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ORIGINAL PAPER

Dispersion of radon in the atmosphere around old uranium mill tailings

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Abstract. This paper presents the results of investigations of radon levels in the atmosphere around old uranium tailings aiming to estimate the influence of inactive uranium sites to the population and personnel. These tailings are situated in the area of a former uranium processing activity of a Pridniprovsk Chemical Plant in the city of Dniprodzierzhinsk. The radon-222 measurements have been carried out using an etched track system TRACK 2010Z. The minimum detectable activity of radon-222 has made up 2 Bq/m^3 with the exposure of 30 days. Corresponding data sets of radon-222 and its daughters have been analysed. We have calculated distribution of the radon equilibrium factor (F), i.e. the ratio between radon and radon daughters for the investigated site. Our study shows a contrast spatial radon-222 dispersion in the atmosphere, while radon-222 is lowered to the background levels. The average value of the F makes up 0.146 for the undisturbed open atmosphere. Atmospheric inversions cause a significant rise of F that goes up to 0.487. The present research has been carried out within the frameworks of the STCU project no. 3290.

Key words: radon • track detector • uranium tailings • equilibrium factor

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Introduction

The present work is part of the research on complex estimation of inactive uranium object impact on population and personnel. The present research aims to determine the parameters of dispersion in the atmosphere of radon-222, emanating from the surface of inactive uranium mill tailings. These parameters include: values of month-average concentrations of radon-222 within the tailings territory and outside its borders, maximum distances on which radon dissolves in the atmosphere to the background level, value of F between radon and its short-lived decay products in the atmosphere. It is necessary to know these parameters to estimate correctly the importance of the radon factor influence on the population and to resolve the problem of its constant monitoring in the populated areas. Besides, knowing of these parameters is necessary for planning the radiation protection of personnel that will implement rehabilitation works on the territory of the tailings.

As the objects of the research, four tailings have been chosen: Sukhachevskoye, Yugo-Vostochnoye, Centralniy Yar and Zapadnoye, earlier belonging to the Pridniprovsk Chemical Plant (PChP) in the city of Dniprodzierzhinsk. Sukhachevskoye tailing is located at a distance of 14 km from the territory of former PChP (Fig. 1). Three other tailings are located on the territory of PChP. On the Sukhachevskoye tailings, as the greatest open tailings (1 section area is 68 hectares) radon halo in the atmosphere has been researched. For the three other tailings, a value of F has been determined.

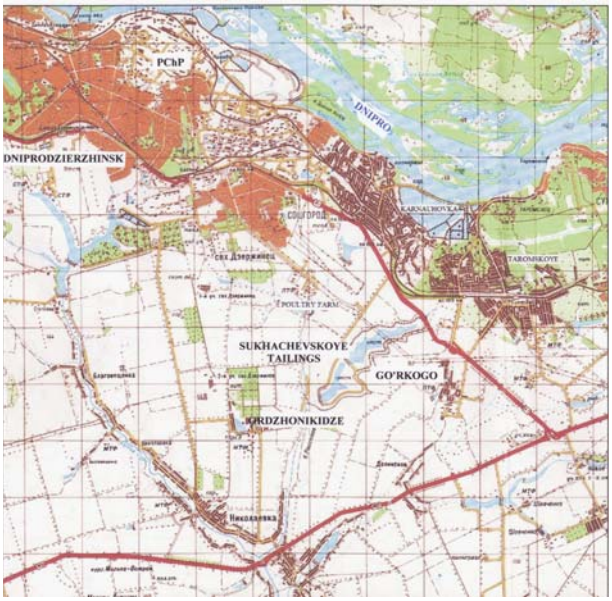

Fig. 1. Region of investigation, scale 1:200 000.

Fig. 2. Tailings Sukhachevskoye. Placement of track detectors cup.

