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Radon in drinking water in the Białystok region of Poland

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Abstract. Water is one of the indoor sources of ^{222}Rn. As radon is soluble in water, it is carried indoor by water supply and there it is released. The presence of radon in groundwaters is caused by direct migration of ^{222}Rn from rocks and soil to waters as well as by radium content in water. Radon inflow indoor is possible in the areas where drinking water shows high radon concentration. Radon concentration changes significantly from low in natural surface water to relatively high from water in drilled wells. It is estimated that out of 10,000 Bq·m^{-3} of radon contained in water supply we can obtain radon concentration increase by 1 Bq·m^{-3} indoor. The aim of the study was to measure radon in water supply in the Białystok region and also estimation of doses and investigation how the treatment influenced radon concentration in water. Water was collected from rural and municipal waterworks as well as from home wells. Measurements of radon concentration in particular stages of drawing and treatment of water in Białystok waterworks were also conducted. A liquid scintillation method was used in the study. The arithmetic mean of radon concentrations in the samples was equal to 5800 Bq·m^{-3}, median – 4800 Bq·m^{-3}, and geometric mean – 4600 Bq·m^{-3}. The lowest values of radon concentration were observed in surface waters (from surface intake). Radon concentrations in waters from drilled wells, shallow home wells and surface intake were compared and statistically significant differences were obtained at $p < 0.05$. The results of radon concentrations in drinking water in the Białystok area revealed radon-poor waters (88%) and low-radon waters (12%).

Key words: radon in water • Białystok region • liquid scintillation

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Introduction

Radon is a natural radioactive element with more than 50% of its contribution to the total effective dose obtained by the Polish population [3]. Elevated Rn-222 concentration indoors can in some cases cause elevated radiological risk connected with lungs and bronchi.

Water is one of the sources of ^{222}Rn presence in flats [8, 12]. As radon is soluble in water, it is transported with water to indoors where it is released. The presence of radon in ground waters is caused by direct migration of ^{222}Rn from rocks and soil (to waters) as well as by small amounts from radium content in water.

In the region, where drinking water shows high radon concentration, a large amount of this gas can be transported to indoors. Radon release from water to air depends on the way water is used. Boiling and spraying increase radon escape, which, in consequence, leads to an increase of its concentration in bathrooms and kitchens. As a result, radon concentration in air also depends on the amount of water used, building's volume and its ventilation. Radon concentration changes markedly from low in fresh superficial water to relatively high in drilled well water [6, 14]. It is estimated that radon in the indoor air is increased by 1 Bq·m^{-3} out of

10,000 Bq·m^{-3} of radon contained in the water supplied to houses [2]. On the other hand, higher contribution of radon can occur from water in places where it is warmed. Radon concentration in water decreases together with rise of temperature. A similar effect can be obtained by adding activated carbon to water as well as by airing the water [1].

Due to radon concentration, underground waters can be divided into: radon-free water – below 1 kBq·m^{-3}; radon-poor water – up to 9.9 kBq·m^{-3}; low-radon water – up to 99.9 kBq·m^{-3}; radon water – up to 999.9 kBq·m^{-3}; high-radon water – up to 9999.9 kBq·m^{-3}; extreme-radon water – above 10,000 kBq·m^{-3} [9].

Radon-free waters and extreme-radon waters occur rarely, while poor-radon waters and low-radon waters are most frequent [9].

The aim of the study was the measurement of radon contained in water supply to buildings in the Białystok region and also the estimation of doses and investigation how the treatment influenced radon concentration in water.

Material and methods

The method based on liquid-scintillation measurements was used in the study. Water samples were collected to glass containers with a rubber-teflon gasket to prevent ^{222}Rn escape from the containers. 10 ml of a liquid scintillator OPTI-FLUOR and, afterwards, 10 ml of the examined water were pipetted to 20 ml measuring glassware. Each viol was shaken for 15 s to extract ^{222}Rn from water to the scintillator. After extraction, counting was postponed for 4 h to let radon progeny reach equilibrium with ^{222}Rn. The measurements were conducted with the use of an automatic liquid-scintillation counter TRI-CARB. The error of the method assessed by the manufacturer did not exceed 10%.

As the distribution of radon concentration in the whole set of measurements was close to the log-normal one, the statistical analysis was performed with non-parametrical Mann-Whitney and Kruskal-Walis tests. It was assumed that the differences between the compared groups are statistically significant if $p < 0.05$.

Results and discussion

Measurements of radon concentration at particular stages of consumption and treatment of water in the Białystok water supply were performed.

Białystok has intakes of drinking water at Jurowce and Wasilków (Fig. 1). There are two water intakes at Wasilków: one from the infiltrative-retentive ponds and the other one – the bank intake in the Supraśl river.

