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Radiological maps in beach sands along some coastal regions of Turkey

B. Kucukomeroglu [a], A. Karadeniz [b], N. Damla [c,*], C.M. Yesilkanat [d], U. Cevik [a]

[a] Karadeniz Technical University, Department of Physics, Trabzon, Turkey
[b] İstanbul Aydın University, İstanbul, Turkey
[c] Batman University, Department of Physics, Batman, Turkey
[d] Artvin Çoruh University, Department of Physics, Artvin, Turkey

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ABSTRACT

In the present research, the gamma-emitting radionuclides in beach sands along the coastal regions of the Ordu, Giresun and Trabzon provinces, Turkey have been determined. The natural and anthropogenic radionuclide concentrations of the samples have been measured employing a germanium (HPGe) detector with high resolution and purity. The activity for ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs of the samples were found to vary in the range from below detection limit (BDL) to 65 Bq·kg^{-1}, from BDL to 28 Bq·kg^{-1}, from 9 to 1936 Bq·kg^{-1} and from BDL to 22 Bq·kg^{-1}, respectively. The activity concentrations were compared with those in the literature. The associated radiological hazard indices were estimated, and were compared to the internationally recommended values. The radiological map of beach sand in the surveyed area was imaged. The data presented in the study are crucial since they constitute a baseline for the radiological mapping of the region in the future.

1. Introduction

Naturally occurring radioactive materials (NORM) by and large comprise terrestrial original radionuclides that are also defined as primordial radionuclides remnant since the formation of the earth; and exist in different amounts in the surrounding environment, including the human body itself. NORM are typically long lived with half-lives of almost hundreds of millions of years. Radiation emitted from natural sources is, to a great extent, because of primordial radionuclides, cardinally ^{238}U and ^{232}Th series and their decay products, besides singly occurring ^{40}K (UNSCEAR, 2000; Ravisankar et al., 2014). The evaluation of the radiation dose is of exceptional importance as radionuclides are the largest source of external exposure to individuals (Veiga et al., 2006; Ravisankar et al., 2014). Additionally, anthropogenic radionuclides can come into existence after nuclear weapon tests are carried out and the accidents happen at nuclear reactors and due to the removal of radioactive waste from nuclear plants.

The knowledge of radionuclide level in beach sand is of great importance since it provides significant information for keeping reference data records to determine possible changes in environmental radioactivity (Garcia-Talavera et al., 2007). The dose rates are prevalent on the earth environment, and they are present in different geological formations for instance soil, sand, water and air with changing concentrations based upon the geographical and geological conditions and formations that vary from one place to another (Florou and Kritidis, 1992; UNSCEAR, 2000; Veiga et al., 2006; Yii et al., 2009). Beach sands, containing inorganic silicon-rich rough materials, are weathering-resistant remainders of geological formations carried to their original place, the coast, after transportation mechanisms such as wind, rivers, and glaciers; and are accumulated on the seaside by movements of waves and currents (De Meijer et al., 2001; Huang et al., 2015; Seddek et al., 2005).

In various regions of the world, radioactivity measurements of coastal sands were recently conducted by numerous researchers (Rosell et al., 1991; Kannan et al., 2002; Navarro and Roldan, 1994; Veiga et al., 2006; Vassas et al., 2006; Xinwei and Xiaolan, 2006; Örgun et al., 2007; Harb, 2008; Malain et al., 2010; Malik et al., 2011; Santawamaitre et al., 2011; Korkulu and Özkan, 2013; Özmen et al., 2014; Huang et al., 2015). As far as we know, there has so far been no information available about the radioactivity levels of beach sands in the study area. Therefore, in the present study, the levels of radionuclides in beach sand samples along the coastal regions of the Ordu, Giresun and Trabzon provinces in Turkey have been surveyed. The activity of radionuclides in ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K were found out via gamma-ray spectrometry. The outcomes were used to assess the radiological hazards corresponding with the absorbed gamma dose rates in air, the annual effective dose equivalent from outdoor terrestrial gamma radiation and the excess lifetime cancer risk. The radiological maps of beach sand in the survey area were generated. The results were compared with the internationally recommended values. The data obtained in this work might contribute to the radioactivity level

* Corresponding author.
E-mail addresses: nevzat.damla@batman.edu.tr, ndamla@ktu.edu.tr (N. Damla).

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database of beach sands in seaside areas, Turkey; and supply appropriate and better protection guidelines and reference for monitoring radiation for the public.

2. Materials and methods

2.1. Survey area and sampling

The total study area covers about 250 km from which 101 sand samples were collected at a distance of 3 km intervals along the coastal regions of the Ordu, Giresun and Trabzon provinces, Turkey in June 2012. The exact position of each sampling site was written down employing a Hand Held GARMIN GPS (Global Positioning System). The sampling area is shown in Fig. 1.

2.2. Sample preparation

During the study, beach sand samples were collected from 101 predetermined sampling spots. An area of nearly 1 m^2 was marked out at each sampling location. Afterwards, approximately 1 kg of beach sand sample was gathered at a depth of about 15 cm from each corner of the marked area and its center. The collected samples were mixed and put in labeled polyethylene bags and carried to the Nuclear Physics laboratory at the Karadeniz Technical University. Then, the samples were dried at room temperature and ground so that they could pass through a sieve. After this, the samples were dried at a temperature of 105 °C until constant weight was obtained. The prepared samples, each of which is about 180 g, were transferred to sealed gas tight, radon impermeable, cylindrical polyethylene plastic containers. Prior to measurements, the containers were kept sealed for 4 weeks, so that they could reach the equilibrium of the ^{238}U and ^{232}Th series and their respective progeny.

