Barnet, I., Neznal, M., Pacherová, P. (Eds.): Radon investigations in the Czech Republic X and the seventh international workshop on the geological aspects of radon risk mapping; Czech Geol. Survey and Radon corp., Prague 2004, 49-53.

Radon risk mapping by means of hydrogeological investigations - example of the Grisons, Switzerland

Christian Böhm, consulting geologist/hydrogeologist, Obere Gasse 40, CH-7000 Chur; Switzerland; cb@boehmgeol.ch; www.boehmgeol.ch.

Abstract

Approximately 1300 water samples from all over the Grisons were analysed for their radon activity concentrations. The radon levels found are mainly low. No severe health risks from radon in water are to be expected in the considered area neither regarding to ingestion of water nor to inhalation of radon gas after aeration (few levels over 150 Bq/L). Areas with crystalline basement rocks on the average show three times higher radon activities in water (35 Bq/L) than regions in sedimentary basins (12 Bq/L).

Areas with radon activities of >50 Bq/L in water usually coincide with increased radon values in the air of dwellings (radon risk areas). It only needs few radon measurements in springs or groundwater to reveal the radon risk of a certain area.

In general no correlation seems to exist between radon and the chemical composition of water. Nevertheless radon measurements in water are an easy way to determine the vulnerability of springs or groundwater - low radon values indicating vulnerable springs - and therefore should accompany chemical and microbiological analyses of water samples.

Keywords: Radon, radon risk mapping, hydrogeology, groundwater, vulnerability

Introduction

Radon analyses of groundwater samples can - beside of health implications - supply useful information for hydrological and hydrogeological purposes, e.g. mixing proportions between chemically undistinguishable waters, groundwater quality (missing or existence of a protective soil cover), infiltration and exfiltration of groundwater, and age determinations of groundwater after seepage.

In the Grisons, the south-eastern part of Switzerland, one third of the communities had to be declared as radon risk territories (fig. 3). The mean radon level in dwellings is 118 Bq/m^3 [BAG 2003]. The mean radon levels per community range from 40 to 900 Bq/m^3 in living rooms [Deflorin 2004]. Currently the Swiss legislation fixes a limit value of radon in inhabited rooms of 1000 Bq/m^3, and a guideline value of 400 Bq/m^3. No reference levels do exist for radon in water.

During the last years in the Grisons some 1300 water samples were analysed for radon by the author [Boehm 2002]. After aeration of the water samples the analyses were mainly done by alpha spectrometry, by a solid state alpha detector (Niton Rad7). There are three main kinds of water samples investigated: springs, pumped groundwater and public water supplies.

Results

As an effect of degassing ***streams and lakes*** contain very little radon (in general <1 Bq/L). The measured radon levels in ***public water supplies*** range from 1 to 130 Bq/L. Even the highest of these values are normally considered not to be hazardous. Following the 1:10'000-rule [Nazaroff et al. 1988] degassing of water with 100 Bq/L of radon is giving rise to an additional radon activity concentration of 10 Bq/m³ in dwellings. Only persons working in some water supply plants could eventually be exposed to a considerable radon risk. For the measured radon activities the risk of stomach cancer is also neglectable [www.epa.gov].

The radon activities measured in ***springs and groundwater*** range from <1 to 741 Bq/L. The two highest radon values ever measured in the Grisons and in the whole of Switzerland belong to the historic radon source of Disentis (715 Bq/L), where the underground consists of the granitic rocks of the Aar massif, and a newly found spring in Valchava/Val Müstair (the very eastern part of the Grisons) with radon values of up to 741 Bq/L and a Verrucano (volcaniclastic) underground. Elevated radon values can be found all over the region, and are bound to a reasonably good permeability of the underground, and to a certain age of the water. Groundwater in medium permeable soils ($1*10^{-4}$ to $1*10^{-3}$ m/s) show the highest radon activities, while an adsorption of radon to organic materials could take place at lower permeability. At a higher permeability and convective flow conditions the contact area between soil grains and water is too small to allow the build-up of higher radon levels [Boehm 2002].

