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Terrestrial gamma radiation levels outdoors in Cantabria, Spain

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Abstract. Terrestrial gamma-ray dose rates have been measured outdoors throughout the region of Cantabria, located in the north of Spain. Results obtained are shown in tabular and cartographical form and are related to the nature of the ground and other influencing factors. The mean absorbed dose rate in air outdoors is 35.46 nGy h^{-1}. The mean annual effective dose equivalent, when the duration of outdoor exposure and distribution of the population are considered, is about 32 μSv. This dose is in addition to those doses received from other sources of natural radiation, principally from the presence of radon gas indoors.

1. Introduction

There are four main components of human exposure to natural sources of radiation: external irradiation from cosmic rays and terrestrial gamma rays, and internal irradiation from radioactivity in the diet and from the decay products of radon isotopes in inhaled air [1]. Almost 90% of the radiation exposure for the population of Cantabria, a region located in the north of Spain, close to the Cantabric sea, arises from these natural sources and only 10% is derived from medical exposure and miscellaneous sources with an artificial origin.

Terrestrial gamma rays derive essentially from potassium-40 and the radionuclides in the uranium-238 and thorium-232 radioactive decay series, and these radionuclides are widely dispersed in the earth's crust. Masonry building materials are extracted from the earth and, therefore, they contain these radionuclides too. Human beings are thus exposed to gamma radiation both outdoors and in buildings [2].

The study of outdoor gamma radiation exposure described in this paper has been developed according to the following objectives.

1. To complete the assessment of radiation doses to the Cantabria population from terrestrial gamma rays outdoors.
2. To correlate the data with the radon map available from the regional survey carried out in Cantabria.
3. To provide background data for the purposes of monitoring after a possible nuclear accident.

2. Methods

Practical matters such as portability, reliability, cost and ease of use were taken into account when selecting instruments for the survey. The device chosen was the Mini-Instruments Environmental Monitor type 6-80 with an energy compensated Geiger-Müller tube, MC-70. The MC-70 probe, based on a Mullard ZP1220 Geiger-Müller tube was specially designed to measure environmental levels of gamma radiation: its response is reasonably independent of radiation energy from about 50 keV to 1.2 MeV. The forward axial response is approximately 40% of the radial response. When the detector is positioned vertically, the gamma-ray contribution from the ground is received symmetrically [3]. Our instrument was fully calibrated and also checked in the NRPB calibration facilities and in our laboratory.

Results of the measurements of absorbed dose rate in air are reported in units of nanograys per hour (nGy h^{-1}). All the values given are for dose rates from terrestrial gamma rays 1 m above the ground and exclude any contribution from either cosmic rays or instrument background. The random uncertainty in indi-

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vidual measurements is typically 8% and the systematic uncertainty is judged to be of the same order.

The procedure of measurement was to make at least one measurement in every readily accessible 8 km square of the Ordnance survey grid throughout Cantabria. The measurement point within each 8 km grid square was not preselected, but was chosen on the spot by the investigators, who favoured open, level, ground well away from man-made structures such as roads, walls and buildings and from other features such as large bodies of water, wetlands and woodlands, all of which might have given atypical results. Measurements were not taken during or immediately after heavy rain when dose rates may be increased by the washout of gamma emitting radon decay products from the air. All measurements were made with the Geiger-Müller tube in the vertical position and the centre 1 m above the ground. To ensure that a standard procedure was used by the various persons involved in the survey, a measurement protocol and a results form were provided together with advice on instrument care.

In total, over 60 measurements were made covering the region. In addition, in a few cases, for squares where no measurements could be made, usually because of their inaccessibility, the values of the absorbed dose rate in air were estimated from the data for the adjacent squares using a kernel estimation technique also used in other similar research studies [4].

3. Results and discussion

As has been shown above, the first objective of our study was to carry out an evaluation of the assessment of radiation doses derived from terrestrial gamma rays to people living in Cantabria.

Figure 1 shows the infilled, unsmoothed data for each 8 km square. The values of the associated parameters are given in table 1 where we can see a geometric mean of 35.46 nG h^{-1} for the set of measurements in the region. The administrative area with the highest dose rate is La Lomba with an average value of 110.58 nGy h^{-1} and the lowest is Arredondo with 13.29 nGy h^{-1}.

