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Groundwater in eco-hydrology

title: **Assessment of the groundwater ecosystem**

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INTRODUCTION

The role of organisms in the groundwater ecosystem for the global turnover of materials and energy is not known. Estimations that 6–40% of the bacterial biomass of the earth is living subterranean (Griebler, Lüders, 2008), show that the biomass of this ecosystem has great importance. The groundwater ecosystem plays a role in the global carbon and nitrogen cycles and has importance for the quality of drinking water resources and surface water.

The groundwater ecosystem is characterized by geological, geochemical and hydrological conditions as abiotical factors. Under the given circumstances a typical biocoenosis is built, which is fundamentally different from those in surface waters. Due to the darkness in the groundwater biotop there are no primary production by photosynthesis. Nutrients are not produced on site but yielded from outside. The area groundwater is largely anaerobic.

The quality of groundwater in Germany are assessed only by chemical criteria, at which toxicological aspects for humans stood in front as standards (Geringfügigkeitsschwellenwerte — no deterioration clause). A groundwater damage occurred when these human toxicological standards were exceeded. In surface waters the quality is detected since a long time by indicator organisms. This time research projects deal with the transfer of this system to groundwater and to find some indicator organisms in groundwater. The EC groundwater directive (2006/118/EC) demands "Research should be conducted to provide better criteria for ensuring groundwater ecosystem quality".

INDICATOR ORGANISMS IN GROUNDWATER

Due to the anaerobic conditions in the groundwater biotop the diversitiy of microorganisms is much higher than the diversity of invertebrates. Invertebrates needs oxygen for their life and are not able to exist in anaerobic deeper groundwater. Investigations to detect indicator organisms like crustaceans or nematods in groundwater for an assessment of biocoenosis can only be used in groundwater areas under aerobic conditions. The research of this groundwater invertebrates are just beginning so this time neither an sufficient amount of species nor the knowledge of their pretension to habitats and environmental conditions are present. There is a lack of bioindicators for groundwater habitats.

Another problem is the sampling technique. The conditions in the well water are different from the environment. So it is necessary to use a sampling technique that collects organisms of the representative groundwater area. This is much easier for microorganisms than for invertebrates, because one can use a radial pump with high through flow according to the DIN/ISO. This makes possible one sampling of groundwater for chemical and micro- and molecularbiological investigations. The results of the KORA project show that emissions out of landfills into the groundwater have an influence of the ecosystem. The DGGE-fingerprints of bacteria in groundwater influenced by landfill emissions differ, dependent from the concentrations of the emissions, significantly from those of the not influenced ones (Struppe, 2006). So an assessment of the groundwater ecosystem has to refer to main and can only refer to microorganisms.

METHODS

In this investigation the groundwater microbiocoenosis in the area of nine German landfills are characterised by DGGE-Fingerprints and DNA-Microarrays. The DGGE-Fingerprints were done as described by Kilb (1999) and Eschweiler (1999). Parallel the emissions from the landfills into the groundwater are determined.

The sample was taken according to the DIN 38 402 T13 with a Grundfos MP1-pump when the in situ parameters show constant values and the volume of the well tube was exchanged three times. Relative high through flow (10–12-L/min.) provides that sessile microorganisms will be teared from aquifer material and registered. The groundwater sample then were anaerobically filtered and the DNA was extracted, cleaned amplified by PCR and then separated by denaturing gel electroohoresis (DGGE). The DGGE-Fingerprints were compared by Sørensen-indices and Cluster analysis. The resulting dendrograms show the similarity between wells at one landfill. For more information an additional quantification of the bacteria was done using fluorescent dyes.

There is a definition of groundwater damage by Kerndorff et al. (2006), which we used too for influence definition (Fig. 2). To define not influenced groundwater, the background concentrations have to be detected. This is done by adding the 84.1%-percentiles of the groundwater main ions (Na, K, Ca, Mg, Fe, Mn, HCO_3, NO_3, NH_4, Cl, SO_4, TOC) of numerous groundwater (Schleyer, Kerndoff, 1992). The sum is 760 mg/L. So groundwater with concentrations of groundwater main ions <800 mg/L are defined as not influenced (neutral wells).

RESULTS

The results show that the landfills cause groundwater damages or at least an increase compared to the upstream. Normally the concentrations downstream are higher at the border of the landfills and were decreasing with distance. A dendrogram of the Sørensen-indices of a landfill shows that the microbiocoenosis of two wells is separated from the others (Fig. 1).

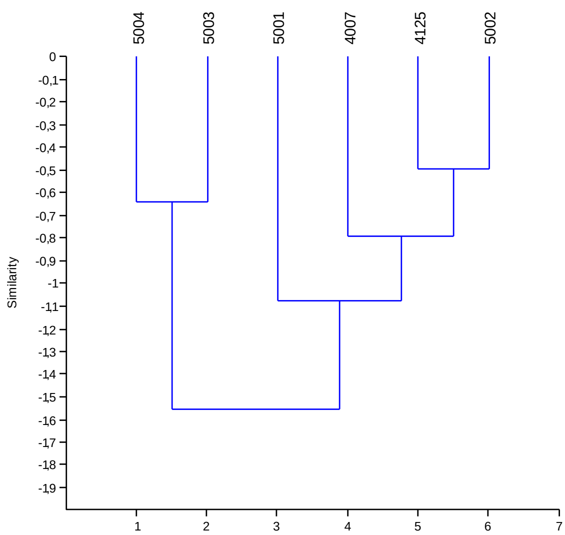

Figure 1. Clusterdendrogram of Sørensen-Indices from wells of a landfill.

