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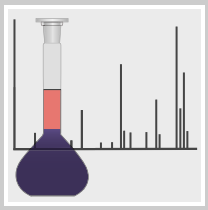

Highlights of Analytical Sciences in Switzerland

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Neutron Activation Analysis – Another Approach to Uranium and Thorium Analysis in Environmental Samples

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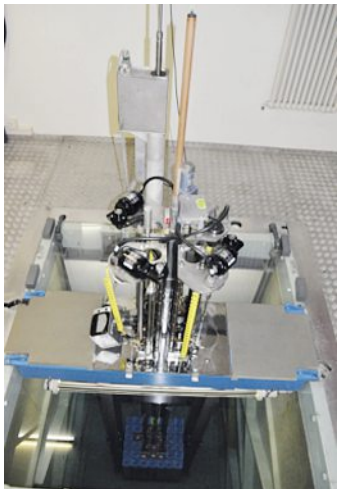
Uranium (U) and thorium (Th) are the starting elements of two natural decay series. The isotopic abundance in the Earth's crust for ^{238}U and for ^{232}Th is 2 and 7 mg/kg, respectively; however, in suspended matter they are enriched (30–40 mg/kg uranium; 30–60 mg/kg thorium). Normally, these isotopes are analysed with spectroscopic methods, such as ICP/MS or ICP/OES, alpha spectrometry, or by means of gamma ray detection *via* either their daughter nuclides (^{234}Th for ^{238}U, at 92.4 keV) or by analysing directly the weak low-energy gamma line of ^{232}Th at 63.8 keV.

Another possibility is to use instrumental neutron activation analysis (INAA). The analytes are irradiated with neutrons produced in a nuclear reactor. The activation processes are as follows:

$^{238}U + n \rightarrow {}^{239}U \rightarrow {}^{239}Np + \beta + \gamma \rightarrow {}^{239}Pu + \beta + \gamma$ (half-life of 2.4 d)

$^{232}Th + n \rightarrow {}^{233}Th \rightarrow {}^{233}Pa + \beta + \gamma \rightarrow {}^{233}U + \beta + \gamma \rightarrow \ldots$ (half-life of 27 d)

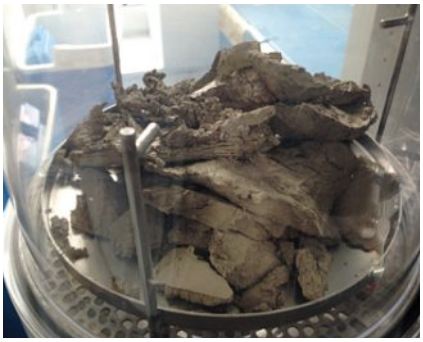
The international monitoring station Weil am Rhein, Germany (photo by S. Zehringer).



Nuclear reactor core at the University of Basel. The AGN-211-P is a light-water moderated swimming pool reactor with a power of 2 kW and a neutron flux of 3.8E+10 neutrons/cm^2/s (photo by G. Testa).

The gamma rays of the irradiated samples are analysed with high-purity germanium detectors. Gold is used as an internal standard (activated to ^{198}Au, half-life: 65 h).

At the international monitoring station Weil am Rhein, Germany, the main task is the daily control of the Rhine water. As a completion, suspended matter is collected and analysed for substances of environmental concern, such as heavy metals, polychlorinated biphenyls and last but not least, artificial and naturally occurring radionuclides. Periodically, suspended matter is extracted by means of a centrifuge. After freeze-drying and grinding, the sample is ready for INAA. 1 g sample is irradiated for 30 min by means of the nuclear reactor at the Department of Physics, University of Basel. After a cool-down period of 2 hours the sample is counted at the Kantonales Laboratorium by means of a gamma spectrometer for at least 2000 s.



Suspended matter collected with the centrifuge at the international monitoring station Weil am Rhein. Collecting time depends on the turbidity of the river water, typically, it is 24–48 h (photo by R. Dolf).

Recently, discussion started about elevated uranium concentrations in ground- and river waters. Phosphate fertilisers are a natural source of uranium and other actinides. For this reason, the treatment of agricultural soils with phosphate fertilisers can lead to an accumulation of uranium and other actinides in the soils. Uranium-VI is soluble and can be leached from the soils into ground- and river waters.

INAA is an alternative method for the determination of U and Th in soil, sediment and suspended matter samples. The method omits interferences from the γ-decay of natural nuclides in the measured gamma ray spectra.

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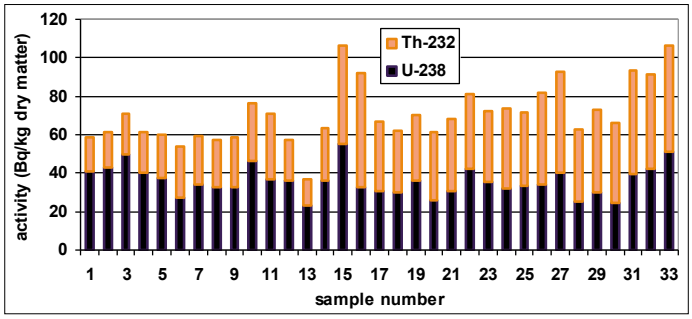

Activities of uranium and thorium in suspended matter of the River Rhine at Weil, 2011–2012.

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