Working Levels in some Croatian Spas

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Abstract. Traditionally, people like bathing in spas. Water in spas has been used as a basic therapeutic agent for different balneological treatments in the form of a bath or inhalation. Thermal water applied at spas comes from underground sources of mineral waters that are rather high in radium concentration. Radon for therapy comes from underground sources of mineral radioactive water, or is used for treatments in the form of collective inhalations inside the caves. In the air of the treatment rooms radon occurs together with its radioactive decay products. Concentration of radon progeny (working levels) has been determined at some spas in Republic of Croatia. The potential alpha energy concentration of radon-decay products was estimated on the basis of the alpha activity measurements of radioactive aerosols collected on filters during the process of air sampling. Results of the determination of potential energy concentrations and those of exposure value were expressed in working level month units.

1. Introduction

The healing power of thermal springs and mud in our region was already discovered by the ancient Romans. From those times, many health resorts have been developed in Croatia. Radon has been used as a basic therapeutic agent for different balneological treatments in the form of a bath or inhalation.

Of the several isotopes of radon, $^{222}\text{Rn}$ has the most important impact on human health, because it has the longest half-life ($T_{1/2} = 3.8235$ d). An inert gas at temperatures above -61.8 °C, $^{222}\text{Rn}$ is a naturally occurring decay product of $^{226}\text{Ra}$, the fifth daughter of $^{228}\text{U}$. Both uranium and radium are present in most soils and rocks in widely varied concentrations. As radon forms from the decay of radium, it can leave the soil or rock and enter the surrounding air or water. Because $^{222}\text{Rn}$ is an inert gas it doesn’t undergo chemical reaction in the environment. It passes freely into and out of the lung, with minimal uptake by the respiratory system. On the other hand, radon daughters deposit preferentially in the respiratory tract. Thus, in the air of the treatment rooms in the spas, radon occurs together with its radioactive decay products. The personnel engaged in treatments are occupationally exposed to radioactive aerosols.

2. Methods and Locations

The radon decay products are considered as the main contributors to the radiation lung exposure of subjects exposed to high levels of radon and radon daughter products in the atmosphere. The $^{222}\text{Rn}$ daughters have relatively short half-lives: $^{218}\text{Po}$ ($T_{1/2} = 3.05$ m), $^{214}\text{Pb}$ ($T_{1/2} = 26.8$ m), $^{214}\text{Bi}$ ($T_{1/2} = 19.9$ m) and $^{214}\text{Po}$ ($T_{1/2} = 164.3$ µs) [1]. Since the energy values of the radiation from the radon daughters differ from each other, and since tissue damage can be related to the total absorbed energy, it follows that the possible danger of these radionuclide is more satisfactorily described by their potential alpha energy, than by the concentration in Becquerel. To cope with this problem the concept of a working level (WL) was developed. Working level month (WLM) is defined as “A unit of exposure to radon progeny or thoron progeny. One working level month is 3.54 mJ·h·m⁻³ or 170 WL·h, where one working level (WL) is any combination of radon or thoron progeny in one litre of air that will result the ultimate emission of 1.3·10⁵ MeV of alpha energy. In SI units the working level is equivalent to 2.1·10⁵ J·m⁻³.”[2].

The radon or radon daughter measurement techniques vary considerably from double filter methods [3], to modified film badge type detectors [4] and even solid state alpha spectrometry. The Tsivoglou method [5]
is one of the oldest techniques for radon progeny determinations, but the 30 minutes counting period limits the processing rate to two samples per hour. The most common method for measuring WL is the *Kusnetz method* [6], but it is not sensitive enough to measure WL in the range below about 0.3 WL.

With the method developed by Scott, the *M-R-K method* [7] it is possible to transfer a filter paper from air pump to portable scalar within 40 seconds, and next 15 seconds is ample time to note down the scalar reading and restart. Our procedure therefore consists in collecting an air sample for five minutes, and than after five minutes delay, count the total alpha activity on the filter for next five minutes, what make this method very convenient for field use.

The radon progeny monitor consists of an alpha scintillation detector (ZnS/Ag), photomultiplier tube, a light-tight outer housing, and all battery operated for a field use. The air samples were collected on glass fibre filters (with a nominal collection efficiency of 99.9 % for 0.3 µm particles) by means of an air sampler at a flow rate of about 30-40 L·min⁻¹.

