EXPOSURE OF WORKERS TO RADON PROGENY IN THE BARADLA CAVE AT AGGTELEK

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The number of those countries where radiation protection considers not only radiation workers but all employees in general is growing. An Euro conform regulation assumes that at least worker′s exposure to radon be assessed and limited to a certain value. This is based on ICRP 65 recommendations [1] in most countries. In the new Hungarian radiation protection regulation [2], in accordance with EU legislation, rules have been adopted also for the protection of workers from radon exposure at work. The limit of exposure for non-radiation workers is expressed in action level and is set to 1000 Bq/m^3 yearly mean radon concentration and is in effect from 1st January 2003. In case of 2000 hours/year working time, this corresponds to 3-12 mSv effective dose, depending on the local circumstances.
Among others, show caves are explicitly mentioned in the new directive where the exposure of personnel must be monitored because of the likely high radon levels. This is probably because of the extensive radon related research work done in caves in the past 20 years in Hungary [3]. These studies revealed that the mean radon level in Hungarian caves is around 2 kBq/m^3. Furthermore, it turned out that the well known show caves of Budapest all have yearly mean radon level much higher than the current action level. Some 10 years ago, radon research in these caves included also the assessment of radiation dose of tour guides and speleotherapy personnel [4]. The largest and most popular show cave of the country, the Baradla cave at Aggtelek (NE Hungary), however, has never been investigated in detail from this point of view, although the highest number of tour guides are employed full- or part-time there. This is the subject of the present work.
The most popular way of assessing radon exposure is using track etched detectors. This can be easily carried by a person, readily available and is indeed cheap. In principle, it is assumed to be always exposed to the same radon concentration as the person in question and, therefore, is widely considered as an adequate device for personnel radon dosimetry.
It has, however, several drawbacks.

- It is a passive device, it cannot be switched on/off, therefore it is exposed to some radon all the time. This unwanted exposure gives background tracks, which is difficult to determine and it will anyway significantly increase the uncertainty of net track density. This is particularly true in those cases where the time of exposure to be monitored is only 10-20 % of the total time, such as in show caves.
- It's sensitivity is fairly low, it would give only 4-6 tracks/cm^2/working day in the Baradla cave which, considering monthly monitoring period, results in large statistical uncertainty of the net track density.
- In order to avoid exposure to radon progeny present in the monitored atmosphere and also to discriminate against thoron, a sort of barrier is applied in the devices, which in turn, results in slow response to the actual radon concentration. This is usually not a problem when monitoring period is long compared to the response time of the device and may be compensated by leaving the detector unopened for some time after the end of monitoring period. However, when exposure time is short (cca. 1 hour) and the radon level changes along the route (in time), track etched detectors will certainly underestimate exposure.
- Since tracks are also produced by the alpha decaying Rn-progeny born within the detector and there is not sufficient time for them to reach secular equilibrium, the sensitivity of such devices is not constant. This further complicate their application. In fact the proper calibration of the detector is hardly possible for such kind of dosimetric application.

The above problems in cave radon dosimetry may be overcome using another approach. By measuring the radon concentration using active technique in all parts of the cave visited in a tour and furthermore by assessing also the time spent at these locations, it is possible to determine the radon level averaged over a tour. Usually this quantity will show seasonal variations, depending on the specific features of the cave. For the Baradla cave Figure 1 shows part of the cave map where the tour is guided along with the Rn concentration distribution in the warm season. These data have been deduced from several years of radon monitoring in the cave using AlphaGuard (Genitron GbmH, Germany) and PRASSI (Silena SA, Italy) radon monitors.

