduced groundwater zone (above ca. 5 m)

No influenced component

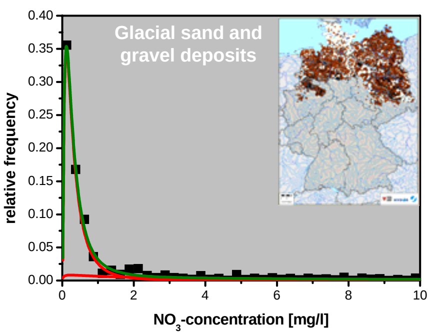


One natural component

- < 0.15 mg Fe(II)/l
- typical distribution of redox-sensitive parameters in oxidized groundwaters

No influenced component

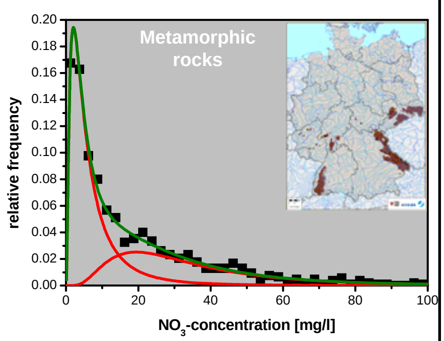
Nitrate: redox-sensitive parameter



No natural components

two influenced components

- Indicated redox-stratification
- Small concentrations (< 1 mg NO_3/l) result from denitrification processes in reduced groundwater rather than small or missing nitrate inputs



no natural components

two influenced components

- indicates diffuse nitrate pollution
- indicates absense of significant „natural" nitrate sources in soils and aquifer

Conclusions

	Components	Concentration distributions	Hydrogeologic unit examples
Na, K, Cl, SO_4, LF	Usually two components	Usually indicating anthropopgenic influences	
Ca, Mg, HCO_3	One or two components	dominated by source rock and/or facies differences	anthropogenic influences only in silicatic rocks
pH	Usually two components	Acidification influence in buffer-poor soils and rocks	Sandstones, crystalline rocks
O_2, Fe, MN, NO_3, NH_4, DOC	One or two components	Mainly influenced by redox status and depth	Glacial lowland deposits
Heavy metals, Al	Usually one component	Influenced by acidifica-tion and detection limits	
PO_4, NO_2,	One component		

Summary

1. **Component separation method was applied**
   - to 17 hydrogeological units of Germany
   - using samples from 26000 monitoring stations
   - for a total of 31 inorganic parameters
2. **Evaluation of separated components with respect to**
   - Anthropogenic influences
   - Facies influence
   - Impact of Redox conditions
3. **Derivation of natural background values**
   - Consistent for each parameter and unit
   - Large differences between units due to the different petrographic and hydrodynamical / hydrological conditions
   - Not all parameters show significant anthropogenic influences