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ORIGINAL PAPER

Spatial distribution of equivalent gamma dose rate in the vicinity of mine water sedimentation ponds in Upper Silesian Coal Basin

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Abstract. In the Upper Silesian Coal Basin highly mineralized mine waters are pumped into numerous sedimentary ponds before discharge to the Vistula river. They contain elevated concentrations of natural radionuclides (mainly radium). In ponds, some fraction of radionuclides is removed from the water column by adsorption on settling particles, precipitation or co-precipitation, thus increasing radioactivity levels in the deposits. Due to fluctuations of water level and wind action, fine fraction of the deposited material can be distributed in the vicinity of ponds. Three ponds have been selected for survey of the gamma equivalent dose: Brzeszcze, Kaniów, and Rontok Duży. The lowest dose rates, below 0.33 μSv/h, were detected in the area of the Brzeszcze pond. The highest values were measured over the sediments of the Kaniów pond (8.37 μSv/h), being 30 times higher than the dose rate received by population in Poland from natural sources.

Key words: spatial equivalent gamma dose rate • natural radioactivity • sedimentation pond

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Introduction

Highly mineralized mine waters from the Upper Silesian Coal Basin after pumping to the surface are stored in sedimentation ponds. They contain elevated concentrations of natural radionuclides, mainly radium, which is partly removed from the water column as a result of precipitation and adsorption on settling particles and is accumulating in the bottom sediments. Fluctuations of water level in the dosing tanks lead to partial exposure of sediments to the atmosphere. Consequently, sediment particles containing elevated concentrations of radium can become mobile. They are transported with wind and deposited around the ponds increasing the local gamma dose rate.

Although activities of radium isotopes in mine waters and pond sediments were investigated by several authors [1, 2, 5], less attention was paid to the problem of effective dose rate received by human population due to contamination of pond deposits and their vicinities [3, 4].

To estimate the radiological hazard around sedimentation ponds, three such objects have been selected for further investigations. Two of them (Brzeszcze and Kaniów) are in operation and receive mine waters from the Brzeszcze and Silesia mines, respectively. The third reservoir (Rontok Duży) had been in use between 1977 and 1997 and collected waters from the Silesia Mine.

Fig. 1. Location of the studied sedimentation ponds.

Materials and methods

The sedimentation ponds are located on the edge of Oświęcimska Valley, in the Małopolska and Silesia region (Fig. 1). Waters accumulated in the ponds, after storage and dilution are discharged into the Vistula river.

Measurement points were chosen in the direct neighbourhood of the reservoirs: on the embankments, in the selected locations of the escarpment, on the fields and meadows in the vicinity of the ponds and on the gangue's repositories. The locations were selected taking into account their accessibility by people. Spatial distribution of the measurement areas is presented in Figs. 2 and 3.

Most of measurements were carried out one meter above the ground level with a low-level gamma radiometer Ludlum Model 19 Micro R Meter. This type of radiometer with a sodium iodide (NaI(Tl)) scintillation detector is recommended for environmental gamma radiation measurements. The radiometer was calibrated at the Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences (IFJ PAN, Kraków, Poland). Measurements were performed according to the procedure described in a manual [6]. The accuracy of measurements was better than 10%, depending on measurement range. Precision was in the range between 1 and 7% of the measured dose. At several locations (embankments of the Kaniów and Brzeszcze ponds) measurements were performed directly above the soil surface.

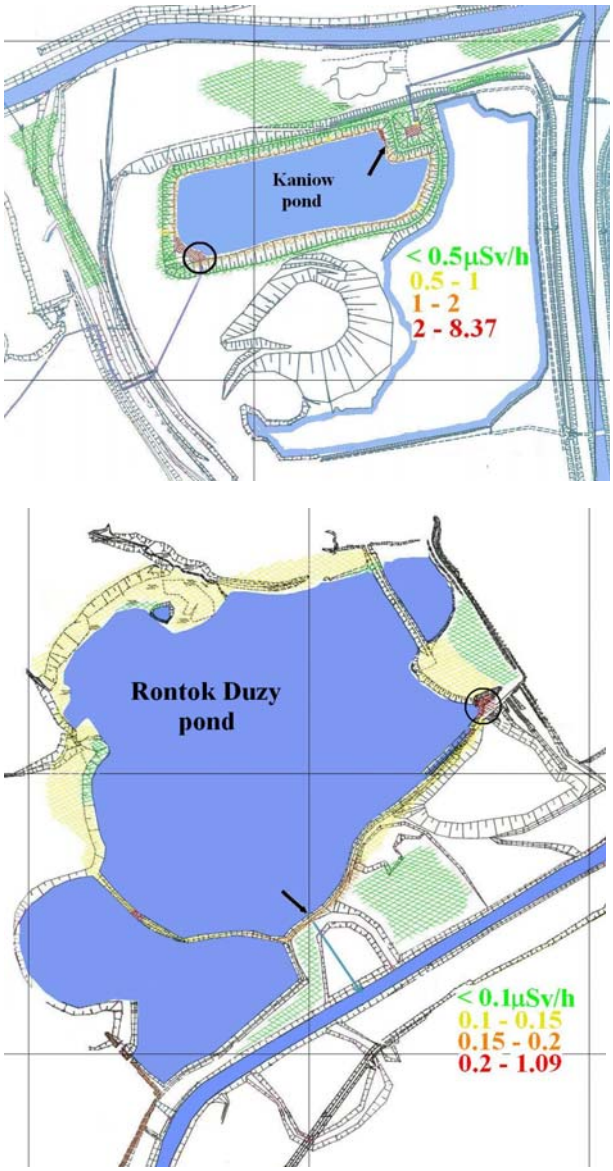

Fig. 2. Measured spatial equivalent gamma dose rates in the vicinity of the Kaniów, Rontok Duży sedimentation ponds. Inflow pipes are indicated by circles, arrows denote outflows.