The predominant rock type or geological formation in each 8 km grid square and its approximate percentage occurrence within the square were identified from standard geological maps. From them and the measurements of natural radioactivity in Cantabria carried out in our laboratory [5], it can be concluded that the areas of higher dose rates match the areas with higher uranium and thorium contents in soils. Nevertheless, chalk and clays, which are components of almost 80% of the geological structure of the region, show lower average dose rates which reflect their lower activity contents.

Figure 1. Outdoor gamma-ray dose rates by administrative area.

Table 1. Outdoor gamma ray dose rates in Cantabria.

	Absorbed dose rate in air ($nGy\ h^{-1}$)
Arithmetic mean	39.56
Geometric mean	35.46
Geometric standard deviation	1.6
Number of measurements	66

The population density data from the census by grid square were combined with the dose rate data to yield a population weighted mean dose rate for Cantabria of 33.45 $nGy\ h^{-1}$. This is lower than the unweighted mean of 35.46 $nGy\ h^{-1}$ shown above and reflects the fact that many of the larger centres of population are situated in geological areas with low dose rates. Nevertheless, a degree of caution is necessary in using this value since the measurements relate to essentially unaltered ground, whereas people spend some of their time outdoors in paved areas. However, assuming that local masonry is made of local earth materials, the value is a good indication of the likely state of affairs.

Taking into account that people spend about 15% of their time outdoors in Cantabria, the mean annual effective dose equivalent to the population is 32 μSv and the annual collective dose equivalent is about 18 manSv. These values are based on a conversion coefficient from absorbed dose in air to effective dose equivalent in the human body of 0.7 [6].

The second objective of our research was to correlate the data on radiation doses with the radon map available from the regional survey we carried out during the years 1989 and 1990. More than 700 individual measurements in houses were made during the survey throughout the region. The set of indoor radon measurements was fitted by a log normal distribution with a geometric mean concentration of 52.5 $Bq\ m^{-3}$, somewhat higher than we obtained in a recent national survey of 41.1 $Bq\ m^{-3}$, and a standard deviation of 2.9.

Figure 2 shows the areas of the region where indoor radon concentrations were measured. Results shown in this figure have been obtained as an average of more than 30 individual measurements in each location. Comparing figure 2 with figure 1 shown above, we find that no meaningful relationship can be established between gamma radiation dose rates outdoors and indoor radon levels. This is, in fact, related to the importance that other parameters (such as permeability of soil, cracks or pressure differences) have on radon exhalation processes, which control radon levels in the houses. These parameters may not be directly related to the terrestrial gamma radiation emitted from the same soil.

Finally, a third objective of the study was the provision of background data for the purposes of comparative monitoring after a nuclear accident. A nuclear power plant is in fact situated 40 km from the border of the region.

Figure 2. Indoor radon levels in Cantabria.

Data reported in this paper provide a good data base from which it should be possible to evaluate the impact of accidental or routine radioactive man made emissions into the environment.

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Résumé

Nous avons mesuré, à l'extérieur, les débits de dose du rayonnement gamma terrestre, dans l'ensemble de la région de Cantabrique, au nord de l'Espagne. Nous présentons les résultats obtenus sous la forme de tableaux, de graphes et de cartes; nous les relions à la nature du sol et à d'autres facteurs ayant de l'influence. A l'extérieur, le débit de dose absorbée moyen est de 35,46 nGy h^{-1}. L'équivalent de dose effectif annuel moyen est d'environ 32 μSv. Cette dose vient s'ajouter aux doses reçues en provenance d'autres sources de rayonnement naturel en particulier à cause de la présence de radon gazeux à l'intérieur des habitations.

Zusammenfassung

Terrestrische Gamma-Strahlen-Dosisleistungen wurden in der freien Natur in der gesamten Region von Cantabria, im Norden Spaniens, gemessen. Die erzielten Resultate werden in tabellarischer, graphischer und kartographischer Form dargestellt; sie berücksichtigen die Bodenbeschaffenheit und andere Einflußfaktoren. Die mittlere absorbierte Dosisleistung in der Luft in freier Natur ist 35,46 nGy h^{-1}. Die mittlere jährliche effektive Äquivalentdosis ist ungefähr 32 μSv, wenn man die Dauer der Strahlenbelastung im Freien und die Verteilung der Bevölkerung berücksichtigt. Diese Dosis wirkt zusätzlich zu den Dosen, die von anderen natürlichen Strahlenquellen aufgenommen werden, im wesentlichen durch Radon-Gas in Gebäuden.

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