Indoor and outdoor radon levels in Iceland

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Abstract

We report on a nation-wide survey of indoor radon (Rn-222) in Icelandic homes. The annual mean radon concentration was measured on the ground floor or basement of 250 homes around the island with etch track detectors. Volunteers were sought so the measurement locations were not randomly assigned. Additionally, measurements were made in 32 kindergartens and 19 public swimming pools.

The results show that the radon concentration in Iceland is very low. The mean is 13 Bq/m^3, and the median 9 Bq/m^3. The distribution of the results is heavily biased towards the lower values with a number of the results at or below the minimum detectable activity, 95% of the results below 40 Bq/m^3 and the highest value is 79 Bq/m^3. No appreciable differences were found between the different regions of Iceland except that in the North of the country, slightly higher values were found. Measurements in kindergartens and swimming pools gave even lower values.

These results, which match expectations given what is known about the Icelandic bedrock and from previous spot measurements, imply a mean dose to the population from radon inhalation around 0,2 mSv/year[1]. This value is almost certainly an overestimate, since only ground floors and basements are included in the study.

We have ongoing continuous measurements of radon in outdoor air in Reykjavík by a liquid scintillation system, done in collaboration with the University of Iceland‘s Science Institute. The measurement system is called Autoradon and results from a few months of measuring show that outdoor air in Reykjavík has a radon concentration of about 1-5 Bq/m^3. Simultaneous, continuous measurements of indoor radon in a university building show little or no variation in daily or weekly radon concentration.

Introduction

The bedrock in Iceland is predominantly made of basalt with low levels of uranium. Therefore one should expect low concentrations of radon in air. Measurements of radon in Iceland have mostly been done in the context of geological/geophysical research, for example in an attempt to predict earthquakes. No large surveys have been done previously on indoor radon levels in Iceland but two earlier studies are noteworthy.

The Icelandic and Danish radiation protection institutes made joint measurements in 18 basements around Iceland in 1982 [2]. The results showed low radon levels, 11 Bq/m^3 in Reykjavik (average from 10 measurements), the highest value was 26 Bq/m^3, and many of the measurements where around or under the detection limit.

In 2003 a study was made on a method of radon measurements with liquid scintillator vials [3]. 51 houses in the capital area were measured during the summer. The sample locations were not standardized as the study focused on the measurement method rather than the indoor radon levels. This method measures the average radon level of the previous 12 hours. The results showed again low radon levels, with a mean of 4,7 Bq/m^3 and median 2,8 Bq/m^3.

Because of these results of earlier studies, and the composition of the Icelandic bedrock, radon has not been considered a general health risk in Iceland.

In 2011, IRSA joined in the European Commission's (EC) European Indoor Radon Map (EIRM) project coordinated by the EC's Joint Research Centre (JRC), so in 2012 - 2013 a nationwide survey on indoor radon concertation was conducted [1].

Methods

Sampling period

IRSA acquired 500 etch track detectors from Radosys in Hungary (PADC/CR-39 detecor chip). These detectors are usually exposed for 3 - 6 months sampling periods with a lower limit of detection (LLD) at about 15-30 Bq/m^3.The LLD is approximately inversely related to exposure time, but longer exposure time can cause increased uncertainty due to the plastic hardening. At the request of IRSA, Radosys investigated the detector response curve for a 12 month exposure to a low level radon concentration. With the resulting correction factor, IRSA was assured that the uncertainty would be under 15% for a 12 month exposure at a reference concentration of 150 Bq/m^3, but due to the increased sample period a LLD of approximately 7 Bq/m^3 was achieved.

Sampling locations

Volunteers were sought passively through a website and actively by phone, where needed. Attempt were made to distribute sample points as broadly as possible while tracing the population density, but the sampling location were not random. In all, detectors were sent to 278 homes (of which 250 were retrieved) across the country. Measurements were also made at two kind of work places: kindergartens and public swimming pools. The kindergartens were selected due to being most often in a single-floor in building and with high occupancy. Swimming pools where of interest because of the large volume of water (in some places geothermal water) used. Detectors were sent to 31 kindergartens and 30 swimming pools (31 and 19 respectively were retrieved).A map of all the sampling locations is in Figure 1.