Results and discussion

The results of measurements of the spatial equivalent gamma dose rate performed in the vicinity of the selected ponds are presented in Table 1.

Table 1. The spatial equivalent gamma dose rates in the vicinity of the Kaniów, Rontok Duży and Brzeszcze ponds. The number of measurement points in individual locations is given in brackets

Location	Spatial equivalent gamma dose rate (μSv/h)		
	Kaniów	Rontok Duży	Brzeszcze
Water supply area	0.47–1.19 (10)	0.19–0.55 (12)	0.09–0.12 (5)
Embankment	0.13–0.35 (32)	0.07–0.22 (44)	0.07–0.17 (24)
Meadows near the pond	0.11–0.22 (12)	0.10–0.14 (26)	0.07–0.14 (14)
Over the sediments	0.59–8.37 (17)	0.47–1.09 (9)	0.16–0.18 (8)
Gangue repository	0.37–0.45 (10)	not measured	0.13–0.33 (44)

Fig. 3. Measured spatial equivalent gamma dose rates in the vicinity of the Brzeszcze sedimentation pond. As in Fig. 2 inflow pipe is indicated by circle and arrow denote outflow.

The annual mean dose rate received by general public in Poland in 2010 was equal to 3.3 mSv/year, which corresponds to 0.38 μSv/h [7]. The highest measured gamma dose rates in the vicinity of the studied ponds were more than 20 times higher than this reference value. Dose rate received from natural sources (construction materials, Earth crust, cosmic rays) was estimated at a level of ca. 2.4 mSv/year (0.27 μSv/h). In the uncontaminated area the mean measured dose rate did not exceed 0.11 μSv/h (0.96 mSv/year). Those measurements were made in the Grzawa and Osiek villages. The first one is located between Brzeszcze and Kaniów, the second one is situated about 25 km E from Brzeszcze.

The lowest dose rates in the study area were detected over the meadows near the ponds: for Kaniów pond the values were between 0.11 and 0.22 μSv/h (1.9 mSv/year), for Rontok Duży pond were between 0.10 and 0.14 μSv/h (1.23 mSv/year) and for Brzeszcze pond were between 0.07 and 0.14 μSv/h (1.23 mSv/year).

Over the embankment of the Kaniów pond the maximum dose rate was equal to 0.35 μSv/h (between 0.13 and 0.35 μSv/h), which corresponds to 3.1 mSv/year. Directly over the sediments, the measured values were between 0.59 and 8.37 μSv/h (73.4 mSv/year). The latter value is 30 times higher than the mean dose rate received by human population in Poland from natural sources.

Near the Rontok Duży pond, the spatial equivalent gamma dose rate measured over the embankment was between 0.07 and 0.22 μSv/h (1.9 mSv/year), and directly over the sediments – between 0.47 and 1.09 μSv/h (9.6 mSv/year). The dose rates in the vicinity of Rontok Duży pond were significantly lower than around the Kaniów pond.

The lowest spatial equivalent dose rates (comparable with values for uncontaminated area) were detected in the Brzeszcze pond. The spatial equivalent gamma dose rate over the embankment was between 0.07 and 0.17 μSv/h (1.49 mSv/year), and over the sediments between 0.16 and 0.18 μSv/h (1.58 mSv/year).

Additionally, some spatial equivalent gamma dose rate measurements over the gangue repositories adjoining the Kaniów and Brzeszcze sedimentation ponds were performed. Over the repository of the Brzeszcze pond the gamma dose rates were between 0.13 and 0.33 μSv/h (2.9 mSv/year). Analogous values for the Kaniów pond were between 0.37 and 0.45 μSv/h (3.9 mSv/year).

Although the measured spatial equivalent dose rates are in the order of the dose received by population in Poland from natural sources (0.27 μSv/h), in some locations significantly higher dose rates were detected. However, since the studied area is not inhabited, there is no immediate danger to the population from the elevated levels of radioactivity in the vicinity of the investigated sedimentation ponds.

Conclusions

Results of the performed investigations have shown, that the highest values of the spatial equivalent gamma dose are detected over the exposed sediments, especially near the inflow pipes. The maximum value recorded was equal to 73.4 mSv/year and was measured directly over the Kaniów pond sediments. The distribution of the spatial equivalent gamma dose rate over the meadows adjacent to the investigated ponds revealed the values within the natural background. This indicates that from the radiological point of view the sedimentation ponds containing elevated levels of radium isotopes do not pose significant radiation hazard to the population.

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