Preliminary Study of Natural Radioactivity in Underground Waters in the Silesia Voivodeship

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Abstract

Studies of natural radioactivity in drinking water from free water intakes in the Silesia Voivodeship were performed. Activity concentrations of radon $^{222}$Rn, radium isotopes $^{226,228}$Ra and uranium isotopes $^{234,238}$U were determined using different nuclear spectrometry techniques in water samples from six selected localities. The highest annual effective dose arising from radon inhalation was obtained for the Psary-Prodlo intake and was estimated at 0.9 mSv/year. The highest summed effective dose (for radium and uranium isotopes) was obtained for Psary-2 intake and was estimated at 2.7 μSv/year.

Keywords: Radon, Radium, Uranium, Drinking Water, Effective Dose

Introduction

Due to the high prices of public supply water and, at some areas, inadequate water quality, inhabitants from regions outside big cities in the Silesia Voivodeship take advantage of free access intakes to water which seems to be pure and clean. They use this water for daily consumption. Epidemiology services were informed about this procedure and some of these waters were bacteriologically examined. Information about the usability of water was placed next to the intakes. In all examined cases the results were negative and water consumption forbidden, however the official ban was completely ignored. None of these waters have ever been investigated for their radioactivity content. The Silesia Voivodeship situated in the Upper Silesia Coal Basin is a region with mixed geological structure. This not only concerns the deep underground layers but also the younger Carboniferous period which covers older sediments. Coal mining and mining industry have induced changes in geological structure, especially by creating faults and fissures through which water of different origin may flow in. Groundwater reacts with surrounding rocks and releases elements which can be dissolved in it. Since the investigated water does not belong to the Upper Silesian Water Public Supplier it is not routinely examined by legal services, nor is its origin well known. The investigated water may also be subsoil water, exposed additionally to impurities and pollution, or underground water.

The goal of this study was to determine the activity concentration of radon $^{222}$Rn, radium isotopes $^{226,228}$Ra and uranium isotopes $^{234,238}$U in water using different nuclear spectrometry techniques. Investigations were performed in the region of five different towns in the Silesia Voivodeship: Psary, Malinowice, Dąbie, Rogoźnik and Twardowice. The geological structure of the investigated area is formed mainly of sedimentary rocks such as sandstone, mudstone, hard coal, marls or limestone and dolomite. Underground water at Dąbie, Malinowice and Psary is available from a bore hole, while water at Rogoźnik and Twardowice comes from a natural spring.
Experimental procedures

The measurements of radon and radium activity concentrations were performed with the use of the 1414 WinSpectral α/β liquid scintillation counter from Wallac. This detector is equipped with a pulse-shape analyzer (PSA) which separates pulses coming from alpha and beta radionuclides into different spectra. Radon activity concentrations were determined according to the procedure developed by J. Suomela [1]. A sample of 10 ml of water was drawn by a disposable syringe and transferred to a scintillation vial filled with 10 ml scintillation cocktail Insta-Fluor from Packard. The procedure for chemical treatment of samples for the determination of radium was based on radiochemical preconcentration by coprecipitation with BaSO₄ and purification of its derivatives [2]. The Lower Limit of Detection (LLD) was calculated with the use of Currie’s method [3] and was equal to 1 Bq/l for radon and 0.01 Bq/l for ²²⁶Ra and 0.03 Bq/l for ²²⁸Ra at 3600 s counting time.

The determination of uranium was performed with the use of the alpha spectrometer 7401VR from Canberra – Packard, USA and the silicon surface barrier detector with a surface area of 300 mm² (Ortec Instruments). The chemical separation of uranium from other radionuclides was based on a slightly modified procedure published by J. Suomela [4] and the alpha – spectrometry source was prepared from the uranium fraction by coprecipitation with NdF₃ [5]. The efficiency of the detector was 34% and LLD was 0.5 mBq for 48h counting time. Chemical recoveries were typically 70-80%.