Volunteer instructions

Participants were instructed to place the detectors on the building's lowest floor and in an inhabited room (preferably a bedroom). In 2012 there were around 129.000 homes in Iceland [4], so the survey included 0,2% of all homes. The detectors were sent to volunteers over a 3 month period and collected about year later so the sampling time was around 9-13 months. The detectors were then sent back to the manufacturer for reading, in a vacuum sealed plastic package (to prevent a radon contamination during the travel from Iceland). Half of the measurements were in the capital area (49%) but most of the populated areas in Iceland were covered (Figure 1).

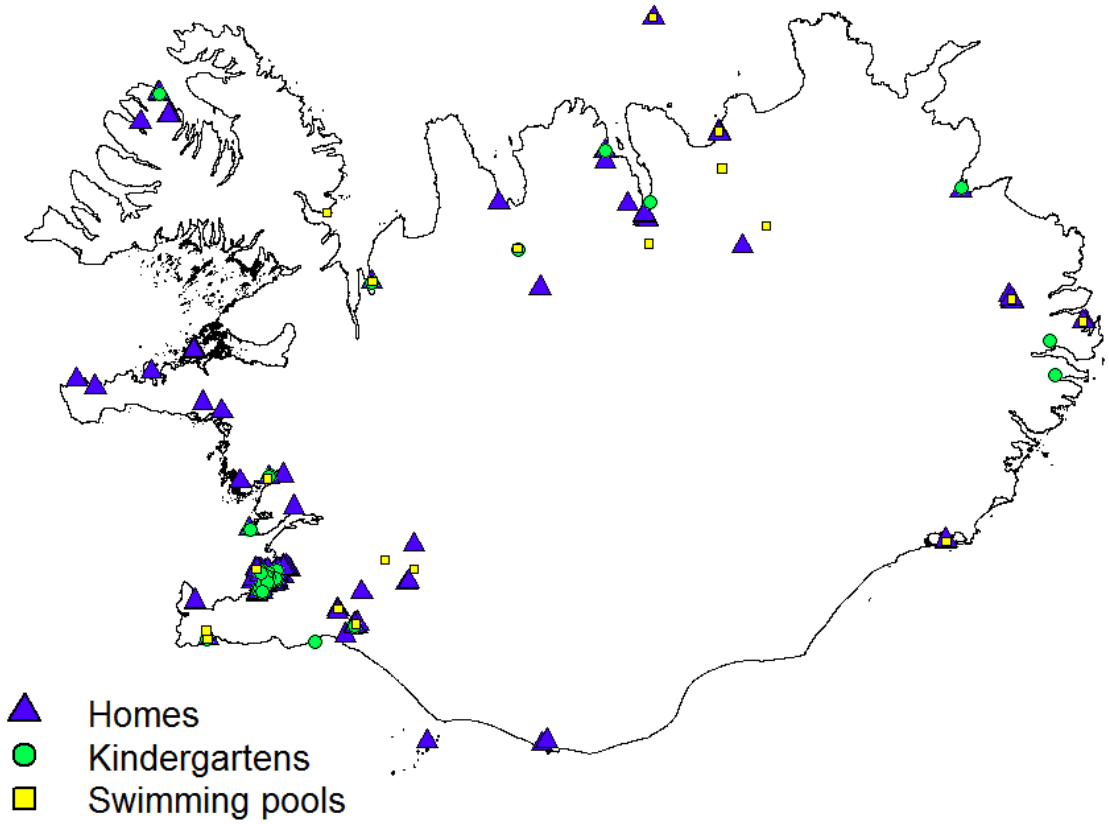

Figure 1. Distribution of etch track detectors around Iceland.

Continuous measurements

In collaboration with the Science Institute of University of Iceland, IRSA made continuous radon measurements in a basement in a university building (Raunvísindastofnun) and on outdoor air. The measurement system used is called Autoradon. It has 15 ml liquid scintillator fluid continuously pumped with the sampled air. The system is inside a 5 cm lead shield and the measurements are done with 214-Po counting [5]. The background is 6 counts/24 hour which is equivalent to a mean concentration of 0,4 Bq/m^3 over 24 hours. The LLD of the system is 0,9 Bq/m^3 for 24 hour measurements. Two system were running simultaneously, one measuring indoor radon level in the basement and the other measuring the nearby outdoor radon levels at 1 meter height. The building is nearby the coast. The Autoradon system automatically records a measurements once every hour so it could capture diurnal variation, but the radon concentration results were averaged over whole days (24 hours).

