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Environmental radioactivity measurements in Aragón (Spain)

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Abstract. *Natural radioactivity is a inherent phenomenon in the environment. Nowhere is without radioactivity and all the materials around us are, to a greater or lesser extent, radioactive. The radioactivity level varies over time and from one place to another. Land composition, altitude above sea level, meteorological conditions, sun activity, etc. are factors which affect radioactivity variability. In order to detect abnormal radioactivity levels in a specific place, it is necessary to have a previous knowledge of standard values. This ongoing research aims to provide information on environmental radioactivity in Aragón (Spain), as the first phase in establishing a monitoring system. In this work, we present the characteristics of the locations selected for sampling and the specific measurements collected. The fact that these data are geographically referenced leads to a geostatistical approach in order to be able to highlight spatial dependence. A preliminary exploratory analysis of the data available thus far is presented.*

Keywords. *Radioactivity; Environmental; Geostatistics.*

1 Introduction

Natural radioactivity is a phenomenon inherent in the environment. Nowhere is without radioactivity and all the materials surrounding us are, to a greater or lesser extent, radioactive. At the present time, there are no systematic studies of environmental radioactivity levels in Aragón (Spain) to be used as a reference for the future. Obtaining detailed knowledge of environmental radioactivity is a complex process which requires many steps and measurements. A first step is to obtain the value of several general parameters

which allow us to gather relevant information on radioactivity levels in the atmospheric environment. Environmental radioactivity arises as a sum of natural radioactivity and radioactivity induced by human activity. The natural radioactivity level varies from one place to another and fluctuates through time. The composition of soil, the height above sea level, weather conditions (wind, rain, etc.) and even solar activity are factors that determine its variability. Radioactivity induced by human activity includes production and possible dissemination to the environment of artificial radioisotopes and the incorporation of natural radionuclides in concentrations higher than in the natural context, due to industrial processes.

The main goal of this research work is the measurement of environmental radioactive levels in selected locations of Aragón in order to be able, in a second phase, to establish a map of environmental radioactivity. In this work, we present the sampling plan design, the characteristics of the measurements recorded and a preliminary analysis of the data available thus far. In the near future, when more data are available, this study will be completed in order to explore the spatial distribution and fit an adequate model. Regarding other studies related to environmental radioactivity, the Spanish Nuclear Security Council (CSN) has made an aerial map of gamma radioactivity (MARNA) of Spain. Moreover, with the purpose of having a continuous control of the natural and non natural radioactivity levels existing in Spain, the CSN has established a network, called REVIRA, whose main function is to control the environmental radioactivity. Eighteen Spanish Universities and Research Centers collaborate with the REVIRA programme [2]. At the University of Zaragoza measurements related with this programme have been made annually since 1998 by members of the research team at two selected points of the city of Zaragoza, providing partial knowledge of radioactivity levels in air, soil and water. Madurga [3] gives details of the environmental radioactivity monitoring program in Portugal. However, as far as we know, this is the first time that these kind of data are studied using spatial statistics models.

2 Sampling

The autonomous region of Aragón, located in northeastern Spain, borders France in the middle Pyrenees. The region comprises three provinces and is administratively subdivided into 33 'comarcas' comprising a number of municipalities. As of 2008, the population was 1,326,918 with half of the region's inhabitants living in the city of Zaragoza. It covers an area of 47,719 km2 (9.43% of Spain's surface). It is a land of extreme natural contrasts, both in climate and geologically. The climate of Aragón is continental moderate and is determined by its variations in elevation. The terrain ranges diversely from permanent glaciers to verdant valleys or arid steppe. In order to determine the sampling locations, our first commitment was to select as many 'comarcas' as possible, taking into account the availability of dosimeters. Specific locations were decided bearing in mind the characteristics of the terrain and the existence of a place were the dosimeters could be safely installed. A distinctive aspect of the research project is that primary and secondary schools are involved in the sense that dosimeters are placed in their facilities. The 26 locations finally selected are shown in Figure 1.

