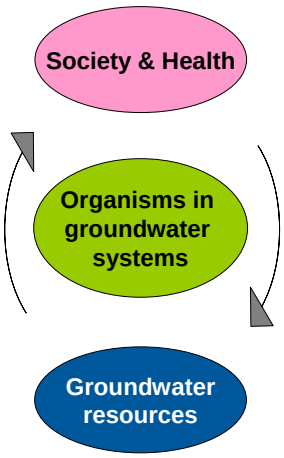
Ecological assessment of groundwater ecosystems

„Protect GW Quality by protecting Ecosystem Functions“ (Job & Simons, 1994; US-EPA)



Christian Griebler
Institute of Groundwater Ecology, Helmholtz Zentrum München (HMGU), German Research Center for Environmental Health, Ingolstädter Landstrasse 1, D-85764 Neuherberg

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Groundwater ecological aspects in national and international regulations, directives and guidelines

- **1998** Swiss Water Protection Ordinance mentions the ecological status: “the biocenosis in groundwater should be in a natural state adapted to the habitat and characteristic of water that is not or only slightly polluted”
- **2003** Western Australian Guidance for the assessment of environmental factors – “Consideration of subterranean fauna in groundwater and caves during environmental impact assessment”
- **2006** EU-GWD - “Research should be conducted in order to provide better criteria for ensuring groundwater ecosystem quality “

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Do we need an ecological assessment scheme?

Advantages

- Physical-chemical analysis generally describe the conditions at a certain time point and can only cover a selected number of parameters.
- Biological and ecological parameters have the potential to provide a time-integrated picture of the system's status. Indirect detection of 'unknown' threats is possible.
- Impacts present may be categorized according to their influence on ecosystem functions and services.
- Biological and ecological parameters are extremely especially useful subsequent to an impact – help to document the return to natural conditions.

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Do we need an ecological assessment scheme?

Disadvantages

- Physical-chemical parameters are standardized (from sampling to analysis) while biological and ecological parameters in most cases lack routine protocols.
- We know comparable little about the distribution of individual groundwater organisms, their sensitivity towards certain impacts, and their autecology.
- Additional 'new' parameters cause 'new' additional costs. Can this be argued by the improved information?

It requires ecological criteria to assess an ecosystem!

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Ecological criteria are routine in the assessment of surface waters

Implementation into the EU-Waterframework Directive

Groups of organisms considered

… not really useful in groundwater assessment

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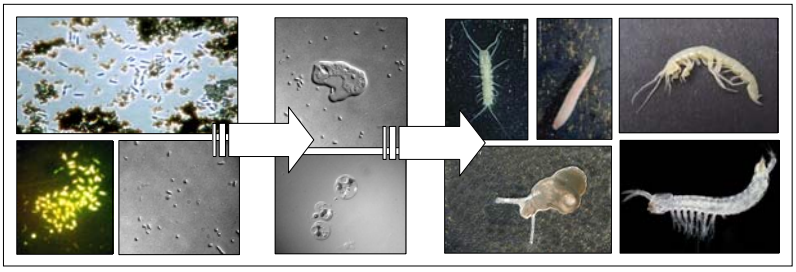
Biocenoses in groundwater ecosystems



Bacteria and Archaea | Protozoa | Invertebrates

Microbial communities contain promising indicators for …

… **Eutrophication** (Pearl et al. 2003)

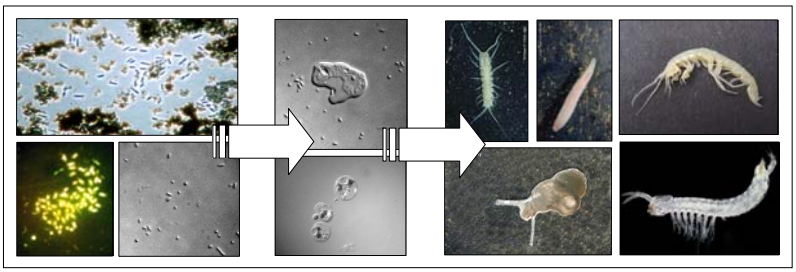
… **the impact by organic compounds and heavy metals** (Solé et al. 2008)

