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Radon levels in household waters in southern Poland

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Abstract Determination of radon concentrations in household waters were performed in 1997 in three regions of south-western Poland which are considered to have an enhanced natural radioactivity level: in the Jelenia Gora and Walbrzych regions (both in south-western Sudety Mountains) and in the Upper Silesian Coal Basin. Water samples were collected from taps, wells and springs and were analyzed in a liquid scintillation counter. In the Upper Silesian Coal Basin all values are below 50 Bq/dm^3 with a maximum of 32 Bq/dm^3 and in the Sudety Mts. the radon concentration in water exceed this level in 68% of houses, reaching a maximum value of ca. 1400 Bq/dm^3 in drilled well water in the Jelenia Gora region. The annual ingestion dose calculated for this value equals to ca. 0.5 mSv for infants, 0.4 mSv for children and 0.3 mSv for adults. The average annual effective whole body doses calculated for tap water samples for a representative population in the investigated regions range from about 0.02 mSv to 0.32 mSv and the maximum value reaches 1.39 mSv. The inhalation doses corresponding to the unit of water-borne radon concentration are about one order higher than the ingestion ones for tap water supplies.

Key words dose assessment • household water • limits • liquid scintillation • radon

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Introduction

Radon in household water contributes to the internal exposure, resulting both from ingestion and also from inhalation, because radon is easily released to the indoor air during various household water uses like heating, shower, flushing, dishwashing. It is estimated that de-emanation of radon from tap water constitutes about 2 percentage contribution in radon concentration in the air for the model masonry building in a temperate climate [17]. However, in many houses served by private drill wells in Finland [2] and in the USA [12] (about 2% of the US housing stock), which reach a very high average radon concentration, of the order of 100 to 1000 Bq/dm^3, the contribution of water radon to indoor concentration may be about 50 Bq/m^3 or more.

There are many results published of radon level measurements in waters of various origin [2–7, 10, 13–16] but the knowledge regarding the health risk associated with radon and radon daughters in drinking water is still limited and is altering. The estimate of the ingestion dose coefficient for water-borne radon recommended in United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) 2000 [18] is about five times lower than the one in UNSCEAR 1993 [17] for a representative population. The US Environmental Protection Agency (EPA) has proposed a Maximum Contaminant Level (MCL) of 11 Bq/dm^3 and requires that action be taken to reduce radon levels above an Alternative Maximum Contaminant Level (AMCL) of 150 Bq/dm^3 [8]. Some European countries have already introduced reference levels for radon in water supplies (Table 1) [1], however, they differ from each other

Country	Private water supplies (Bq/dm^3)		Public water supplies (Bq/dm^3)	
	Enforced level	Advisory level	Enforced level	Advisory level
Czech Republic		200	300	50
Finland			300	
Norway			500	
Russia	120		120	
Slovak Republic	1000	50	1000	50
Sweden		100*), 1000**)	100*), 1000**)	
UK				100
USA				150***)

Table 1. Reference levels of radon concentration in water supplies in various countries [1].

*) fit for consumption with reservations.
**) unfit for human consumption.
***) for public waters.

significantly. Poland does not have any regulations concerning radon level in drinking water.

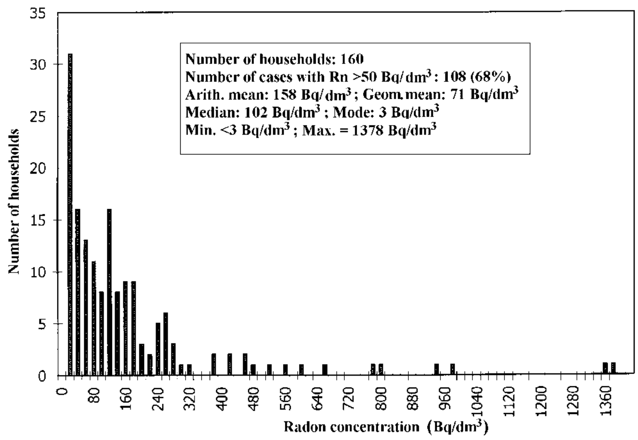

Fig. 1. Radon in household waters in the Jelenia Gora region.

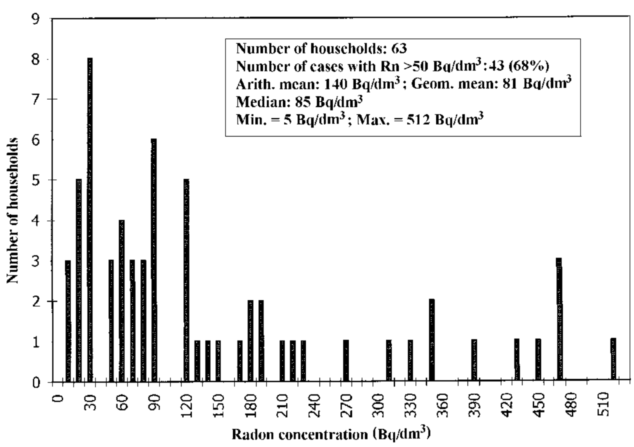

Fig. 2. Radon in household waters in the Walbrzych region.

