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Radon concentration assessment in water sources of public drinking of Covilhã's county, Portugal

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ABSTRACT

Radon, the heaviest of the noble gases on the periodic table of elements, is a natural radioactive element that can be found on water, soils and rocks.

The main goal of this work is to present an evaluation of radon concentration on samples of water, used for human consumption, collected on uranium-rich granitic rock areas. Once the geological features of the sampling region evidence the presence of this natural radionuclides, their slow dissolution steadily increases concentration in ground water.

Although, the most important contribution of natural radiation, for most populations, is from inhaled radon (generic term used commonly to refer to the isotope ^{222}Rn), in some circumstances, exposure to natural radionuclides, through drinking water, could exceed acceptable levels, and also present a hazard.

Despite the fact that radon can be reduced if the water is boiled, this gas, dissolved in ground water, can be released into the air during household activities such as showering, dishwashing and laundry. So, the short lived radon decay products will contribute to increase the number of those which are present in particles suspended in the indoor air and can be accumulated up to dangerous concentrations. Once the radon progeny emits highly ionizing alpha-radiation, they may cause substantial health damage after long-term exposure.

Radon concentration measurements were performed on thirty three samples collected from water wells at different depths and types of aquifers, at Covilhã's County, Portugal with the radon gas analyser DURRIDGE RAD7. Twenty three, of the total of water samples collected, gave, values over 100 Bq/L, being that 1690 Bq/L was the highest measured value.
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1. Introduction

Natural sources of radiation are responsible for the large majority of radiation exposure, and radon typically contributes up to 50% to the background radiation.

Radon is a natural odourless, tasteless and colourless radioactive gas, which occurs naturally everywhere on earth from the natural radioactive decay of uranium, found in different quantities in most rocks, soils and water (Nuclear, 2010). This gas is recognised as a carcinogenic agent, being appointed by the World Health Organization as the second leading cause of lung cancer after tobacco smoke (Alina et al., 2012).

This unstable radionuclide disintegrates through short lived decay products which stay suspended in air that we breathe. In the open space the risk is very low, once diluted in the air, however, in closed spaces they can accumulate up to very dangerous concentrations and, for a long-term exposure, may cause health damage.

The effects of the ingested radon are not fully understood but, although only one percent of exposure to it is from drinking water, we can't neglect that this radioactive gas can present a hazard.

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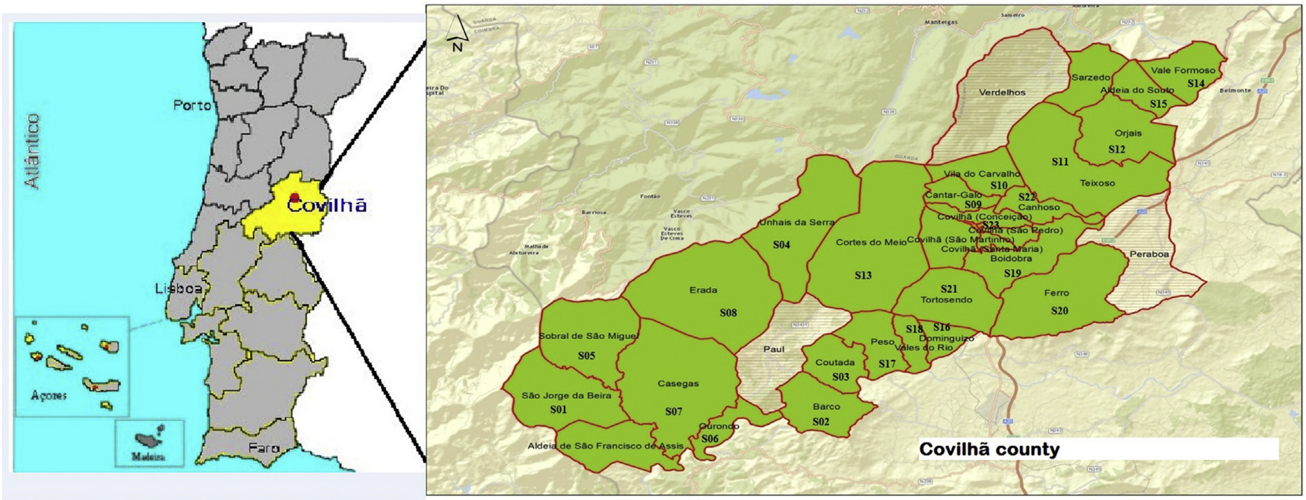