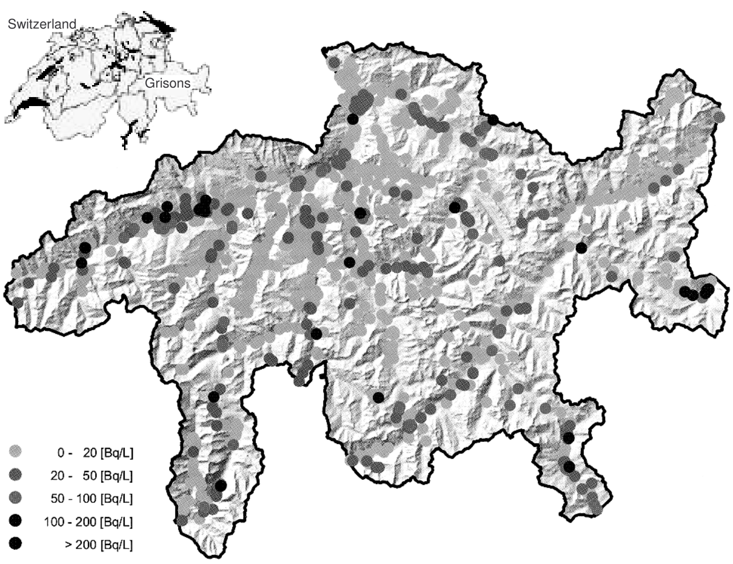

Figure 1:
Radon in water samples of the Grisons; individual values.

There are distinct differences between samples of sedimentary and crystalline areas. In general samples out of sedimentary basins contain three times less radon than those of the crystalline (table 1 and figure 2).

Table 1: Average of radon in water samples (arithmetic mean and median)

Water samples from the Grisons/CH	mean radon level [Bq/L]	median radon level [Bq/L]	number of samples
Springs - sedimentary	11.2	6.5	(465)
Springs - crystalline	36.2	18.0	(250)
Total of springs	19.9	8.3	(715)
Groundwater - sedimentary	20.3	17.1	(107)
Groundwater - crystalline	57.8	40.5	(68)
Total of groundwaters	34.9	22.6	(175)
Streams and lakes	2.2	0.5	(6)
Water supplies - sedimentary	6.6	4.2	(104)
Water supplies - crystalline	17.0	8.0	(95)
Total of water supplies	11.6	5.4	(199)
Total for sedimentary basins	11.9	6.9	(677)
Total for crystalline	35.0	17.9	(418)
Grand total	20.7	9.1	(1095)

The comparison of figures 2 (geology), 3 (official radon risk map), and 4 (radon risk deduced by measurements of water samples) shows quite a good correspondence of the three parameters.

The highest radon values in groundwater mainly occure in crystalline regions and especially at places where the bedrock is formed of granitic rocks, orthogenic gneisses or volcanic/volcaniclastic rocks, rock types that are known to be rich in uranium, the source of radium and radon.

Pumped groundwater is showing radon activities that are about 75 % higher than for springs. This can be explained by the fact that spring water is often superficial and subject to degassing or in contact to radon poor soil gas, while groundwater is in contact with soil gas enriched in radon.

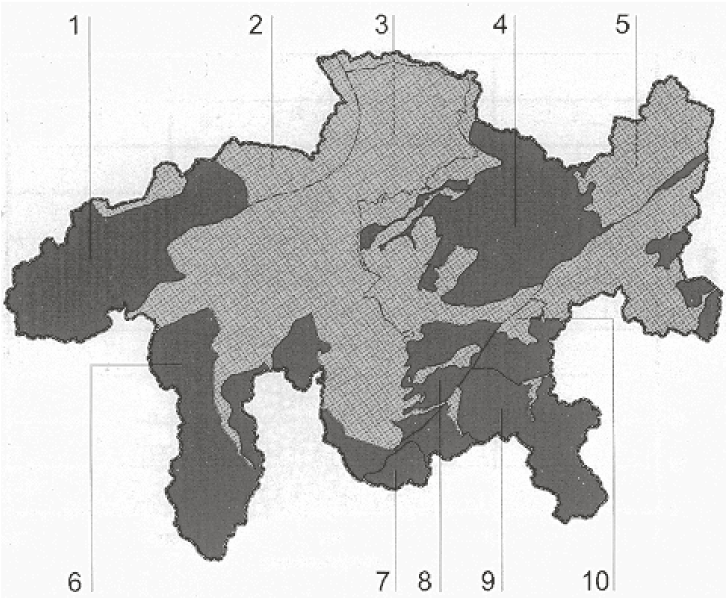

Figure 2:
Tectonic sketch map of the Grisons
Dark grey: crystalline units
Light grey: sedimentary units