Results

Etch track detectors

As suspected, radon levels in Iceland are found to be very low by each measurement. From the etch track detectors in homes, the mean radon levels is 13 Bq/m^3 and the median 9 Bq/m^3. Only 5 % of the results are over 40 Bq/m^3 and the highest measurement was 79 Bq/m^3. Many of the etch track detector results are at or around the detection limit so the mean and the median reported here are likely overestimates. Distributions of measurements is shown in Figure 2.

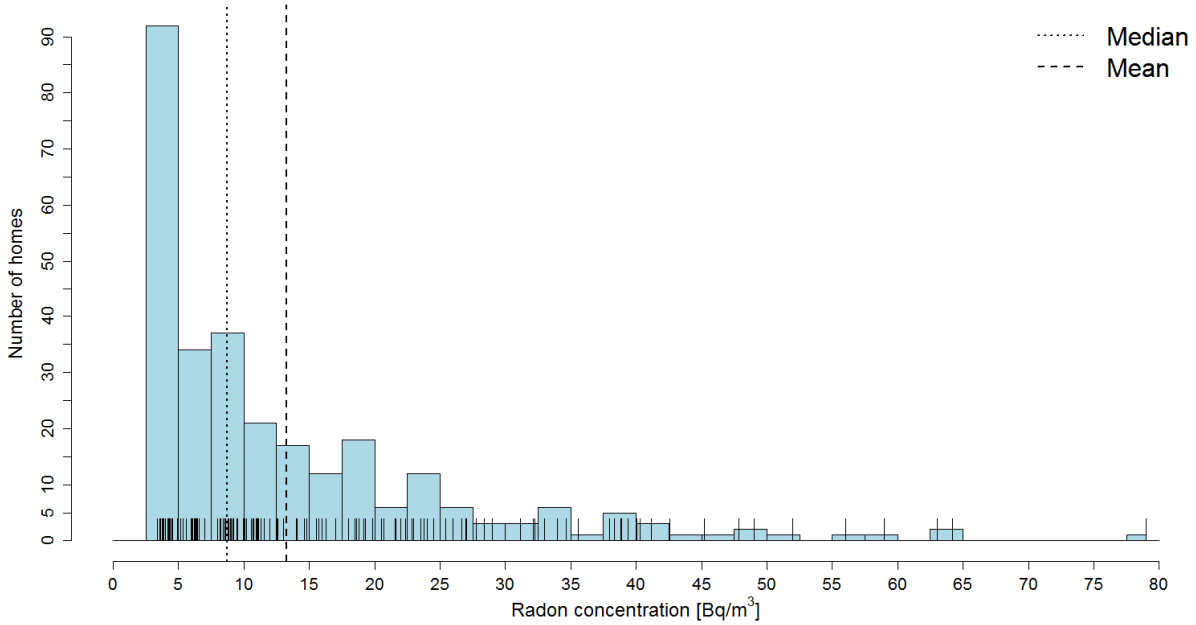

Figure 2. A histogram of radon concentration in 250 Icelandic homes. The short lines at the x-axis represent individual measurements.

The measurements in kindergartens and swimming pools gave even lower results, perhaps due to better air-conditioning. For kindergarten the mean radon levels is 11 Bq/m^3 and the median 6 Bq/m^3 and for public swimming pools the mean radon levels is 6 Bq/m^3 and the median 5 Bq/m^3. Comparison between these measurements can be seen in Figure 3.

