Study of radioisotope distribution in sediments and quartz properties as factors influencing the precision of dose rate estimation in luminescence dating – an innovative comprehensive approach

Luminescence dating is a technique used to determine the age of minerals such as quartz and feldspar, making it an essential part of geological, archaeological, and paleoenvironmental studies. Precise age estimation relies heavily on accurate determination of two key parameters: the equivalent dose (D_e) and the annual dose rate (D_r). Despite this, many researchers focus primarily on improving the accuracy of the equivalent dose estimation, while overlooking the intricacies of the dose rate and its influence on the dating results. Issues such as disequilibrium in decay chains, the heterogeneous distribution of radiation sources or heavy mineral contribution, and their radionuclide-bearing properties can significantly affect the dating accuracy of geological materials. Additionally, the process of quartz etching in 40% hydrofluoric acid – a step directly preceding the determination of the internal dose rate – is complex and non-uniform, contrary to the popular assumption, thus potentially influencing the obtained radioactivity of the extracted and chemically treated quartz.

As a result, it became apparent that an exhaustive analysis of the factors influencing the dose rate is much needed. This project aims to address these challenges by adopting a holistic approach that considers all aspects that affect the dose rate. By integrating multiple advanced methodologies, the project focusses on providing a comprehensive understanding of the variables that influence the dose rate calculations. To achieve these goals, samples of sandy and loess sediments will be collected and prepared for various analyses. Internal and external dose rates will be measured using advanced systems like μDOSE and μDOSE+, developed and patented at the Institute of Physics – CSE at the Silesian University of Technology, and high-resolution gamma spectrometry to assess radionuclide concentrations. Sediment and quartz analysis will be conducted using techniques such as laser diffraction and image analysis to assess parameters like size, shape, mineral characteristics and composition. To establish the equivalent dose and, at the end, the age of the collected samples, optically stimulated luminescence (OSL) measurements will be conducted. The precise goals of the project are defined below.

a) Heavy and light mineral contributions to bulk sediments, their attenuating and radionuclide-bearing properties, and impact on external dose rate;
b) Determination and quantification of disequilibria of the ^{238}U and ^{232}Th decay chains within bulk sediments and profiles for the estimation of the external dose rate;
c) Investigation of possible isotope migration within bulk sediments and profiles and its impact on external dose rate;
d) Studying the impact of radionuclide distribution within and on the surface of source grains on dosimeter grains in dose rate estimation for different sediment types and fractions;
e) Investigation of the behaviour of quartz grains during etching in hydrofluoric acid, including grain size distribution and shape analysis before and after HF etching.

The proposed project builds on previous research and efforts made to improve the precision of the dose rate estimation at the Gliwice Luminescence Laboratory (Institute of Physics – CSE, Silesian University of Technology). It will involve using solutions and technologies developed and patented here, such as the airtight sample container for gamma spectrometry, γBEAKER, the μDOSE/μDOSE+ System, for measuring low-level radioactivities, and the μRate application, created for efficient dose rate calculation. The research is set to make substantial contributions to the trapped-charge dating community, and the implications of this work are significant, potentially transforming the way luminescence dating is approached, and offering new tools and methods for scientists.