The methods of investigation

To investigate the halo of integral concentration of radon-222 in the atmosphere we have used a high sensitivity variant of alpha track method. For this purpose, we have used TRACK 2010Z system produced by the Ukrainian-German joint venture Pozitron GmbH. The system operation is based on the principle of spark-gap count using a nitro-cellulose film as an integrated detector (LR-115). The high sensitivity of the measurements was reached by using the film detector of a large area (3.7 s·m^2) and its positioning in the center of the plastic cup, which allows to detect alpha particles from both sides. The minimum detectable activity of Rn-222 with exposition of 30 days makes up 2 Bq/m^3, with 7 days exposition – 9 Bq/m^3.

In the area of Sukhachevskoye tailings we have set up around 30 track detectors along the cross-sections traversing the tailings bawl, making it possible to detect the ultimate border of the radon dispersion in the atmosphere. Some track detectors have been also set up at a distance of more than 5 km from the tailings to determine the background level of radon in the atmosphere. The track detectors have been placed at a breath level of an adult that is at a height of 1.5–1.6 m up from the ground surface in the point of setting up. They were fixed to trees (Fig. 2). The exposition time of the detectors was up to 55 days. The measurements were carried out in the summer time when the level of radon-222 exhalation from the surface of tailings is in its peak.

To determine the average value of the F for the conditions of the tailings under research, we have carried out pair measurements of radon-222 and its decay products in the air. As we know, the F can be presented by the ratio of equivalent equilibrium concentration (EEC) of radon-222 to volume activity of radon-222 in air. This factor characterizes the displacement of the equilibrium between the mixture of short-living daughters of radon and their parent nuclide. Consequently,

$$F = \frac{C_{eq}}{C_o} \quad (1)$$

where C_{eq} – EEC of radon-222 in air, Bq/m^3; C_o – volume activity of radon-222 in air, Bq/m^3.

On each of the three tailings 3 or 4 points have been chosen, one of them was situated in the center, the other – round the perimeter of the tailings. At these points, the pair simultaneous measurements have been made at a height of human breath level – 1.6 m from the ground surface. The EEC measurements of radon-222 have been implemented by a radiometer RGA-09M, and radon-222 volume activity has been measured by a radon radiometer RRA-01M-01 Alpharad. Both the radiometers have an autonomous power. In the RGA-09M radiometer a grab-sampling method of Markov (modified by Terentyev) has been used. The sampling of aerosols on a filter has been implemented using an inserted pump with a speed of 20 l/min. The measurement of alpha activity of the filter was effected by a semiconductor detector in the counting mode. In the RRA-01M-01 Alpharad radiometer for registration of radon-222, we used a cylindrical electrostatic cell (V = 1 l) with a semiconductor detector, functioning in the spectrometric mode. The air entered inside the cell through the filter with the help of the inserted pump.

The results and discussion

On the basis of track detector measurements data we have built isolines of radon-222 month-average concentrations in the atmosphere at a height of human breath in the area of Sukhachevskoye tailings (Fig. 3). The received results show that the zone of radon influence of the tailings varies from 300 to 800 m. At these distances from the tailings borders, radon concentrations in the atmosphere go down to a value of 20 Bq/m^3, which has been taken for a background value, according to the results of some "background" track detectors. The highest value of radon-222 concentration in the atmosphere has been observed directly above the tailings, reaching 300 Bq/m^3.

The analysis of the Fig. 3 shows that the radon-222 cannot influence the population as at a distance of up to 800 m the inhabited areas are absent. That is why there