… **the impact by pathogenic microbes and viruses** (Lucena et al. 2006)

… **the ecological assessment of the hyphorheic zone** (US-EPA 1998)

… **active degradation pathways** (natural attenuation)(Winderl et al. 2007)

Biocenoses in groundwater ecosystems



Bacteria and Archaea Protozoa Invertebrates

Within the fauna we have indicators for …

… Influence from **surface waters** (Husmann 1971; Sket 1973; Malard et al. 2004; Hahn 2006)

… **Eutrophication** (Holsinger 1966; Sket 1973; Culver et al. 1992; u.a.)

… **Sediment structure** and **porosity** (Mösslacher 1998, Paran et al. 2004; u.a.)

… **Redox conditions** (Mösslacher 1998, Dole-Olivier et al. 2004; u.a.)

… **Biogeographic aspects** (Dole-Olivier et al. 2004; u.a.)

The UBA Project

„Ecological assessment of groundwater ecosystems“

(2007 – 2008)

4 Steps to an ecological assessment scheme

1. Typology of aquifers (groundwater ecosystems)
2. Definition of a reference status (Natural Background Values)
3. Identification of bioindicators and definition of NBTs (Natural Background Thresholds)
4. Evaluation model

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4 Steps to an ecological assessment scheme

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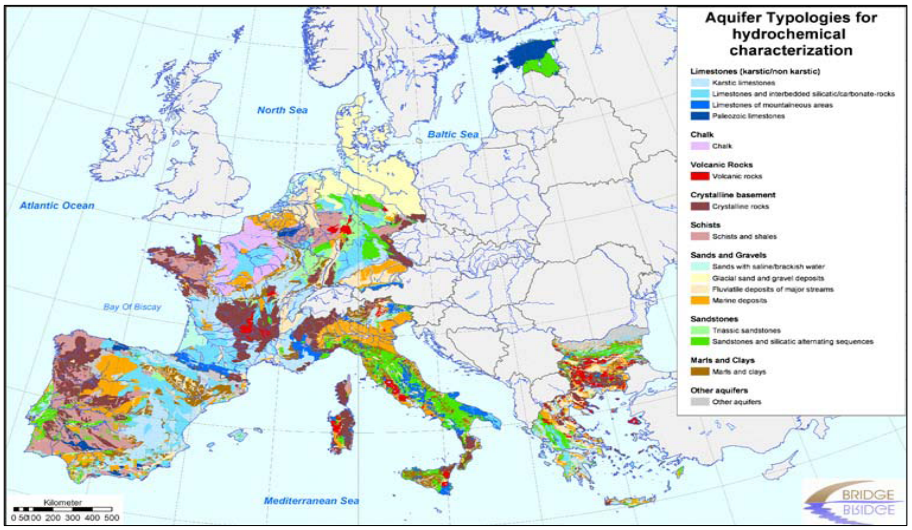
Typology of groundwater systems in the EU



Wendtland et al. 2007 Environmental Geology – compile part of the outcome of the EU-Projekt BRIDGE

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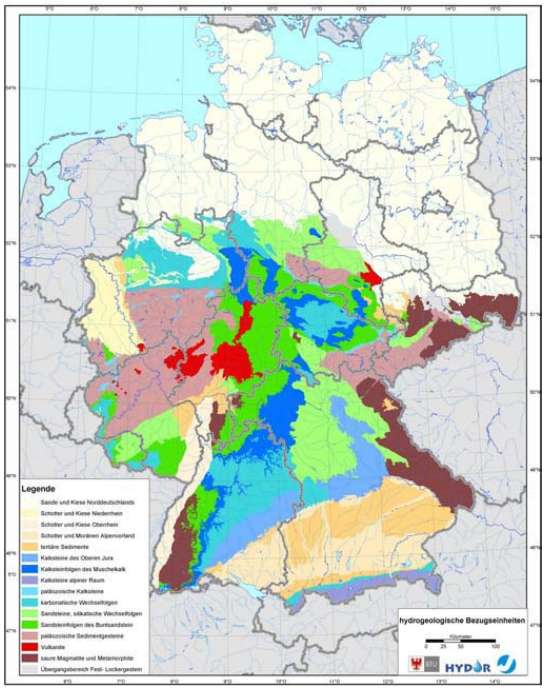
Typology of groundwater systems in Germany