Fig. 1. Location map of Covilhã in Portugal.

In the sampling region some households obtain drinking water from underground sources and, in spite of exposure to radon occurs primarily through inhalation, resulting in radiation to the lung and to a lesser degree other organs through radon gas dissolved in blood, a very high concentrations on drinking water can be a primary source of exposure of organs other than the lung (Auvinen et al., 2005).

In terms of ingested radon, the radiation exposure is primarily due to radon gas itself, being the contribution on its progeny less than in the case of indoor radon (Council, 1999). The organ that receives the highest radon dose is the stomach, about ninety percent of the total effective dose (Kendall & Smith, 2002).

Since most of the radon escapes, leaving only minimal amounts in the water itself, the health risk, from ingesting radon, is considered negligible. However, it should be noted that, if the radon levels are sufficiently high, they can affect considerably airborne radon concentrations. So, in the case of radon concentrations, in drinking water, exceed 100 Bq/L, it is recommended to intervene to reduce the release of radon from the drinking water into indoor air.

This paper shows the results of radon concentrations measurements of underground water samples obtained during the autumn and winter of 2015 in and around the city of Covilhã. There is no previous study concerning the radon content in well water of Covilhã. Because almost all of the water for household use and drinking is fed by wells in the city of Covilhã, the results are considered very important for public health. This study also draws a general picture of the natural radioactivity of well underground waters consumed by people living in Covilhã county.

2. Location of study area and geology

Covilhã municipality as an area of 550 km^2 and an estimated population of 51.797 people. Partially located on the Serra da Estrela Natural Park, it is mainly constituted of granitic bedrock aged between 340 and 280 *My*, enclosed on metamorphic formations as schists and greywackes with 650 to 500 *My*. These main geological formations are crossed by an extensive filonian network of quartz, pegmatites and dolerits (CISE, 2015). Sampling sites are shown on the map of Fig. 1.

3. Material and methods

In order to determine the radon concentration on water sample a rad7 radon equipament from the american manufactures

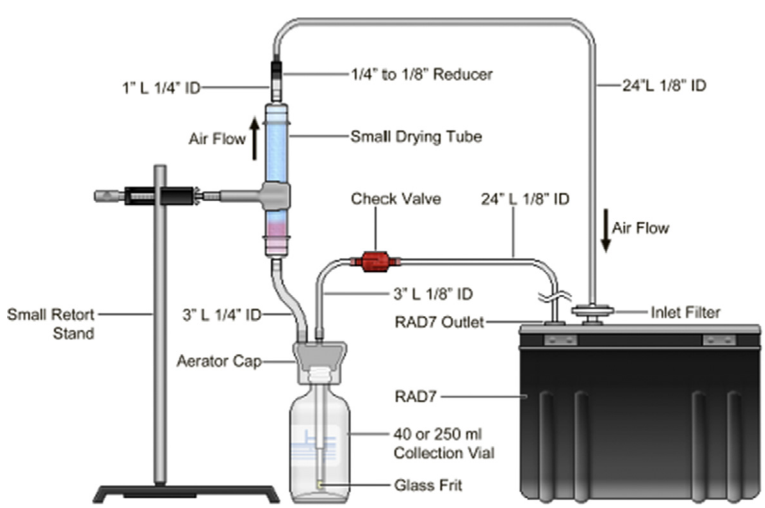

Fig. 2. Schematic representation of Radon on water concentration experimental setup (DURRIDGE, 2015).

