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RADON EXPOSURE IN URANIUM MINING INDUSTRY VS. EXPOSURE IN TOURIST CAVES

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There is a fairly general consensus among health physicists and radiation professionals that exposure to radon progeny is the largest and most variable contribution to the population's exposure to natural sources of radiation. However, this exposure is the subject of continuing debate concerning the validity of risk assessment and recommendations on how to act in radon-prone areas.

The purpose of this contribution is to situate the radon issue in Spain in two very different settings. The first is a uranium mining industry located in Saelices el Chico (Salamanca), which is under strict control of the Spanish Nuclear Safety Council (CSN). We have measured radon concentrations in different workplaces in this mine over a five-year period. The second setting comprises four tourist caves, three of which are located in the province of Cantabria and the fourth on the Canary Island of Lanzarote. These caves are not subject to any administrative control of radiation exposure.

Measured air ^{222}Rn concentrations were used to estimate annual effective doses due to radon inhalation in the two settings, and dose values were found to be from 2 to 10 times lower in the uranium mine than in the tourist caves. These results were analysed in the context of the new European Basic Safety Standards Directive (EU-BSS, 1996).

INTRODUCTION

The new EURATOM Directive on the Basic Standards for Radiological Protection(1) recently incorporated into Spanish law (BOE 178/2001) contains, in Title VII, which deals with exposure to radiation from natural sources, a request to EC Member States to identify workplaces that are of interest with regard to natural radiation exposure.

Of the possible sources of exposure to natural radiation, the most important are those due to radon and its progeny(2). The significance of radon as a source of radiation exposure was recognised in the 1950s when it was discovered that exposures to this gas and its decay products could explain the excess in lung cancer detected among uranium miners. The extensive mining and processing of uranium for military purposes during that period made radon a central issue and led to research work, mainly centred on dose evaluation. The first results indicating a significant excess of lung cancer among the uranium miners were obtained in the 1960s in the United States.

Nevertheless, high concentrations of radon also exist in non-uranium mines and caves, in various underground excavation works and other underground workplaces. In this regard, in its 1990 publication, the ICRP recommended that high exposures to radon in workplaces should be regarded as the responsibility of the operating management and should be considered as occupational exposure(3). This paper compares radon values in a uranium mining industry, which is under strict control of the Spanish Nuclear Safety Council (CSN), and tourist caves where there is no administrative control of radiation exposure.

Finally, since the new EURATOM Directive has yet to be applied to occupational exposure to radon and since the number of workplaces where radon may present a risk continues to increase, the data reported in this paper point to ways to focus discussion on some potential issues and ways to implement the Directive in Spain.

MATERIALS AND METHODS

The caves selected in this study were Puente Viesgo, Covalanas and Los Corrales in the province of Cantabria and Los Verdes on the Canary island of Lanzarote. The uranium mining industry studied is located in Saelices el Chico in the western province of Salamanca and was the only uranium mine in Spain that was in production until 2003. Integrated ^{222}Rn measurements were made in all cases by using nuclear-etched-track detectors (Landauer Inc., Glenwood, IL).

The selected sample points in the caves were located along guided tour paths while in the uranium mining industry the selection of sample points was related to the different tasks performed by the workers both during the production phase (1999–2002) and during implementation of the restoration plan. In the years 2001 and 2002, production and restoration were carried out at the same time until the complete cessation of production in January 2003.

For two of the caves (Los Verdes and Puente Viesgo), monthly mean radon concentrations were measured for the year 2002, while only annual

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average values were recorded in the other two caves (Covalanas and Los Corrales). Owing to the official control by the Spanish Nuclear Safety Council, radon measurements in the uranium mining industry were made monthly in all workplaces. Except for Covalanas and Los Corrales caves, the annual average radon concentration at each workplace was derived from the monthly mean radon levels obtained during the period of measurement.

As the action level for radon is usually defined as an annual average radon concentration during working hours[4], annual average effective doses due to radon exposure have been assessed when possible by having workers wear radon detectors on their clothing or by placing detectors at the workplaces during working hours. Outside working hours, the detectors were stored in a radon-free place.

