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OCCURRENCE OF RADON DECAY PRODUCTS IN SILESIAN INDUSTRY REGION

The variability of radon decay products depends on numerous complex processes affected by pressure, temperature, velocity and direction of wind and the state of atmosphere balance. The criteria indicating the influence of power industry upon the air radioactivity were determined. The dustfall, the self-cleaning coefficient, the washout rate and extinction coefficient are included.

The measurements were performed in the 1977–1985 period.

The results presented are average values of the concentrations of radon decay products.

1. INTRODUCTION

Radioisotopes can be introduced into circulation within the natural environment with chimney dust from coal power stations and with waste materials from mining and power industry stored at dumping grounds. MILISZKIEWICZ [2] reported that there is observed an increase in radon in the atmosphere of urban areas, resulting from both the use of elements prefabricated from coal ash and the combustion of coal, natural gas and liquid fuels.

Higher radon concentrations may be the reason of increase in the number of aberrations in human chromosomes and of increase (by about 10%) in number of deaths caused by cancer [2].

The above reports justified undertaking a research on dynamic changes of radon decay product concentrations in the atmosphere.

2. METHODS OF MEASUREMENT

^{218}Po, ^{214}Pb, ^{214}Bi concentrations were determined using a modified Tsivoglou method [5]. Samples of the air were collected for 5 minutes on Whatman filters by

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means of Staplex device. Velocity of the air flow was 1.2×10^{-2} m^3/s. The number of alfa impulses were measured for 5, 15 and 30 min using SSA-1 probe immediately after sampling. Calculations of concentrations need correction related to the period between sampling and measurement (30 s).

The modified Tsivoglou method allows application of the total number of counts to calculations concerning the following periods: $t = 0–5,\ 0–15,\ 0–30$ min. During measurements, a time shift (30 s) was taken into account. Concentrations of radon decay products were calculated on the basis of formulas obtained [1]–[3]:

$$^{218}\mathrm{Po}: C = \frac{0.037 \cdot \lambda_A \cdot K}{V}\left[1.6225\ L_5 - 1.107\ L_{15} + 0.2945\ L_{30}\right]\frac{\mathrm{mBq}}{\mathrm{dm}^3}, \tag{1}$$

$$^{214}\mathrm{Pb}: C = \frac{0.037 \cdot \lambda_B \cdot K}{V}\left[3.444\ L_5 - 5.478\ L_{15} + 2.591\ L_{30}\right]\frac{\mathrm{mBq}}{\mathrm{dm}^3}, \tag{2}$$

$$^{214}\mathrm{Bi}: C = \frac{0.037 \cdot \lambda_C \cdot K}{V}\left[-3.640\ L_5 + 3.816\ L_{15} + 1.161\ L_{30}\right]\frac{\mathrm{mBq}}{\mathrm{dm}^3}, \tag{3}$$

where:

K – calibration constant, $K = 161–162$,

$\lambda_{A, B, C}$ – decay constans for ^{218}Po, ^{214}Pb, ^{214}Bi; $\lambda_A = 0.2273\ \mathrm{min}^{-1}$, $\lambda_B = 0.2586\ \mathrm{min}^{-1}$, $\lambda_C = 0.035184\ \mathrm{min}^{-1}$,

V – velocity of air flow,

L_5, L_{15}, L_{30} – total numbers of counts for 0–5, 0–15, 0–30 min, respectively.

3. DISCUSSION

In order to determine the parameters modelling the occurrence of radon decay products, the concentrations of ^{218}Po, ^{214}Pb, and ^{214}Bi in the atmosphere were measured in the weather station in Chorzów, Poland. Pressure, temperature of the air, as well as velocity and direction of wind were measured at the same time. Other factors, such as precipitation and temperature distribution in soil at the depths of $h = 5$, 10, 20 and 50 cm, were also taken into account. The detailed meteorological data have not been given in the paper. Occurrence of radon decay products in the ground layer of atmosphere in the areas characterized by different dustfall was examined simultaneously in 1976–1985.