Table 1
Concentration of ^{222}Rn (Bq/L) on water samples and respective effective annual dose due to ingestion for adults and children.

S/N.	Sample ID	Average radon level (Bq/L)	$(E_{ing})_{adults}$ (mSv/y)	$(E_{ing})_{children}$ (mSv/y)
1	S01.1	58±8	0.423	0.847
2	S01.2	63±8	0.456	0.913
3	S01.3	98±10	0.717	1.434
4	S02.1	64±8	0.469	0.939
5	S03.1	54±7	0.392	0.784
6	S04.1	1690±42	12.34	24.674
7	S05.1	933±30	6.811	13.622
8	S05.2	248±15	1.810	3.621
9	S06.1	195±14	1.424	2.847
10	S07.1	262±16	1.913	3.825
11	S08.1	191±13	1.394	2.789
12	S09.1	390±20	2.847	5.694
13	S10.1	981±31	7.161	14.323
14	S11.1	769±27	5.614	11.227
15	S12.1	612±24	4.468	8.935
16	S12.2	589±24	4.300	8.599
17	S13.1	276±16	2.015	4.030
18	S14.1	262±15	1.913	3.825
19	S15.1	704±25	5.139	10.278
20	S16.1	144±11	1.051	2.102
21	S17.1	226±14	1.650	3.300
22	S18.1	141±12	1.029	2.059
23	S19.1	112±10	0.818	1.635
24	S20.1	135±11	0.986	1.971
25	S21.1	214±14	1.562	3.124
26	S22.1	4±2	0.028	0.055
27	S23.1	7±3	0.054	0.109
28	S23.2	277±16	2.022	4.044
28	S23.3	561±23	4.095	8.191
30	S23.4	1340±37	9.782	19.564
31	S24.5	12±3	0.085	0.169
32	S24.6	2±1	0.018	0.035
33	S24.7	28±5	0.207	0.415

Durridge was used. The RAD H2O was developed by the manufacturer specifically to perform radon concentration measurements on water (Fig. 2) and is able to present results after a 30 min analysis. A ^{222}Rn nucleus, that decays within the cell leaves its transformed nucleus, ^{218}Po, as a positively charged ion. The electric field within the cell drives this positively charged ion to the detector, to which sticks. When the short-lived ^{218}Po nucleus decays upon the detector's active surface, its alpha particle has 50% probability of entering the detector and producing an electrical signal proportional, in strength, to the energy of the alpha particle. Subsequent decays of the same nucleus produce beta particles, which are not detected, or alpha particles of different energy. Different isotopes

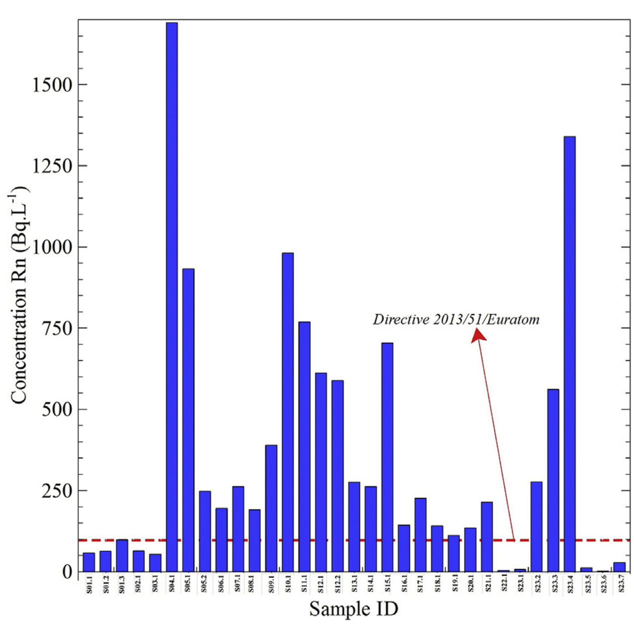

Fig. 3. Radon concentration distribution on collected samples.

