Gamma dose rates and radionuclide concentrations in and around contrasting soil and sediment contexts

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Determination of dose rates from naturally occurring radioactive materials is key to establishing their locations, concentrations and the effects on the environment of the ionising radiation they emit, which is fundamental in the luminescence dating of artefacts and their contexts. Radiologically contrasting environmental settings are being examined in terms of spatial variability of dose rate at different scales. An important aspect of this focusses on variability at the decimetre to hectometre scale, which is relevant to the representativity of gamma radiation measurements *per se*, and on the level of dosimetric uncertainty associated with e.g. movement of objects around a site.
Settings under investigation include soils and subsoils: terra-rossa/limestone, organic/granite, schist, uraniferous schist; and sediments: alluvial clay, alluvial poorly sorted quartz + clay, and dune sand. The combination of backpack area survey, 2π spot- and 4π buried- measurements using NaI gamma spectrometry, is compared with neutron activation analysis (INAA), and HPGe gamma spectrometry of unactivated sample material (<2 mm). In all cases evaluation of radionuclide concentrations and dose rates is based on comparative methods: field systems were calibrated relative to the SUERC doped concrete pads, laboratory measurements were evaluated relative to a selection of geological reference samples.
Survey areas per site ranged from 0.7 to 3 ha, numbers of spot measurements from 2 to 7, focussed around one 4π measurement location associated with a 10 kg core sample for laboratory analysis (plus 100 kg of surrounding material, Franco et al., this volume). Measured activity concentrations of K, U, Th ($Bq.kg^{-1}$) and gamma dose rates (4π, $mGy.a^{-1}$) at the investigated sites ranged respectively from 100 to 1600, 7 to 4500, 8 to 140, and 0.1 to 42, with intra-site % Std.Dev. of 6 to 60, 10 to 130, 6 to 40, and 7 to 110.
Backpack survey enabled the identification of the original dune alignment and spacing at the lowest activity site, an area of remodelled dunes, and the efficient localisation of a U "hotspot" for study at the highest activity site. Highest dose rates and greatest variability were observed at the uraniferous schist site and relate to the localised U concentrations. % Std.Dev. ca. 20% was observed at all other sites except the dune sand and schist soil (non-uraniferous). In the dune sand and alluvia sites significant differences were observed between surface and buried measurements. These dosimetric deviations reflect contrasts in radioactivity between materials present in each environment, and radionuclide mobility. The combination varies from case to case, but can be accounted for experimentally by comparing the results of different in situ and laboratory measurements.

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The R package 'Luminescence' – Further improvements in functionality, usability and flexibility

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The first version of the **R** package 'Luminescence' was introduced in 2012 in order to provide a flexible toolbox for analysis and visualisation of OSL data [1]. Since then the package has been continuously improved by implementing new functions to support further measurement protocols, adding age models and extending the existing functions.

In addition to recent publications providing practical guides and a workflow for data analysis [2, 3] to ease the access for users who are new to **R**, the implementation of S4 objects improved both the usability and flexibility of the package. While users have to worry less about different data structures in **R**, simultaneously the object oriented approach enables more flexible and individual workflows from initial measurement data processing to data visualisation and statistical analysis.

Furthermore, the functionality of the package expanded beyond its initial scope of measurement data analysis and visualisation, e.g., newly implemented functions to estimate the aliquot size by Monte Carlo simulation or the cosmic ray dose rate cover further aspects of luminescence dating.

Our contribution summarises the concept, current content and further roadmap of the **R** package 'Luminescence' and focuses on some newly implemented functions. These include (a) a new way of visualising dose estimates and their standard errors introducing a so-called Abanico Plot, (b) a method to estimate the amount of mineral grains on a sample disc and (c) a function to estimate the cosmic dose rate which considers both the soft- and hard-component of the cosmic ray flux.

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[3] Fuchs, M.C, Kreutzer, S., Burow, C., Dietze, M., Fischer, M., Schmidt, C. and Fuchs, M. (subm.). A practical workflow for data analyses in luminescence dating using the R package 'Luminescence': A case study from the Panj River, Pamir, submitted to Quaternary International.