1: Aar and Gotthard massifs
2: Helvetic realm
3: Penninic realm: sedimentary rocks
4: Eastern alpine realm: crystalline
5: Penninic realm: sedimentary rocks
6: Penninic realm: crystalline nappe cores
7: Bergell intrusion
8/9: Eastern alpine: crystalline nappes
10: Eastern alpine: sedimentary

Figure 3:
Radon risk areas (dark grey) in the Grisons [BAG 2003]

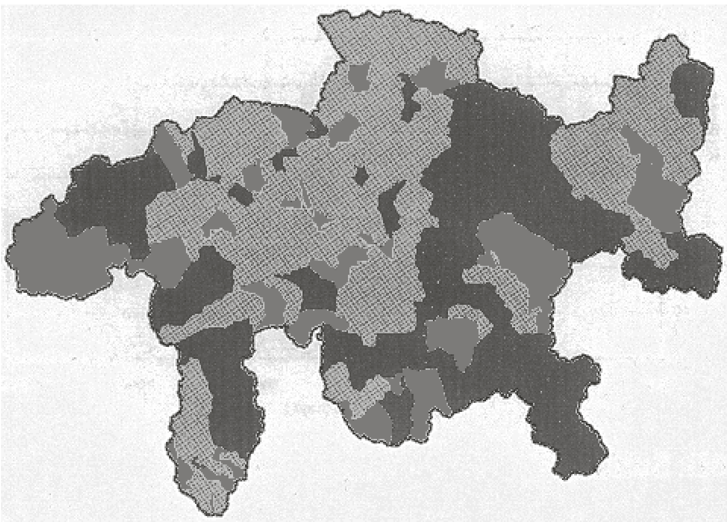

Figure 4:
Radon measurements in water and resulting radon prone areas in the Grisons; highest detected value per community.

Dark grey: >50 Bq/L high radon risk
Medium: 30 - 50 Bq/L
Light grey: <30 Bq/L low radon risk

Radon activities of groundwater samples reflect quite well the radon-prone areas (compare figures 3 and 4). Values >50 Bq/L are a strong hint for a radon risk area [Surbeck 1995]. Activity concentrations between 30 and 50 Bq/L ask for further interpretation.

Optimal correlations between radon in water and radon in the air of dwellings were obtained wherever a local spring could be sampled in the vicinity of the related village. No agreement could be found where local springs or groundwater were not accessible for water sampling. In a few cases representative water analyses suggest a radon-prone area, which until now is not defined as such by the radon measurements in the air. In other cases all geological and hydrogeological evidences are contradicting the official radon risk map. Perhaps future measurements will lead to a better knowledge and a revision of either the air or water based radon risk map.

Vulnerability

As a side mark another example of the use of radon analysis is stressed. Radon values can be a sign of quality in hydrogeological investigations: spring water containing very little radon is likely to be either very young and of local infiltration, or to be subject to degassing, which is likely to happen under the absence of a continuous soil cover. These waters are exposed to environmental influences and are very likely to be contaminated. Radon analysis is revealing the vulnerability of these waters, a fact which in general can't be detected by means of chemical and only under special hydrological conditions by microbiological analyses.

Conclusions

A single radon measurement in water can in some cases be indicative for the radon risk in dwellings of a whole village. Not very useful are investigations of water supply samples if the water is coming from far away springs and is likely to be partially degassed. Most useful are local springs, or groundwater samples of shallow aquifers which are in contact with the local soil gas system.

References

BAG Bundesamt für Gesundheit (2003): Umweltradioaktivität und Strahlendosen in der Schweiz 2002. - Hrsg. BAG/SUeR Bern/Fribourg.

Böhm, Ch. (2002): Radon im Wasser - Überblick für den Kanton Graubünden. - Jber. Natf. Ges. Graubünden, 111, 49-79 [PDF available at www.boehmgeol.ch].

Deflorin, O. (2004): Natürliche Radionuklide in Grundwässern des Kantons Graubünden. - Ph.D. Thesis, Neuchâtel.

Nazaroff, W.W., Doyle, S. M., Nero, A.V., Sextro, R.G. (1988): Radon Entry Via Potable Water. - In: Nazaroff, W.W. and Nero, A.V. (eds.): Radon and its Decay Products in Indoor Air. - John Wiley & Sons, New York; 131-157.

Surbeck, H. (1995): Natürliche Radionuklide im Wasser. - In: BAG: Umweltradioaktivität und Strahlendosen in der Schweiz 1994, B.38.1-B.3.8.9. - BAG/SUeR Bern/Fribourg.

www.epa.gov (2004).