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SCIENCE DIRECT
Radiation Measurements 41 (2006) 598–601
Radiation Measurements
www.elsevier.com/locate/radmeas

Assessment of dose rates around Manisa (Turkey)

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Received 24 June 2004; received in revised form 25 October 2004; accepted 29 November 2005

Abstract

Natural radionuclide activity concentration of surface soils at 64 locations in central Manisa were measured using gamma spectrometry (ORTEC). The natural gamma radioactivity of the terrestrial radionuclides in soil samples and the gamma-absorbed dose rates of these radionuclides in air were calculated. In this study, track etch film (CR-39) was used to determine the distribution of radon levels in dwellings. The average annual effective dose equivalents from the calculated outdoor terrestrial gamma radiation for a person in Manisa is 66 μSv, whilst the annual effective dose equivalent from ^{222}Rn is calculated to be 4.83 mSv/yr.

Keywords: Soil; Gamma ray spectrometry; Radon; Indoor; Track etch technique

1. Introduction

People are exposed to ionizing radiation from naturally occurring radionuclides that are present in the soil. Radionuclides in soils, belonging to ^{232}Th and ^{238}U series as well as radioisotope of potassium (^{40}K) are the major contributors of outdoor terrestrial natural radiation.

The city of Manisa is in the western part of Anatolia, Turkey and has a population of approximately 1,260,000 and has an area of approximately 13.830 km^2. The Köprübaşı Region (Salihli Basin) in Manisa City contain uranium deposits in fluvial sedimentary rocks, which are underlaid by high-grade metamorphic rocks of the Menderes Massif.

The terrestrial component of the natural background is dependent on the composition of the soils. The specific activity levels of ^{232}Th, ^{238}U and ^{40}K in soils were used in an assessment of the associated terrestrial external gamma radiation dose rate prevalent in the monitored areas by using appropriate activity to dose rate conversion factors for the aforementioned radionuclides, given by UNSCEAR (2000). UNSCEAR (1993) gives a world average value of 2.4 mSv for annual effective dose equivalent from natural background radiation of which 1.4 mSv comes from radon, thoron and their daughter products. Indoor Rn-222 accounts for the approximately 60% of the total natural background radiation (Saravanan et al., 2003).

Knowledge of the distribution pattern of both anthropogenic and natural radionuclides is essential in maintaining some sense of control of prevailing radiation levels. Measurement of natural and fallout radioactivities in soil gives information on natural sources, cumulative deposition from nuclear device testing and nuclear accidents (Baklanov et al., 2002).

Measurements of uranium, radium and gamma activity within the Salihli area have been previously determined and the concentrations of eU, eTh and radioactive potassium in sediment and soil samples were found to vary between 0.53–4.46 ppm, 3.85–17.10 ppm, 0.37–2.15%, respectively (Bakaç, 2003). This work presents levels of ^{232}Th, ^{238}U, ^{40}K in soils, the associated external gamma dose rate estimates and the indoor radon concentrations for the central area of the city of Manisa, Turkey. The results will form a baseline data set, which will enable estimations of population exposure. Radioactivity levels in soil samples from other areas in Turkey have been documented in previously published papers (Kumru and Bakaç, 2003; Bakaç, 2003; Karahan and Bayulken, 2000; Karakelle et al., 2002) and will be used for comparison purposes.

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doi:10.1016/j.radmeas.2005.11.004

