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Gamma dose rate measurements in dwellings of Campania region, South Italy

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ABSTRACT

A survey of gamma exposure in dwellings of Campania region, southern Italy has been performed using Thermo Luminescent Dosimeters (TLD). In each dwelling TLDs were exposed for six months in the room where the inhabitant spent most of their time, generally the bedroom or living room. The arithmetic mean was found to be 264 ± 111 nGy/h, after the subtraction of the cosmic contribution. The effects of building materials and geographic location were also examined. Using UNSCEAR model, the annual effective dose due to indoor gamma radiation was evaluated and it was found to be 1.3 mSv/y, that is higher than Italian national average of 0.4 mSv/y.

1. Introduction

Ionizing radiation from natural sources such as cosmic rays and terrestrial radiation, is the major contribute to the exposure for public population (UNSCEAR, 2000; Al-Saleh, 2007; Almgren et al., 2008). The exposure to cosmic rays depends on altitude and solar activity (UNSCEAR, 2000) while terrestrial radiation comes from primordial nuclides present in the earth's crust (Hazrati et al., 2010), whose distribution depends on geological characteristics of locations. Some of these radioactive radioisotopes, the most important of which are ^{232}Th, ^{238}U (and their decay products) and ^{40}K, are naturally contained in construction materials and their presence produces an additional radiation exposure respect to radon for people in the indoor environments (Reddy et al., 2010). In particular gamma rays from building materials, due to their high penetration factor (Al-Saleh, 2007) constitute the most intense source of external human exposure. Today it is assessed that the majority of inhabitants in urban areas spends about 80% of their time indoor, so their exposure to ionizing radiation from building material could be relevant (UNSCEAR, 2000). For this reason many surveys have been carried out in the world (Ulbak et al., 1988; Miller, 1992; Ren et al., 1992; Arvela et al., 1995; Al-Saleh, 2007; Almgren et al., 2008). In Italy, information about indoor gamma radiation exposure are limited. In fact only a national survey on gamma radiation exposure was carried out in 1991 (Campos Venuti et al., 1992). In Campania region, the presence of uranium and thorium traces in the pyroclastic materials, largely used in houses construction, makes the natural radiation exposure particularly meaningful (Gialanella et al., 1988; Sabbarese et al., 1993) and only a little information about the activity concentration of ^{238}U and ^{232}Th and their decay products and ^{40}K from some kinds materials is available (Sciocchetti et al., 1983; Roca et al., 2004). The aim of the present study is to evaluate the indoor gamma exposure starting from the dose measurements in 746 dwellings in Campania using Thermo Luminescencent Dosimeters. Additional purposes were the examination of the dependence of dose rate on building materials and measurement sites. Finally the effective mean indoor dose rate for population was estimated.

2. Materials and methods

2.1. Study area

Campania region is located in southern Italy, on an area of 13.590 km^2 with about 6 million of inhabitants. It is the second region of Italy for population, and the first for density. In terms of administrative staff, Campania is divided into 5 provinces: Avellino, Benevento, Caserta, Napoli and Salerno. Its mean altitude is about 322 m above the sea level. This region can be divided into two climatic zones, the mild climate zone, influenced by the sea, which includes the coast of province of Caserta, Napoli and Salerno, and the colder one, which includes the inland areas with provinces of Avellino and Benevento. The Campania region is very various in its

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morphology: the area between the Salerno coast and Avellino is composed of alluvium mixed with pyroclastic materials, yellow and grey tuff. On the coastal area of Napoli, where some active volcanoes are present, concentrations of undifferentiated pyroclastic rock are elevated. These characteristics make the Campania the Italian region with the highest presence of natural radioisotopes (Ortolani and Pagliuca, 1987). These soil characteristics generate high radon concentration producing a high effective dose from inhalation of its daughters. In this paper, we studied the dose associated with exposure to gamma rays only.

2.2. Gamma dose rate measurements

Indoor gamma dose rates were measured in 746 dwellings using TLDs exposed for six months. Thanks to their low cost, high sensitivity and low fading, LiF:Mg,Ti (TLD 100) chips are largely used and for the same reasons they have been employed in this survey. Two LiF:Mg,Ti were hosted in a polyethylene box of 3 × 1.3 × 0.4 cm. Calibration of TLD 100 was carried out using a photon beam with an average energy of 3 MeV at the LINAC of Istituto Tumori "Fondazione Pascale" of Napoli. The dosimeters were exposed to doses ranging between 0.2 Gy ÷ 1.2 Gy, for which the TL glow curves were recorded and the areas of the main peak were determined. A calibration curve between the dose rate and TL intensity was built. The calibration factor resulted 4.3 ± 0.4 nC/mGy. The total uncertainty in the measurement and calibration were lower than 10%. After exposure all TLDs have been read at 300 °C using a heating rate of 10 °C/s with TL reader (Harshaw 3500).

