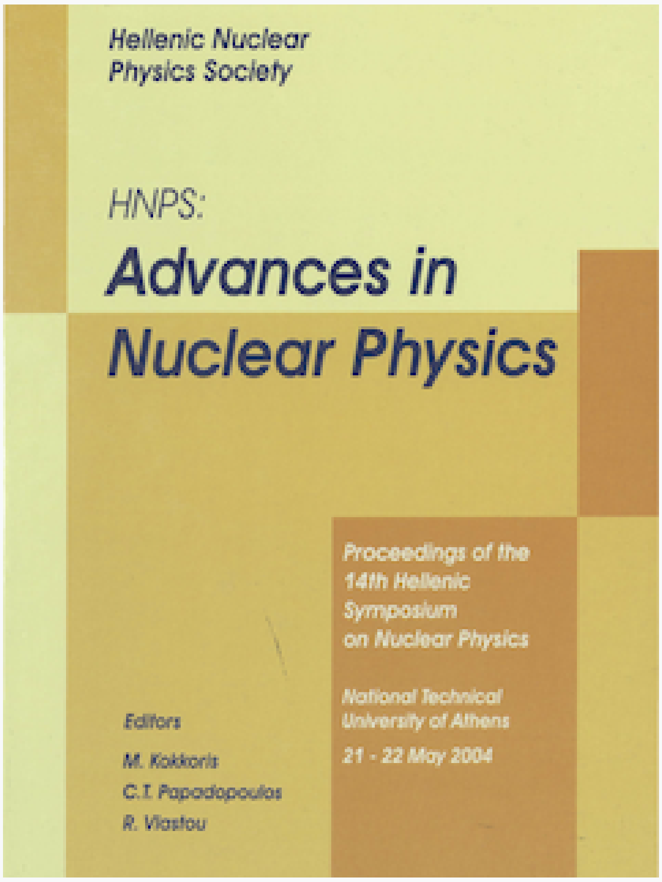
HNPS Advances in Nuclear Physics

Vol 13 (2004)

HNPS2004



Radon Gas Profiles and Exposure Estimates in the Perama Cave, Greece

C. A. Papachristodoulou, K. G. Ioannides, K. C. Stamoulis, D. L. Patiris, S. B. Pavlides

doi: 10.12681/hnps.2951

Radon Gas Profiles and Exposure Estimates in the Perama Cave, Greece

C.A. Papachristodoulou [a] K.G. Ioannides [a] K.C. Stamoulis [a] D.L. Patiris [a] S.B. Pavlides [b]

[a] *Nuclear Physics Laboratory, Department of Physics, The University of Ioannina, 451 10 Ioannina, Greece*

[b] *Department of Geology, Aristotle University of Thessaloniki, 541 24 Thessaloniki, Greece*

Abstract

An investigation of atmospheric radon levels in the Perama Cave, North-western Greece, has been carried out using CR-39 detectors. The detectors were placed at various locations along the guided cave pathway and exposed during different sampling periods. Mean concentrations amounting to 925±418 and 1311±352 Bq m^{-3} were recorded in the summer and winter months, respectively. The quantification of effective doses from radon daughters' inhalation was important, as the Perama Cave is one of the most popular in Greece, attracting more than 85,000 tourists per year. Due to the short duration of the guided tour along the cave, exposure of tourists was found to be insignificant, lying below 5.1 μSv per visit. Permanent cave guides receive doses ranging from 4.2 to 5.9 mSv y^{-1}. Considering the ICRP-65 recommendation that action levels in dwellings and workplaces should be set between 3 and 10 mSv y^{-1}, undertaking remedial measures to reduce the exposure of cave staff may be appropriate.

Key words: alpha-track detector; effective dose; occupational exposure; radon; cave

1. Introduction

The concern that exposure to high radon levels is possibly associated with various malignancies and especially with lung cancer, gave rise to extensive surveys dealing with radon monitoring in dwellings and workplaces. Among others, it has been recognised that most underground places, such as mines, caves, spas or water workplaces are particularly radon-prone areas. In this context, radon research in diverse cave formations has attracted scientific interest since the late 1970s. In a large compilation carried out by Hakl et al. [1], the distribution of radon data from 220 caves worldwide was found to range from 0.1 to 20 kBq m^{-3}, with an arithmetic mean of 2.8 kBq m^{-3}. Although the effective doses from radon inhalation are unlikely to pose a health risk to visitors, the doses received by cave workers and guides usually exceed the action levels suggested for workplaces by official regulations.

