Animals in drinking water distribution networks

Ecology and combat against the backdrop of climate change

By Hans Jürgen Hahn

1 The groundwater habitat

Groundwater is not an inanimate, sterile resource, but one of the largest habitats on earth. Hundreds of animal species are known to live in German groundwater, and it is estimated that there are 50,000 - 100,000 worldwide. There are also countless bacteria and fungi. Together they provide a gigantic ecosystem service: the purification of groundwater. The fact that our groundwater is as clean as we know and appreciate it is largely the result of biological processes. Only healthy groundwater ecosystems provide healthy drinking water.

1.1 Adaptations of groundwater animals

All groundwater animals show remarkable adaptations to the groundwater habitat[1] **(Fig. 1)**.

Figure 1: Groundwater animals: Cave amphipod at top left, a groundwater isopod at bottom right (both photos: K. Grabow, Karlsruhe), mussel crab, caterpillar hopper and water crab in the middle (from bottom left to top right). Real groundwater animals are usually blind, unpigmented, elongated and have a reduced metabolism in order to save scarce energy.

They are "tough as nails" and can therefore colonize an extreme habitat that remains closed to the more demanding surface species. Groundwater animals are first and foremost hunger artists: food is scarce in groundwater. It is carried into the groundwater as particles, e.g. plant residues, or in dissolved form, e.g. sugar or humic acids, from the earth's surface. Dissolved organic material is removed from the water by microorganisms and converted into bacterial biomass. Groundwater animals feed on these bacteria, as well as on the dead particulate organic material. Biological processes in groundwater therefore primarily involve the decomposition of organic material using oxygen, thereby purifying the water.
As the retention time of the water increases, the food supply and available oxygen therefore become increasingly scarce. Groundwater animals **(Fig. 1)** are adapted to this. They can already manage with very low oxygen concentrations (> 1 mg/l).

Their metabolism is greatly reduced; to save energy, they move very slowly and their reproductive rate is very low. Eyes and skin pigments can be saved as these are superfluous due to the lack of light. Groundwater animals are therefore blind and colorless. However, their antennae and other tactile organs are excellently developed. The animals live in the water-filled void system of the subsoil. As an adaptation to this, they have developed a slender, elongated physique.
Over the last three million years, the average groundwater temperature in Central Europe is unlikely to have exceeded 14 °C more than once. Real groundwater animals are therefore sensitive to heat and usually die within a few days at higher temperatures.

1.2 What does groundwater recharge mean from an ecological point of view?

Groundwater ecosystems are primarily characterized by three key parameters: the available organic material, oxygen and temperature. It is precisely these parameters that change on the way from the surface water to the groundwater. Organic material and oxygen are degraded and the temperature fluctuations become smaller and smaller and the maximum temperatures in summer become lower and lower **(Fig. 2)**.
Along these gradients one also finds correspondingly adapted animals: The stygoxen (groundwater alien) surface species live in those areas where the food and oxygen supply is still good and the summer temperatures are often quite high. The reproduction rates of the surface forms are high and increase even further with moderate temperature increases. Many surface species have the potential for mass reproduction. If such mass propagation takes place in treatment plants or pipe networks, this can initially lead to aesthetic irritations ("animals in the coffee cup"), but then also to problems with increased bacterial counts. In short, animals, especially in large numbers, are anything but desirable in pipe networks.