In 434 dwellings two dosimeter packages each containing two TLD chips were placed while, in the remaining dwellings one package with two TLD chips was placed. In each dwelling the TLDs were placed in the room were the resident spent most of their time, generally the bedroom or living room. The inhabitants of dwellings received a form containing questions about relevant characteristics of dwelling, such as house typology, number of the stories, floor of the monitored room, kind of walls and floor materials.

3. Results and discussion

3.1. Gamma dose rate measurements

Indoor gamma dose rates were measured in 746 dwellings for one semester using TL dosimeters. In particular each dosimeter package contained two TLD chips. This allowed us to perform for all the dosimeters an internal quality control analysis. The correlation between the gamma dose rates measured by the two TLDs chips in each of the 940 dosimeters packages is good ($r = 0.91$). The frequency distribution of Coefficient of Variation (COV) of the TLDs pairs is shown in Fig. 1. The mean COV of the distribution is 4.5% ± 6.3%. Moreover, about 90% of the pairs of TLD chips present a COV lower than of 10%.

The measurement of indoor gamma dose rates, including the cosmic radiation, gives a mean value of 290 ± 110 nGy/h, ranging from 106 nGy/h to 726 nGy/h. The gamma dose rates from terrestrial sources were estimated subtracting the contribution of cosmic component. The absorbed dose rate from cosmic radiation component depends mainly on altitude and it can be evaluated according to Sakellariou's study as (Sakellariou et al., 1995):

$$CE_{out} = 30.80 + 2.57\,y + 6.90\,y^2 \quad (1)$$

where CE_{out} is expressed in nGy/h and y is the altitude ranging from sea level up to 3 km. Indoor gamma dose rate due to terrestrial gamma radiation are evaluated using the formula:

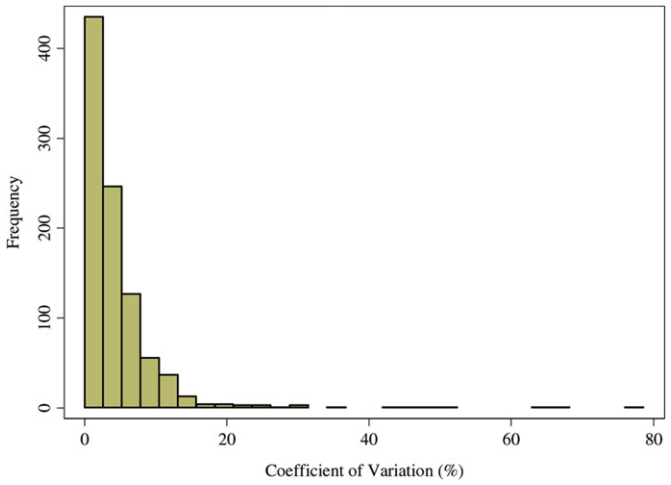

Fig. 1. Frequency distribution of coefficients of variation of the pairs of TLD.

$$\gamma_{in} = C_{TLD} - 0.8\,CE_{out} \quad (2)$$

where C_{TLD} is the measured value expressed in nGy/h, 0.8 is the mean building shielding factor to derive the indoor effective dose rate (UNSCEAR, 2000).

The frequency distribution of gamma dose rate in air from terrestrial sources is shown in Fig. 2. The Shapiro–Wilks test assesses that data are not Gaussian distributed, nor are the log-transformed values. The non-normality of the distribution may be the result of the overlap of two distributions, as you can see from Fig. 2. The lowest value measured was 78 nGy/h and the highest 702 nGy/h. The arithmetic mean was found to be 264 ± 111 nGy/h. This value is higher than the national average that is 105 ± 10 nGy/h (Bochicchio et al., 1996).

3.2. Analysis of factors affecting gamma dose rate

The results of the survey show a considerable variation between the gamma dose rate measured in houses of the different provinces. The mean value and standard deviation for each province are reported in Table 1. The statistical analysis shows that the highest mean value of gamma dose rate is in the province

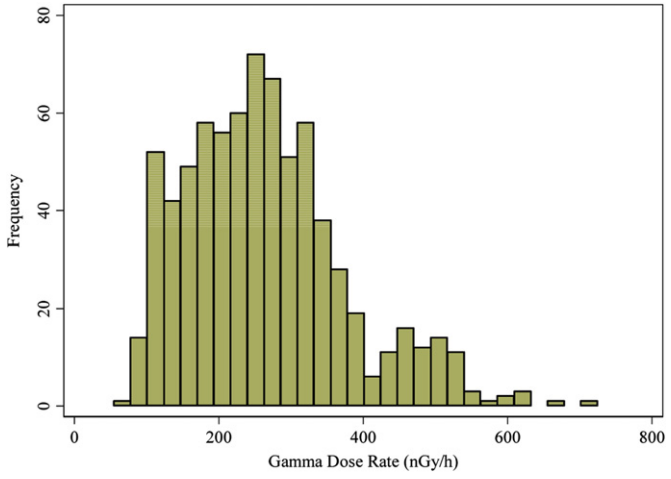

Fig. 2. Frequency distribution of indoor gamma dose rate (nGy/h) in dwellings of Campania survey. The contribution of cosmic radiation was subtracted.