Concentrations of radon decay products (y) are function of dustfall (x) and change according to the following equations:

$$y = ax + b,$$

$$y = 0.2 \cdot x + 1.04 \quad (\text{for } ^{218}\mathrm{Po}), \tag{4}$$

$$y = 0.4 \cdot x + 0.96 \quad (\text{for } {}^{214}\text{Pb}), \tag{5}$$

$$y = 0.65 \cdot x + 0.88 \quad (\text{for } {}^{214}\text{Bi}). \tag{6}$$

The absolute terms b in these equations are interpreted as background concentration of given radioisotope, resulting from the average (in most cases secondarily changed) geochemical characteristic of the area. The data presented in fig. 1 come from different places in Upper Silesia. The empirical correlations (fig. 1) have practical aspect in forecasting the changes of the radon decay products in the atmosphere. The equations obtained give estimative level of radon decay products in the areas investigated.

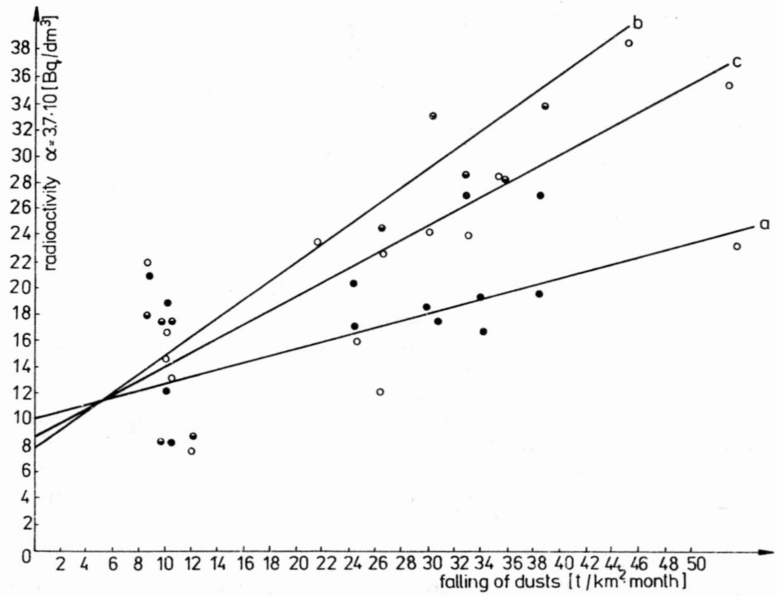

Fig. 1. Concentrations of radionuclides as a function of dustfall
a – ^{218}Po, b – ^{214}Pb, c – ^{214}Bi

The period of the investigations was long and the statistical analyses were made at significance level $\alpha = 0.01$. This fact points to the relationship, provided that the meteorological steady state subsequently changed step by step.

For the population selected comprising $n =$ 68 cases (weather and physiographical conditions as well as wind rose) there were stated correlations between the concentration of the given radioisotope and dustfall volume, expressed by the following correlation coefficients:

^{218}Po, $r = 0.58$,
^{214}Pb, $r = 0.73$,
^{214}Bi, $r = 0.51$.

The correlation is significant at $\alpha = 0.01$. This implies that all isotope values higher than background ones (the coefficient b in equations (4), (5), (6)) indicate the inflow of dust containing radioisotopes of industrial origin.

These results allow us to describe the phenomenon of self-purification of the atmosphere from natural radioisotopes. Generally, contents of radioisotopes examined in air during rainfalls diminished by 50%. The process of atmosphere self-purification may be defined by self-cleaning coefficient S and washout rate W[4]:

$$S = \frac{C}{q}, \quad W = \frac{C}{q} \cdot h$$

where:

C – concentration of an element in precipitation,

q – concentration of an element in the air,

h – amount of precipitation in time unit for 10 last years.

In the areas where the air is constantly polluted with industrial dust, the atmosphere can be cleaned to a very limited extent during rainfalls (see the table).

Table

Self-purification of atmosphere from radon decay products
Number of measurements $n = 78$

Area	Self-cleaning			Washout		
	^{218}Po	^{214}Bi	^{214}Pb	^{218}Po	^{214}Bi	^{214}Pb
Recreational	0.08	0.05	0.04	8.8	5.1	4.9
Industrial	0.002	0.001	0.002	0.15	0.1	0.14

In comparison with recreational areas, the rate of radon decay product washout is 50–80 times lower in industrial areas, whereas the self-cleaning coefficient is about 20–50 times lower.

