LARGE DECREASE OF RADON CONCENTRATIONS IN NEW-BUILT SWEDISH DWELLINGS

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Abstract

From the analysis of about 100,000 radon measurements in Swedish dwellings stored in the database of Radonova, it has been found that the number of dwellings above the Swedish reference level of 200 Bq/m^3 (5.4 pCi/l) has decreased a lot for new buildings. Only 2% of the single-family houses built during 2014-2016 had radon concentration above the reference level whereas about 30% of the houses built during 1950-1980 had radon levels exceeding the reference level. The data show the importance of good building practice. The development in building technique which can have influenced this improvement will be discussed. Similar data will also be presented for multi-family houses as well as data showing how the radon levels in houses built around 2005 have changed from measurement at that time until now.

Introduction

An efficient way to reduce radon exposures in dwellings is to build new houses so that high radon levels are prevented. Radonova has a large radon database with results from several hundred thousand measurements in Swedish dwellings. Through evaluation of these data, conclusions can be made how the radon concentrations depend on building year as well as building parameters such as foundation and ventilation types.

Between 1929 and 1975, a light-weight concrete based on alum shale, called “blue concrete”, was used in many Swedish building. This building material contain elevated levels of radium and can give a significant contribution to the radon concentrations. In the analysis of the data from this period, it will be considered if this material is used or not.

Between 1960 and 1980, there was a large peak in the number of new-built dwellings in Sweden of which many houses were built with the radon-emitting “blue concrete”.

Methodology

Measurement data was mainly extracted from measurement analyzed by Radonova during 2015-01-01 until 2017-12-31 except for building years between 1950 and 1980 where data were taken from measurements during 2015-07-01 until 2016-12-31 due to the large number of measurements from this building period. The measurements have been made as long-term measurements using alpha-track detectors.

The data was analyzed to see if any differences in radon concentrations could be observed for different foundation and ventilation types. How frequent different foundation and ventilation types were used at different building periods has also been analyzed. The information about

the building has been given by the customers of Radonova which for the single-family houses are the house owners.
Data are compared against the Swedish reference level of 200 Bq/m^3 (5.4 pCi/l).

Results

As can be seen in Table 1, the fraction of single-family dwellings with radon concentration above the reference level decreased from 27% for houses built 1950-1980 (houses with no "blue concrete") down to 2 % for houses built 2014-2016. For multi-family houses the corresponding decrease was from 10 % down to 0.3 % (Table 2). In both single-family and multi-family dwellings, the "blue concrete" building material give an extra average radon contribution of about 2.5 pCi/l. High radon levels, more than 10 times the reference level, are found independent on the building year.

Building year	**Number of measurements**	**Average radon concentration (pCi/l)**	**Highest value (pCi/l)**	**Above 5.4 pCi/l**
1950-1980 (all)	7495	5.0	116	33 %
1950-1980 (blue concrete)	1886	6.8	90	53 %
1950-1980 (no blue concrete)	2519	4.4	110	27 %
1980-2000	8099	2.4	123	11 %
2000-2010	1434	1.7	52	6.1 %
2014-2016	2255	1.1	165	2.0 %

Table (1): Radon concentrations in single-family houses

Building year	**Number of measurements**	**Average radon concentration (pCi/l)**	**Highest value (pCi/l)**	**Above 5.4 pCi/l**
1950-1980 (all)	10080	3.4	124	20 %
1950-1980 (blue concrete)	2824	5.2	48	38 %
1950-1980 (no blue concrete)	1567	2.5	124	10 %
1980-2000	8691	1.4	56	5.1 %
2000-2010	3170	1.3	38	3.9 %
2014-2016	3942	0.8	41	0.3 %

Table (2): Radon concentrations in multi-family houses

One question on the conclusions drawn above could be if the radon concentrations were dependent on the time from the year built to the measurement made or if the differences observed were mainly related to the year built independent when the measurement was performed. To investigate this, data from building years between 2002 and 2004 were evaluated with regard on the measurement year. Table 3 and Table 4 the results of radon concentrations at different years of measurement in the single-family and multi-family house, respectively. We have performed a non-parametric statistical test to find out whether the average radon concentration depends on the year when the measurement was performed. The

result of the Kruskal-Wallis test reveals that there is no statistical difference among average radon concentrations for various years (p-value = 0.4159).

Measurement year	Number of measurements	Average radon concentration (pCi/l)	Highest value (pCi/l)	Above 5.4 pCi/l
2005-2006	988	1.9	136	6.6 %
2007-2008	967	1.9	106	5.7 %
2009-2010	551	2.1	43	8.5 %
2011-2012	240	2.3	46	10.4 %
2013-2014	227	1.8	18	9.7 %
2015-2016	154	2.0	52	6.5 %

Table (3): Radon concentrations in single-family houses built 2002-2004

Measurement year	Number of measurements	Average radon concentration (pCi/l)	Highest value (pCi/l)	Above 5.4 pCi/l
2005-2006	498	1.7	14	5.6 %
2007-2008	342	1.2	11	1.8 %
2009-2010	775	1.4	22	4.3 %
2011-2012	340	1.2	11	2.9 %
2013-2014	477	1.6	18	5.6 %
2015-2016	502	1.3	18	3.8 %

Table (4): Radon concentrations in multi-family houses built 2002-2004

To get a better understanding of the observed decrease in radon concentrations in new-built houses, data were evaluated against foundation and ventilation types. Only measurements from buildings without “blue concrete” building material were included in this analysis. To get a more comparable analysis of the dependence of ventilation type, only measurements made in houses with slab on grade were included in that analysis.