Results

The results of the measured activity concentrations of ²²²Rn, ²²⁶,²²⁸Ra and ²³⁴,²³⁸U isotopes in underground water are presented in Table 1. The activity concentrations for radon vary from 12 to 63 Bq/l, for ²²⁶Ra are below or equal to 0.01 Bq/l and for uranium isotopes vary from 2.1 mBq/l to 22.3 mBq/l and from 1.8 Bq/l to 14.4 mBq/l for ²³⁴U and ²³⁸U, respectively. Four out of six water samples showed activity concentration below LLD for ²²⁶Ra and all for ²²⁸Ra. The total effective radiation dose was calculated for a statistical adult who uses 2 l of water for consumption per day (Table 1). Dose conversion factors used for the calculations were taken from a WHO publication [6] and were equal to 2.8·10⁻⁷Sv/Bq, 4.9·10⁻⁸Sv/Bq and 4.5·10⁻⁸Sv/Bq for ²²⁶Ra, ²³⁴U and ²³⁸U, respectively.

It is difficult to quantify the actual dose caused by inhalation of radon during water processing, for example boiling. However, using the method published by Barnett et. al. [7] the annual effective dose from radon inhalation was also estimated (Table 1).

Discussion of results

According to the regulation of the Polish Ministry of Health about requirements concerning the quality of drinking water [8], the total annual effective dose from all radionuclides except for tritium should not exceed the value of 100 μSv. The highest value of the summed effective dose (without radon) equal to 2.7 μSv/year was obtained for water sample from Psary-2. This value is still much below the limit. This indicates that the contribution to the annual effective dose arising from the consumption of water from selected free intakes is low.

The effective dose from the inhalation of radon varies between 0.2 to 0.9 mSv/year but it should be emphasized that this dose is only an estimate.

Table 1. Activity concentration in [Bq/l] of ²²²Rn, ²²⁶,²²⁸Ra, ²³⁴,²³⁸U in drinking water from free water intakes and respective annual effective doses for inhabitants

<table>
<thead>
<tr>
<th>Intake</th>
<th>²²²Rn [Bq/l]</th>
<th>Effective dose from ²²²Rn inhalation [mSv/year]</th>
<th>²²⁶Ra [Bq/l]</th>
<th>Effective dose from ²²⁶Ra [µSv/year]</th>
<th>²³⁴U [mBq/l]</th>
<th>Effective dose from ²³⁴U [µSv/year]</th>
<th>²³⁸U [mBq/l]</th>
<th>Effective dose from ²³⁸U [µSv/year]</th>
<th>Summed Effective dose (without ²²²Rn) [µSv/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Psary-Prodlo</td>
<td>63 ± 3</td>
<td>0.9</td>
<td>&lt;0.01</td>
<td>-</td>
<td>4.1 ± 0.5</td>
<td>0.15</td>
<td>1.9 ± 0.3</td>
<td>-</td>
<td>0.06</td>
</tr>
<tr>
<td>Psary-2</td>
<td>21 ± 1</td>
<td>0.3</td>
<td>0.01 ± 0.001</td>
<td>2.0</td>
<td>12.6 ± 1.1</td>
<td>0.45</td>
<td>5.8 ± 0.6</td>
<td>-</td>
<td>0.19</td>
</tr>
<tr>
<td>Malinowice</td>
<td>31 ± 2</td>
<td>0.5</td>
<td>&lt;0.01</td>
<td>-</td>
<td>2.1 ± 0.4</td>
<td>0.07</td>
<td>1.8 ± 0.3</td>
<td>-</td>
<td>0.06</td>
</tr>
<tr>
<td>Dąbie</td>
<td>20 ± 2</td>
<td>0.3</td>
<td>0.01 ± 0.001</td>
<td>1.4</td>
<td>21.2 ± 1.7</td>
<td>0.76</td>
<td>14.4 ± 1.2</td>
<td>-</td>
<td>0.47</td>
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<tr>
<td>Twardowice</td>
<td>37 ± 3</td>
<td>0.5</td>
<td>&lt;0.01</td>
<td>-</td>
<td>18.9 ± 2.0</td>
<td>0.67</td>
<td>12.1 ± 1.4</td>
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<td>0.40</td>
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<tr>
<td>Rogoźnik</td>
<td>12 ± 1</td>
<td>0.2</td>
<td>&lt;0.01</td>
<td>-</td>
<td>22.3 ± 1.9</td>
<td>0.80</td>
<td>12.6 ± 1.2</td>
<td>-</td>
<td>0.42</td>
</tr>
</tbody>
</table>

References