In recent years, the problem of pollution shift in ground layers of the air has absorbed a great deal of attention. The phenomenon of secondary change in air composition, which is the result of advective and turbulent movements of air masses, is extremely complex. It may be presumed, however, that oscillations of some contaminants take place in both day-and-night and seasonal cycles. Planning the series of measurements, the authors took into account a possibility of the increase in dustfall volume under some atmospheric conditions.

A twenty four hour measurements of ^{218}Po, ^{214}Bi and ^{214}Pb concentrations carried out in both industrial and recreational areas at various heights above the ground level indicate that there are three maxima of concentrations of these elements: in the midday, evening and night.

The midday and night maxima depend on the season. The curve presenting the day's changes in concentrations of radon decay products in air, depending on time, show a certain shift in relation to the curve showing the dependence of extinction coefficient upon time (fig. 2). It is known that extinction coefficient B_{500} depends on the mass of suspended matter in vertical section of atmosphere. The estimation of extinction coefficient was described by SZTYLER [6]. In order to examine the spatial distribution of radon decay products above ground surface, two experiments were carried out, in the layer of 0–60 m and in the layer of 0–720 cm.

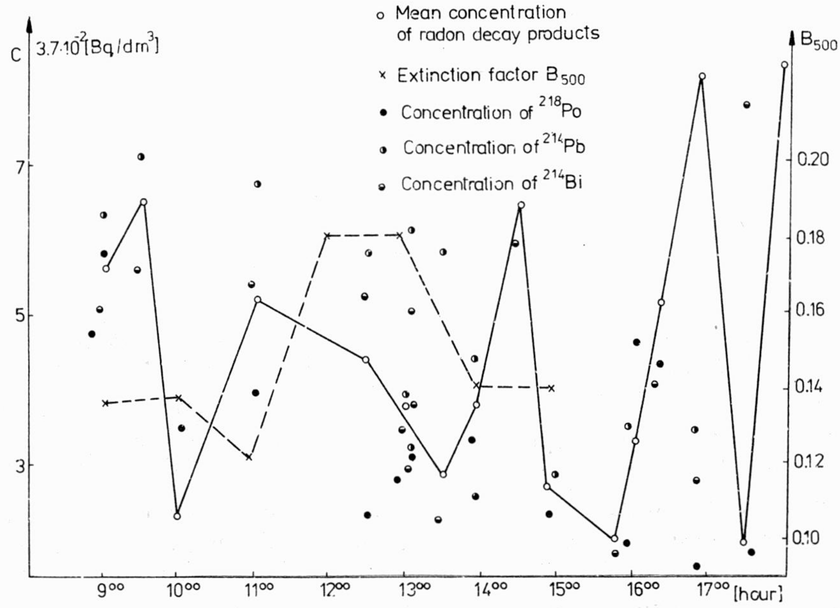

Fig. 2. Daily changes of radon decay products in comparison with changes in extinction factor

From the results it can be shown that a considerable decline of radioactivity is observed in the layer of air up to 10 m, whereas in higher layers (20–25 and 30–35 m) the increase in alfa specific radioactivity was stated. The facts mentioned above prove the stratified nature of contamination in the atmosphere. However, in the immobile air (wind velocity equal 0) at the height of 720 cm above ground level, ^{218}Po, ^{214}Pb and ^{214}Bi concentrations were half the concentration at the ground level. Maximal concentrations were found at the height of 40–60 cm above ground level (fig. 3).

For statistical analysis of the relationship examined (i.e. concentrations of polonium, lead, bismuth as a function of a given meteorological parameter), the following values were calculated: correlation coefficients, coefficients of determination, coefficient of variation, regression equations, ranges of radioisotope concentration changes, average content and its standard deviation, confidence intervals of the mean value for $\alpha = 0.05$ of relation in question at given probability.