- Sande und Kiese des Norddeutschen Flachlandes
- Schotter und Kiese des Niederrheins
- Schotter und Kiese des Oberrheins
- Schotter und Moränen des Alpenvorlands
- Tertiäre Sedimente
- Kalksteine der Oberen Jura
- Kalksteine des Muschelkalks
- Kalksteine des alpinen Raums
- Paläozoische Kalksteine
- Karbonatische Wechselfolgen
- *Sandsteine und silikatische Wechselfolgen*
- *Sandsteinfolgen des Buntsandsteins*
- *Paläozoische Sedimentgesteine*
- *Vulkanite*
- *Saure Magmatite und Metamorphite*
- *Übergangsbereich Fest- Lockergestein*



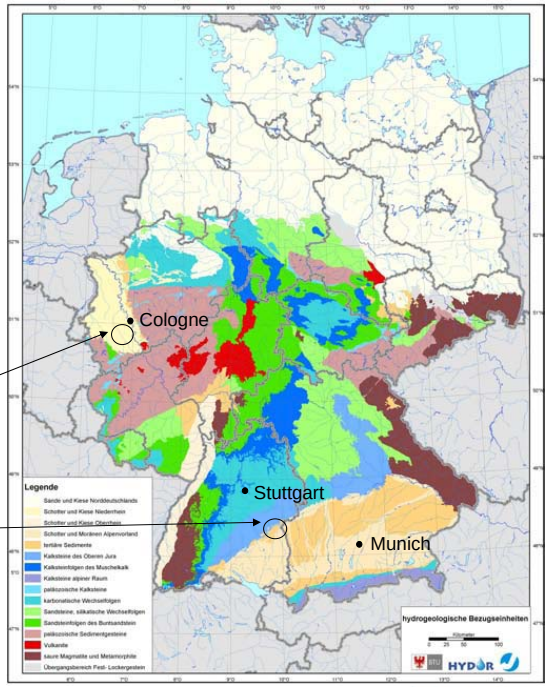
The UBA Project

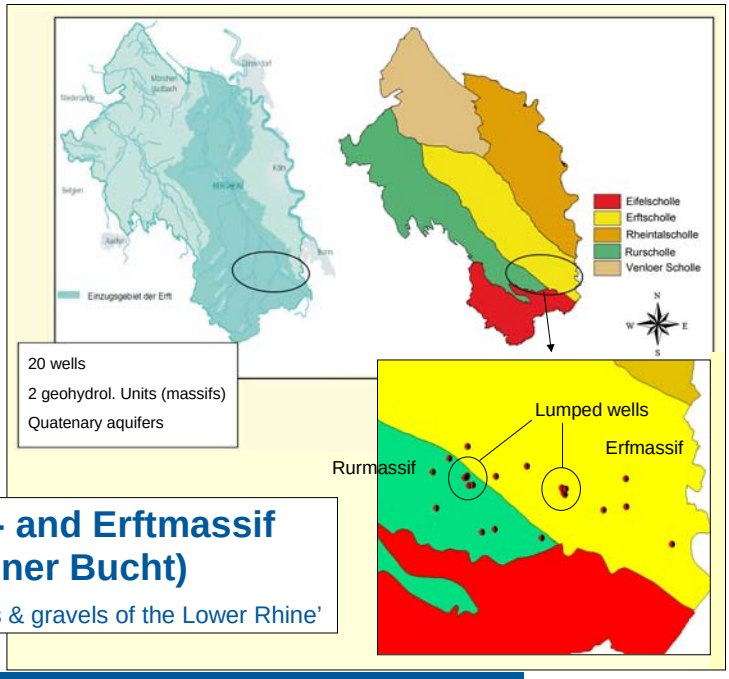
„Ecological assessment of groundwater ecosystems“ (2007 – 2008)

We selected 3 groundwater landscapes and sampled 20 wells each two times a year (spring and autumn).