RESULTS

Monthly mean radon concentrations measured in Los Verdes Cave (Lanzarote) and Puente Viesgo Cave (Cantabria) during 2002 and in four of the workplaces in the uranium mine surveyed during the production phase (1999–2002) are shown in Figures 1 and 2, respectively. The two caves showed similar seasonal variations in average radon concentrations, with the typical summer maxima and winter minima of cold karstic caves[5], while in the uranium mining industry these variations revealed no clear pattern.

DOSE ASSESSMENT

The new EURATOM Directive on Basic Safety Standards for Radiological Protection establishes a common conversion factor from potential alpha energy exposure to effective dose for radon in workplaces of 1.4 Sv per J h m^{-3} [6]. The ratio of potential alpha energy exposure to the equilibrium equivalent radon exposure is 5.56×10^{-9} J h m^{-3} [7]. On this basis, the effective dose (E) measured in Sv can be calculated by using the equation:

$$E = 7.78 \times 10^{-9} \cdot F \cdot T \cdot C, \qquad (1)$$

where F is the equilibrium factor, T is the time in h and C the radon concentration expressed in Bq m^{-3}.

The action level recommended by IAEA at which measures would need to be undertaken to reduce radon exposures is 1000 Bq m^{-3} [8]. This value is at the midpoint of the range 500–1500 Bq m^{-3} recommended by the ICRP[6]. However, regulatory bodies are free to set occupational action levels for radon <1000 Bq m^{-3} if national circumstances make this practicable, as in the case of United Kingdom, where a level of 400 Bq m^{-3} is stipulated[9]. Assuming an equilibrium factor between radon and its progeny of 0.4 and an occupancy of 2000 h y^{-1}, the above-mentioned action level of 1000 Bq m^{-3} equates to an effective dose of 6 mSv.

The equilibrium factor F was determined experimentally by means of open and closed detectors in the caves and uranium mining industry, and

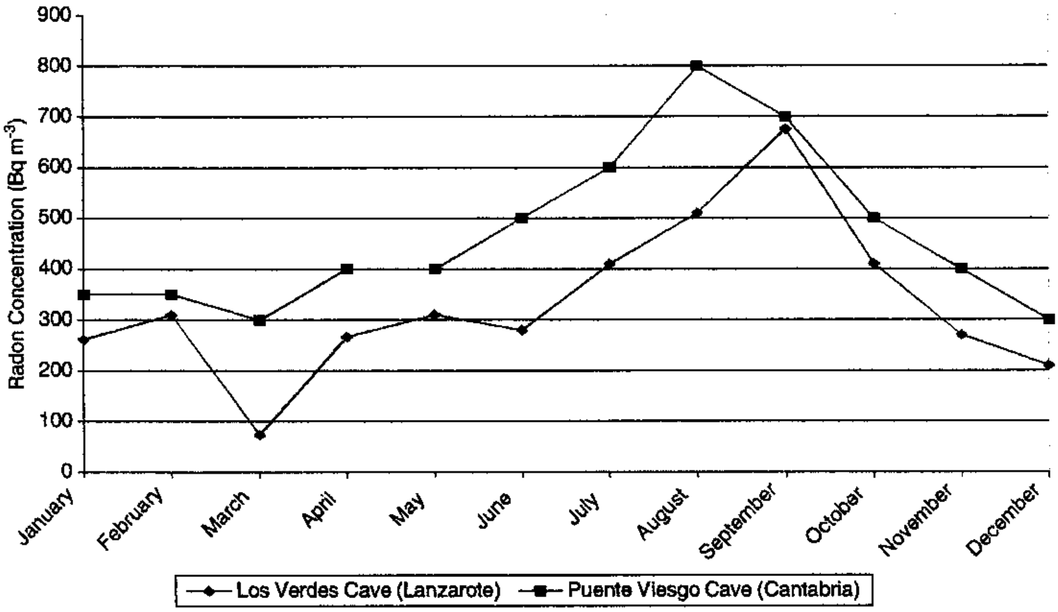

Figure 1. Monthly mean radon concentrations in Los Verdes and Puente Viesgo Caves during the year 2002.