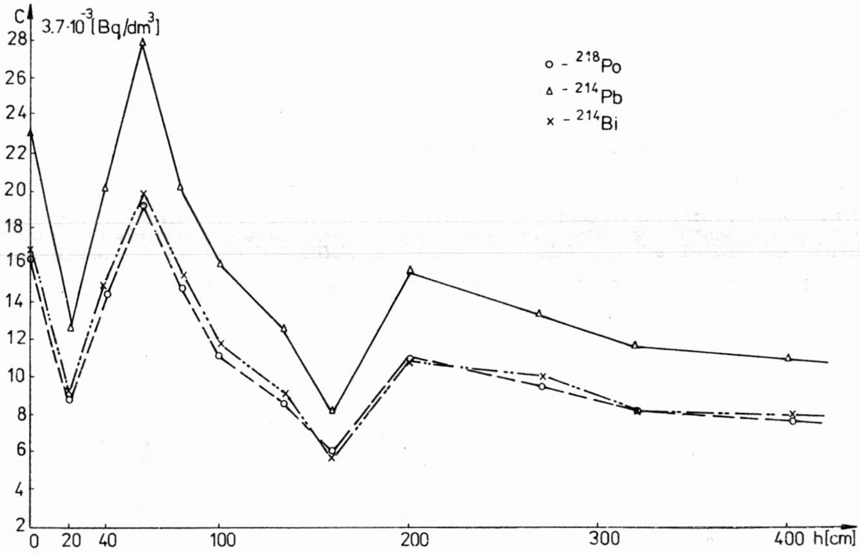

Fig. 3. Concentration changes of radionuclides with heights above ground level in Chorzów

Statistical analysis of results proves that the parameters modelling the radon decay product occurrence are of seasonal character.

Increase in atmospheric pressure in winter and autumn causes increase in concentration of radon decay products in the air, while in spring this tendency is reversed.

Decline of radon decay product concentrations accompanied by temperature increase is observed in winter and spring. In autumn and summer these relations are reversed.

In most cases, higher air humidity is accompanied by lower concentrations of polonium, lead and bismuth. Increased wind velocity in winter causes decline of ^{218}Po, ^{214}Bi, ^{214}Pb contents. The reverse phenomenon was observed in spring. In autumn we did not state such correlations.

Increase in soil temperature at depths $h = 0.5$, 10, 20 cm in the evening and night implies decline of radon decay product concentrations, whereas higher soil temperature during the day causes increase in these concentrations.

4. CONCLUSIONS

1. The variability of dynamics of radon decay products is determined by the following factors: self-cleaning rate, washout, dustfall and amount of dust suspended above the given area, time (i.e. time of day, season), height above ground level, meteorological parameters such as pressure, temperature and humidity of air, wind velocity and direction.

2. ^{218}Po, ^{214}Pb, ^{214}Bi concentrations at the ground level depend on the amount of dustfall in given area. Maximal concentrations were observed in winter.

3. The influence of meteorological parameters on ^{218}Po, ^{214}Pb and ^{214}Bi concentrations is of seasonal and local character.

4. In the industrial areas, higher contents of radon decay products in the air were observed. These contents can be defined by logarithmic-normal distribution, while the contents of radon decay products in recreational areas are characterized by normal distribution.

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PARAMETRY MODELUJĄCE WYSTĘPOWANIE PRODUKTÓW ROZPADU RADONU

Dynamika zmienności występowania produktów rozpadu radonu jest określona wieloma złożonymi procesami, na które mają wpływ: ciśnienie, temperatura, kierunek i prędkość wiatru, a także stan równowagi atmosfery. Określono kryteria wpływu przemysłu energetycznego na radioaktywność powietrza. Są to: opad pyłu, współczynnik zdolności i szybkości wymywania oraz zmiana współczynnika ekstynkcji [6].

Badania nad występowaniem produktów rozpadu radonu w przyziemnej warstwie atmosfery wykonano w latach 1977–1985. Prezentowane wyniki badań są wartościami średnimi stężeń produktów rozpadu radonu.

ПАРАМЕТРЫ, МОДУЛИРУЮЩИЕ ВЫСТУПАНИЕ ПРОДУКТОВ РАСПАДА РАДОНА

Динамика изменчивости выступания продуктов распада радона определена многими сложными процессами, на которые оказывают влияние: давление, температура, направление и скорость ветра, а также состаяние равновесия атмосферы. Определены критерии влияния энергетической промышленности на радиоактивность воздуха. К ним принадлежат: оседание пыли, коэффициент вымывающей способности и быстроты вымывания, а также изменение коэффициента экстинкции [6].

Исследования выступания продуктов распада радона в приземном слое атмосферы были проведены в годы 1977–1985. Представленные результаты исследований являются средними значениями концентраций продуктов распада радона.