Despite the abundant research in the field, radon concentrations in Greek caves are poorly documented, with the exception of the Petralona Cave [2]. The present study aims to assess radon concentrations and estimate exposure levels in the Perama Cave, located in the vicinity of Lake Pamvotis, 4 km north of the city of Ioannina, NW Greece (Fig. 1). After its discovery in 1948, the cave was explored in detail in 1954 and became the first in Greece to operate as a show cave. Its approximate surface is 14800 m^2, with an 850 m long path currently accessible for guided tours. The cave attracts 85 to 88 thousands of visitors each year, particularly during the summer period, from July to September.

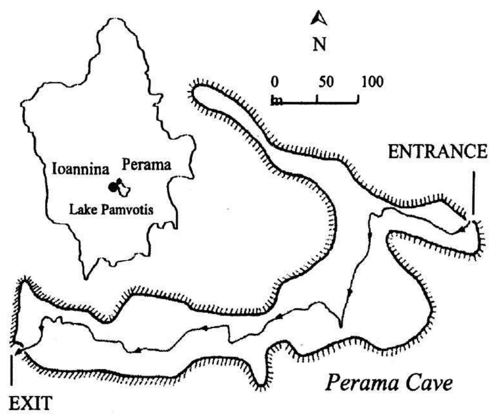


Fig. 1: Geographic location and sketch diagram of the Perama Cave .

2. Experimental

Radon measurements were carried out using CR-39 track-etch detectors, fixed in plastic containers (5 cm height, 3 cm diameter) and covered with a 50 μm thick polyethylene foil to exclude ^{220}Rn and ^{219}Rn isotopes, humidity and dust particles. The detecting devices were placed on natural ledges along the cave walls, at approximately 0.5 to 1 m from the ground surface, avoiding dripping water and keeping out of sight of cave visitors. To assess any seasonally dependent variations in radon levels, measurements were carried out during three different periods – winter (November, NOV), spring (April, APR) and summer (August, AUG).

Following a minimum exposure of 20 days, the detectors were recovered and chemically etched in a 5 N NaOH solution at 80°C for 8 h. Alpha tracks were visualized through a semi-automatic arrangement, equipped with a microscope–video camera–frame grabber–computer chain. Tracks densities were automatically obtained using the specially developed computer code TRACKA© [3]. Radon readings from each detector were deduced as the mean value of readings from ten optical fields. Standard deviations from the mean are given as statistical errors in radon concentration. The detection arrangement was calibrated in the NRPB laboratories in Didcot, UK and has a sensitivity of 0.2 tracks cm^{-2} kBq^{-1} m^3 h^{-1}. For a 30 d exposure period, the lower detection limit is 126 Bq m^{-3}.

3. Results and Discussion

3.1. Radon gas activities

The distribution of radon inside the cave is shown in Fig. 2. Concentration ranges are listed in Table 1. Compared with data from caves worldwide, radon levels in the Perama Cave were not unusually high and showed quite moderate spatial fluctuations. During the winter period, the maximum-to-minimum radon ratio between different locations in the cave was lower than 3, while fluctuations by up to a factor of 8 were observed during spring and summer.

A Student's t-test, performed to check the hypothesis that mean concentrations recorded during different periods are statistically different, revealed that the winter readings are significantly higher ($p=0.01$) than the summer ones. As deduced from meteorological data (not shown here), this trend was independent of temperature and atmospheric pressure gradients between external and internal air; it should be rather attributed to changes in the ventilation conditions in the cave interiors. During winter, due to the low visiting frequency, the air inside the cave is more isolated causing radon accumulation. In August, guided tours normally take place every 10 min resulting in a continuous airflow, accompanied by lower radon levels. The complicated morphology of tunnels and chambers further accounts for local radon variations.