The foundation dependent data for single-family houses (Table 5 and Table 6) show that from 1980, the radon concentrations in houses with crawl space or slab on grade had significantly lower radon concentrations compared with basement and split-level foundations. From 1980, the fraction of single-family houses built with basement was very small and slab on grade become the dominating foundation type. This change of chosen foundation type is probably one of the reasons to the decreased radon concentrations.

The ventilation dependent data for single-family houses (Table 7 and Table 8) show that from 1980, the radon concentrations in houses with mechanical ventilation had significantly lower radon concentrations compared with houses with natural ventilation. From 1980, the fraction of single-family houses with only natural ventilation was very small. The predominant use of mechanical ventilation is another reason to the decreased radon concentrations and seems to be of larger importance than the previously observed effects of foundation type.

Building year	Crawl space (pCi/l)	Basement (pCi/l)	Slab on grade (pCi/l)	Split level (pCi/l)
1950-1980	3.7	4.7	4.4	4.6
1980-2000	2.3	3.4	2.3	3.4
2000-2010	2.1	3.2	1.4	2.8
2014-2016	0.7	2.0	1.1	1.4

Table (5): Average radon concentrations in single-family houses with different foundation types.

Building year	Crawl space (%)	Basement (%)	Slab on grade (%)	Split level (%)
1950-1980	11	38	37	10
1980-2000	21	5	66	7
2000-2010	18	5	70	7
2014-2016	9	2	85	4

Table (6): Fraction of single-family houses with different foundation types.

Building year	Natural ventilation (pCi/l)	Mechanical exhaust (pCi/l)	Balanced mechanical ventilation (pCi/l)
1950-1980	4.5	4.4	5.1
1980-2000	4.2	2.4	2.0
2000-2010	2.1	1.3	1.1
2014-2016	3.7	1.0	0.9

Table (7): Average radon concentrations in single-family houses with different ventilation types for houses with slab on grade foundation type.

Building year	Natural ventilation (%)	Mechanical exhaust (%)	Balanced mechanical ventilation (%)
1950-1980	53	42	5
1980-2000	4	55	41
2000-2010	8	61	31
2014-2016	4	55	41

Table (8): Fraction of single-family houses with different ventilation types for houses with slab on grade foundation type.

In the evaluation of multi-family measurements with respect to foundation type, it is important to point out that the Swedish Measurement Protocol (Strålsäkerhetsmyndigheten, 2013) require that all apartments on the lowest level should be measured if the level has a direct ground contact which is the case for the slab on grade, crawl space and split level. In multi-family houses with basement, the requirement is that at least every fifth apartment on

the ground floor should be measured. Due to the measurement protocol, relatively more measurements are expected in multi-family houses with slab on grade compared to houses with basement and that a larger part of the measurements are made on the lowest floor. This may bias the results from houses with slab on grade towards slightly higher values compared with multi-family houses with basement (Table 9).

The foundation dependent data for multi-family houses (Table 9 and Table 10) show only small differences depending on the foundation type. However, the ventilation type dependent data (Table 11 and Table 12) show that houses with mechanical ventilation have lower radon concentrations compared to houses with only natural ventilation and that a balanced mechanical ventilation is preferable. The low fraction of multi-family houses with natural ventilation after year 2000 makes these natural ventilation data uncertain. The increased use of mechanical ventilation in multi-family houses and in particular balanced mechanical ventilation is probably an important reason to the decreased radon levels in multi-family houses.

Building year	**Crawl space (pCi/l)**	**Basement (pCi/l)**	**Slab on grade (pCi/l)**	**Split level (pCi/l)**
1950-1980	4.1	2.1	3.7	4.9
1980-2000	1.2	1.1	1.6	1.5
2000-2010	0.9	1.1	1.4	1.9
2014-2016	1.5	0.8	0.8	1.2

Table (9): Average radon concentrations in multi-family houses with different foundation types.

Building year	**Crawl space (%)**	**Basement (%)**	**Slab on grade (%)**	**Split level (%)**
1950-1980	1	68	30	2
1980-2000	6	26	62	7
2000-2010	4	24	62	5
2014-2016	1	43	53	2

Table (10): Fraction of multi-family houses with different foundation types.

Building year	**Natural ventilation (pCi/l)**	**Mechanical exhaust (pCi/l)**	**Balanced mechanical ventilation (pCi/l)**
1950-1980	3.1	2.4	1.6
1980-2000	2.6	1.7	0.9
2000-2010	1.2	1.6	1.2
2014-2016	1.2	0.9	0.8

Table (11): Average radon concentrations in multi-family houses with different ventilation types for houses with slab on grade foundation type.

Building year	Natural ventilation (%)	Mechanical exhaust (%)	Balanced mechanical ventilation (%)
1950-1980	23	74	3
1980-2000	5	60	35
2000-2010	4	74	22
2014-2016	2	38	61

Table (12): Fraction of multi-family houses with different ventilation types for houses with slab on grade foundation type.

Conclusions

A large decrease of average radon concentrations in Swedish new-built single-family and multi-family houses has been observed. A major factor for this improvement is most probably better building practice. The measurement data also show that most single-family houses today are built with slab on grade foundation and with mechanical ventilation and that this is part of the explanation for decreased radon levels. For multi-family houses, almost all new houses have mechanical ventilation which might have decreased radon levels.

References

Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority), 2013, Mätning av radon i bostäder - metodbeskrivning