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First Water-Isotope-Map ($\delta^{18}O$, $\delta^{2}H$, ^{3}H) of Austria: Applications, Extremes and Trends

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Abstract

The isotopic ratios of oxygen and hydrogen in water ($^{2}H/^{1}H$ and $^{18}O/^{16}O$) are important tools to characterise waters cycles. Tritium formed by natural cosmic radiation in the upper atmosphere and in the last century by tests of thermonuclear bombs, is an ideal age-marker during the last 60 years. To determine the origin and mean age of waters in many projects concerning water supply, engineering and scientific projects in the last 45 years on more than 1,350 sites more than 40,000 isotope measurements were performed in Austria. The median value of all sites of oxygen-18 is $\delta\ ^{18}O$ -10.7 ‰ and for hydrogen-2 $\delta\ ^{2}H$ -75 ‰. As the fractionation is mainly temperature dependent the lowest negative values are observed in winter precipitation (oxygen-18 as low as $\delta\ ^{18}O$ -23 ‰) and in springs in the mountain regions ($\delta\ ^{18}O$ -15.1 ‰). In contrast the highest values were observed in summer precipitation (up to $\delta\ ^{18}O$ – 0.5 ‰) and in shallow lakes in the Seewinkel close to the Hungarian border (up to $\delta\ ^{18}O$ + 5 ‰). The precipitation in the region of South of the main Alpine crest (East-Tyrol, Carinthia and South-East Styria) is approximately 1 ‰ higher in $\delta\ ^{18}O$-values as sites at the same altitude in the northern part. This is most probably caused by the stronger influence of precipitation from the Mediterranean area. The median value of all 1,120 sampling sites of decay corrected (2015) tritium measurements is 6.2 tritium units (TU). This is somewhat smaller than the median value of all precipitation stations with 7.2 TU. The tritium concentration increases in the summer up to 10 – 11 TU and decreases in winter down to 3 – 4 TU. A mean tritium concentration in aquifers smaller than approximately 3.5 TU indicates large amounts of this water are older than 60 years. Waters containing approximately more than 12 TU containing still tritium from the 1960s and 1970s formed originally by thermonuclear bomb experiments. In Austria the highest Tritium values can be observed in the rivers Danube and March which show periodic or permanent tritium contamination up to 70 TU coming from nuclear power plants in the neighbouring countries.

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Keywords: $\delta\ ^{18}O$; $\delta\ ^{2}H$; tritium; isotope map; Austria

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1. Introduction

The isotopic ratios of oxygen and hydrogen in water ($^{2}H/^{1}H$ and $^{18}O/^{16}O$) are important tools to characterise waters and their cycles. This starts in the atmosphere as rain or snow and continues in the surface water and ends in shallow groundwater as well as in deep groundwater. Tritium formed by natural cosmic radiation in the upper atmosphere and in the last century by tests of thermonuclear bombs in the atmosphere, is characterised by its radioactive decay with a half-life of 12.32 years and is an ideal age-marker during the last 60 years.

To determine the origin and mean age of waters in many projects concerning water supply, engineering and scientific projects in the last 45 years on more than 1,350 sites more than 40,000 isotope measurements were performed in Austria.

2. Methods

Coordinates (referenc-systemWGS84) were allocated to all sites (precipitation, surface water, spring, wells and deep groundwater) with more than two (up two 100) isotope measurements in Austria performed since 1971. The documentation is based on survey measurements, maps and descriptions. The median value was calculated from all available isotope measurements from one site. Annual mean values were calculated from precipitation data weighted by the amount of precipitation. To make tritium data more comparable each measurement was decay corrected to the year 2015. All data are shown in a map 1:500,000 and can be downloaded from the internet[1]. A more detailed description of data compilation, statistical treatment and data presentation is given in[2].