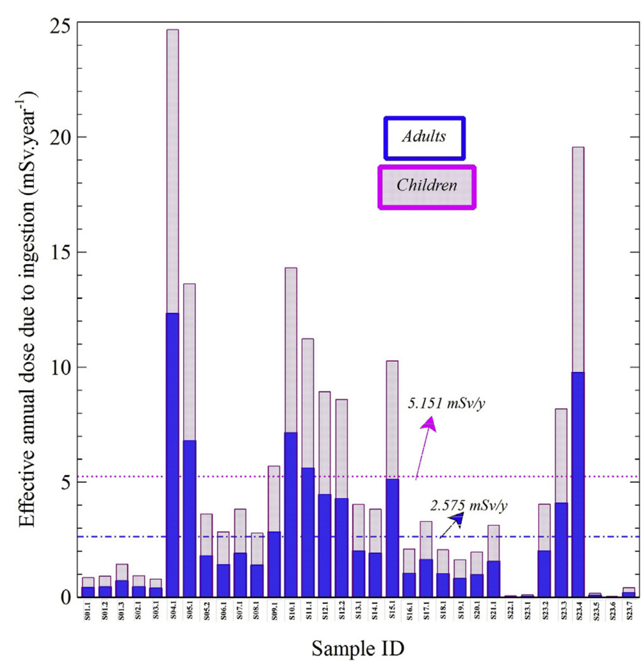

Fig. 4. Annual effective dose due to ingestion.