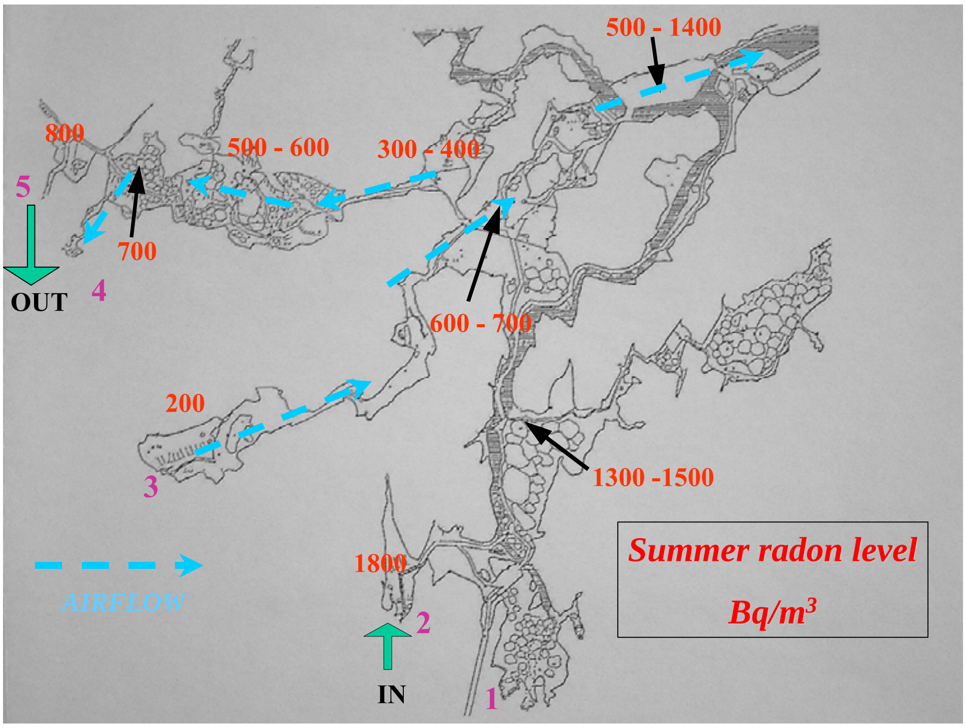

Figure 1. Radon concentrations along the guided tour route in the Baradla cave in summer.

Visitors enter the cave at the main entrance (marked No. 2 in Fig. 1), where Rn level is 1800 Bq/m^3, then go down the stairs. Some 100 m further inside the cave, at the Tortoise Rn concentration is some 20% smaller. Then the tour goes through a narrow passage and the next stop is the Concert Hall with even smaller Rn level. This is caused by the incoming air (see Fig. 1. blue arrows) from a side passage which ends at the possibly ancient main entrance of the cave (marked No. 3 in Fig. 1.). After having some time here at the so named Black Hall the tour enters the lowest Rn-level region of the cave. The time averaged radon concentration along the route has been estimated to 970 Bq/m^3. This is the summer case.

In the cold season the air circulation of the cave is reversed, and in addition, along much of the tour route fresh air is entering the cave, resulting in low radon levels. The only exception is the main passage, the Concert and Black Halls where Rn-rich air moves in from deep in the cave and gives 900-1100 Bq/m^3 steady radon concentration at these locations. In this case the time averaged radon concentration has been estimated to 410 Bq/m^3 for a tour.

From the many measurements made in the past few years in this region of the cave we also concluded that in 62 % of the year cave climate shows warm season and only in 38 % cold season Rn-levels. On this basis the yearly mean radon concentration averaged over the tour comes to 750 Bq/m^3. One, however, should not use this figure to estimate exposure. For during summer a very large number of tourists visit the cave, while in the cold season only a small number. Consequently, tour guides work much more in summer. Time tables show that a guide takes 750 tours in summer and only 270 tours in the cold season. With this occupancy taking into account, the yearly mean Rn concentration comes to 820 Bq/m^3.

Since the dose is delivered by radon progeny and not radon itself, one has to also assess the equilibrium factor representative in the cave. The data available in the literature shows that F is always larger than under normal ambient conditions. Published values are between 0.5 - 0.8. As part of this work, several radon progeny concentration measurements have also been made in the Baradla cave at different locations. On the one hand, these confirm the existence of high F-value in caves. Furthermore, it turned out that the presence of humans, either as visitors, or cavers increases equilibrium factor. In the so called virgin cave F= 0.5 - 0.6, which, after human activity, increases steadily to about 0.8. In fact, this specific behaviour of F has already been measured and published by others [4], but went unnoticed at that time. In this work for the dose assessment F=0.8 has been used.

Now given all the data needed for the dose estimation: occupancy, mean Rn concentration and equilibrium factor. Using the ICRP 65 dosimetry model, one can readily calculate exposure. This comes to 4.04 $mJhm^3$. In terms of effective dose this corresponds to 5.8 mSv.

References

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