The locations of the spas chosen for this investigation are presented in Figure 1. Spas are numbered and listed in alphabetical order:

1. Bizovac Spa
2. Istrian Spa
3. Krapina Spa
4. Stubička Spa
5. Tuhelj Spa
6. Varazdin Spa

![FIG. 1. Locations of Investigated Spas in Republic of Croatia](image-url)
Symbols used for better description of the spas are [8]:

- B = balneological therapy
- tmv = thermomineral water
- tv = thermal water (t > 20 °C)
- fe = ferrous water (Fe^{2+} > 10 mgL^{-1})
- s = sulphureous water (H_2S > 1 mgL^{-1})
- r = radioactive water
- p = peloid

**Bizovac Spa (Bizovacke toplice)**
In the rich plains of Slavonia, eastern Croatia, you can find springs of the long lost Panonian Sea. The story of the medicinal thermo-mineral springs starts in 1967. It is the only hyper-thermal salt well in Europe with multiple therapeutic functions. Water springs from the depth of almost 2000 meters is exceptionally rich in minerals, warmer than any other known thermal water. Water temperature on the spring reaches almost 96 °C and salinity is 25 ‰. (B/tmv/fe)

**Istrian Spa (Istarske toplice)**
Istarske toplice are located in the central part of northern Istria peninsula, near town of Motovun. The base of the 85 m high rock is source of thermal sulphur and radioactive springs. The written documentation about the therapeutic value of these springs can be found in documents in the XVII century. The characteristic of the spa are that the water is radioactive, with high degree of sulphur, temperature around 35 °C. The peloid (in Istrian spa called fango), used in therapeutic treatment is a sulphurous, radioactive clay lime rich with organic and inorganic compounds. (B/tmv/s/r/p)

**Krapina Spa (Krapinske toplice)**
The famous health resort is located in Hrvatsko Zagorje at 160 m above the sea level. Krapinske toplice have centuries old tradition in medical treatment and rehabilitation. Its four thermal springs are rich with calcium, magnesium, and hydrocarbonate. The temperature of the water is around 40 °C. (B/tv)

**Stubica Spa (Stubicke toplice)**
Under the northern slopes of Medvednica Mountain is set the town of Stubicke toplice, in the vicinity of the capital Zagreb. The thermal springs were well known already in Roman times, and the first written document marking their therapeutic value dates from 1209. The contemporary health resort originates from 1811, when was build a spa with an indoor pool. The thermal water comes from the deep layers originating from Mesozoic. The temperature by the spring is 69 °C, and water has optimal mineral composition. Therefore, it is healthy to drink and not only to swim in it. (B/tv/r)

**Tuhelj Spa (Tuheljske toplice)**
In the valley surrounded by woody hillocks, at 160 m above sea level, in northwest part of Croatia is located Tuheljske toplice. Thermal springs of therapeutic water of 33 °C, rich in sulphur, fill indoor and outdoor pools. Widely known therapeutic peloid is used in medial treatment of different types illnesses. (B/tv/s/p)

**Varazdin Spa (Varazdinske toplice)**
In the vicinity of Varazdin, at 230 m above sea level, in northwest part of Croatia is located Varazdinske toplice. Therapeutic thermal springs have been exploited since the ancient times. The contemporary health resort originates from 1871, when was build a spa. The rich springs producing thermal water (57 °C) abundant with sulphur, together with therapeutic peloid, led to the development of medical tourism. (B/tmv/s/p)
3. **Results and Discussion**

The following results were obtained from the WL measurements performed at six spas. On each location three separate WL measurements were made, and arithmetical mean was taken for further evaluation. Calculations have been made on the basis of 170 working hours per month, and the results of WLM are presented at Table 1.

<table>
<thead>
<tr>
<th>Location</th>
<th>WLM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bizovac Spa</td>
<td>0.79</td>
</tr>
<tr>
<td>Istrian Spa</td>
<td>8.46</td>
</tr>
<tr>
<td>Krapina Spa</td>
<td>1.12</td>
</tr>
<tr>
<td>Stubica Spa</td>
<td>3.40</td>
</tr>
<tr>
<td>Tuhelj Spa</td>
<td>1.70</td>
</tr>
<tr>
<td>Varazdin Spa</td>
<td>0.34</td>
</tr>
</tbody>
</table>

The highest values of WL, and therefore of WLM, were measured in Istrian Spa. These measurements were performed directly one meter above the spring, but the workers spend there very short period of time.

The legislation presently valid in the Republic of Croatia is based on the IAEA recommendation. The latest guideline for occupational exposure to radon progeny as recommended by the IAEA is 4 WLM per year averaged over five consecutive years, or 10 WLM in any single year [2].

4. **Conclusion**

According to the obtained results, even the highest WLM value (with exception of measuring place in Istrian Spa), is lower than the permissible occupational exposure to radon decay products and poses no risk to any worker. One can conclude that the doses resulting from the short-term and temporary exposures to radon progeny from waters used in spas are no subject to the dose limits.

There is a need for constant control of radioactivity, especially at the places where the workers are occupationally exposed. The staff in the spas should be regularly monitored because of their continuous exposure to enhanced radiation over a long period of time.

5. **References**


Acknowledgement

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