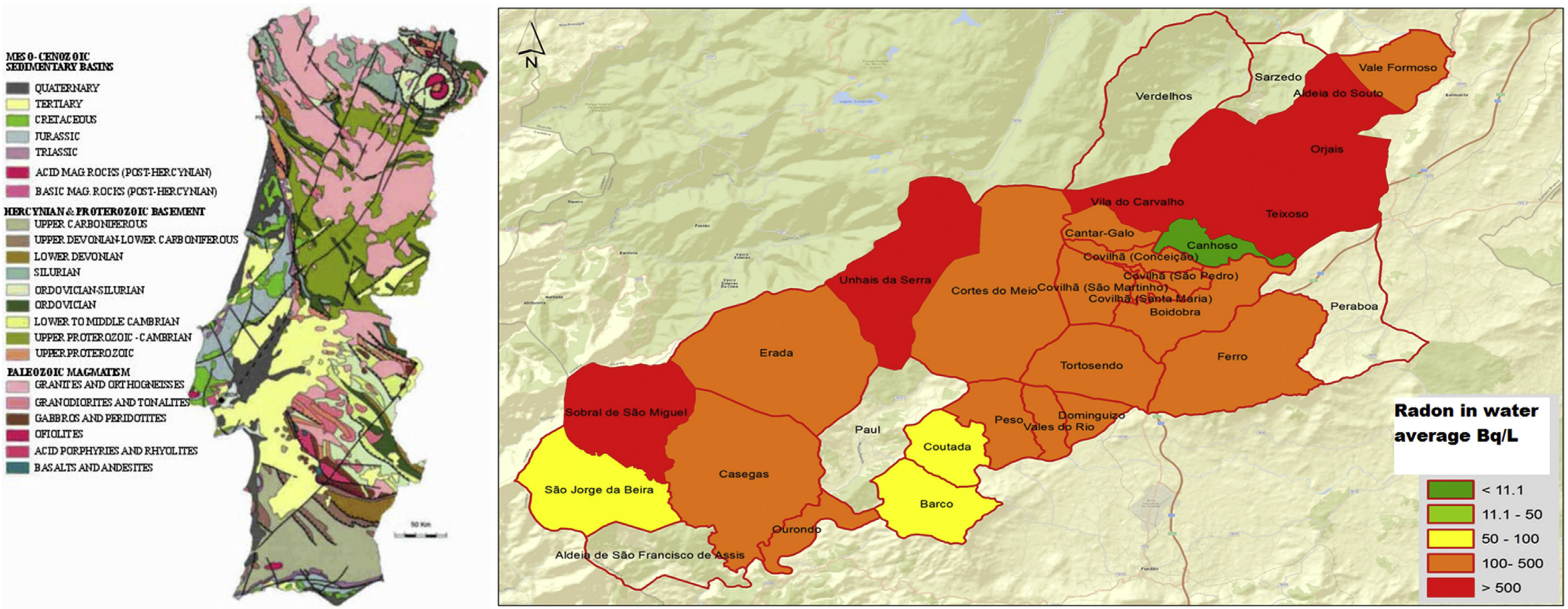

Fig. 5. Map on the Geology of Portugal (LNEG, 2016), and concentration of radon in water on Covilhã's county.

have different alpha energies, and produce different strength signals in the detector. The rad7 amplifies, filters, and sorts the signals according to their strength and uses only the ^{218}Po signal to determine radon concentration (DURRIDGE, 2015).

The ingestion of drinking water containing large concentration of radon and its progeny, contributes to the increased radiation dose exposure on stomach. The average effective annual dose for ingestion is calculated through the following equation:

$$E_{ing} = K_{ing} \times C_{Rn} \times C_W \times t \quad (1)$$

where E_{ing} is the annual effective dose due to water ingestion containing radon and is expressed in Sv, K_{ing} is the conversion factor for ingestion dose of radon (1×10^{-8} Sv/Bq for adults and 2×10^{-8} Sv/Bq for children), C_{Rn} is the radon concentration expressed in Bq/L, C_W is water consumption and t the time span of the consumption, on this paper a consumption of 2 L/day during 365 days was considered (F.P.T., 2010; Károly, TokonamiIshikawa, & Vancsurac , 2007; WHO, 2004).

4. Measurement results

Measurements of the radon concentration held in water samples collected from public sources located in Covilha's municipality, allowed the determination of the average annual dose in the stomach, for adults and children.

On Table 1 water sample location and respective radon concentration is shown, as well as ingested dose for adults and children.

From the graphic, represented on Fig. 3, it is clear that twenty three of the total water sample collected show values over 100 Bq/L, the recommended reference value of the Council Directive 2013/51/EURATOM 22nd of October 2013.

Results show that the annual effective dose due to ingestion, E_{ing}, are clearly over the recommended reference limit value (Reference Dose Level - RDL), that advises an effective mean dose of 0.1 mSv/y (WHO, 2004).

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) suggests that the contribution of ingestion of radon in water for the total mean annual dose should be 0.002 mSv (U.N.S.C., 2000).

The average of the results on this study, as we can see in Fig. 4, is 2.575 mSv/y, for adults, and 5.151 mSv/y, for children, clearly above the aforementioned reference values.

The observed values of radon concentration in water from the collected samples is dependent not only of the geological setting on the geographic location of this study, but also of the public water supply source and track to the public distribution point. The correlation between geology and radon concentration is clear when overlapping the geological information map where metamorphic terrains of the south tend to show smaller concentration on radon in water, Fig. 5, and granitic areas show increased values.

5. Conclusions

Uranium, parent material of radon daughter isotope, is widely distributed in rocks and soils of the Covilhã's county. From a health viewpoint, ^{222}Rn is the most important radon isotope because its decay products, ^{218}Po and ^{214}Po, can have a marked adverse effect in human tissues. We decided to measure radon in underground water because about 50% of population natural exposure is from this radioactive gas and, the highest percentage of radon enters the human body by breathing, during bath, and from drinking water. Based on the portable device rad7, radon was measured in water and the results shows that its concentration average value, in thirty three samples of water collected, are higher than the Council Directive 2013/51/EURATOM advised level of 100 Bq/L. Taking into account public health it is recommended that the measured water sources are considered not safe for drinking purposes, accordingly to those international limits, and will be advantageous boiling it if used for that purpose.

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