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^{222}Rn concentrations and the radiation exposure levels in the Nerja Cave

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Abstract

^{222}Rn concentrations in the air in one sampling point located in Nerja Cave (Spain) (3°52′35″ W 36°43′50″ N) have been measured over one year, since July 2003–June 2004. ^{222}Rn levels were continuously monitored using Alpha-Guard (Genitron instruments) equipment, model PQ2000PRO. Firstly, the aim of this study was to perceive the daily, monthly and seasonal variations patterns of ^{222}Rn concentrations. Diurnal cycles are presented by season showing that the ^{222}Rn concentrations in spring–summer are higher than autumn–winter. The hourly variations are discussed in relation to various meteorological factors measured in the Cave and also on the outdoor. We have evaluated the radiation exposure levels for workers and tourists; those represent only a low percentage of the exposure guides for the general population (ICRP, 1994. Protection against Radon-222 at home and at work. Pergamon Press, Oxford (publication 65)).

Keywords: Radon; Exposure level; Nerja Cave

1. Introduction

The Nerja Cave was discovered in 1959 and now is the second natural monument with more visitors per year in Spain. The cave has three entrances, two of them are natural and one was constructed in 1960. It extends along a line 35°E with a main axis of about 250 m in length. It consists of a series of halls and side chambers separated by numerous banks of speleothems. Starting from the entrance, we find successively the Vestibule hall, the Ballet hall, the Mirador hall and the C. Hercules hall (Fig. 1).

2. Results and discussion

2.1. Temporal variation of ^{222}Rn concentration at the Ballet hall

The ^{222}Rn average monthly concentrations at the Ballet hall are shown in Fig. 2. The Box-and-Whisker Plot is particularly useful for comparing parallel batches of data. The central box covers the middle 50% of the data; the sides of the box are the lower and upper quartiles, and the horizontal line drawn through the box is the median. The whiskers extend out to the lower and upper values of the data (the range). The lower whisker is drawn from the lower quartile to the smallest point within 1.5 interquartile ranges from the lower quartile. The other whisker is drawn from the upper quartile to the largest point within 1.5 interquartile ranges from the upper quartile. We can see numerous anomalous data (outliers) which mainly correspond to May, August, September and October months and the high values

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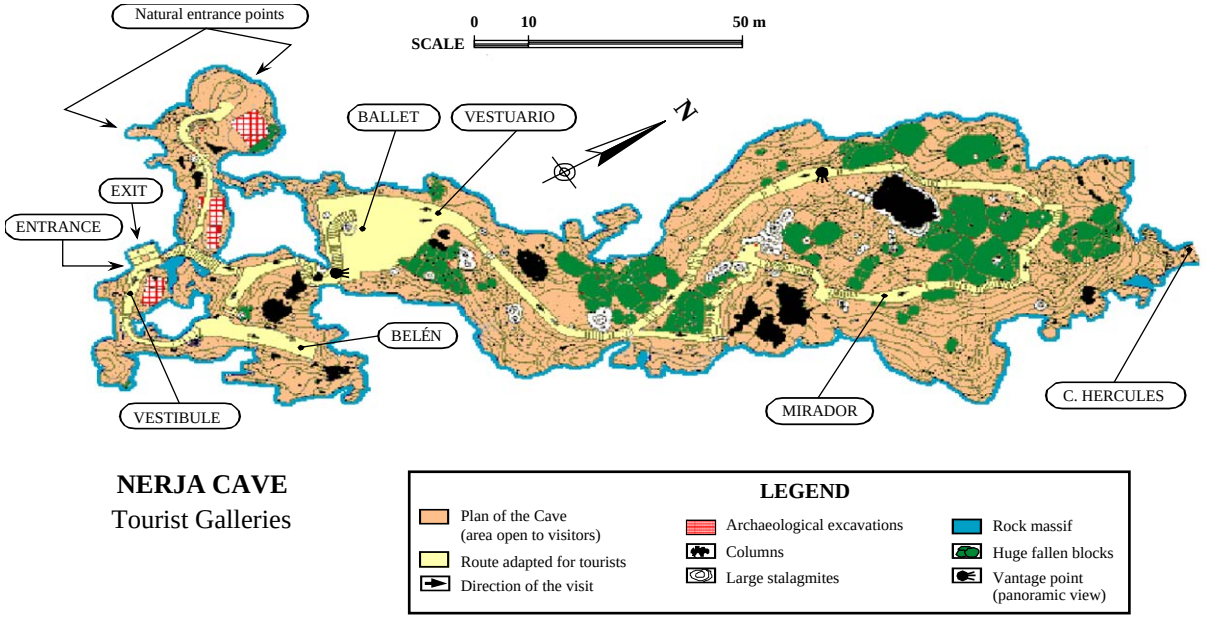

Fig. 1. The main features of the Nerja Cave and localization of the sampling site.