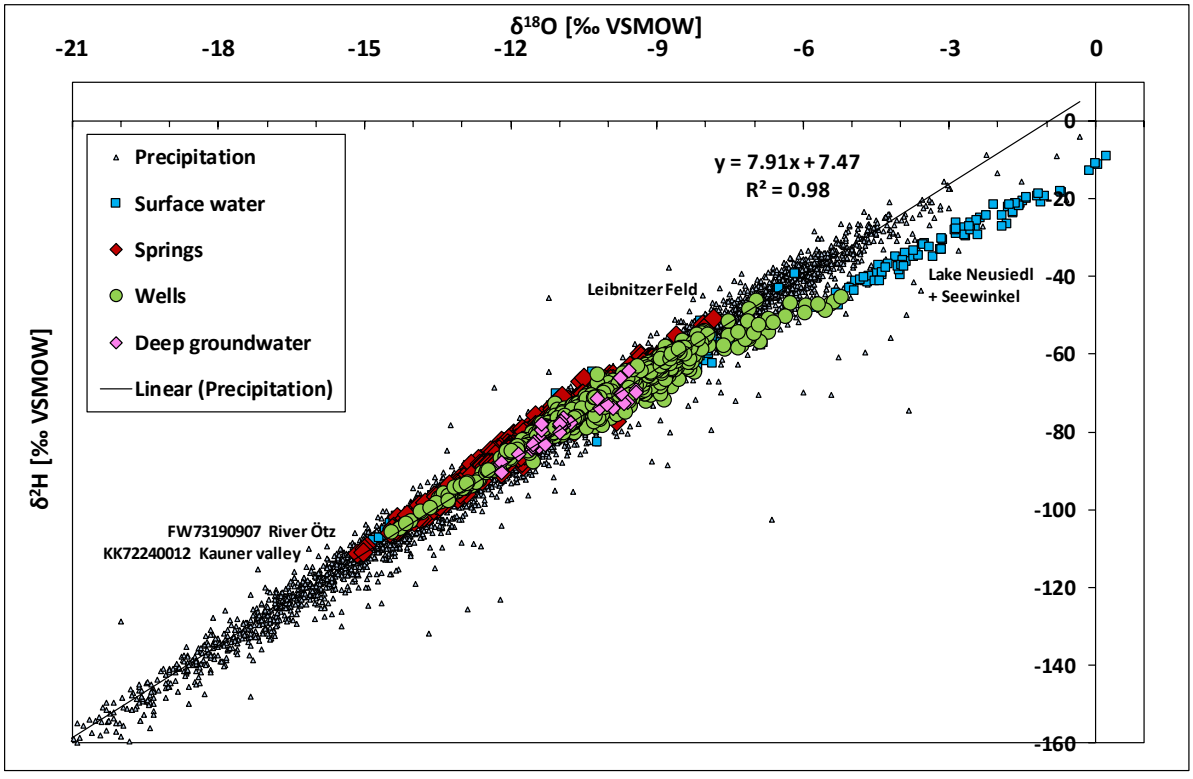

Fig. 1. δ ^{18}O vs. δ ^{2}H of more than 10,000 isotope measurements of precipitation, surface water, spring, well and deep groundwater stations.

3. Results

The median value of all sites of oxygen-18 is δ ^{18}O = -10.7 ‰ and for hydrogen-2 δ ^{2}H = -75 ‰. As the fractionation is mainly temperature dependent the lowest negative values are observed in winter precipitation (oxygen-18 as low as δ ^{18}O = -23 ‰) and in springs in the mountain regions (δ ^{18}O = -15.1 ‰) (Kauner valley Fig.1). In contrast the highest values were observed in summer precipitation (up to δ ^{18}O = – 0.5 ‰) and in shallow lakes in the Seewinkel area close to the Hungarian border (up to δ ^{18}O = + 5 ‰). The precipitation in the region of South of the main Alpine crest (East-Tyrol, Carinthia and South-East Styria) is approximately 1 ‰ higher in δ ^{18}O-values as sites at the same altitude in the northern part.