At Jurowce, the intake is drilled to the Quaternary aquiferous levels. Water is treated before introducing it to the water supply system in the multi-stage process. The stages of the treatment of water from infiltrative intakes are as follows: initial ozonization, contact filters, disinfection (directly), indirect ozonization, carbon filters, disinfection (last three processes are performed together with superficial water in the Water Treatment Plant Pietrasze).

Fig. 1. Localization of the investigated water intake.

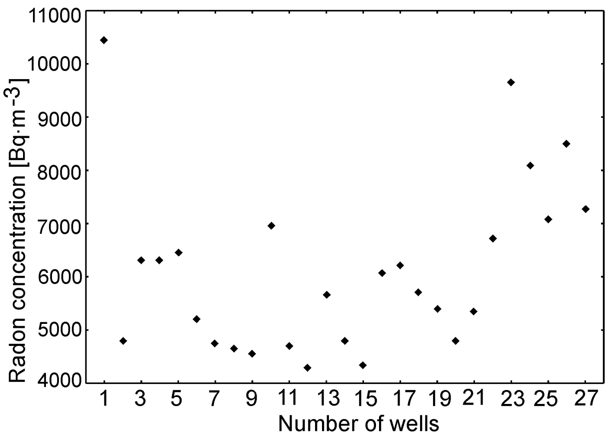

Fig. 2. Radon concentration in drilled wells of water intakes at Jurowce. Each point shows a particular well.

Water from the superficial intake from the Supraśl river, is treated using initial ozonization, volume coagulation, passage through fast filters, indirect ozonization, carbon filters, and disinfection. Water from drilled wells is treated by initial ozonization, fast filters, and disinfection.

Water samples were collected from 29 wells at Jurowce and values of radon concentration were presented in Fig. 2. The values of radon concentration in water before treatment ranged from 4500 Bq·m^{-3} to 10,400 Bq·m^{-3}. Mean value of the radon concentration in water after treatment processes was 7300 Bq·m^{-3}. Waters obtained from drilled wells at Jurowce are radon-poor and low-radon water, according to the above-mentioned classification [9].

At Wasilków, the water was collected from infiltrative wells and from the Supraśl river. The values of radon concentration obtained in the Wasilków intake were presented in Fig. 3.

The values of radon concentration from the infiltrative wells at Wasilków ranged from 9300 Bq·m^{-3} to 11,900 Bq·m^{-3}. Radon concentration in the river water was equal to 5400 Bq·m^{-3}. The samples of river water were taken in 8 points at different depth from the river

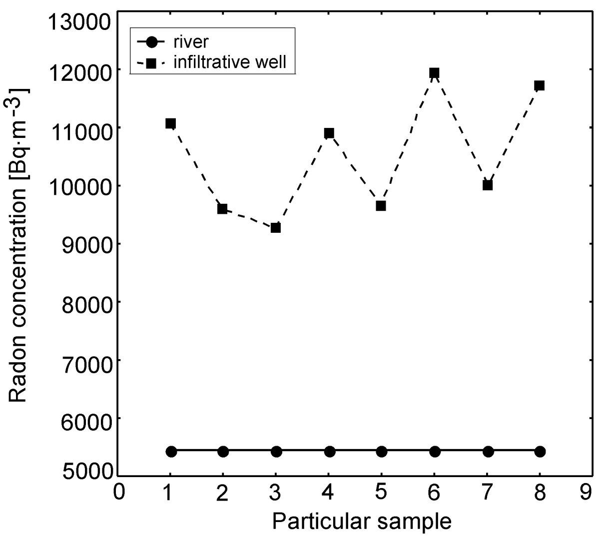

Fig. 3. Radon concentration in water from Wasilków. Each point shows a particular well and samples taken from the Supraśl river.

sector of 150 m. Waters from both intakes are mixed together in the urban system. Radon concentration in the water supplying towns was equal to 4800 Bq·m^{-3} after the processes of water treatment had been completed. Approximate time between the introducing of water to the system and the consumption in the house is from 18 to 36 h.

We performed 281 measurements of radon concentration in drinking water used by the population of Białystok region. Each intake was only once sampled. The collected water was placed in three vials and measurement results were averaged. Samples were collected in houses supplied with water by country (63) and urban (124) water supplies as well as home wells (94). We also gathered information concerning the kind of water intake in a particular household. The arithmetic mean of radon concentration in the collected samples was 5800 Bq·m^{-3}, median – 4800 Bq·m^{-3}, geometric mean – 4600 Bq·m^{-3}. The highest measured value was 32,000 Bq·m^{-3}.

The relation between radon concentration and the type of water intake was analyzed. We distinguished 3 types of water intakes: drilled wells (depth from 20 to 50 m), superficial intakes, and home private wells, approximately 10 m deep. The statistical parameters of the obtained results are presented in Table 1. The lowest values of radon concentration were observed in waters from superficial intakes, because the water has the opportunity to be degassed and radon is released to the atmosphere quickly and easily. The differences between the compared groups are statistically significant at $p < 0.05$.

