REVIEW OF DOCTORAL THESIS

Title:

Application of the European Basic Safety Standards Directive in Underground Mines: A Comprehensive Radioecology Study in a Hungarian Manganese Mine

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Reviewer:

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The submitted Doctoral thesis presents radon, its progeny, gamma emitter terrestrial radionuclides measurements and dose estimation related to an underground manganese mine in Hungary. The study of radon (and its progeny) concentration in workplaces is a very meaningful matter since it has the highest effective dose contribution amongst the naturally occurring radionuclides.

It is very important to emphasize, to accomplish measurements in underground environments, especially in an underground mine, is a very challenging and difficult task, therefore, credit has to be given to the Ph.D. candidate.

The number of the measurements carried out by the Ph.D. candidate is very impressive, more than enough to a high-quality doctoral thesis.

The selection and application of measurement methods are correct and very demonstrative since most of the available radon measurement techniques were used during the doctoral work.

However, the scope of the thesis is too broad and the Ph.D. candidate was not able to build up a clear and well written doctoral dissertation and properly discuss the results of his research activity.

Looking through the conference and publication activity of the Ph.D. candidate, he was involved in many research works that might have affected his main topic disadvantageously.

The dissertation has four final theses based on three papers presented in journals with impact factor. However, not clear the relation of the 3rd paper (**Shahrokhi, A.**, Erika, N., Anita, C., János, S., & Tibor, K. (2016). Distribution of indoor radon concentrations between selected Hungarian thermal baths. Nukleonika, 61(3), 333-336.) to the doctoral thesis since radon in thermal baths was not discussed.

Specific comments, critics

- The scientific discussions are not detailed enough. In some cases, the results are presented but not discussed or explained.
- The terminology applied to the mining is not satisfactory.
- Description of the mining process is poor. Difficult to understand the meaning of "mining activity" that can cause radon increment. Probably, the radon was increased after the explosion of the manganese ore, however, it was not explained clearly.
- The introduction and discussion of the Manganese Ore Mining Residue are not comprehensive enough, consequently this thesis (No.4) is not so solid compared to the others.
- Figure 39 and 40 present information improperly
- There are many typos in the list of presentation and format inconsistency.
- The usage of correct terminology is very important, otherwise misunderstanding or mistranslation occurs that should be avoided in a scientific communication. For example, "radon in air" ("munkahelyi radon" or "radon a munkahelyi levegőben" in Hungarian) was discussed in the original thesis, while „radon in atmosphere" ("légköri radon" in Hungarian) was presented in the Hungarian version of the booklet. However, the „radon in air" is also not a correct English expression. Application of „radon in the workplace", „occupational radon exposure" or „indoor radon" etc. would have been appropriate in the original thesis.

Questions

1. Please explain the contribution of radon to the average exposure of the population. Is it around 50% or more?
2. Table 9. Please explain, how it is possible that the radon emanated (110.3 kBq) from the Pylon 2000A radon source is higher than the source Ra-226 activity (105.7 kBq).
3. What is the relevance of K-40 measurement to radon study?
4. The Ra-226, Th-232, and K-40 were determined in 32 rock samples. However, in Fig 32 much less points presented for the distribution of Ra-226 and Th-232. Please explain why.
5. Considering the presented results in Fig 31 and 32 the distribution of K-40 is different from Ra-226 and Th-232. Please explain why.
6. What is the explanation of the significant Ra-226 enrichment (one magnitude!) comparing to U-238 in carbonate ore samples?
7. The Th-232 (Th-228) concentration was similar or higher than the Ra-226 in many rock samples. Probably thoron was also released during the explosion of ore. Please explain the thoron influence on the radon measurement results.
8. Radon concentration results of two Iranian manganese mines (Robat-Karim and Venarch-Qom) can be found in the literature. The lowest radon concentrations (10-84 Bq/m^3) was reported from the Venarch-Qom manganese mine while the Ra-226 concentration in the ore samples from this mine was one magnitude higher than in the samples from the Urkut manganese mine. What is the explanation of higher radon level in the Urkut manganese mine if the Ra-226 is lower than in other mines?

   M. Ghiassi-Nejad, M. M. Beitollahi, N. Fathabadi, P. Nasiree; Exposure to ^{222}Rn in Ten Underground Mines in Iran, *Radiation Protection Dosimetry*, Volume 98, Issue 2, 1 January 2002, Pages 223–225, https://doi.org/10.1093/oxfordjournals.rpd.a006713

   N. Fathabadi, M. Ghiassi-Nejad, B. Haddadi, M. Moradi; Miners' exposure to radon and its decay products in some Iranian non-uranium underground mines, *Radiation Protection Dosimetry*, Volume 118, Issue 1, 1 April 2006, Pages 111–116, https://doi.org/10.1093/rpd/nci324

9. Table 22. Please explain why the working time of miners has uncertainty.
10. Please explain why A5 point had the highest water radon concentration.

Even though the weak points of the doctoral work, it fulfils the requirements and criteriums laid down by the Doctoral School of Chemistry and Environmental Sciences, University of Pannonia, Hungary.

In conclusion, I recommend to accept the doctoral thesis and give the opportunity to the Ph.D. candidate to answer the questions and defend orally his theses.

Chiba, Japan, December 1, 2018

Norbert Kavasi