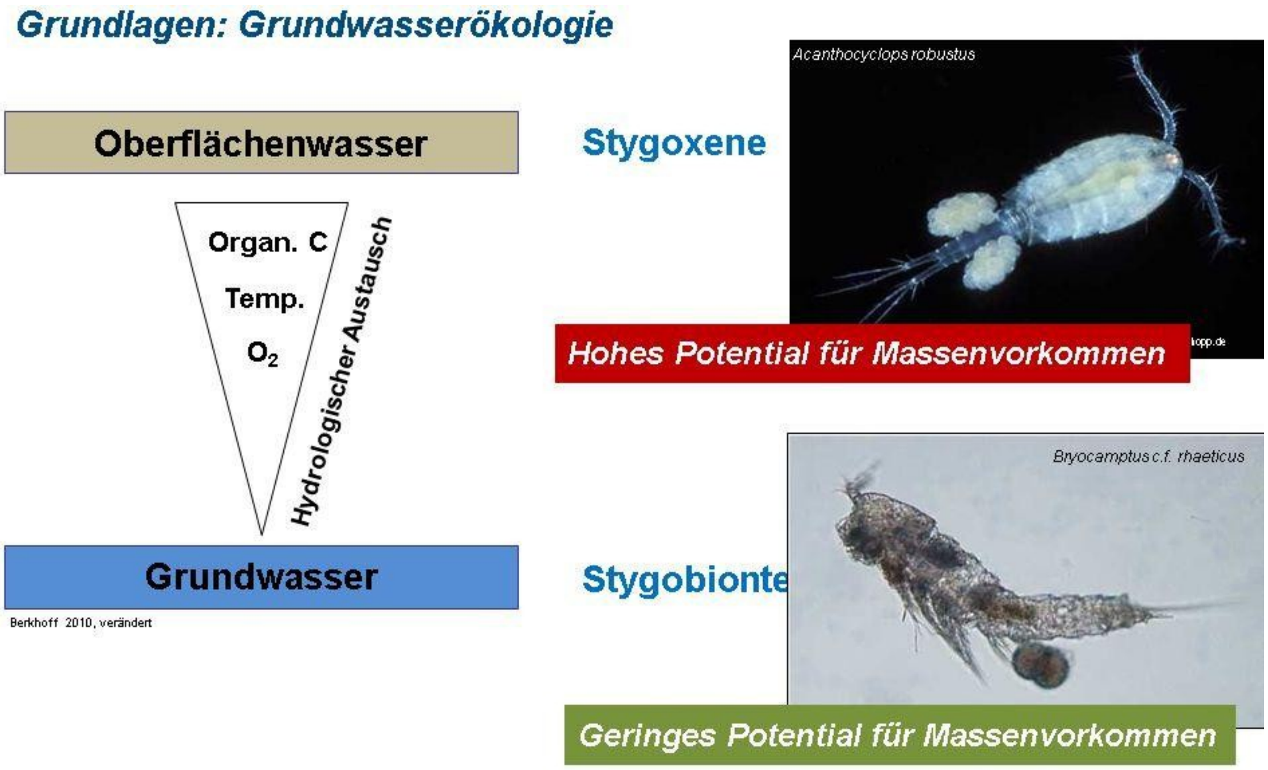

Figure 2: Groundwater recharge is characterized by steep gradients in organic carbon (DOC), oxygen and temperature amplitude. The fauna is adapted to these gradients.

Groundwater animals cannot build up mass populations. Where surface forms occur, the groundwater fauna is displaced by these rapidly reproducing species, or they cannot tolerate the high summer temperatures. Their territory is the well-shielded waters with a poor food and oxygen supply - real groundwater, which offers them a refuge from the surface species.

1.3 Pipeline network habitat

Pipeline networks are nothing more than artificial groundwater habitats. The same ecological "rules of the game" therefore apply as in open groundwater: a good food supply combined with a sufficient oxygen supply and increased temperatures promotes surface species and, conversely, groundwater animals benefit from low temperatures and a poor supply of organic material.

One thing must be made clear: Treating and transporting groundwater in transmission networks means nothing other than bringing it closer to the character of surface water in terms of its key ecological parameters:

– Oxygenation ensures that the water is optimally supplied with oxygen.
– Biofilms in the pipes fix the dissolved organic carbon (DOC) from the water over years and decades, thus enriching the entire system with organic material. At the same time, the biofilms grow, can clog the pipes and provide flow-calmed habitats for the animals.

– Water temperatures can rise to well over 20 °C in summer, especially in shallow pipes and domestic installations

The problematic surface types in particular benefit from this. The operation of treatment and piping systems for drinking water is therefore always associated with an increased risk of animal infestation. However, multicellular animals are found in almost all drinking water supply systems.
The art of the network operator is to operate and maintain the systems in such a way that surface species cannot reproduce there and, above all, cannot build up mass populations. Groundwater species in pipe networks, on the other hand, must initially be regarded as unproblematic and even as an indicator of excellent water quality.

1.4 What consequences does climate change have for grid hygiene?

Over the next 100 years, the average temperature on Earth will increase significantly. Depending on the calculation model and region, experts assume a rise of 2 - 4 °C. In Central Europe, longer, drier and warmer summers are to be expected.
As a result, the maximum temperatures in many building installations and especially in shallow drinking water pipes will rise significantly.
It is well known that the growth rate of bacteria increases exponentially with increasing temperature up to approx. 35 °C, provided there is sufficient organic material. The resulting hygiene problems cannot be ruled out. The positive correlation between reproduction and temperature is also known for surface water-dwelling animal species. Groundwater animals, on the other hand, react negatively to this[2] .
Figure 3 clearly shows the relationship between fluctuating temperature (including higher summer temperatures) and animal colonization in groundwater.

