Following our DREAMS (DREsden Accelerator Mass Spectrometry)

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Since 2011 the DREAMS (DREsden Accelerator Mass Spectrometry) facility [1] has produced data of several long-lived radionuclides (Tab. 1).

Table 1: Radionuclides measured at DREAMS. Updated from [1]. ^{44}Ti and actinides are under development.

Nuclide(s)	$t_{1/2}$ [Ma]	AMS material	Blank level [10^{-16}]	Sample ratios [10^{-12}]
^{10}Be ($/^{9}$Be)	1.387	BeO	5	0.01-300
^{26}Al ($/^{27}$Al)	0.705	Al_2O_3	6	0.001-60
^{36}Cl ($/^{35}$Cl)	0.301	AgCl	4	0.007-700
^{41}Ca ($/^{40}$Ca)	0.104	CaF_2	20	0.006-9000
^{129}I ($/^{127}$I)	15.7	AgI	200	0.5-200

AMS reduces background and interfering signals resulting from molecular ions and isobars enormously. Thus, AMS provides much lower detection limits compared to conventional MS or decay counting. DREAMS offers excellent measurement capabilities also for external users (see www.hzdr.de/ibc for beam time application).

Long-lived radionuclides have thousands of exciting applications, especially within environmental and geosciences. In nature, the so-called cosmogenic nuclides (CNs) are products of nuclear reactions induced by primary and secondary cosmic rays. Hence, they can be found in extraterrestrial material such as meteorites - originating from the asteroid belt, the Moon or Mars - and lunar samples in higher concentrations (e.g. ~10^{10} ^{10}Be atoms/g or < 0.5 mBq/g). A combination of several CNs is used to reconstruct the exposure history of this unique material while in space (irradiation age) and on Earth (terrestrial age).

Though, in terrestrial material the concentrations are typically only on the order of 10^4-10^9 atoms/g (i.e. µBq/g - nBq/g) for ^{10}Be produced in the Earth's atmosphere, then transported to the surface and further absorbed and incorporated at and in e.g. sediments or ice. Some of the lowest ^{10}Be concentrations (~10^3 atoms/g), produced in-situ by neutron- and muon-induced nuclear reactions from e.g. oxygen and silicon in quartz, can be found in samples taken from the Earth's surface. The concentrations of atmospheric or in-situ produced CNs record information that is used to reconstruct sudden geomorphological events such as volcanic eruptions, rock avalanches, tsunamis, meteor impacts, earthquakes [e.g. 2] and glacier movements. These movements and data from ice cores give also hints for the reconstruction of historic climate changes and provide information for the validation of climate model predicting future changes. Slower processes such as sedimentation, river incision and erosion rates can also be investigated and indirect dating of bones as old as several Ma is possible. Finally, remnants of supernova-produced nuclides can also be found in deep-sea archives (sediment, crust, nodule) [e.g. 3].

Anthropogenic production e.g. by release from nuclear reprocessing, accidents and weapon tests led to increased radionuclide levels in surface water, ice and soil (^{36}Cl, ^{129}I,…). Hence, some nuclides can be used as tracers to follow pathways in oceanography, to date and identify sources of groundwater, to perform retrospective dosimetry and to study aspects in radioecology and pharmacology. Obviously, also nuclear installation materials are radioactive (^{41}Ca,…).

Radiochemistry

Typical measurement times are on the order of one hour per sample. However, radiochemical separation of the nuclides of interest is absolutely essential and may take from several days for simple matrices (ice, water) to several weeks for more complicated ones (rock, sediments,…).

DREAMS offers external users to perform this sample preparation of AMS targets in two dedicated chemistry labs at Dresden since 2009. Up to several hundreds of samples from interdisciplinary research topics such as astronomy, climate, cosmochemistry and geology could be transformed into AMS material (Tab. 1) showing reasonable to excellent performance. Besides our constant approach to become a little better every day, sometimes very new challenges can arise due to the low availability of the sample material, low radionuclide concentration or a possible contamination of the sample with disturbing elements and nuclides.

Two examples of challenges

Ice samples are always in our focus. As we were facing problems with ^{10}Be contamination in "dirty" ground ice, instead, we measured ^{36}Cl and ^{nat}Cl by isotope dilution in permafrost ice wedge samples as heavy as 1.6 kg. The chemical yield of AgCl was only 20-35% (and is a function of total ^{nat}Cl), which might be improved by preceding preconcentration steps.

The determination of in-situ or atmospherically produced ^{26}Al in marine and terrestrial sediments suffered sometimes from very low chemical yields. This seems to be mainly caused by redissolving $Al(OH)_3$ in the very last washings. We hope to overcome the problem by longer waiting times, i.e. increased altering of the hydroxides making them less-soluble.

Acknowledgments: Thanks to J. Feige, A. Gärtner, S. Gurlit, P. Ludwig, D. Rodrigues, T. Opel, T. Smith and several students for providing/processing samples and/or ICP-MS.

[1] G. Rugel et al., *Nucl. Instr. Meth. Phys. Res. B.* **2016**, *370*, 94-100.
[2] W. Schwanghart et al., *Science* **2016**, *351*, 147-150.
[3] A. Wallner et al., *Nature* **2016**, *532*, 69-72.