20 wells were located in the Erft-Region near Cologne
• Groundwater landscape: ‘Sands & gravels of the Lower Rhine’

40 wells were located at the Swabean Alb
• Groundwater landscape: Karst of the alpine region’
• Groundwater landscape: ‘Alluvial sediments of the Danube River’





Rur- and Erftmassif (Kölner Bucht)

'Sands & gravels of the Lower Rhine'

4 Steps to an ecological assessment scheme

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Definition of a reference status
(Natural Background Values)

The ecological reference status has to be defined for every type of groundwater ecosystem (or even for sub-units)

How to do that:

- 1. Investigation of natural (pristine) zones of aquifers

  If not available

- 2. Use of data from comparable aquifers

  If not available

- 3. Use of historical data

  If 1-3 not available

- 4. Experience of experts

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Definition of a reference status
(Natural Background Values)

The ecological reference status of a local or a regional aquifer may be defined based on natural background values (NBVs) for individual abiotic and biotic parameters.

↓

Combining of individual NBVs to a holistic picture.

↓

Definition of a good ecological status.

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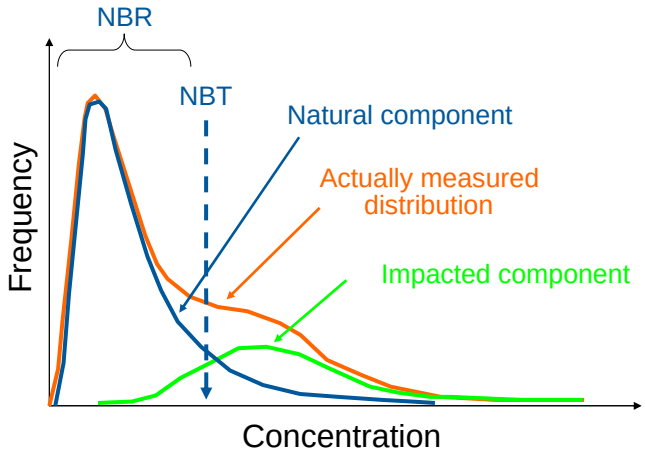
Derivation of natural background values

Natural Background Ranges (NBR) und Threshholds (NBT)



Modified from Kunkel et al. 2004

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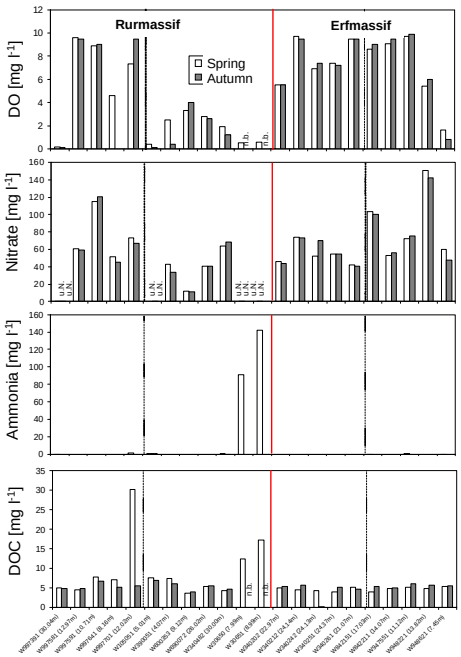
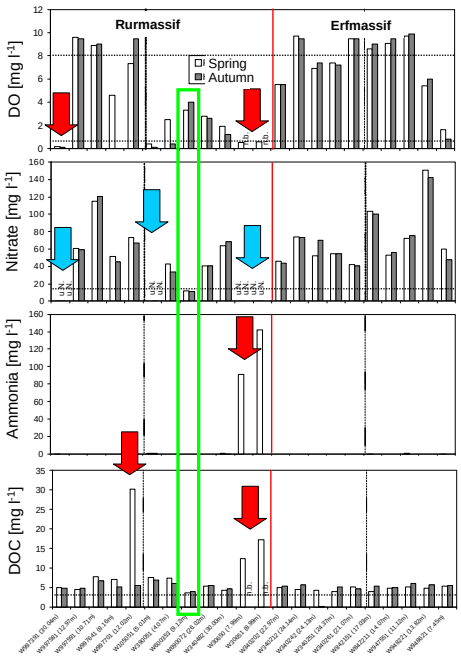
Impacts ?