Table 1
Radon concentrations (Bq m^{-3}) measured throughout this study

Period	Min	Max	Mean ± S.D.
NOV	691	1929	1311±352
APR	197	1597	804±381
AUG	203	1622	925±418

3.2. Exposure estimates

The effective doses, E (mSv y^{-1}), due to exposure to radon decay products were calculated as:

$$E = C_{Rn} \times F \times t \times d \times u$$

where

C_{Rn} (Bq m^{-3}) is the air radon concentration,

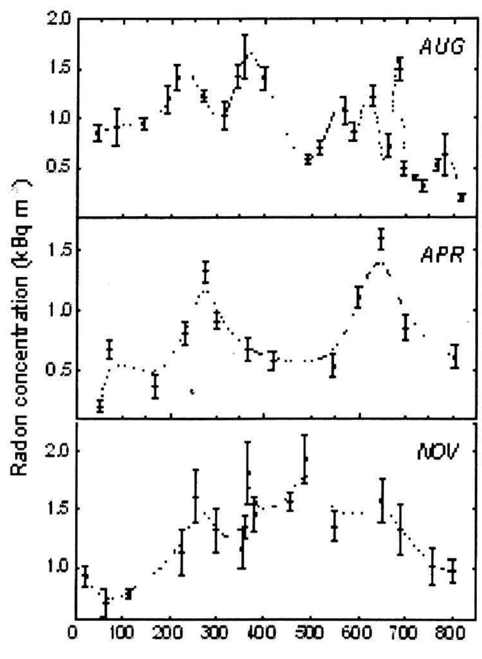
F is the equilibrium factor between radon and its decay products; F was assigned the value of 0.5, typical for limestone caves [4, 5],

t (h y^{-1}) is the time spent inside the cave,

d [=1.4 mSv per mJ h m^{-3}] is the dose conversion factor [6] and

u [=5.6×10-6 mJ m^{-3} per Bq m^{-3}] is a unit conversion factor.

Doses received by visitors were calculated assuming a typical 1h duration for each guided tour. As estimated from communication with the cave management, permanent and seasonal guides spend 1150 h and 500 h underground annually. Results are given in Table 2.



The exposure of tourists is minor compared with typical doses received from radon inhalation at home. The dose received by seasonal guides is comparable with the natural one, considering that the worldwide average dose due to inhalation of radon and thoron decay products is 1.15 and 0.10 mSv y^{-1},

Table 2
Estimation of effective doses

Period	Effective dose
Tourists (μSv per visit)	5.1 (NOV) 3.6 (AUG)
Guides (mSv y^{-1})	
Seasonal	1.8
Permanent	4.2-5.9

respectively, while the internal and external exposure to all natural radiation sources amounts to 2.4 mSv y^{-1} [7].

The exposure of permanent guides falls within the 3 to 10 mSv y^{-1} range of *action levels*, recommended for dwellings and workplaces by ICRP-65 [6]. However, radiation protection philosophy encourages the reduction of all radiation exposures to levels "as low as reasonably achievable" (ALARA). In this context, undertaking remedial measures to reduce exposure in the cave may be appropriate.

4. Concluding remarks

Radon levels measured at different locations of the Perama Cave yield an average of 1311±352 Bq m^{-3} in winter and 925±418 Bq m^{-3} in summer. The spatial distribution of radon was devoid of sharp anomalies and no clear seasonal variation patterns were observed. Due to the short duration of the guided tour along the cave, the risk from radon inhalation for members of the public was found to be negligible. The exposure of seasonal guides is not significant, whereas permanent guides receive doses that fall within the range of action levels recommended by the ICRP. A full analysis of radon doses in the Perama Cave would require detailed seasonal and spatial information on the equilibrium factor between radon and its decay products. It should be further noted that the passive measurements performed in the present study may not accurately reflect the radon levels during day-time, when increased human activity is expected.

Acknowledgments

This study was partly funded by the Greek Secretariat of Research and Technology, in the frame of the bilateral Greek-Slovenian cooperation (2003-2004).

References

[1] J. Hakl, I. Hunyadi, A. Varhegyi, in: S.A. Durrani, R. Ilic (Ed.), Radon measurements by etch-track detectors, World Scientific Publishing Co. Pte. Ltd., Singapore, 1997, Ch. 6.

[2] C. Papastefanou, M. Manolopoulou, E. Savvides, S. Charalambous, Health Phys, 50 (1986) 281.

[3] K.G. Ioannides, K.C. Stamoulis, C.A. Papachristodoulou, Health Phys, 79 (2000) 697.

[4] J. Vaupotic, I. Csige, V. Radolic, I. Hunyadi, J. Planinic, I. Kobal , Health Phys, 80 (2001) 142.

[5] G.K. Gillmore, P.S. Phillips, A.R. Denman, D.D. Gilbertson, J Environ Radioact, 62 (2002) 165.

[6] ICRP 65-International Commission on Radiological Protection, Pergamon Press, Oxford, 1993.

[7] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), United Nations, New York, 2000.