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Absorbed dose rate and radon flux in western Liguria

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The interest on the natural radioactivity, which is almost entirely related to U, Th series and K-40, derives essentially from dangers to humans, which is mainly controlled by the radioisotopes amount in the ecosystem, their average life and chemical-physical properties. This determines the degree of scattering, concentration and, above all, absorptivity of the radionuclides from the environment. In situ gamma-ray scintillation spectrometry provides a fast and cheap method for measurement of radioisotope concentrations of over large rock volumes and consequently on their possible biological effects over wide areas. In addition, it allows the assessment of ^{222}Rn as a ^{238}U product, provided that secular radioactive equilibrium holds in the uranium decay series.

In this paper, we present data for air absorbed dose rate and estimates of radon exhalation from concentrations of radioactive elements in the Alpine units of western Liguria (Italy), derived from a field gamma-ray spectrometry survey. The large variety of sedimentary, metasedimentary and metavolcanic rock types cropping out over a relatively narrow area provides an opportunity for testing the radiometric technique. The analysis of the Th/U, K/U and K/Th ratios may give information on the enrichment or depletion processes, which affected the investigated rocks and contributed to form uranium deposits of economic interest.

We carried out in situ gamma-ray activity by means of a portable apparatus consisting of a thallium-activated sodium iodide scintillation detector and a 256-channel spectrometer unit. The detector is enclosed in a single integral unit with a photomultiplier tube, a high-voltage supply and signal preamplifier. It is thermally insulated and housed in an aluminium cylinder. In our experiments, we used a ^{137}Cs check source to control automatically the system gain and prevent from gain shifting caused by temperature effect or component ageing. The determinations of U and Th are based on measured gamma-radiation from the decay of ^{214}Bi (1.76 MeV) in the ^{238}U decay series and from ^{208}Tl (2.62 MeV) in the ^{232}Th series. The primary decay of ^{40}K (1.46 MeV) is measured directly. The energy window of total count is set from 0.12 to 3.00 MeV. Based on counting statistics, in common rocks the relative uncertainty of the measured concentrations is minimum for K (3%) and maximum for U (up to 8%). For a counting time of 300 s, the detection limit is estimated to be 0.2 and 0.3 ppm for U and Th, respectively, and 0.03% for K.

The correction for the background radiation was estimated on selected serpentinite outcrops, characterized by U, Th and K contents below the detection limits. Due to the wide height range over the investigated area (from 0 to about 1000 m a.s.l.), particular care was taken in evaluating the variation of background radiation with elevation. Moreover, the problem of gamma-ray surveying in tunnel was tackled in an abandoned uranium mine. Field data, compared with laboratory gamma-ray spectrometry analyses on samples collected at selected points along the mine tunnel, show an apparent increase in U, Th and K concentrations. This discrepancy can be ascribed to deviations to the ideal geometry and the energy spectrum of each radionuclide. We estimated average correction factor to reduce field data is about 2 for K and Th and 2-2.5 for U.

U, Th and K concentrations of the bedrock surface of the different lithological units were measured at more than 400 sites over an investigated area of about 100 km^2. Such a data density represents an exhaustive inventory of the outcropping rocks. The results show that the radioisotope concentrations of the metavolcanic rocks are related to the magma original composition and track the magmatic differentiation processes. For the metasedimentary rocks, relationships between U, Th and K concentrations and the depositional environment can be argued. The mean values of absorbed dose rate and the effective dose equivalent due to the gamma-ray emission are 63 nGy/h and 78 μSv, respectively. Maxima (about 120 nGy/h and 145 μSv) occur in the metavolcanic rocks and are below a significant risk threshold. The flux of ^{222}Rn, estimated from the concentration of uranium and assuming appropriate specific exhalation coefficient, ranges from 2 in limestones to more than 25 Bq/(m^{2}h) in the metamorphic lithological units. The expected indoor radon concentration exceeds the limit for the recommended annual average concentration of radon gas (200 Bq/m^3) in 40% of the investigated area. Both the effective dose and the indoor radon concentration reach maxima, about 800 μSv and 12000 Bq/m^3 in the abandoned mine tunnel.