Impacts ?



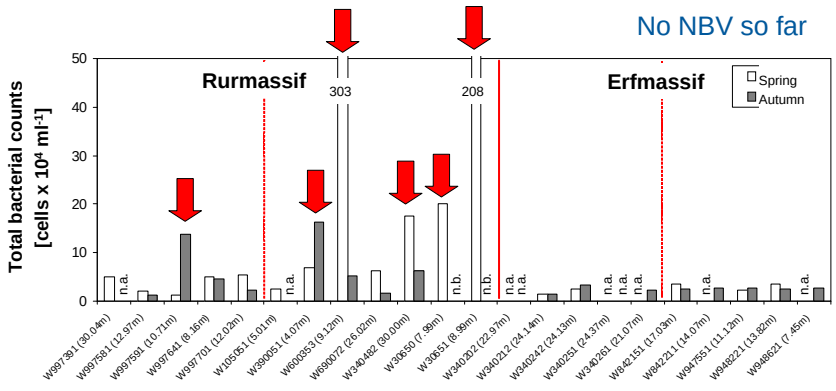
NBV 0.1 to 9.1

NBV 13

NBV 2.5

NBVs from
Kunkel et al. 2004

Rur- and Erftmassif

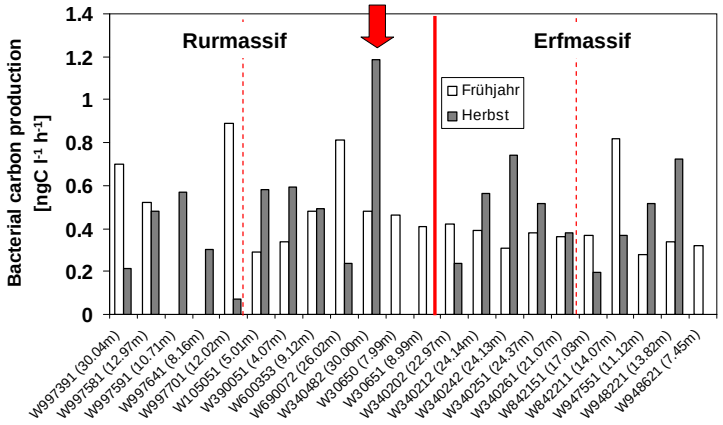


?

No NBV so far

Microbial biomass ‚sometimes' agree with chemistry!

Rur- and Erftmassif



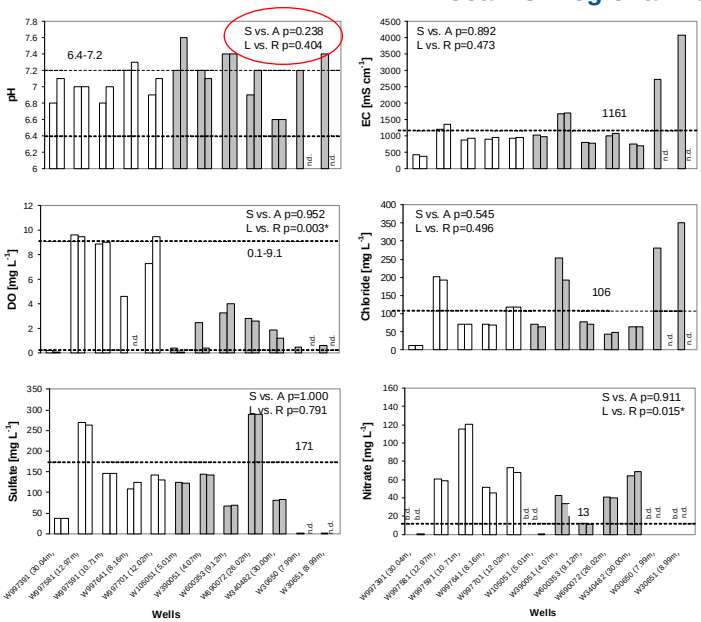
?