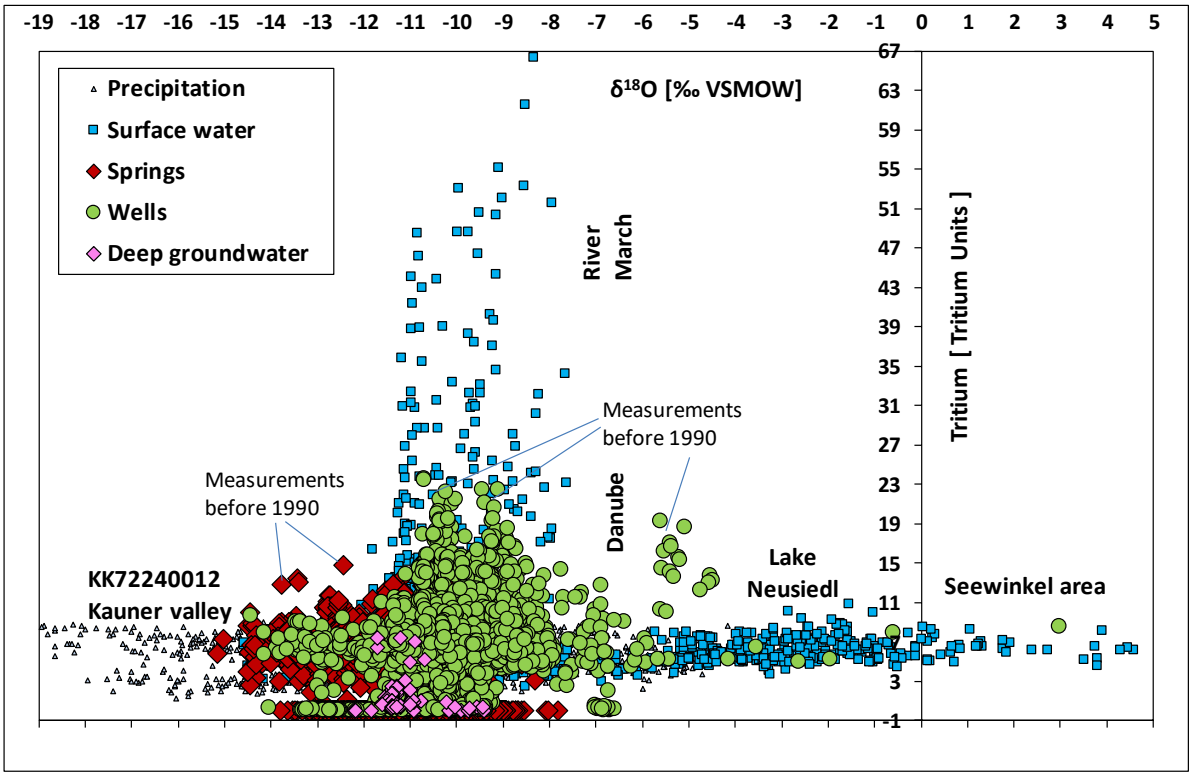

Fig. 2. δ ^{18}O vs. tritium of more than 12,000 isotope measurements of precipitation, surface water, spring, well and deep groundwater stations.

The median of all deuterium-excess values is d-excess = 9.4 ‰. The lowest negative value of -7.4 ‰ was measured in the surface water sample of a gravel pit in the Leibnitzer Feld (Southern Styria). The highest d-excess value of 15.7 ‰ is documented from a mountain spring at the southern border of Austria.

The median value of all 1,120 sampling sites of decay corrected (2015) tritium measurements is 6.2 tritium units (TU). This is somewhat smaller than the median value of all precipitation stations with 7.2 TU. The tritium concentration increases in the summer up to 10 – 11 TU and decreases in winter down to 3 – 4 TU.

Tritium concentrations less than 3.5 TU are more frequent in the shallow groundwater (< 50 m) at the most eastern part of Austria not far from the Hungarian and Slovak border. In Austria the highest Tritium values are observed in the rivers Danube and March which show periodic or permanent tritium values up to 70 TU (Fig. 2).

4. Discussion

As the isotope fractionation of the δ ^{18}O and δ ^{2}H-values is temperature dependent, the lowest values are found in winter precipitation in the mountains and the highest in the summer precipitation and even more enriched in

evaporitic lakes of the Seewinkel area (Fig. 1 and 2). The isotopic ratios of the Austrian waters are also influenced by the origin of the evaporated water masses. Therefore, the precipitation in the region of South of the main Alpine crest (East-Tyrol, Carinthia and South-East Styria) is approximately 1 ‰ higher in $\delta\ ^{18}O$-values as sites at the same altitude in the northern part. This is most probably caused by the stronger influence of precipitation from the Mediterranean area.

The d-excess of all Austrian precipitation measurements are in the range of 7.5 - 8.4 ‰ and the median of all water sites slightly lower (9.1 ‰) than the Global Water Line. However, the median of d-excess in the mountain springs is with 11 ‰ significantly higher and can reach values up to 15.7 ‰. In Austria the d-excess-values are weakly correlated with the altitude of the water sites, which can be explained by recycling of water in the mountains evaporated in the warmer valleys[3].

The median value of tritium from all precipitation stations is equal to 7.2 TU. This can be explained by the fact that in most cases in groundwater the median value (6.0 TU) has been reduced by decay according to the residence time underground. The tritium concentration increases in the summer up to 10 – 11 TU and decreases in winter down to 3 – 4 TU. This is due to the better circulation in the atmosphere in spring which brings the tritium formed by cosmic radiation down to the lower atmosphere and precipitation.

Tritium concentrations less than 3.5 TU are more frequent in the shallow groundwater (< 50 m) at the most eastern part of Austria not far from the Hungarian and Slovak border indicate large amounts of water older than 60 years. A smaller mean tritium concentration in aquifers than approximately 3.5 TU indicates large amounts of water older than 60 years. Waters containing approximately more than 12 TU containing still tritium from the 1960s and 1970s formed originally by thermonuclear bomb experiments. In Austria the highest Tritium values can be observed in the rivers Danube and March which show periodic or permanent tritium contamination up to 70 TU coming from nuclear power plants in the neighbouring countries (Fig. 2).

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