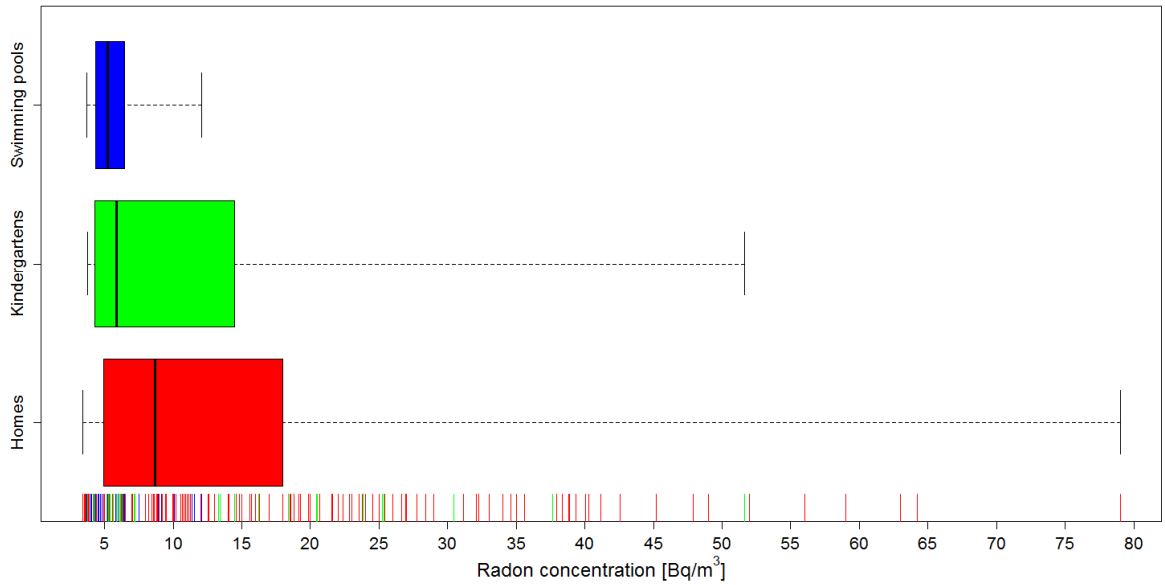

Figure 3. A box plot with whiskers of the radon concentration results divided into location type: homes (Red), kindergartens (green), swimming pools (blue). The short lines at the x-axis represent individual measurements.

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Comparison between different parts of the country (Figure 4) shows similarly low levels. Slightly higher radon levels are seen in the northern part of Iceland but the variability between different parts of the country is much lower than variability of the measurements within each part.