No NBV so far

Microbial activity does not perform like chemistry!

Rurmassif

Spring vs. Autumn samples
Local vs. Regional wells



Steube et al. (2008) Hydrogeol. J. (*early online*)

Rur- and Erftmassif

Summarizing first results from the UBA project

- Significant correlation ocurred so far only between individual physical-chemical variables
- Hardly any direct correlation between biological variables and abiotic ones
- Bacterial abundance sucessfully indicated organic impact, CFUs and BCP did not.
- Almost no variables show a significant difference between spring and autumn values, neither in trends (Spearman Rank Correlation analysis) nor in mean values (Student‘s t-Test bzw. Mann-Whitney-U Test).
- No significant differences for most parameters between locally lumped wells and those distributed regionally (Student‘s t-Test bzw. Mann-Whitney-U Test).

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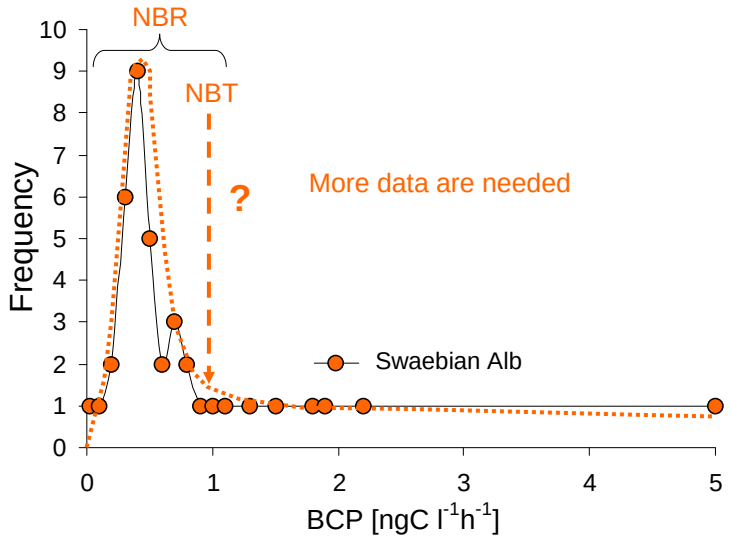
Derivation of natural background values

Natural Background Ranges (NBR) und Threshholds (NBT)



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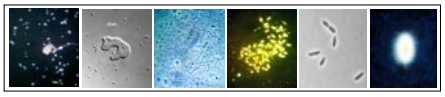
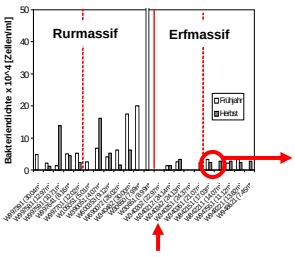
Microbial indicators