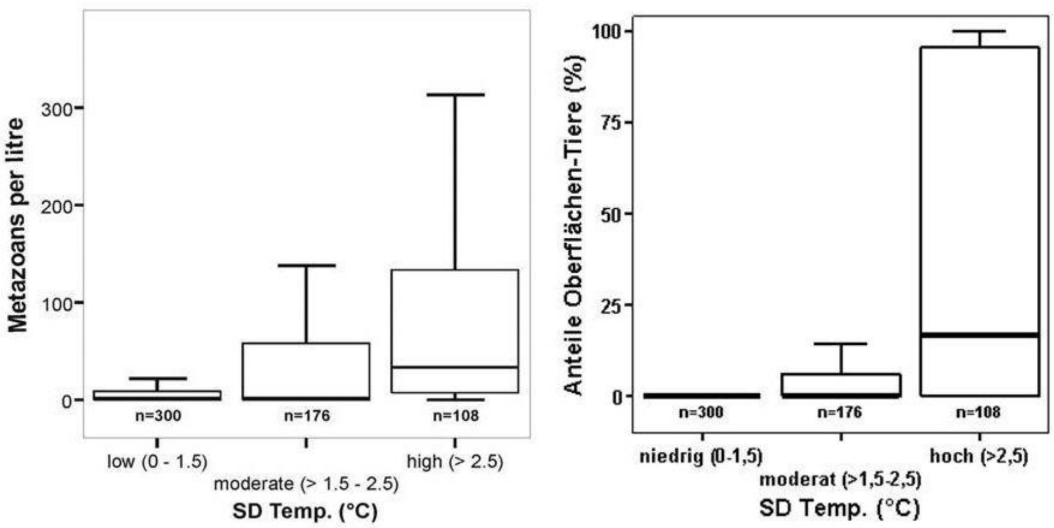

Figure 3: With increasing temperature amplitude, the colonization density and the proportion of animals foreign to groundwater increase.

The higher the standard deviation (fluctuation) of the temperature, the denser the colonization and the higher the proportion of surface species foreign to groundwater. Even if the standard deviation of the temperature, or the associated maximum temperatures, is not the only parameter influencing the fauna, the basic correlations are clear: higher temperatures in pipes are associated with an increased risk of a strong increase in surface water-dwelling animal species.
Against the backdrop of increasingly probable climate change, this is precisely one of the major challenges for the planning, construction and operation of future drinking water supply networks.

1.5 Measures against multicellular animals in cable networks.

Animals in supply networks are completely normal. Despite this, they are considered an "ugh topic" and are hardly discussed even within the company. A representative survey conducted by the author in Hesse in 2011 revealed that only 6% of all waterworks surveyed there addressed the issue of "animals in pipe networks". On this basis, dealing with this phenomenon, especially targeted countermeasures, is very difficult. Internal communication and a professional approach to the biology of groundwater - and above all the company's own systems - are the prerequisites for successful "animal management".
If the characteristics of the system are known (where do the animals occur? what species are involved? are there biofilms etc.?), suitable measures can be taken if necessary at all.
Acutely, the affected network areas can be flushed, usually with little success. Even the use of CO_2 only provides short-term relief, as it does not eliminate the causes of the infestation. It is much more efficient to remove the biofilms together with the animals living in and on them using suitable methods, such as air-bound impulse flushing methods. Depending on the carbon content of the water, it can then take years for the biofilms to grow back to a critical density.
The only truly sustainable solution is to modify the network, e.g. to avoid stagnation zones or heating the water by lowering the pipes. Ultimately, it may also be necessary to shut down critical wells or springs. In many cases, however, the costs and effort involved in such measures are disproportionate to the result. With or without climate change: we must learn to live with the animals and control their populations with adapted network hygiene.

2 Literature

[1] Hahn, H. J.: Metazoans/Vielzellige Tiere. In Groundwater Biology - Fundamentals and Applications T5/2012, DWA Topics, pp. 71-82, 2012

[2] Brielmann, H., Griebler, C., Schmidt, S. I., Michel, R. & Lueders, T.: Effects of thermal energy discharge on shallow groundwater ecosystems. FEMS Microbiol Ecol 68, pp. 273-286, 2009

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