3 Measurements

The sampling sites having been selected, the ambient dose levels are obtained by using thermoluminescent dosimeters (TLD). The dosimetry system is based on the Panasonic TLD-716 automatic reader (see Figure 2) and on Panasonic UD802A cards containing four thermoluminescent crystals, E_1, E_2, E_3 and E_4 ($2\times Li_2B_4O_7$, $2\times CaSO_4$). At each location a kit containing four dosimeters is exposed to the

Figure 1: Sampling locations.

environment for a period of time. Four dosimeters are used in order to be able to assess the variability associated with them. The TLDs are then read and the measurement results expressed in terms of the ambient dose equivalent rate. Moreover, in the cities of Zaragoza, Huesca and Teruel, soil and water samples have also been taken. These have been analyzed by gamma spectrometry, and total alpha activity, total beta activity and strontium have been determined. All measurements have been made following the standards UNE 73311-5:2002, UNE 73311-4:2002, UNE 73350-2:2003 and UNE 73340-3:2004. The radioactivity levels are determined by:

- Total Alpha: joint activity of all alpha emitters in the sample.
- Total Beta: joint activity of all beta emitters in the sample.
- Strontium: the determination is made by chemical separation of Strontium and the measurement is made in a beta counter.
- Gamma Spectrometry: this determines each of the emitters present in the sample. The most important to be detected are:
  - Radionuclides of natural origin: ^{7}Be, ^{40}K, ^{208}Tl, ^{212}Pb, ^{214}Bi, ^{214}Pb.
  - Radionuclides of artificial origin: ^{51}Cr, ^{54}Mn, ^{58}Co, ^{60}Co, ^{59}Fe, ^{65}Zn, ^{95}Nb, ^{95}Zr, ^{103}Ru, ^{131}I, ^{134}Cs, ^{137}Cs, ^{140}Ba, ^{140}La, ^{144}Ce.

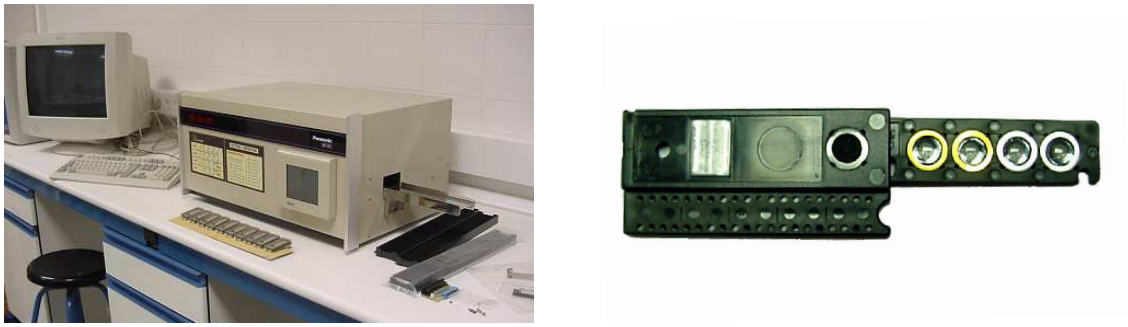

Figure 2: Thermoluminescent dosimeter reader and a dosimeter.

At the moment of writing this paper, we have recorded data from eight locations: Zaragoza, Biescas, Canfranc, Cariñena, Grañen, Huesca, Tarazona and Teruel. Figure 3 shows the data relative to the crystals E_1, E_2, E_3 and E_4. For each location, the measurements of the four dosimeters as well as their average are shown. After a exploratory analysis of these data we have detected a certain influence of the period time of exposure, which has to be analyzed in depth when more data are available.

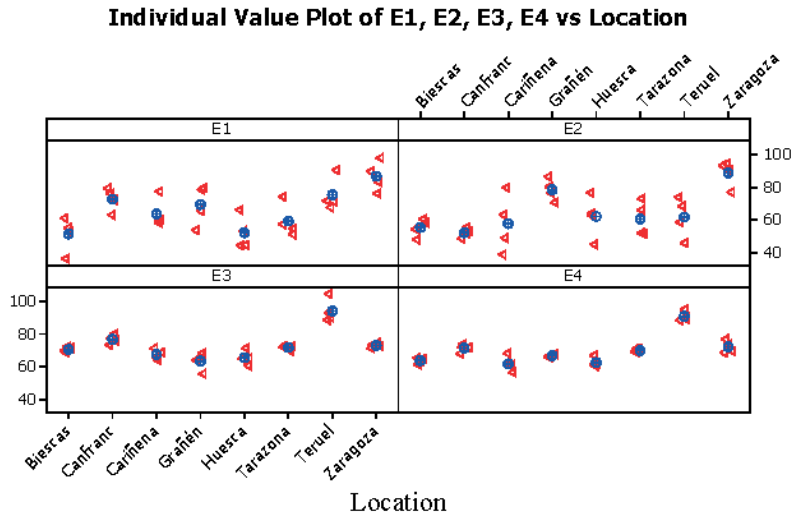

Figure 3: For each location, the measurements of the four dosimeters as well as their average.

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