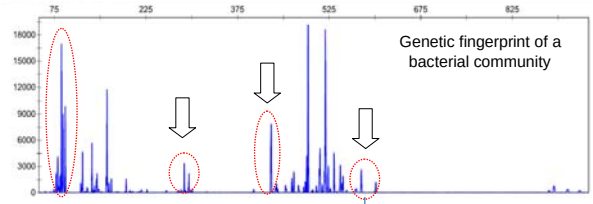
From single analysis to routine

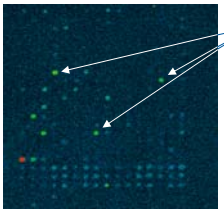


Sample

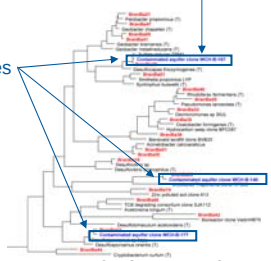


Fingerprint





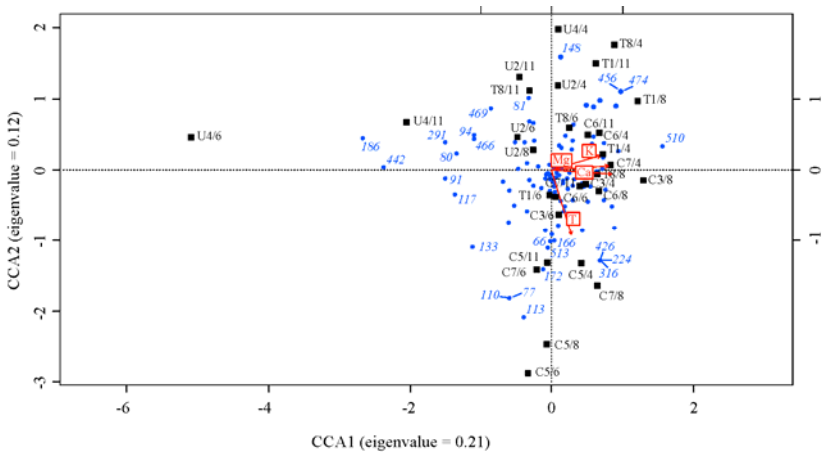
Indicator sequences



DNA – Chip (Phylochip)

Phylogenetic tree

Identification of indicator fragments (T-RFs) by means of Canonical Correspondence analysis (CCA)

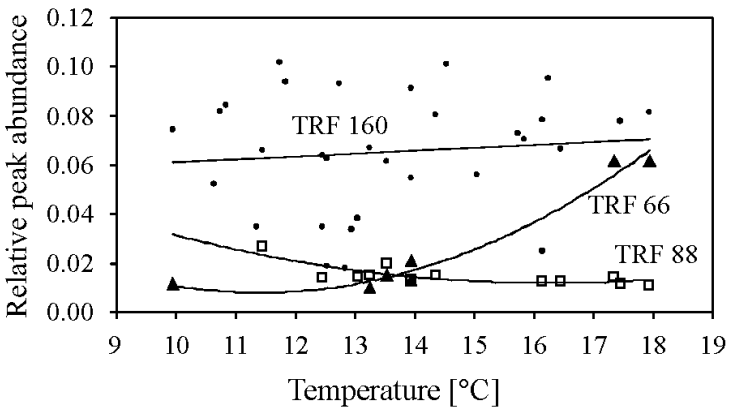


Example from a recent geothermy project

(Brielmann, Schmidt, Griebler & Lüders, FEMS Microbiol. Ecol., accepted)

SEITE 27

Identification of indicator fragments (T-RFs)

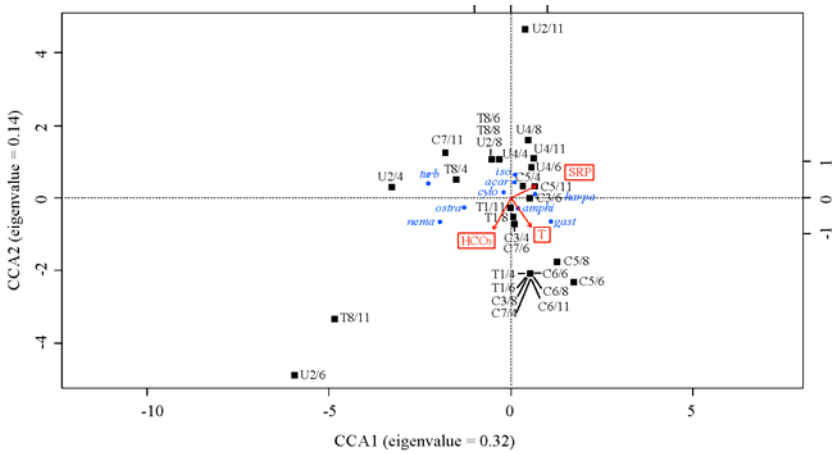


Example from a recent geothermy project

(Brielmann, Schmidt, Griebler & Lüders, FEMS Microbiol. Ecol., accepted)

SEITE 28

Identification of indicator groups within the fauna by means of Canonical Correspondence analysis (CCA)



