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Time series data from routine in situ gamma spectroscopy measurements

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ABSTRACT

Time series of in situ gamma spectroscopy data from 6 sites, obtained over a period of 13 years as part of a routine surveillance program, have been investigated for variability, reproducibility and occurrence of trends. Natural isotopes (^{40}K, ^{208}Tl, ^{212}Pb and ^{214}Pb) show variability up to a factor of 2, with time patterns varying from site to site. At five (level) sites ^{137}Cs values decreased at a rate higher than given by the physical half-life, consistent with literature data on migration of Cs. At one (downhill) site, an increase of ^{137}Cs with time was observed. The finding can be explained by erosion processes from uphill territories. The observed variations were larger than the experimental uncertainty, and the equipment long-term stability appeared to be satisfactory. It can be concluded that the obtained routine in situ data provide a valuable data pool with potential usefulness for scientific work.

1. Introduction

Like several other countries, Germany conducts a routine surveillance program for environmental radioactivity. This so-called IMIS ("**I**ntegriertes **M**ess- und **I**nformations**S**ystem") (Weiss and Leeb, 1993) serves two purposes: first, to provide representative nationwide data on the status of "background" contamination with artificial radioisotopes, and second, to act as a reliable data source in case of a new contamination, i.e. to support decision-making in nuclear emergencies. In addition to laboratory measurements of relevant environmental media ranging from air to food, in situ measurements form an important part of the obtained data sets. Two kinds of measurement devices are used: about 1800 permanently operating detectors produce an almost real-time map of the ambient dose rate, and about 60 portable high resolution gamma spectrometers are used to detect nuclide-specific surface contamination and nuclide-specific ambient dose rates derived from these activity data (Weiler, 2012).

Whilst the permanent ambient dose rate network is operated by one central institution (the Federal Office of Radiation Protection, BfS), the portable gamma spectrometers belong either to BfS, to the German Weather Service DWD or to one of the 16 federal German states and are thus being operated under very different conditions either at fixed sites or as mobile devices. Altogether, more than 1000 in situ gamma spectra are recorded per year at more than 200 locations distributed quite evenly over the territory of the country (Fig. 1).

The question may arise whether the data produced with this equipment under variable conditions might be useful for more than emergency preparedness, i.e. whether the data satisfy scientific criteria like precision and reproducibility. A positive result would indicate that the huge data pool might be useful for scientific purposes like the investigation of nuclide migration in soil. This is of particular interest as the regulations for IMIS provide a data storage period of 30 years. In order to gain some more insight into the quality of routine data, time series of in situ spectroscopy results from the Bremen federal state situated in north-west Germany have been reviewed.

1.1. Experimental data pool

In situ gamma spectroscopy within IMIS means the semi-automatic recording of uncollimated gamma spectra with a detector positioned at 1 m above ground (Fig. 2). The equipment is designed in a way that it can be operated by trained technical staff, i.e. it is not routinely run by scientists. Spectral data are converted into nuclide-specific dose rate values at 1 m height in μSv h^{-1} and into surface contamination values in Bq m^{-2}. The conversions are performed applying predefined and system-specific factors and, for surface contamination, assuming a relaxation length within the soil of either 3 mm (for dry deposition) or 10 mm (for wet deposition). In the present case, measurements have been taken only during dry weather periods, so 3 mm is used for the relaxation length. The detection limit required by the IMIS regulations is 200 Bq m^{-2} for