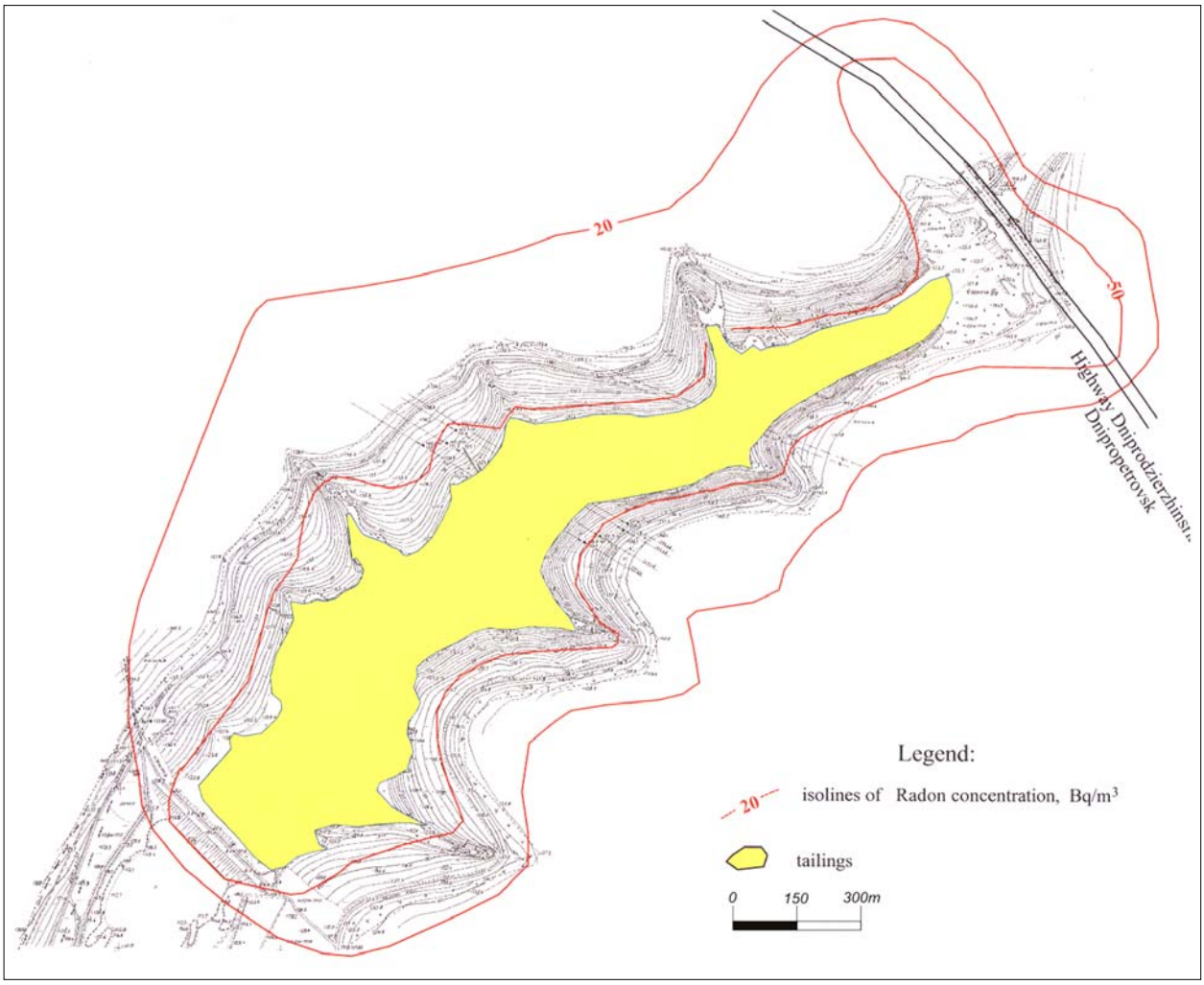

Fig. 3. Radon dispersion in atmosphere around Sukhachevskoye tailings.

is no need to carry out a radon monitoring in the nearest settled areas, such as the villages Gorkogo, Paultry Farm, Taromskoye, that are situated at distances of more than 1.5 km from the tailings (see Introduction). Radon can make some impact on the agriculture workers, who work near the fence of the tailings, on automobile drivers going the motorway Dniprodzierzhinsk-Dnipropetrovsk and on the personnel who will fulfill rehabilitation works directly on the tailings territory. However, the magnitude of this impact will depend on the time of exposure, radon concentration and the value of F. It is well known, that the main contribution to the dose on person is made by the radon daughters, not by radon itself. According to the literature sources [1], the value of the F for open atmosphere equals to 0.6. Though, our research (Table 1), involving 29 measurement pairs, has shown that the average value of F for undisturbed atmosphere is equal to 0.146. This value is obtained as an average from the measurements on the tailings Yugo-Vostochnoye and Centralniy Yar. The measurements on the Zapadnoye tailings, held during the period of atmospheric inversion, have shown that in these conditions the value of F increases to 0.487.