Example from a recent geothermy project
(Brielmann, Schmidt, Griebler & Lüders, FEMS Microbiol. Ecol., accepted)

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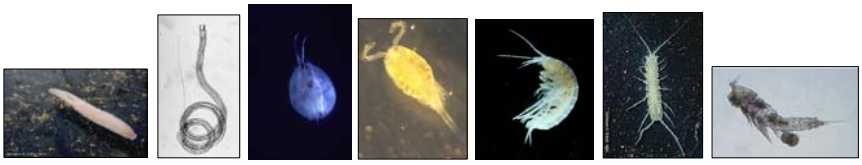

Turb Nem Ostra Cyclo Amphi Iso Harp

Temperature gradient

11°C ⟷ 18°C

Example from a recent geothermy project
(Brielmann, Schmidt, Griebler & Lüders, FEMS Microbiol. Ecol., accepted)

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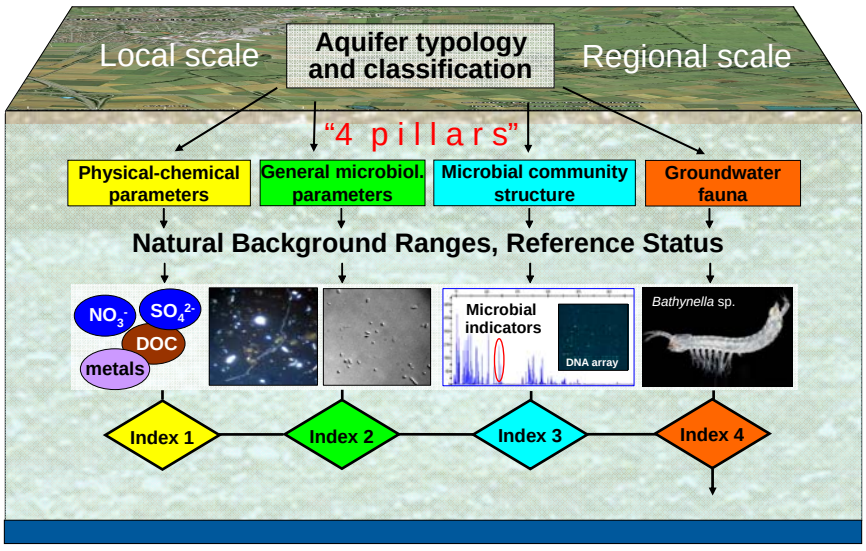
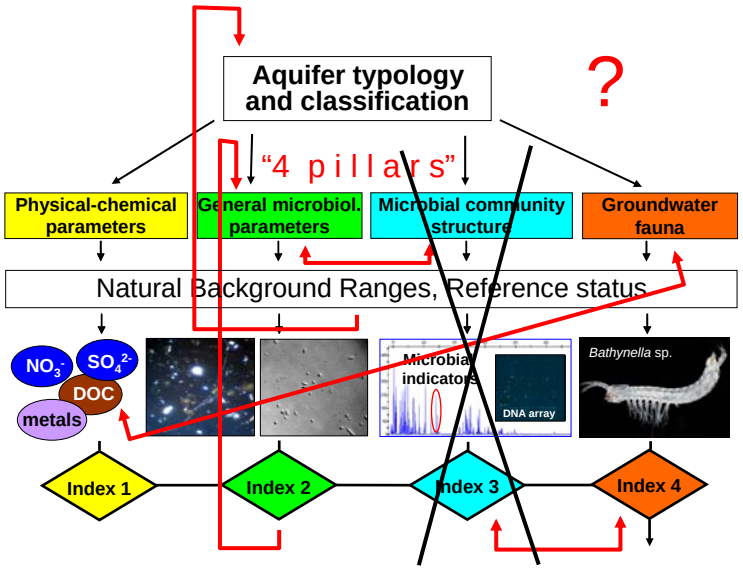
Concept for an evaluation scheme



The future will show !



Thanks goes to …

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Life Science Foundation

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- Simone Richter (UBA) and the scientific committee of the UBA project

for collaboration

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