

EXPERIENTIAL LEARNING FOR HIGH SCHOOL STUDENTS TO MEASURE NATURAL RADIOACTIVITY USING PORTABLE GAMMA-RAY DETECTOR

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Abstract

Radioactivity is a fundamental property of matter and the environment, ensuring that all living organisms on Earth have been continuously exposed to ionizing radiation. The theoretical approach to teaching this concept often overlooks the chance to address common misconceptions about natural radioactivity. This omission represents a missed pedagogical moment that may contribute to discouraging future generations from pursuing careers to achieving a sustainable future. This study presents a hands-on learning experience for high school students at the National Laboratory of Frascati (LNF) of the National Institute of Nuclear Physics (INFN). Using the CAEN GammaEDU system, students mapped the natural radioactivity in the LNF area.

A total of 71 in-situ gamma-ray measurements were conducted within the 0.12 km² area, each with a duration of 7 minutes. The CAEN GammaEDU system is a portable spectrometer, which incorporates a 3" NaI (Tl) scintillator, acquired real-time gamma energy spectra to determine the activity concentration and abundance of K, equivalent uranium (eU), and equivalent thorium (eTh), gathering geographic coordinates and photographic documentation via dedicated app. The measurements were performed across seven surface types (asphalt, bricks, cement, grass, gravel, porphyry, and playground) with a field-of-view of 70 cm in diameter. Collocated Co-kriging, a multivariate interpolation method, leverages spatial autocorrelation of sparsely sampled radioelement concentrations and their cross-correlation with surface type to produce a natural radioactivity map.

It resulted that the average concentrations in the area (7.0 ± 0.5 µg/g for eU, 40.5 ± 5.8 µg/g for eTh, and $2.7 \pm 0.4\%$ for K) are higher than the global average soil abundances (2.9 ± 0.3 µg/g for eU, 8.0 ± 0.7 µg/g for eTh, and $1.20 \pm 0.07\%$ for K). The average total activity concentration in the area is 1087 ± 215 Bq/kg with the highest values (1896 ± 192 Bq/kg) in asphalt and the lowest concentration (417 ± 265 Bq/kg) in the bricks surface type.

This hands-on approach provided students with direct experience in operating scientific instrumentation, acquiring empirical data, and quantifying surface characteristics, thereby demonstrating the complete cycle of a scientific experiment. The practical engagement not only enhanced their conceptual understanding of natural radioactivity but also fostered a connection between theoretical knowledge and applied research, which subsequently increased student interest and motivation.