Identification of Groundwater Habitats Using Radon as a Tracer

Floodplains harbor a complex network of aquatic habitats that are fed by surface water as well as ground water. With the help of the radon method, it is possible to identify habitats that are primarily influenced by ground water. In the "middle floodplain" of Valle di Blenio, we were able to distinguish three types of ground water by determining radon along with sulfate concentrations. Each type of ground water is characterized by a different proportion of freshly-infiltrated surface water.

Floodplains are sections of a stream system that are periodically flooded [1]. They are often found in gravel deposits along valley floors and have a characteristic plant and wildlife community, depending on the duration and frequency of flooding events. In floodplains, there is an intense exchange between surface water and ground water; surface water can infiltrate into ground water and vice versa.

Radon as a Tracer in Ground Water

Groundwater habitats in floodplains are characterized by varying mixing ratios of surface water and ground water and by variable residence times of the mixed water [1]. Using the naturally occurring tracer radon, we can estimate this mixing proportion. Ground water naturally contains the radioactive noble gas radon (isotope Rn-222, referred to as Rn; see box) in detectable concentrations. Surface water, in contrast, contains virtually no Rn, since it is released as gas into the atmosphere. Surface water that has freshly infiltrated to the subsurface will take up Rn and reach a steady-state concentration after approximately 15 days (Fig. 2) [2].

Radon

The radioactive isotope Radon-222 (half-life 3.8 days) is produced by the natural decay of Radium-226, itself a decay product of Uranium-238. Chemically, radon is an inert noble gas. Radon has a strong ability to penetrate rock; if uranium and/or radium is present in permeable rock, radon can be released by diffusion and recoil (emanation). Thus radon can reach ground water or soil gas, from where it is released as gas into the atmosphere. Radioactivity is measured as number of decays per second, which is the definition of the unit Becquerel (Bq). The concentration of radioactivity in ground water is described as Bq/l.

Groundwater Influence in the Floodplains of Valle di Blenio

An EAWAG case study in the "middle floodplain" of Valle di Blenio (Acquarossa – Ponto Valentino, Canton Ticino; Fig. 1) aimed at determining the extent to which aquatic habitats in floodplains are influenced by ground water. Part of the middle floodplain is fed by hillslope water [3]. Hillslope water is ground water that flows from the valley sides towards the valley bottom and emerges in the floodplain as springs. Such springs, for example, can be found in the gravel deposits associated with the tributary stream Uregn. Additionally, there are springs and groundwater upwellings along the stream bed and banks of the Brenno that are fed by valley floor ground water. A relatively high proportion of freshly infiltrated surface water characterizes this ground water.

Nine sites in the middle floodplain were sampled on three days (July and October 1999, April 2000). At these sites, groundwater samples were pumped from depths of up to 10 m. For comparison, water from two springs of the sulfate-rich Trias formation and surface water from the tributary Uregn and the main channel of the Brenno was sampled (Fig. 1). Radon concentrations in the water samples were immediately measured in the field with a semiconductor detector.

Three Types of Ground Water

Measured Rn concentrations were between 5 and 45 Bq/l (unit Bq: see box). As expected, the surface water from the Brenno and the Uregn contained virtually no Rn. The water from the two triassic springs, on the other hand, showed high Rn concentrations (>33 Bq/l), reflecting the fact that this is older, unmixed ground water. The

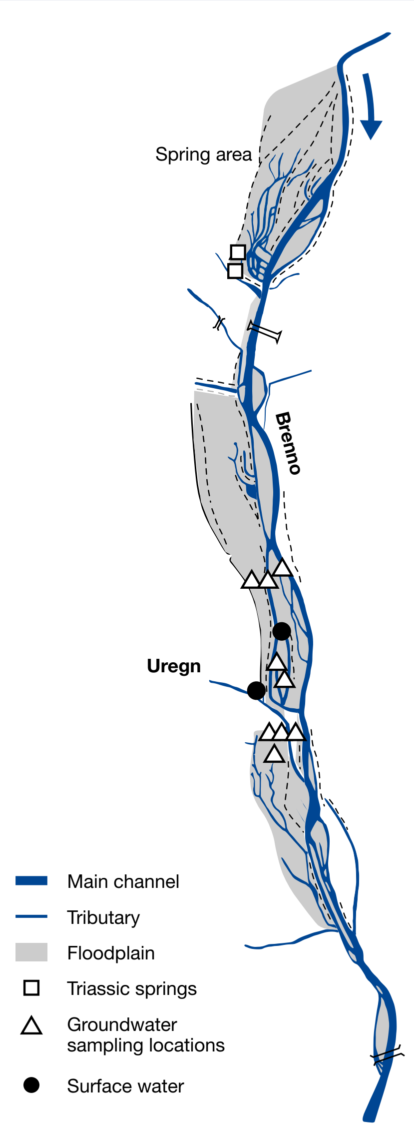

Fig. 1: Map of the middle floodplain of the Valle di Blenio (Canton Ticino), with sampling locations.

