

## Disposal sites and Isotopes



WATER

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TRACER TESTS

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Isotopy & Chemistry in Environmental Hydrology & Food



## DISPOSAL SITES AND ISOTOPES

In dense populated and industrialized areas, it is often very complex to accurately identify the origins of hazardous compounds and contaminants, which reached the groundwater. Commonly applied hydrochemical investigation technologies can be used only in unambiguous situations, for example in which the origin, the input conditions, the contaminant plumes, and the biological transformation processes are known.

Under more complex hydrogeological conditions and in case of multiple sources, the validity of hydrochemical investigation technologies is limited. In these cases, isotope analyses of the compounds and contaminants in groundwater can help to evaluate the situation.

### Background

Most chemical elements have isotopes. For example, hydrogen has two stable isotopes,  $^1\text{H}$  (99,99 %) and  $^2\text{H}$  (Deuterium, 0,01 %), and one radioactive isotope  $^3\text{H}$  (Tritium).

Analyzing stable isotopes, no absolute values, but isotope ratios are determined. These ratios are specified in reference to an international standard.

By physical, chemical and biological processes the isotope ratios can be changed. These isotope effects lead to a spatial and temporal marking of different element cycles.

In case of the radioactive isotope tritium, the radioactive decay is measured and specified by tritium units (TU = 23 Bq/L).



### Initial situation

The content of a municipal waste landfill effects the environment mainly by the discharge of gas and leachate. In most instances, the isotope signatures of  $\text{CH}_4$  and  $\text{CO}_2$  in the leachates of municipal waste landfills differ significantly from natural isotope ratios. Experience has shown that isotope methods are a very useful tool for the determination of the processes occurring in disposal sites.

Thus, dispersing leachates and their contact to groundwater can be identified.



## DISPOSAL SITES AND ISOTOPES

### Deuterium ( $\delta^2\text{H}$ ) and Oxygen-18 ( $\delta^{18}\text{O}$ ) in water

Plotting  $\delta^2\text{H}$  against  $\delta^{18}\text{O}$  in a diagram, the values of meteoric water are on the so-called meteoric water line.

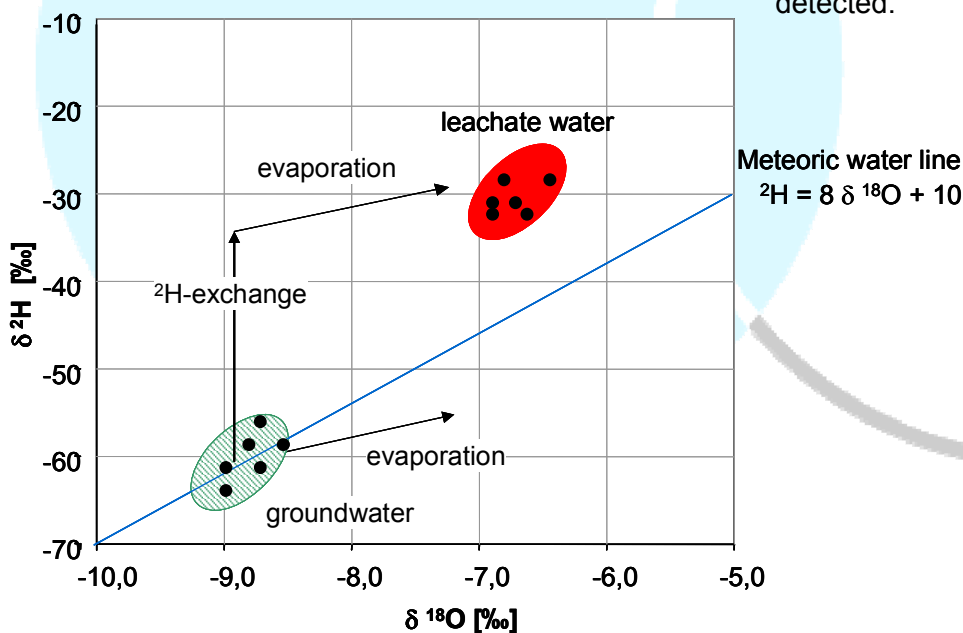
If the precipitation water experiences evaporation, which is characteristic for stagnant water bodies under warm climate conditions, or by irrigation of effluents,  $^{18}\text{O}$  and  $^2\text{H}$  in water becomes enriched and, therefore, shift rightward of the meteoric water line.

In disposal sites with organic burials (e.g. municipal waste landfills) water is formed by the decomposition of the organic material. In this process, hydrogen ( $\text{H}_2$ ) and methane ( $\text{CH}_4$ ) are formed, which causes isotope fractionation between  $\text{H}_2/\text{CH}_4$  and water. The heavy hydrogen  $^2\text{H}$  is favored to be incorporated into the water molecule. Therefore, water formed in a disposal site is enriched in  $^2\text{H}$  in comparison to meteoric water.



The enrichment in  $^2\text{H}$  and a potential enrichment in  $^{18}\text{O}$  due to irrigation or evaporation leads to a characteristic isotope signature. This is shown in the figure by an upward and rightward shift from the meteoric water line.