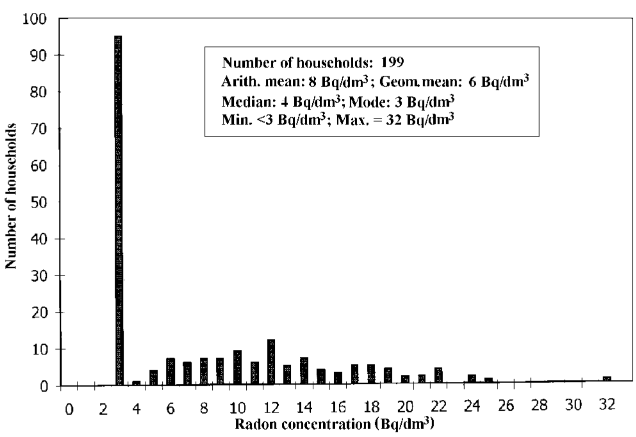

Fig. 3. Radon in household waters in the Upper Silesian Coal Basin.

In this paper we present results of radon concentration in household waters measured in 422 houses in three areas: in the Jelenia Gora region – 160 houses, the Walbrzych region – 63 houses, and in the Upper Silesian Coal Basin (USCB) – 199 houses. We also assess annual effective doses to lung and stomach corresponding to the mean and maximum radon levels measured in tap public system waters according to the model adopted by UNSCEAR 2000 [18].

Sampling and analytical technique

The water samples were collected from 422 households. There were three types of water sources: taps, wells and springs. A special attention was drawn to minimize aeration and fill a vial to the brim without leaving any space for trapped air. The collected samples were delivered to the Laboratory during one day to be eluted with an Opti-Fluor O liquid scintillation cocktail from NITON Co. After 3 hours of waiting for the equilibrium between radon and its progeny, the samples were analyzed in a Liquid Scintillation Analyzer Canberra-Packard model TRI CARB 1900TR using parameters and procedures described in Packard PicoRad 5.9 program for radon in water measurements. The lower limit of detection of this method is ca. 3 Bq/dm^3 for a 10 min count.

Results and conclusions

Radon concentrations

The distributions of results for the tree investigated areas with the mean, mode, median, maximum values are shown

Table 2. Arithmetic means and ranges of radon concentrations for three types of water supplies (number of samples in brackets).

Supplies	Region		
	Jelenia Gora (Bq/dm^3)	Walbrzych (Bq/dm^3)	USCB (Bq/dm^3)
Tap water			
mean	74 (60)	116 (28)	8 (199)
range	<3–253	5–512	<3–32
Wells			
mean	207 (98)	174 (25)	–
range	<3–1378	16–466	
Springs			
mean	283 (2)	131 (9)	–
range	264, 302	8–427	
All			
mean	158 (160)	140 (63)	8 (199)
range	<3–1378	5–512	<3–32

Region		Rn concentration (Bq/dm^3)	Investigation dose ($\mu Sv/y$)	Inhalation dose ($\mu Sv/y$)	Whole body dose ($\mu Sv/y$)
Jelenia Gora	arith. mean	74	16	185	201
	max. value	253	54	633	687
Walbrzych	arith. mean	116	25	290	315
	max. value	512	109	1280	1389
USCB	arith. mean	8	2	20	22
	max. value	32	7	80	87

Table 3. The population-weighted annual effective doses from radon in tap waters (for arithmetic means and maximum values of radon concentrations).

in Figs. 1–3. The average water-borne radon concentrations in the Jelenia Gora – 158 Bq/dm^3 and in the Walbrzych region – 140 Bq/dm^3 are significantly higher than in USCB – 32 Bq/dm^3, because of the enhanced natural radioactivity in these two regions due to geological bedrock rich in gneiss and granites. The highest value of 1378 Bq/dm^3 was detected in the Jelenia Gora region in a drilled well water.

The water samples were also grouped by three types of water supplies: tap water, wells and springs (Table 2). The mean values for the three groups in the Walbrzych region: 116, 174 and 131 Bq/dm^3 do not differ essentially. The highest mean value of 207 Bq/dm^3 corresponds to drilled wells in the Jelenia Gora region.

The number of households with radon concentration in water exceeding Czech and Slovak limit of 50 Bq/dm^3 is the same in the Jelenia Gora and Walbrzych regions and constitutes 68% of all results. In the Upper Silesian Coal Basin the highest value of 32 Bq/dm^3 was found.

In all households covered under this project the survey of indoor radon was also conducted [9]. Investigation of the correlation between radon concentration in water and radon concentration in indoor air in the same household gave negative results for all three regions.

Water-borne radon doses

It is believed that water-borne radon may cause higher health risk than all other contaminants combined appearing in drinking water [15]. It enters human body through the gastro-intestinal tract when is drunk in water and other drinks and through the respiratory tract when released from water is inhaled with the air. Thus, water-borne radon is a source of radiation dose to stomach and to lungs. In order to calculate the annual effective doses to these organs and to the whole body we adopted patterns in accordance with UNSCEAR 2000 [18]. For the ingestion dose the following parameters were applied:

- the ingestion dose coefficient after NRC 1998 [11] equal to 3.5 nSv/Bq;
- annual intakes by infants, children and adults of about 100, 75 and 50 dm^3, respectively;
- the proportion of these groups in the representative population is 5% infants, 30% children and 65% adults.