However, such atmospheric conditions are relatively rare, therefore to estimate the influence on the population it is better to use the coefficient value equal to 0.146. Taking it into consideration, we obtain the maximum value of EEC radon-222 for the air directly above the tailings (300 Bq/m^3), equal to 43.8 Bq/m^3.

This value does not exceed the standard of 50 Bq/m^3 for new dwelling houses in Ukraine [2] and will not influence seriously the personnel. In the air of the territory, bordering with the tailing, the levels of EEC radon-222 will be even less and within the background variation of radon daughters in atmosphere. In this connection the radon factor will not pose any risk neither for agriculture workers working near the tailings nor for automobile drivers on the motorway Dniprodzierzhinsk-Dnipropetrovsk.

Conclusions

1. Air pollution with radon on the flat areas containing uranium tailings is insignificant. Slightly enhanced radon concentrations can be measured at the maximum of up to 800 m from the tailings. Inhabited areas, situated more distantly from the tailings, do not demand any control of radon and its daughters in atmosphere.
2. An average value of F between radon and its short-living daughters in the atmosphere has been estimated. This value was $F = 0.146$ for the undisturbed atmosphere. The increase of this factor value has

Table 1. Results of measurement of radon-222 and its decay products in the atmosphere above uranium tailings for determination of *F*

No.	Month	Point of measurement	Result of measurement (Bq/m^3)		*F*
			Rn-222	EEC of Rn-222	
1	2	3	4	5	6
			Tailings Centralniy Yar		
1	July	no. 1-CY	150	5.35	0.036
2	July	no. 2-CY	35	5.78	0.165
3	July	no. 3-CY	63	4.47	0.071
4	July	no. 1-CY	292	14.30	0.049
5	July	no. 2-CY	36	7.71	0.214
6	July	no. 3-CY	68	4.45	0.065
7	July	no. 1-CY	122	22.20	0.182
8	July	no. 3-CY	52	12.40	0.239
9	July	no. 2-CY	46	4.28	0.093
10	July	no. 1-CY	43	7.49	0.174
11	July	no. 2-CY	67	5.00	0.075
12	July	no. 3-CY	66	5.99	0.091
13	July	no. 1-CY	74	15.80	0.214
14	July	no. 1-CY	59	5.56	0.094
15	July	no. 1-CY	30	4.37	0.146
16	July	no. 4-CY	154	9.57	0.063
17	August	no. 2-CY	47	7.11	0.151
18	August	no. 1-CY	111	8.58	0.077
				F mean =	0.122
			Tailings Yugo-Vostochnoye		
19	August	no. 1-YV	114	5.13	0.045
20	August	no. 2-YV	121	8.78	0.072
21	August	no. 3-YV	452	4.28	0.009
22	October	no. 3-YV	26	10.06	0.387
23	October	no. 2-YV	23	10.06	0.437
24	October	no. 1-YV	35	4.49	0.128
25	August	no. 2-YV	44	4.52	0.103
				F mean =	0.169
			Tailings Zapadnoye		
26	November	no. 1-Z	35	17.78	0.508
27	November	no. 2-Z	24	12.85	0.535
28	November	no. 3-Z	27	10.49	0.388
29	November	no. 4-Z	22	11.35	0.516
				F mean =	0.487

been noted in the period of atmospheric inversions, but the annual quantity of such periods makes a relatively low figure for the local climate.

3. The radon factor will not pose a significant risk neither for agriculture workers working near the tailings, nor for automobile drivers on the motorway Dniprodzierzhinsk-Dnipropetrovsk.

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