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ESTIMATE OF EXTERNAL GAMMA EXPOSURE OUTDOORS IN SPAIN

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Abstract — Terrestrial gamma ray dose rate has been measured outdoors throughout the whole Spanish territory. This national survey was designed in such a way as to obtain a uniform and representative distribution of the measurement locations. In total, a set of 1053 data is available at this moment. Results obtained are shown in tabular, graphical and cartographical form and are related to the nature of the ground and other influencing factors. The geometric mean terrestrial gamma ray dose rate in air outdoors amounts to 44.03 $nGy.h^{-1}$ with a geometric standard deviation of 1.72. From this value, the mean annual effective dose equivalent can be calculated when the duration of outdoor exposure is included, as well as the mean annual collective dose equivalent if the distribution of the Spanish population is taken into account. This dose is, of course, in addition to those received from other sources of natural radiation; principally, from the presence of radon gas in houses. In this way, a study of the correlation between the values of the absorbed dose rate in air found and the presence of radon gas in houses is also made. Finally, the values of the terrestrial gamma ray dose rate theoretically derived from the radioactivity contents in the soil, experimentally measured, are compared with the corresponding results obtained from the measurements *in situ*

INTRODUCTION

Almost 90% of the radiation exposure for the population arises from natural sources and the other 10% is derived from medical exposure and miscellaneous sources with an artificial origin[1]. At the present, few data are available on human exposure to all sources in Spain.

The study of outdoor gamma radiation exposure described in this paper has been designed to achieve, first, an assessment of radiation doses to the Spanish population from terrestrial gamma rays outdoors in order to define the contribution to the total dose from natural radiation sources in dwellings and, secondly, to provide background data for the identification of areas with high natural radiation, with special emphasis on the presence of radon in houses and the likely impact of a possible nuclear accident derived from an accurate knowledge of the prevailing natural radiation levels.

METHODOLOGY

A Mini-Instrument Environmental Monitor type 6–80 with an energy compensated Geiger–Müller tube MC–70 specially designed to measure environmental levels of gamma radiation with a response reasonably independent of radiation energy from about 50 keV to 1.2 MeV, calibrated and intercompared at the NRPB, was used during the course of the survey[2]. This survey was carried out across the country during the years 1990 and 1991. Each measurement point was not preselected, but was chosen by the investigators according to standard and normalised international criteria to avoid producing atypical results. These have been reported in units of absorbed dose rate in air in $nGy.h^{-1}$. 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 which has been experimentally evaluated to range between 0.92 ± 0.05 $counts.s^{-1}$ at sea-level and 1.08 ± 0.06 $counts.s^{-1}$ at 850 m height. The random uncertainty in the measurements was typically 8%. The systematic uncertainty is estimated to be of the same order.

In total, over 1000 individual measurements were made covering the country.

RESULTS

Table 1 shows, for the 17 different autonomic regions of Spain, a résumé of the results obtained resulting from the survey. From the total number of measurements, the geometric mean value for the terrestrial gamma ray dose rate was 44.03 $nGy.h^{-1}$ with a standard deviation of 1.72 and a range from 25.00 to 82.67 $nGy.h^{-1}$ corresponding to the regions of Pais Valenciano and Madrid, respectively, directly related to the different underlying geological formations. Also given in the table are data on the total number of measurements for each region as well as the surface covering and population in 1985. Taking into account the values measured and these last data the surface weighted and the population weighted averages for the terrestrial gamma ray dose rate resulting are 43.20 $nGy.h^{-1}$ and 46.27 $nGy.h^{-1}$, respectively. By using this last value,

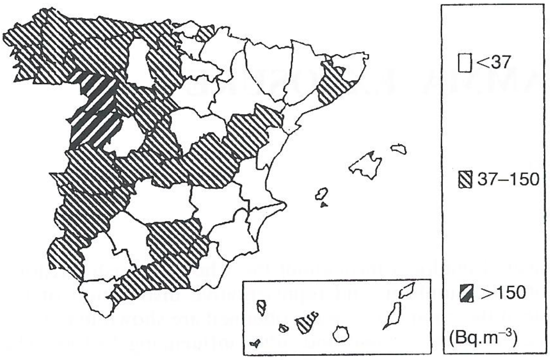

Figure 1. Indoor radon levels, by province, in Spain.

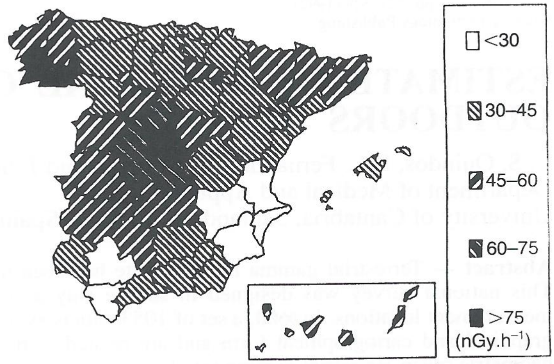

Figure 2. Outdoor gamma ray dose rates, by province, in Spain.

assuming a conversion coefficient from absorbed dose in air to effective dose equivalent in the human body of 0.7[3] and considering that people in Spain, on average, spend about 15% of their time outdoors, the mean annual effective dose equivalent to the Spanish population is 42.55 μSv with an annual collective dose equivalent of about 1612 man.Sv, a little higher than those data referred to in Green *et al*[4].