Therefore, a determination of  $^{18}\text{O}$  and  $^2\text{H}$  signatures can be used to identify biological processes occurring in a disposal site and the percentages of the formed water. By comparing the isotope signature of the water formed in a disposal site with the isotope signature of groundwater, potential mixing processes can be detected.





## DISPOSAL SITES AND ISOTOPES

### Tritium in water

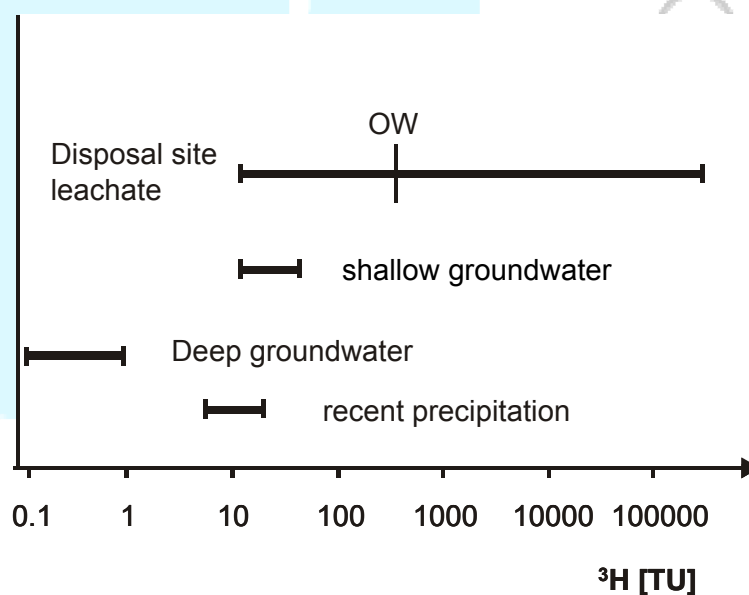
For decades, the aerial nuclear bomb tests between 1950 and 1963 were the main source of the anthropogenic tritium abundant in the environment. Since the termination of these tests, the tritium content continuously decreases because of radioactive decay of tritium.



Experience has shown that leachates from disposal sites have a tritium content of 10 to 200 000 TU. The mean value of 800 TU for leachates clearly exceeds the tritium values of mean precipitation in Europe (approx. 8 TU), shallow groundwater and deep groundwater.

The origin of the high tritium content of leachates can not be explained clearly for the most disposal sites. Potential sources are waste from industry which has produced watches or fluorescence substances. Other sources might be waste from hospitals.

However, if a disposal site is marked with  $^3\text{H}$ , it is an ideal tracer for the dispersion of leachates, because tritium is not influenced by chemical and microbial processes.





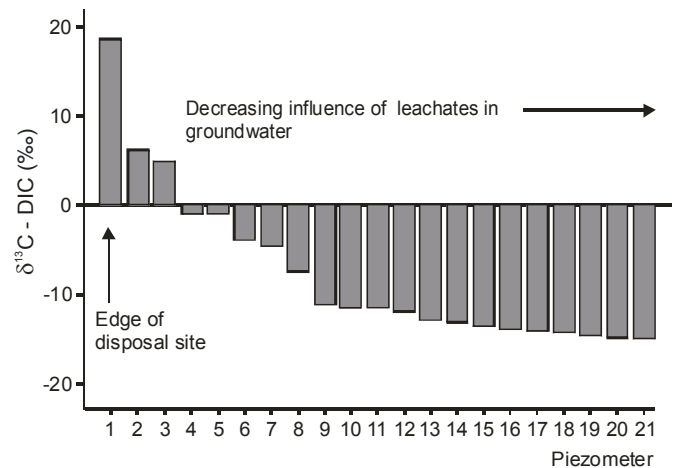
## DISPOSAL SITES AND ISOTOPES

### $^{13}\text{C}$ in DIC

Dissolved inorganic carbon (DIC) in water is mostly available as  $\text{CO}_2$  and hydrocarbonate ( $\text{HCO}_3^-$ ). Hydrocarbonate is formed predominantly by the dissolution of carbonates due to the reaction with  $\text{CO}_2$ .

If  $\text{CO}_2$  is formed organically under anaerobic conditions, the  $\delta^{13}\text{C}$ -value is in the range of the organic material. However, if  $\text{CO}_2$  is formed under anaerobic conditions concurrently with methane ( $\text{CH}_4$ ),  $\text{CO}_2$  is enriched in  $^{13}\text{C}$  (Figure below). The formation of hydrocarbonates leads to a further enrichment of  $^{13}\text{C}$  in hydrocarbonate compared to  $\text{CO}_2$ .

The  $\text{HCO}_3^-$  and therefore the DIC of leachates from disposal sites are therefore highly enriched in  $^{13}\text{C}$ . Additionally, leachates have very high concentrations of DIC compared to most of the groundwater. This method allows a detection of small percentages (in %-range) of leachates in groundwater.



The figure shown above illustrates the  $\delta^{13}\text{C}$  values in DIC of water from a piezometer series. The series begins at the edge and proceeds away from the disposal site. The decreasing  $\delta^{13}\text{C}$  values suggest a diminishing contamination of the groundwater by leachates with increasing distance from the disposal site.