samples from the 9 groundwater sites contained mixed water with Rn concentrations between 5 and 33 Bq/l. Because of the wide range of Rn concentrations found in the mixed water samples, no clear pattern could be determined. In some sampling locations, the Rn concentration changed between sampling dates. The additional determination of sulfate (SO_4^{2-}) concentrations can give us a clearer picture of whether different types of ground water are present.
The water of the Brenno is known for relatively high SO_4^{2-} concentrations. The sulfate is generated by the dissolution of gypsum and anhydrite rocks of the Trias formation in the upper parts of the watershed [4, 5]. Sulfate concentrations were, in fact, between 1 and 2.5 mmol/l for most of the water samples. Groundwater samples and water samples from the Uregn, on the other hand, contained only little SO_4^{2-} (<1 mmol/l).

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The "middle floodplain" of Valle di Blenio, Canton Ticino.

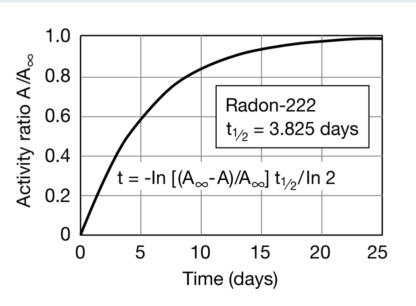

Fig. 2: Equation describing the increase in Rn concentration over time: after 15 days (approximately 4 half-lives, $t_{1/2}$) 94% of the steady-state concentration (A_∞) is reached. Solving this equation for measured Rn concentrations (A) allows us to calculate activity ratios A/A_∞ and, therefore, residence times for the groundwater samples.

Figure 3 demonstrates how Rn and SO_4^{2-} concentrations can be used to define three types of ground water. The first group is characterized by low SO_4^{2-} and intermediate Rn concentrations; this is thought to be relatively old ground water, probably being fed by hillslope ground water from the area of the tributary Uregn. The low SO_4^{2-} concentrations indicate minimal infiltration of surface water. The second group includes samples with intermediate SO_4^{2-} and low Rn concentrations. This combination indicates fairly young mixed water with a relatively high proportion of infiltrated Brenno water. The third group comprises the water samples from the triassic springs, characterized by both high SO_4^{2-} and Rn concentrations.

These results illustrate how Rn concentrations, in this case in combination with SO_4^{2-} concentrations, allow us to determine mixing ratios and the age of ground water. Depending on the quality of the ground water, we can expect different subsurface habitats. In addition to the hydrological aspects described in this article, a comprehensive characterization of groundwater habitats must include detailed biological and geological investigations.

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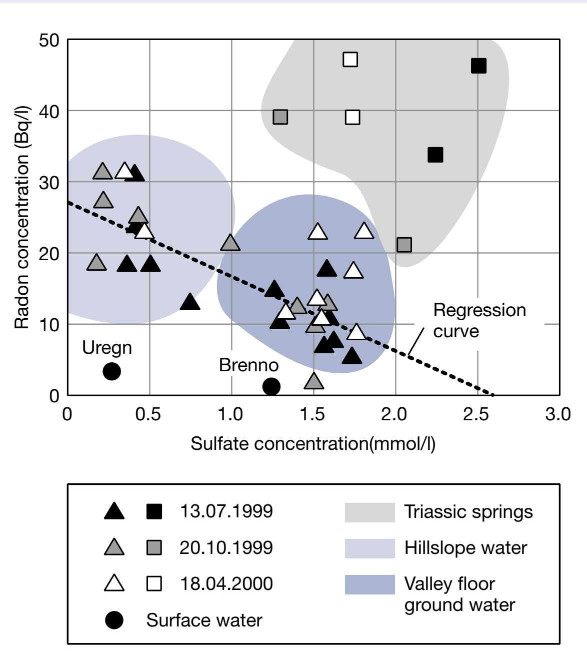

Fig. 3: Determination of groundwater types based on Rn and sulfate. Triangles: groundwater samples; squares: samples from triassic springs.
- **Light blue area: relatively old mixed water with low proportion of surface water and high proportion of ground water (11 samples from 4 locations).**
- **Dark blue area: relatively young mixed water with high proportion of surface water and low proportion of ground water (18 samples from 8 locations).**

Regression curve for these 29 samples: y = -9.5x + 27; r = -0.68.
- **Gray area: older, unmixed ground water from the triassic springs (6 samples from 2 locations).**