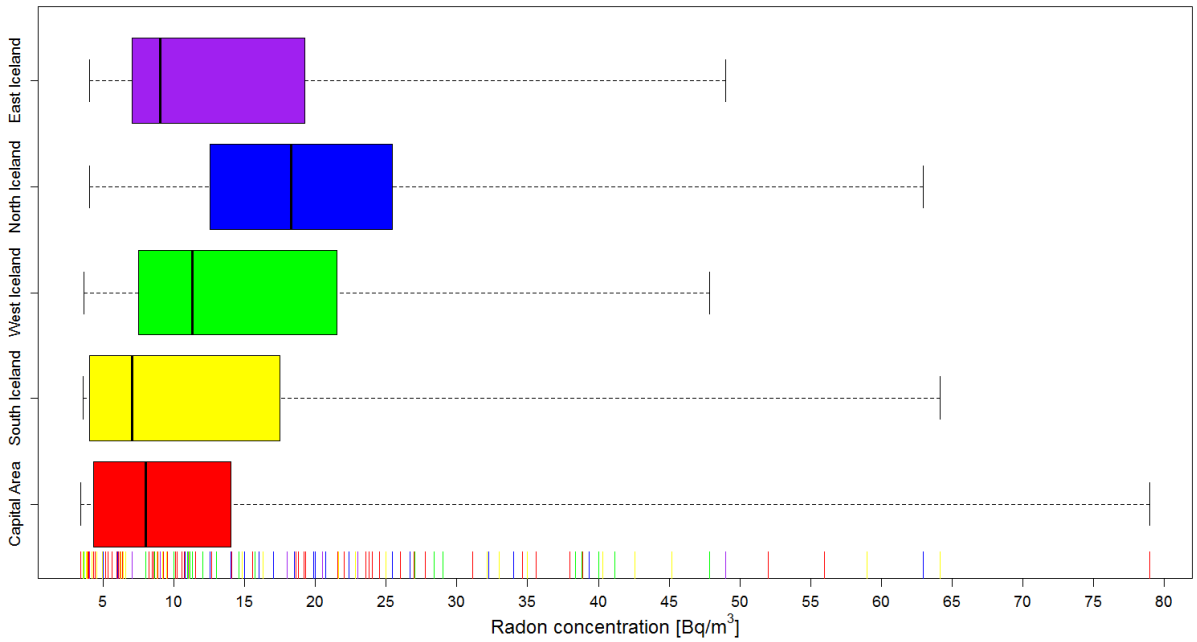

Figure 4. A box plot with whiskers showing the radon concentration, by region: Capital area (red), South (yellow), West (green), North (blue), East (purple). Horizontal lines in the boxes represent the median values. The short lines at the x-axis represen individual measurements.

Autoradon measurements

The radon levels measured by the Autoradon system are very low as expected. From early May to mid-July 2015 the average concentration is 1,6 Bq/m^3 for outdoor air and 3,6 Bq/m^3 for indoor air. Some of the outdoor measurements are close or below the LLD. The difference between the indoor and outdoor measurement is small (see Figure 5). This probably results from generally low levels in both indoor and outdoor air and from good air-conditioning of the University building.

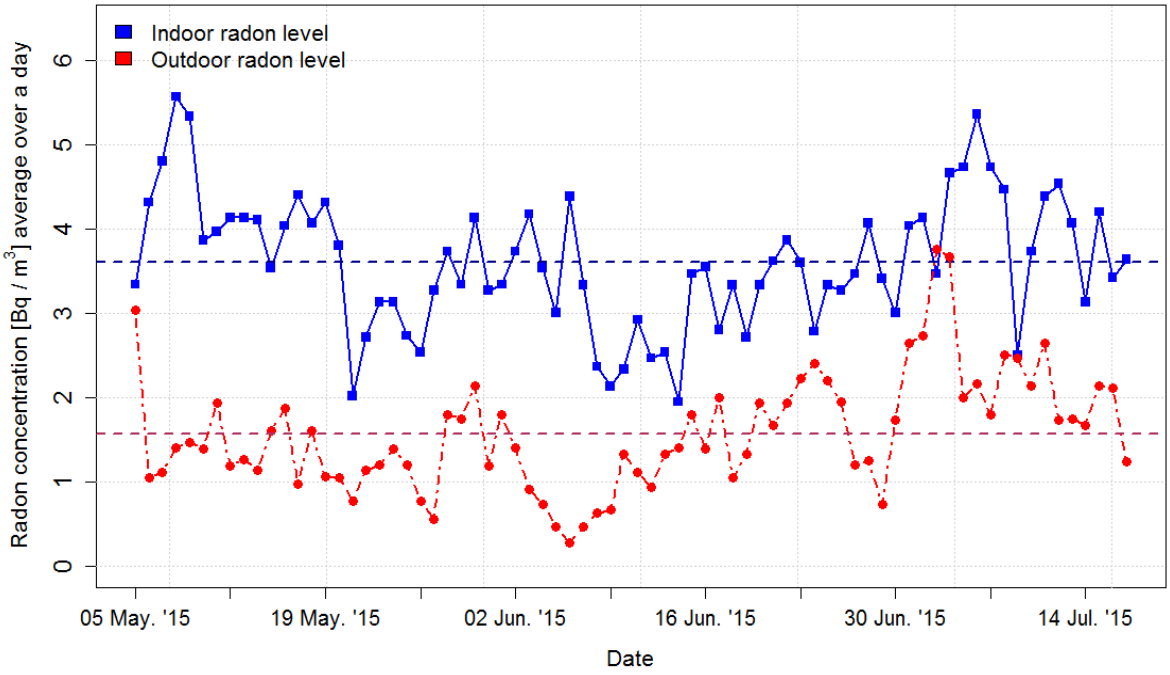

Figure 5. Results from the Autoradon system. Indoor air is from a basement lab at the Science institute. Daily average of radon concentration is plotted against the date. The dotted lines shows the average over the time period.