2.3. Gamma spectrometric analysis

Measurements of the samples were performed using a coaxial high purity germanium (HPGe) detector (Canberra, GC 1519 Model). The detector has 15% relative efficiency and a resolution of 1.2 keV full-widths at half-maximum (FWHM) for the 1332 keV γ-ray line of ^{60}Co. The detector was shielded with 10 cm lead and internally lined with 2 mm Cu foils to minimize the background contribution of the surrounding area. The detector output was connected to a spectroscopy amplifier of Canberra (Cevik et al., 2008, 2010). The spectrum analyses were carried out by means of Genie-2000 software obtained from Canberra. The certified reference materials IAEA-375 have been employed for the energy and efficiency calibration of the system. To obtain better statistics in gamma-spectra, and to achieve minimum counting error, each measurement was carried out with a counting time of 80.000 s. Background and sample measurements were used for equal counting times (Kucukomeroglu et al., 2009; Damla et al., 2010).

^{238}U and ^{232}Th activity concentrations were indirectly specified from their daughter products. To determine the activity concentration of the

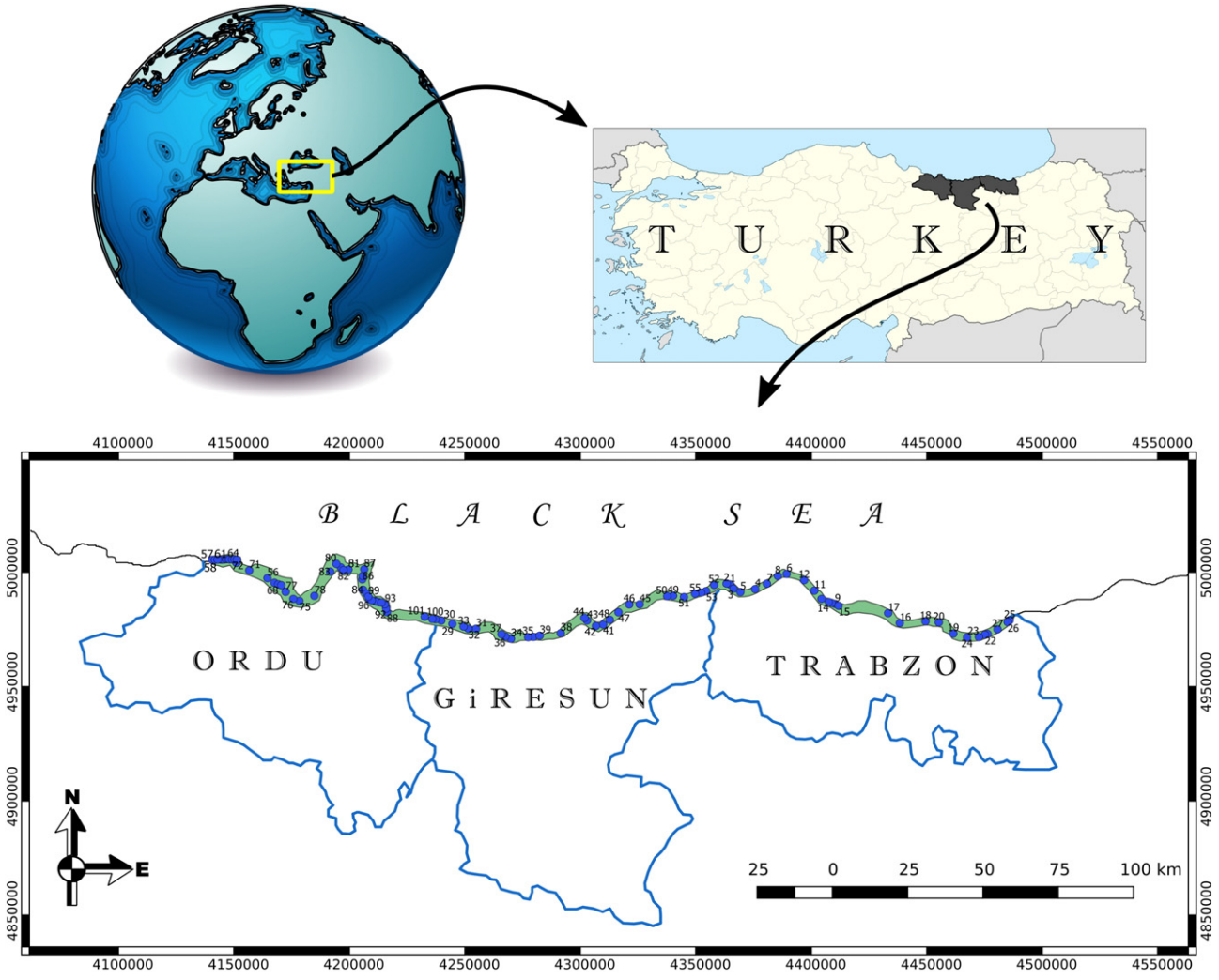

Fig. 1. The sampling sites in the study area.