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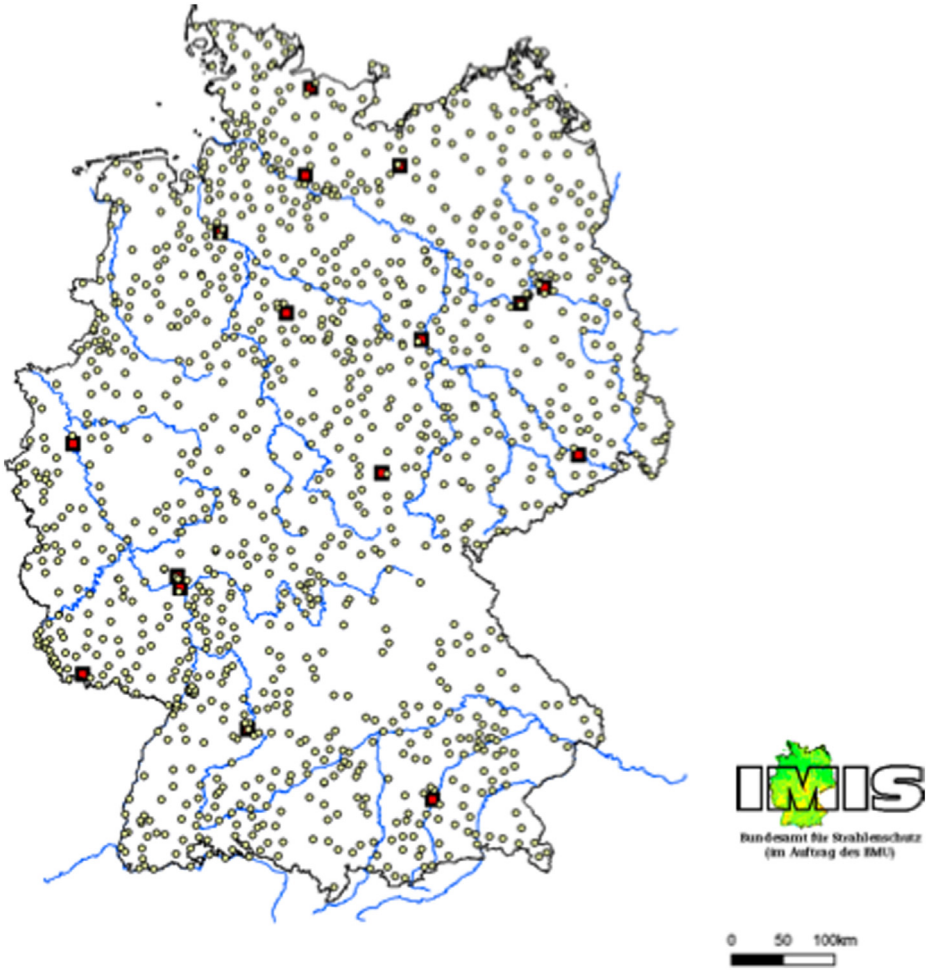

Fig. 1. Map of Germany with all positions of recordings of in situ gamma spectra for IMIS in the year 2011. Source: IMIS.

^{60}Co, which serves as reference isotope. A detailed description of the method is given in the technical guidelines for the IMIS system (Messanleitungen, 1992). Whilst spectra are stored locally, data transferred to the IMIS network comprise just the obtained values for dose rate and surface activity for each identified radionuclide plus the relative standard error. Data for natural isotopes like ^{40}K and Th and U decay chain members are included, where available.

Fig. 2. Exemplary setup for the recording of an in situ gamma spectrum. The hpGe detector is mounted on a tripod facing downwards. The associated electronics remain in the transport van.

For many years, the only artificial isotope detected in Germany by in situ gamma spectroscopy is ^{137}Cs, which originates from both atmospheric bomb test fallout and Chernobyl emissions. This did not change after the Fukushima emissions, as the maximal depositions of I and Cs isotopes were in the range of some Bq m^{-2} or below (Pittauerova et al., 2011).

The equipment (typical for most IMIS stations) consists of a high purity germanium detector of 10% relative efficiency (15% since a detector replacement) and a spectral resolution of about 2 keV (FWHM) at 1332 keV, housed under an aluminum end cap and attached to a small, portable cryostat (7 L liquid nitrogen capacity, sufficient for 3–4 days of operation without refilling). The electronics (high voltage supply, amplifier, analog-to-digital converter, multichannel analyzer) is highly integrated into one small unit, and spectra are displayed and stored on a notebook computer. Efficiency calibration and quality assurance tests are done using ^{152}Eu and ^{133}Ba point sources. Data transfer to IMIS' central servers is performed via the GSM cell phone network. The complete equipment is battery-operated, with the option to obtain 12 V backup battery power from the transport vehicle.

During the multi-year time period considered in this study, the germanium detector had to be exchanged twice due to defects, the portable computer was exchanged once (loss due to theft), and the system was operated by 3 different persons due to changes in laboratory personnel. We consider these numbers as not exceptional, but clearly the conditions are not ideal for long-term stability of a series of measurements.