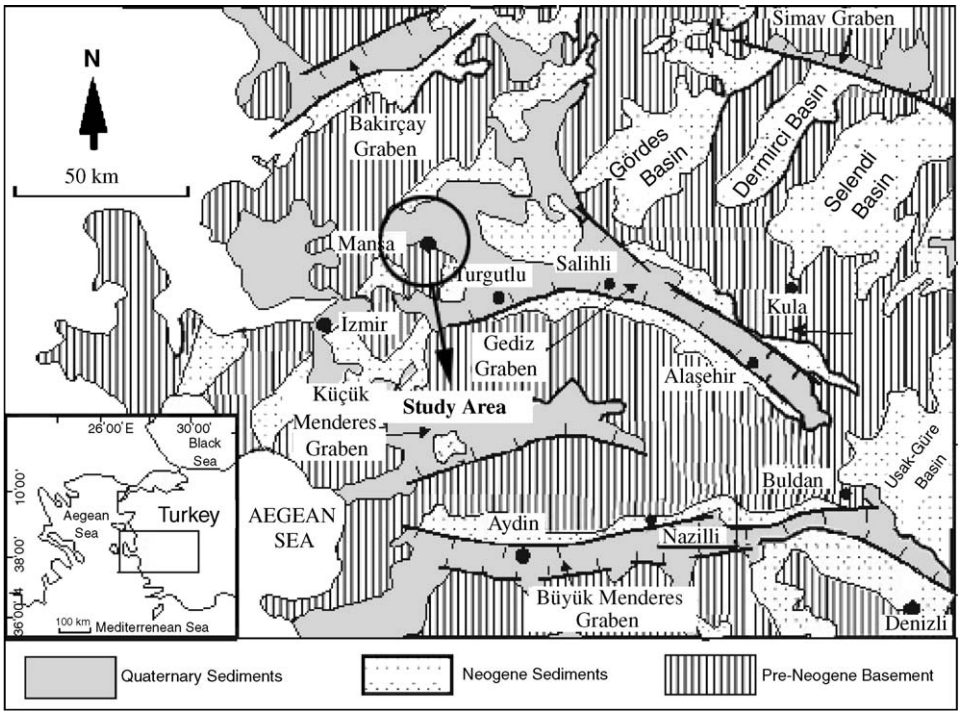

Fig. 1. Regional geological map showing the major structural elements of western Turkey, specifically the Gediz and Büyük Menderes Grabens and surrounding Neogene-Quatemary basins (Sözbilir, 2002). The study area is indicated.

2. Methods

2.1. Natural radioactivity measurements

Surface soil samples (0–15 cm depths) were collected from Manisa in the spring of 2001 (Fig. 1). Soil samples were crushed in the laboratory, oven dried at a temperature of 105 °C for 8 h, and sieved through a 270 mesh, 100 g of the homogenous soil samples and were then packed in a polyethylene beaker, weighed and carefully sealed and stored for at least 4 weeks before counting to allow time for ^{238}U and ^{232}Th to reach equilibrium with their respective radionuclide daughters.

There are several direct and indirect methods for measuring ^{238}U in geological samples. Among these, the most widely used is scintillation gamma spectrometry, based on the detection of high energy gamma rays of ^{214}Bi. However, there is always an important problem due to the ^{238}U and ^{226}Ra disequilibrium in geological materials. That is why the concentration determined through product activities relies on the assumption that the ^{238}U decay series is equilibrium and is called the equivalent uranium (eU) concentration (Kumru and Bakaç, 2003). This method was used for the determination of eU, eTh (equivalent thorium) and K (radioactive potassium) in the present study. The natural radioactivity in soil of region has been measured by gamma ray spectrometry using $3'' \times 3''$ NaI (Tl) dedector (ORTEC-905-4). The best resolution achievable is typically $< 7.5\%$ for the 662 keV gamma ray from Cs-137. In this study, the 1.76 MeV peak of Bi-214, the 2.62 MeV peak of Tl-208 and the 1.46 MeV peak of radioactive potassium were used for quantitative determination of uranium, thorium and potassium, respectively. The samples were counted for 7200 s with background measurements made under the same conditions.

Table 1
Experimental factors

Concentrations equations	
$eTh(ppm) = C(Th)/K_1$	
$eU(ppm) = (C(U) - \alpha C(Th))/K_2$	
$K(\%) = (C(K)\text{-}\gamma(C(U)\text{-}\alpha C(Th))\text{-}\beta C(Th))/K_3$	
Stripping rations	Sensitivity factors
$\alpha = 0.72$	$K_1 = 18.11$
$\beta = 0.84$	$K_2 = 53.12$
$\gamma = 1.41$	$K_3 = 519.3$

C(U), C(Th), C(K): count rates to the each channel of U, Th, and K in the samples.

In order to relate obtained count rates to the concentrations of U, Th, and K in the samples, concentration equations given in Table 1 were applied. In these equations α, β, γ are known as stripping rations and they indicate the interaction among the K, U, Th channels during counting. Determination of the stripping rations was undertaken by accurately measuring count rates in all channels from pure series-equilibrium uranium and thorium sources. K_1, K_2 and K_3 are sensitivity factors for each channel and were determined by the measurement of standard samples (625 ppm eU, 150 ppm eTh and 52% K) under appropriate conditions. The sensitivity factors and stripping rations of the detector were determined using the indicated standards. Experimental values of stripping rations and sensitive factors are given in Table 1.