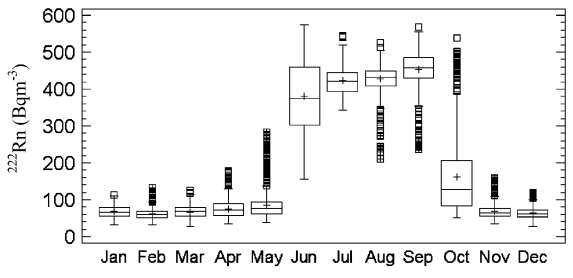

Fig. 2. Summary of monthly evolution of ^{222}Rn concentration at the Ballet hall.

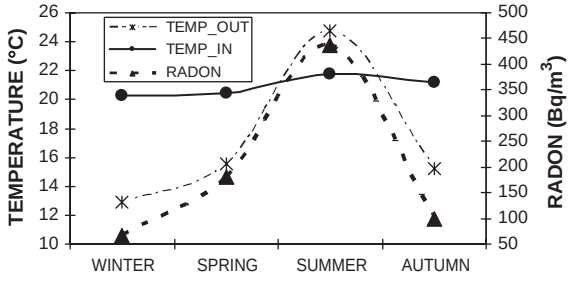

Fig. 3. The evolution of the ^{222}Rn concentration, the outdoor and the indoor temperature.

Table 1
Average, maximum and minimum ^{222}Rn concentration, indoor and outdoor temperature

	Radon (Bq m^{-3})			Indoor temperature (°C)			Outdoor temperature (°C)		
Month	Average	Max	min	Average	Max	min	Average	Max	min
January	65	113	32	20.4	20.7	19.4	13.6	22.2	5.8
February	60	132	31	20.2	20.5	19.2	12.0	18.2	5.8
March	65	125	29	20.1	20.4	19.7	13.0	21.3	3.3
April	72	179	34	20.2	20.6	19.9	14.8	24.8	6.3
May	80	283	39	20.3	20.7	19.9	16.3	26.2	8.7
June	368	575	155	20.8	21.1	19.7	26.5		
July	422	544	342	21.7	22.4	20.2	25.9	34.8	19.5
August	425	525	210	21.8	22.0	20.5	22.7	34.0	16.7
September	450	568	235	21.8	22.0	21.8	18.2	30.2	17.0
October	135	538	51	21.7	22.0	21.4	14.9	26.1	9.5
November	66	159	35	21.2	21.5	20.3	12.5	21.2	9.1
December	61	118	28	20.6	21.1	20.0	16.8	21.8	6.5

ranging between 550 and 575 Bq m^{-3} mainly in the summer months. The month that shows the lowest range is January with 80 Bq m^{-3}, October is the month with the greatest range exceeding 486 Bq m^{-3}. From the same figure, we can infer that ^{222}Rn concentration starts to increase from end of May to September. In June, the highest value is reached with 575 Bq m^{-3}. The lowest value is reached in December with 27 Bq m^{-3}. Table 1 shows the average, maximum and minimum ^{222}Rn concentration and indoor and outdoor temperature. The similar profile of the radon concentration seasonality and the indoor temperature (Fig. 3) suggests that the seasonal pattern is mainly the result of air movements due to differences of outdoor and indoor air densities caused by varying outdoor temperatures, but the internal temperature can be considered as constant.

2.2. Radiation exposure levels for workers and tourists

The values obtained (Table 2) indicate that the estimated effective doses for workers (5 h per day) and tourists (120 min per visit) in this cave are less than the average overall radon doses to the population (ICRP, 1994). The results for the period studied indicate that effective dose to workers was 0.43 mSv year^{-1}.

Table 2
Monthly radiation exposure level at the Ballet hall

Doses (mSv)	*anuary*	*Fe ruary*	*March*	*April*	*May*	*une*	*uly*	*August*	*Septem er*	*cto er*	*ovem er*	*Decem er*
Pu lic	2.3×10^{-4}	2.2×10^{-4}	2.3×10^{-4}	2.5×10^{-4}	3.0×10^{-4}	1.3×10^{-3}	1.5×10^{-3}	1.5×10^{-3}	1.6×10^{-3}	5.7×10^{-4}	2.3×10^{-4}	2.2×10^{-4}
Worker	0.014	0.013	0.014	0.015	0.018	0.080	0.089	0.090	0.095	0.034	0.014	0.013

3. Conclusions

- The factor that most affects the radon concentration in cave air is the outdoor air temperature. The ^{222}Rn concentration is high in summer when the external temperature exceeds the mean cave temperature.
- The estimated effective dose for workers and tourists is smaller than that from one year exposure to the atmospheric concentration of radon gas in Spain.

Acknowledgements

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References

ICRP, 1994. Protection against Radon-222 at home and at work. Pergamon Press, Oxford (publication 65).