The annual effective dose to stomach corresponding to 1 Bq/dm^3 is equal to 0.35 $\mu Sv/y$ for infants, 0.26 $\mu Sv/y$ for children, 0.18 $\mu Sv/y$ for adults and 0.21 $\mu Sv/y$ for the representative population (the weighted estimate of consumption of 60 dm^3/y).

For the inhalation dose assessment we used:
- ratio of radon in air to radon in the tap water supply of about 10^{-4};
- indoor occupancy of 7000 hours/y;
- equilibrium factor between radon and its progeny of 0.4;
- dose conversion factor for radon exposure equal to 9 $nSv/Bq^{-1} h^{-1} m^3$.

The annual effective dose to lungs corresponding to the concentration of 1 Bq/dm^3 in tap water is equal to 2.5 $\mu Sv/y$. Thus, water-borne radon concentration of 1 Bq/dm^3 causes the whole body effective dose of about 2.71 $\mu Sv/y$.

The population-weighted annual effective dose estimated for the maximal value of 1378 Bq/dm^3 found in a private drilled well (Jelenia Gora region) is equal to 289 $\mu Sv/y$ from ingestion and, if it were a tap water, equal to 3445 $\mu Sv/y$ from inhalation which gives a sum of 3734 $\mu Sv/y$ for the whole body. It should be noted that, because this well like all others investigated under this project is manually operated and water is carried in buckets, the ratio of radon in air to radon in the water may differ significantly from the adopted for tap supply value of 10^{-4} and the estimation of the inhalation dose in real condition may be much lower. Therefore, in Table 3 there are given effective doses estimated only for tap water supplies in the investigated regions. The inhalation doses are about one order higher than the ingestion ones. The average annual effective whole body doses range from about 22 μSv in USCB to 315 μSv in the Walbrzych region and the maximal value found also in this region reaches 1389 μSv.

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References

1. Åkerblom G (1999) Radon legislation and national guidelines. European research into radon in construction concerted action. Report no. F14P-CT96-0064(DG12-WSMN) ERRICCA
2. Asikainen M, Kahlos H (1980) Natural radioactivity of drinking water in Finland. Health Phys 39:77–83
3. Barnett JM, Holbert KE, Stewart BD, Wayne KH (1995) Lung dose estimates from ^{222}Rn in Arizona groundwater based on liquid scintillation measurements. Health Phys 68:699–703
4. Field WR, Kross BC (1998) Iowa survey of waterborne ^{222}Rn concentration in private wells. Health Phys 74:249–252
5. Hess CT, Michel J, Horton TR, Prichard HM, Coniglio WA (1985) The occurrence of radioactivity in public water supplies in the United States. Health Phys 48:553–586
6. Horton TR (1985) Methods and results of EPA's study of radon in drinking water EPS. 520/5-83-027. Office of Radiation Programs, US EPA, Washington, DC

7. Kahlos H, Asikainen M (1980) Internal radiation doses from radioactivity of drinking water in Finland. Health Phys 39:108–111
8. Kendall G (2000) Health risks of radon in drinking water in the USA. Radiological Protection Bulletin 220:7–8
9. Kusyk M, Mamont-Ciesla K (2000) Studies of indoor radon concentrations in two radon prone areas of Poland. In: Bi-annual report 1998–1999. CLOR, Warsaw, pp 53–56
10. Mahesh HM, Avadhani DN, Karunakara N, Somashekarappa HP, Narayana Y, Siddappa K (2001) ^{222}Rn concentration in ground waters of coastal Karnataka and Kaiga of south west coast of India. Health Phys 81:724–728
11. National Research Council (1998) Risk assessment of radon in drinking water. National Academy Press, Washington, DC
12. Nero AV, Gadgil AJ, Nazaroff WW, Revzan KL (1990) Indoor radon and decay products: concentrations, causes, and control strategies. Technical Report Series, DOE/ER–0480P. US Department of Energy, Washington, DC
13. Otwoma D, Mustapha AO (1998) Measurement of ^{222}Rn concentration in Kenyan ground water. Health Phys 74:91–95
14. Paulus LR, Gessel TF, Brey RR (1998) An evaluation of ^{222}Rn concentrations in Idaho groundwater. Health Phys 74:237–241
15. Savidou A, Sideris G, Zouridakis N (2001) Radon in public water supplies in Migdonia Basin, central Macedonia, northern Greece. Health Phys 80:170–174
16. Tayyeb ZA, Kinsara AR, Farid SM (1998) A study on the radon concentrations in water in Jeddah (Saudi Arabia) and the associated health effects. J Environ Radioactiv 38:97–104
17. UNSCEAR (1993) Sources and effects of ionizing radiation report to General Assembly, Annex A. United Nations, New York
18. UNSCEAR (2000) Sources and effects of ionizing radiation report to General Assembly, Annex B. United Nations, New York