In order to study the utility of *in situ* gamma radiation measurements in the identification of areas with, principally, the presence of radon gas in houses, Figure 1 shows the data available, by province, obtained during the survey on indoor radon levels carried out in 1989–1990 including the geometric mean concentrations measured. In Figure 2 the values for terrestrial gamma radiation are given. Comparing both figures, no meaningful relationship can be established between the two parameters. This is, in fact, related to the importance of the effects of other parameters, such

Table 1. Outdoor gamma ray dose rates by different Spanish regions.

Community Code — Surface (km^2) — Population (millions) (1985)	G.M. ($nGy.h^{-1}$)	S.D.	No. of measurements	Surface (km^2) per measurement (km square)	A.M. ($nGy.h^{-1}$)	Mean altitude (m)	Mean latitude
1 — 87,267 – 6.680	32.33	1.85	141	619 (25)	38.49	418	0–0°45' N–37°30'
2 — 47,682 – 1.210	38.63	1.44	47	1014 (32)	40.87	612	0–0°45' N–41°20'
3 — 10,565 – 1.140	36.75	1.69	19	556 (23)	41.60	63	0–6°00' N–43°15'
4 — 6396* – 0.667	34.98	1.21	32	157 (12)	35.64	133	E–2°50' N–39°35'
5 — 7500** – 1.420	57.84	1.42	11	175 (13)	61.03	554	0–16°35' N–28°15'
6 — 5289 – 0.523	44.71	1.45	66	80 (9)	48.07	312	0–4°10' N–43°10'
7 — 79,225 – 1.680	44.08	1.72	145	546 (23)	50.73	788	0–3°00' N–39°35'
8 — 94,010 – 2.610	47.45	1.58	227	414 (20)	52.60	831	0–4°45' N–41°45'
9 — 31,932 – 6.040	45.91	1.57	41	778 (28)	49.91	145	E–1°35' N–41°45'
10 — 41,602 – 1.090	52.31	1.58	105	396 (20)	58.00	404	0–6°10' N–39°15'
11 — 29,442 – 2.840	62.95	1.67	58	507 (22)	71.02	339	0–8°00' N–42°45'
12 — 7995 – 4.830	82.67	1.33	62	129 (11)	85.80	751	0–3°40' N–40°35'
13 — 11.317 – 0.990	26.69	1.64	18	628 (25)	30.59	372	0–1°30' N–38°00'
14 — 10,421 – 0.516	33.48	1.30	13	804 (28)	34.60	401	0–1°40' N–42°45'
15 — 5034 – 0.257	55.14	1.15	9	559 (24)	55.66	525	0–2°30' N–42°20'
16 — 7250 – 2.180	37.79	1.34	10	725 (27)	39.25	204	0–2°40' N–43°00'
17 — 23,260 – 3.720	25.00	1.63	49	474 (22)	27.92	283	0–0°45' N–39°25
Spain — 504,750 – 38.40	44.03	1.72	1053	479 (22)	50.43	550	0–3°40' N–40°35'

*Data only refer to Mallorca and Ibiza: 5556 km^2.
**Data only refer to Tenerife: 1928 km^2.

Code: 1, Andalucia; 2, Aragon; 3, Asturias; 4, Baleares; 5, Canarias; 6, Cantabria; 7, Castilla-La Mancha; 8, Castilla-Leon; 9, Cataluña; 10, Extremadura; 11, Galicia; 12, Madrid; 13, Murciana; 14, Navarra; 15, La Rioja; 16, Pais Vasco; 17, Pais Valenciano.

as permeability of soil, cracks or pressure differences, on radon exhalation processes which control radon levels in the houses and may not be directly related to the terrestrial gamma radiation emitted from the soil.

Finally, Figure 3 shows, for a set of 78 samples, the correlation found among *in situ* radiation measurements and dose rates theoretically obtained from radioactivity contents of soils at the same locations[5]. A reasonable relationship can be seen. The significant non-zero value for the origin ordinate might be, in fact, related to the relative non-100% efficiency of the detector, specially for the detection of the 2.61 MeV from thorium. Nevertheless, in order to achieve a better knowledge of this relationship, a more complete and specific study is now going on in our laboratory.

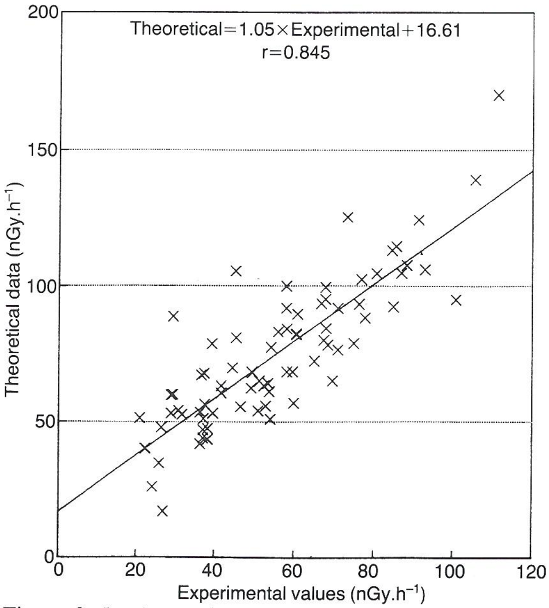

Figure 3. *In situ* outdoor gamma ray dose rates versus calculated values derived from radioactivity content in soil.

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