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Radon in Icelandic Cold Groundwater and Low-Temperature Geothermal Water

Finnbogi Óskarsson[a,1], Ragnheiður St. Ásgeirsdóttir[a]

[a]Iceland GeoSurvey (ISOR), Grensasvegur 9, IS-108 Reykjavik, Iceland

Abstract

Samples of hot and cold water for radon analysis were collected from boreholes and springs in Iceland in 2014 and 2015. The majority of the samples was collected from municipal district heating services or potable water utilities. The total number of samples was 142, covering most towns and villages in Iceland. Radon activity is generally rather low, in most cases less than 5 Bq/L. Only 12 samples had a measured radon activity higher than 5 Bq/L, with a maximum activity of 10.8 Bq/L. The hot water samples generally have a higher radon activity than cold water samples, but samples from boiling borholes have a lower radon activity as radon fractionates into the vapour phase. The geographical distribution of the samples indicates that radon activity is generally lower within the active rift zones. This is most likely due to the very low uranium content of the tholeiites typically erupted within the rift zones. Higher radon values (> 5 Bq/L) are in most cases close to extinct central volcanoes and thus it seems plausible that the water sampled has been in contact with felsic rocks.

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Keywords: Radon; groundwater; low-temperature water; geothermal.

1. Introduction

Radon (Rn) is a radioactive gas that is formed by radioactive decay of radium (Ra). Both elements are parts of the natural decay chains of uranium (U) and thorium (Th), which ultimately lead to the formation of various isotopes of lead (Pb). Out of the 39 known isotopes of radon, only four have half-lives longer than 1 hour. The most stable radon isotope is ^{222}Rn which has a half-life of 3.82 days. Radon is primarily formed in the earth's crust, and is partly carried to the surface either as a gas or dissolved in water.

* Corresponding author. Tel.: +354 528 1500.
E-mail address: finnbogi.oskarsson@isor.is

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As the concentrations of uranium and thorium are known to be low in the young primarily basaltic Icelandic bedrock, radon has not been considered a major health concern and therefore no systematic survey of radon in water has been performed in Iceland. However, in 2012 and 2013 the Icelandic Radiation Protection Agency conducted a survey of radon in residential air[1]. Their results showed low concentrations, with an annual average value of 13 Bq/m^3 but slightly higher in Northern Iceland; 20 Bq/m^3 on average.

Other previous studies of radon in Icelandic water have mainly been focused on its use as an earthquake precursor. As reported by[2] on the monitoring of radon concentrations in seven low-temperature wells in the South Iceland Seismic Zone and two low-temperature wells in the Tjörnes Fracture Zone, both of which are considered regions of high seismic risk. As reported by[3] on the continued monitoring of the same seven wells in South Iceland, from 1977 to 1993. Several authors[4] correlated changes in radon activity in some of the same wells in South Iceland with two large earthquakes in June 2000.

In 2014 and 2015 Iceland GeoSurvey conducted a survey of radon in cold groundwater and low-temperature geothermal water in Iceland. This work was performed for the Centre of Public Health Sciences at the University of Iceland, where researchers were interested in estimating the radon exposure from potable water and district heating services. For this purpose, 142 samples of hot and cold water were collected and the activity of radon of the samples determined. The sampling campaign was focused on low-temperature water which is used by district heating services and potable water which is used by municipalities but to increase the coverage of the survey, samples were also collected from thermal and groundwater boreholes and springs which serve no or very few consumers.

2. Methods

Water samples were collected into clean, air-tight 250 mL screw-cap glass bottles which were rinsed three times with the sample before collection. The samples were run to the bottom of the bottle using a silicone rubber hose and the bottle filled from the bottom up to prevent aeration of the sample. Moreover, at least 250 mL of water were allowed to flow out of the bottle before the hose was removed and the cap tightened. Borehole samples were in most cases collected directly at the wellhead, but some samples were collected from the water pipeline from the well. Spring samples were collected from a depth of about 10 cm (wherever possible) using a peristaltic pump. Samples hotter than 30°C were collected through a stainless steel cooling coil and cooled that way to less than 30°C in order to prevent bubble formation upon cooling. Samples of hot water were generally collected in duplicate.

The samples were analysed within 24 hours of collection using a Durridge RAD7 electronic radon detector with the H_2O RAD accessory for analysis of radon in water. During the analysis, air was bubbled through the water sample in a closed loop in order to release the dissolved gas from the sample, followed by α-decay counting for 4 consecutive periods of 20 minutes each. Therefore, the values reported are the averages of 8 or 4 measurements, depending on whether samples were collected in duplicate or not. The relative standard deviation is on average about 30%, and obviously highest for the samples with lowest radon activity. Two RAD7 instruments were employed and duplicate samples were analysed using both instruments in order to detect any systematic error or bias. The values reported from the two instruments were usually within 5% of each other with no detectable bias.

3. Results

The total number of samples collected for this survey was 142; 75 samples of hot (>30°C) water and 67 samples of cold water. The sample temperatures ranged from 1.7 to 145°C. The radon activity results are reported as bequerel per litre of sample (Bq/L), i.e. dissociations per second and litre. The results are presented in Figure 1, where the blue dots denote cold water samples with radon activities ranging from <1 Bq/L (lightest blue) to >10 Bq/L (darkest blue), and the yellow and red dots denote hot water samples likewise ranging from <1 Bq/L (yellow) to >10 Bq/L (dark red).

The highest radon activity measured was 10.8 Bq/L in a hot water well in Drangsnes, NW-Iceland, but two other samples had activities higher than 10 Bq/L; samples from a hot water well in Hrafnagil, N-Iceland (10.1 Bq/L), and a cold water spring in Svínadalur, W-Iceland (10.6 Bq/L).