

## Project ZEBRA: Non-destructive elemental analysis of residues and contaminated sites

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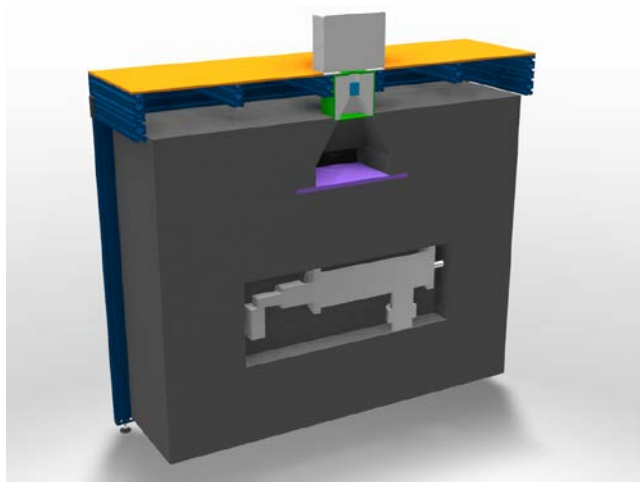
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In collaboration with the Chair of Mathematics at the Center for Computational Engineering Science (MathCCES) at RWTH Aachen University, Aachen Institute for Nuclear Training GmbH (AiNT) has developed a compact measurement system for environmental samples based on prompt and delayed gamma neutron activation analysis (P&DGNA).

The ZEBRA research project (German acronym: “Zerstörungsfreie Bestimmung von Reststoffen und Altlasten”) involves the construction and test operation of the measurement system and the development of new analytical methods for determining the mass fractions of heavy metals in environmental samples. The duration of the project is from autumn 2016 to autumn 2019.

### Design of the measurement system

The measurement system will be comparable in size to standard laboratory instruments for elemental analysis. We plan to use a commercial DD neutron generator and an electrically cooled HPGe detector (N-type, relative efficiency 40%). These are installed in a graphite moderator (see Figure 1). For reasons of radiation protection, the measurement system will be operated in a bunker made of boron-enriched concrete. We will benefit from experience of the construction and operation of the MEDINA facility at Forschungszentrum Jülich [1,2].



**Figure 1:** CAD-Model of the measurement system including a neutron generator (grey), sample chamber (above violet plate) and HPGe detector (green), without additional shielding.

The start-up of the experimental measurement facility is scheduled for summer 2017. The measurement system will be developed for applications in environmental analysis. This

includes the analysis of soil samples, water or animal feed. Table 1 shows a selection of elements to be determined in soil samples as well as their thresholds for different land use according to current German regulations [3]. These values define the required sensitivity of the measurement system for these applications.

**Table 1:** Current limits which are to be detected by the measurement system. Concentrations in mg/kg dry mass of soil, taken from [3].

Element	Residential areas	Industrial areas
Arsenic (As)	50	140
Lead (Pb)	400	2000
Cadmium (Cd)	20	60
Chromium (Cr)	400	1000
Nickel (Ni)	240	900
Mercury (Hg)	20	80

### Innovative spectroscopy software

For the evaluation of the resulting gamma spectra, we will develop an independent spectroscopy software that integrates current IAEA databases. Within the ZEBRA project, novel algorithms for automated multipeak analysis will be developed, implemented and tested.

A multipeak analysis method is intended to automatically identify signatures of individual elements in a spectrum with high accuracy. We will use a fingerprint approach similar to that of state-of-the-art music recognition software in combination with a partial reconstruction of the spectrum.

We will also develop advanced methods for the calculation of measurement uncertainties according to DIN ISO 11929 [4] based on a rigorous application of Bayesian statistics.

### Funding

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- [3] BBodSchV, Anhang 2, <http://www.gesetze-im-internet.de/bbodschv> (December **2016**).
- [4] Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation - Fundamentals and applications (ISO 11929:2010), **2011**.