The Autoradon system that measures the indoor air was moved to a very small storage room under the stairway in the same building. It is used for storing cleaning supplies and poorly ventilated. In this room higher radon concentration was measured, up to 35 Bq/m^3. We did not see any noticeable variation within the day or week in the data from May to July and the data series is not long enough to show any seasonal variation.

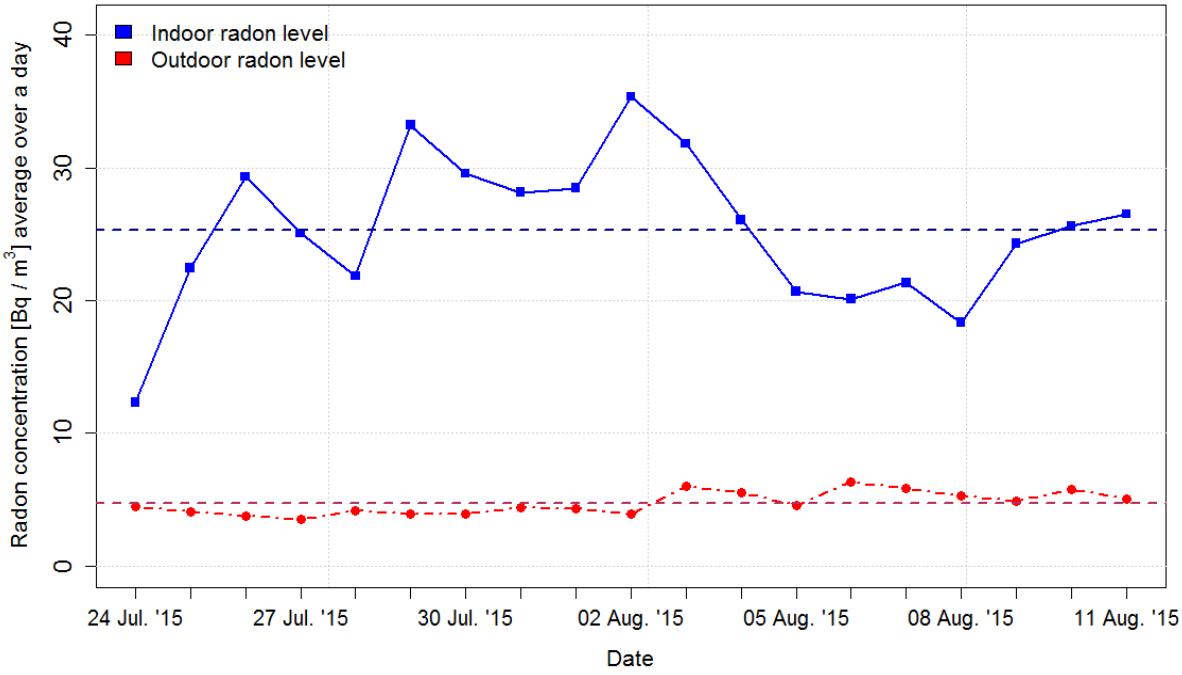

Figure 6. Results from the Autoradon system. Indoor air is from a small storage room (not ventilated) in the basement at the Science institute. Daily average of radon concentration is plotted against the date. The dotted lines shows the average over the time period

Conclusion

As expected, the radon concentrations are very low in Iceland, as both the etch track detectors and the Autoradon system showed. Indoor levels of radon in countries worldwide can range from 10 Bq/m^3 to more than 100 Bq/m^3 [6], so Iceland is among the countries that have the lowest radon concentrations. It should be noted that our measurements only consist of measurement of 1st floor and basement, also that many of the results were around the detection limit.
Based on the results from the etch detectors, the dose to the Icelandic population from radon inhalation has been estimated to be 0,2 mSv/year. This is most likely an overestimation since many of the results from the etch track detectors are around or below the lower limit of detection. Nowhere did our measurements exceed reference levels of radon that our neighboring countries have (from 100-300 Bq/m^3), not even in a small non ventilated supply room in the basement of the University of Iceland.
Outdoor radon levels in Iceland are low as one would expect for an island with a bedrock with low radioactivity. The measuring place for the outdoor air is probably affected by its closeness to the sea. One might suspect a little higher radon levels measured farther away from the coast.
We can conclude that radon is not a health concern in Icelandic homes.

References

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