



## Groundwater Age Dating

*How long was groundwater underground before abstraction? Is it a mixture of different aquifers? Is drinking water quality safe in the long term? Will groundwater resources be renewed in the foreseeable future or is it finite?*

These questions are of great importance for groundwater management and drinking water supply. The analysis of specific tracers and the knowledge of their input functions and flow conditions in the subsurface enable the age-dating of the groundwater. The mean residence times of a pre-modern (>60 years) and a younger groundwater component are often to be determined. For this purpose, tritium ( $^3\text{H}$ ) is determined in combination with fluorocarbons CFC/SF<sub>6</sub>, helium-3 ( $^3\text{He}$ ) or krypton-85 ( $^{85}\text{Kr}$ ), and routinely the stable isotopes of water ( $^2\text{H}/^1\text{H}$ ,  $^{18}\text{O}/^{16}\text{O}$ ). Old groundwater is dated by determining carbon-14 ( $^{14}\text{C}$ ), argon-39 ( $^{39}\text{Ar}$ ), krypton-81 ( $^{81}\text{Kr}$ ) or chlorine-36 ( $^{36}\text{Cl}$ ). The influence of waste water can be verified by the content of certain sweeteners (e.g. acesulfames, saccharine).



**Sampling**



**Preparation**



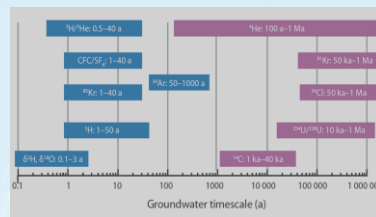
**Analysis**



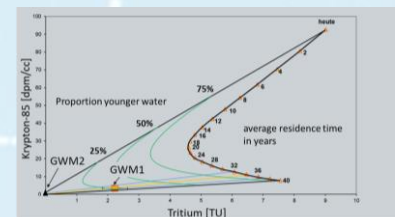
**Expertise**



**Precipitation causes the input function of atmospheric tracers into the subsurface. Their levels provide information on the age of the groundwater.**



**Individual tracer values enable conclusions on mixture of groundwater with specific periods of formation.**



**The amount and age of young groundwater component can be determined by analyzing tritium, CFC/SF<sub>6</sub>,  $^3\text{He}/\text{Ne}$  or  $^{85}\text{Kr}$ .**

### Workflow

- We develop an investigation concept taking into account the site-specific conditions.
- We provide sampling flasks and protocols.
- We determine the concentrations of anthropogenic and isotope tracers.
- We interpret the tracer data to determine groundwater ages and amounts of younger/premodern proportions.

**Costs**  $^2\text{H}/^1\text{H}$ ,  $^{18}\text{O}/^{16}\text{O}$ : 35 – 55 € per sample  
 Tritium ( $^3\text{H}$ ): 140 – 180 € per sample  
 CFC/SF<sub>6</sub>: 360 – 440 € per sample  
 $^{14}\text{C}$  incl.  $^{13}\text{C}/^{12}\text{C}$ : 390 – 490 € per sample

$^3\text{He}$  incl.  $^4\text{He}$ , Ne: 220 - 390 € per sample  
 $^{85}\text{Kr}$ : 1.650 – 1.950 € per sample  
 Sweeteners: 180 – 220 € per sample

### Further reading

Plummer LN (2005) Dating of young groundwater. In Aggarwal PK, Gat JR, Froehlich KFO (eds.), *Isotopes in the Water Cycle*: 193-218.

IAEA (2013) *Isotope methods for dating old groundwater*.

Bethke CM, Johnson TM (2008) Groundwater age and groundwater age dating. *Annu. Rev. Earth Planet. Sci.* 36: 121-152.

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