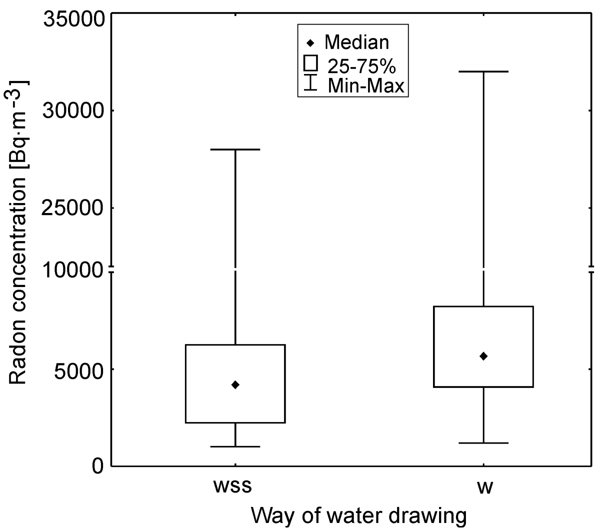

Fig. 4. Radon concentration distribution regarding the way of taking water: wss – water supply system, w – well.

We analyzed the differences in radon concentration in drinking water as for the way water was taken in, i.e. whether it is supplied to the household by a water supply system or taken straight from the home well. The results are shown in Fig. 4.

The values of radon concentration for well water were slightly higher, which can result from the fact that such water is not treated and is used directly without loss of activity due to delay between drawing from the source and supplying by the system to the house.

The differences are statistically significant. Water supply system and water transport cause the decrease in radon concentration, which can be exemplified by England where the private water supply system showed 220 kBq·m^{-3} in the source, 100 kBq·m^{-3} in reservoirs, and 55 kBq·m^{-3} in the tap [4].

The values of the 2nd and 3rd categories (radon-poor waters – 88% and low-radon waters – 12%) were revealed in our measurements of radon concentrations in drinking waters.

There are no law regulations in Poland that describe maximum radon concentrations in drinking water. There is also lack of directions to rationalize activities. The Decree of Minister of Health (2007) gives the total permissible dose coming from drinking water of 0.10 mSv per year [7]. The value recommended by the WHO for radon concentration in water in the intake should be below 100 kBq·m^{-3} [13].

Assuming radon concentration in drinking water in the Białystok region to be at medium level, i.e. 5800 Bq·m^{-3}, (based upon the conversion factor 10^{-8} Sv·Bq^{-1}) [10] the annual effective dose coming from

Table 1. Radon concentration in water depending on type of intake: drilled, superficial, home wells. *N* – number of samples; AM – arithmetic mean; M – median; GM – geometric mean; MAX – maximal value; MIN – minimal value; GSD – geometric standard deviation

	N	AM (Bq·m^{-3})	M (Bq·m^{-3})	GM (Bq·m^{-3})	MAX (Bq·m^{-3})	MIN (Bq·m^{-3})	GSD	Number of samples with values above 11,000 Bq·m^{-3}
Drilled intake	154	5500	4700	4300	28,000	1100	2	7
Superficial intake	33	4500	4200	3700	11,900	1000	1.9	2
Home wells	94	6800	5600	5500	32,000	1200	1.9	15

radon ingestion with water (not inhalation) was estimated approximately at 2 μSv for adults and 8.4 μSv for children. The differences result from various amounts of drinking water and taking into account different speed of metabolism in relation with age. As it was observed by Brown [5], the dose affecting the gastric mucosa is approximately 100 times higher. Therefore, the ingested radon with water gives effective dose for wall of the gastric mucosa several times lower than the inhaled radon from indoor air.

The results of radon concentrations in tap water in the whole Mazury-Podlasie hydro-region carried out in 2000 showed similar values, AM = 6100 $Bq \cdot m^{-3}/m$ and GM = 4100 $Bq \cdot m^{-3}$. In all parts of the hydro-region east to the Vistula river, mean arithmetic values are in the range between 3200 $Bq \cdot m^{-3}$ and 8100 $Bq \cdot m^{-3}$ while mean geometric values – between 1900 $Bq \cdot m^{-3}$ and 4800 $Bq \cdot m^{-3}$ [14]. According to the WHO, mean radon concentrations in tap water from surface waters equals 400 $Bq \cdot m^{-3}$ and in well water – 20 $kBq \cdot m^{-3}$ [13]. Values obtained in our study are middle values of the range. UNSCEAR 2000 gave mean dose from radon in water from inhalation it was 0.025 mSv per year and 0.002 mSv when swallowed [11]. Health risk as far as radon in water is concerned is mainly from inhalation. The values determined in our study are not far from those typical of the world.

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