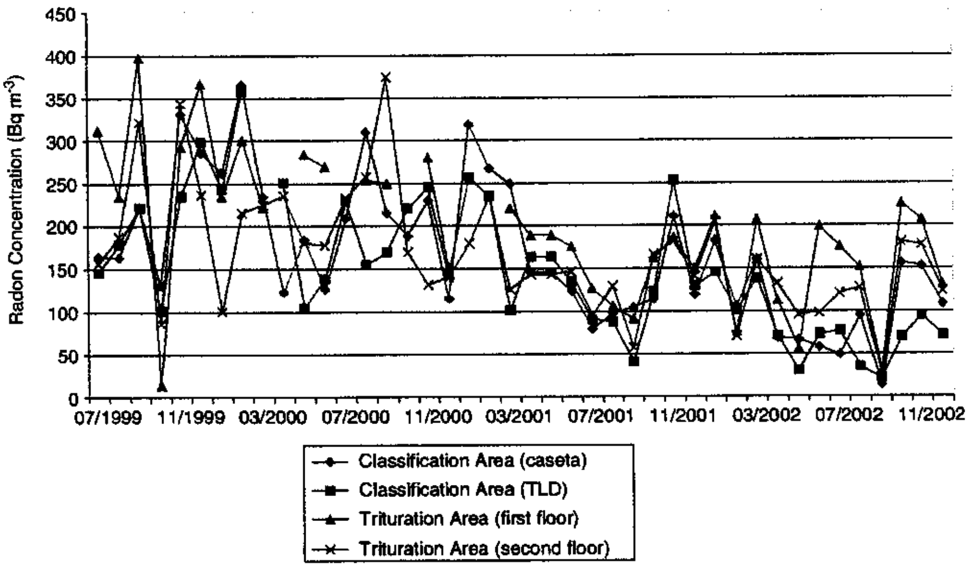

Figure 2. Monthly mean radon concentrations in some of the workplaces surveyed in the Spanish uranium mining industry located at Saelices el Chico (Salamanca) during the period 1999–2002.

Table 1. Annual average radon concentrations and effective doses estimated for the different workplaces studied.

Workplace	Annual radon average (Bq m^{-3})	Equilibrium factor (F)	Working time (h)	Dose (mSv)
Caves				
Puente Viesgo cave	467	0.6	800	1.74
Lanzarote cave	332	0.4	800	0.83
Covalanas cave	910	0.5	400	1.42
Los Corrales cave	3250	0.5	400	5.06
Uranium mining industry				
Classification area (office)	168	0.5	1500	0.98
Classification area (TLD)	150	0.5	1500	0.88
Cono de esteriles I (waste pile)	4662	0.6	50	1.09
Cono de esteriles II	4529	0.6	50	1.06
Trituration area (first floor)	196	0.4	1600	0.98
Trituration area (second floor)	168	0.4	1600	0.84
Truck I	129	0.5	1700	0.85
Truck II	150	0.5	1700	0.99
Truck III	131	0.5	1700	0.87
Truck IV	16	0.5	1700	0.77
Irrigation 631	103	0.6	1500	0.72
Scoop 992-1	153	0.6	1700	1.21
Scoop 992-3	149	0.6	1700	1.18
Level truck	97	0.5	1600	0.60
Komatsu 1	124	0.5	1600	0.77
Komatsu 2	156	0.5	1600	0.97
Roller	90	0.5	1600	0.56
Scoopl B	118	0.4	1600	0.59

average values ranged from 0.4 to 0.6, which is similar to data reported in the literature(2). It should be taken into account that the influence of the working conditions on the dose estimation related with the attached/unattached fractions would be of interest for more accurate calculations. This parameter was not measured in our study.

Table 1 shows the annual average radon concentrations and the corresponding estimated effective doses, as well as the data used in their evaluation from Equation 1, for all the workplaces analysed.

The time spent in the caves and mines by the workers was assessed on the basis of personal communication with the staff and the management. When working times and calculated annual average doses in Table 1 are compared, remarkably large differences can be observed in the dose rates for the different workplaces studied.

DISCUSSION

Tourist guides and cave maintenance workers, who remain underground much longer, receive higher doses than do workers in uranium mines, but in both cases all the calculated doses are lower than the upper limit of 20 mSv y^{-1} recommended by the ICRP[6].

Nevertheless, the main conclusion of this study concerns the tolerant attitude towards natural radioactivity in the new Directive. In this Directive, some of the ICRP 60 practices are considered as work activities, but the stringent regulation in radiological protection may not be applied to the non-nuclear industry, which includes caves, spas, underground workplaces, etc., and responsibility for specific regulations is transferred to the Member States. This, of course, may generate unacceptable differences in competitive positions between Members in relation to their economic circumstances.

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