One well (5003) is added to the neutral well (5004) the others are separated from the neutral well. The concentrations of the main ions in the separated wells ranged from 1100 mg/L up to more than 2500 mg/L. The well 5003 has a concentration of maximal 600 mg/L and the neutral well 390 mg/L. At all landfills it can be shown that downstream wells with concentrations of main ions below 900 mg/L in clusterdendrograms of the DGGE-Fingerprints are added to the neutral wells. If the concentrations of main ions are higher than 1200 mg/L the changes in the groundwater microbiocoenosis compared to those of the neutral wells are so significant that the wells are separated in clusterdendrograms (Tab. 1).

Table 1. Addition and separation of wells in clusteranalysis of Sørensen-Indices.

Landfill	Wells added to the neutral well	Groundwater main ions [mg/L]	Wells separated from the neutral well	Groundwater main ions [mg/L]
1	5003	599	4007, 5001, 4125, 5002	1088–2839
2	none	—	4653, 4654, 4010*, 4024*, 4042*	942–960 (533–940)*
3	4010, 4024, 4042	533–940	4003, 4011, 5008, 5009	1089–1788
4	4019, 5006	969–1015	4002, 4012, 5007, 4001	998–4368
5	none	—	DE16, DE II, DE VI, DE VIII	1303–1673
6	none	—	GWM 8, GWM 9, GWM 12	1733–5400
7	none	—	W08/029, W08/032	1634–5189
8	MA2a, MA16	260–1174	GWM 18	3652
9	P5/01, P4/01	787–808	none	

* wells are added at landfill 3 to the neutral well.

Wells with concentrations between 900 and 1200 mg/L are sometimes separated from neutral and sometimes added to the neutral well. So this is similar to the groundwater damage definition by Kerndorff et al. (2006) (Fig. 2).

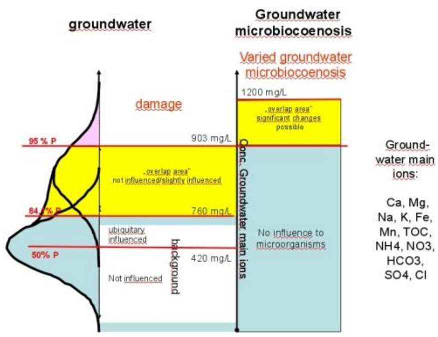

Figure 2. Thresholds for assessment of groundwater and groundwater ecosystem damages.

It is possible to define a threshold of non-toxic emissions, which causes significant differences in the groundwater ecosystem. Of special interest is that the threshold of 900 mg/L is the same for a groundwater damage and for not influenced groundwater microbiocoenosis. These changes in assembles of groundwater microorganisms can cause in two effects. First there are toxic effects of other components in the emissions, which lead to a decrease of bacterial diversity and amount. Second there are adaptations of the bacterial settlement to the emissions, which lead to an increase of bacterial amounts, caused by better nutrition situation downstream of landfills.

Quantifications of bacteria at the investigated landfills show that both effects can be observed. At one landfill the amount of bacteria near the landfill is lower than some 50 meters away, although the concentration of the main ions is higher. This is caused by pesticide containing emissions (Fig 3). At the other landfills the amount of the bacteria show an increase downstream, which is decreasing with distance and concentration of the main ions and nutrients.

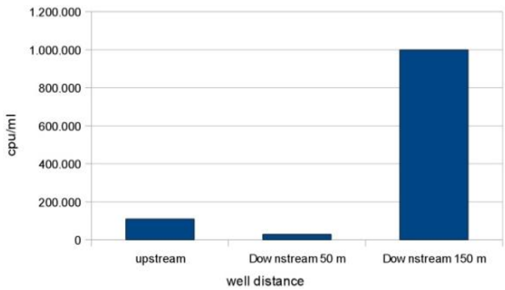

Figure 3. Amount of bacteria in groundwater of a landfill.

SUMMARY AND CONCLUSIONS

A significant change of groundwater biocoenosis caused by non toxic landfill emissions is possible. Above a threshold of 1200 mg/L main ions in groundwater the assemblage of microorganisms changes. This is an adaptation to the nutrient offer and coupled with an increase of the amount of bacteria in groundwater. This adaptation and increase is leading to natural attenuation effects. If the change is caused by toxic emissions the abundance of the bacteria decreases. This is of great importance for the assessment of groundwater biocoenosis. A change in groundwater micorbiocoenosis together with a decrease of the amount of microorganisms is considered as a damage. On the other hand an adaptation leading to natural attenuation is a “positive damage” in microbiocoenosis which reduce the geochemical damage. This is a difference to the assessment of surface water. The DGGE fingerprints allows only the comparison between influenced and not influenced groundwater microbicoenoses. The fingerprints give no information about the species behind the bands in the gel but they detect species, so local differences are emphasized to much. Desiderable are an evidence about the biodiversity in groundwater habitats. This will be possible by using DNA-microarrays which can differentiate groups of microorganisms with respect to their dependence on metabolism. The outlined investigation could be improved by using DNA-microarrays and is a field proved standard for the description of the groundwater ecosystem quality.

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