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Influence of aerosol concentration and multivariate processing on the indication of radon progeny concentration in air

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Abstract Measurements of radon progeny concentration in air by a radon progeny monitor are sensitive to the concentration of particles suspended in air. Minimum detectable concentration and accuracy of the measurement are determined by random errors of the monitor. Multivariate data processing can be used to decrease these random errors. Influence of aerosol concentration on the measured results of radon progeny concentration in air, by an RGR-30 mining radiometer, operating on the principle of alpha radiation detection from radon progeny deposited on an air filter, were determined in a radon chamber experiment. The air suspended particle concentration and the radon concentration in the radon chamber were controlled and the corresponding radon progeny concentration was measured by the radon progeny monitor. Additionally, count rate from the monitor detector, originating from the alpha activity deposited on the air filter, was measured at intervals of one minute and was then used for the three-interval, and Principal Component Regression (PCR) data processing. It was found that for the aerosol concentration in air from 40 p/cm^3 to approximately 9,000 p/cm^3 indications of the radon progeny monitor depends considerably on the aerosol concentration. Radon daughter concentration normalized to the radon concentration against aerosol concentration varied from 0.3 to 0.9. In mines, where the aerosol concentration generally is high, this phenomenon has little effect on the indication of the radon progeny monitor. At low aerosols concentration, appropriate correction of radon progeny concentration has to be taken. Comparison of random errors when measured signal of the monitor (count rate against time) was processed employing the three-interval method and PCR data processing shows that PCR ensures a lower random error.

Key words radon progeny • measurement • data processing

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Introduction

In 1972, Jacobi published a model describing the behavior of radon and thoron progeny in different air atmospheres [7], taking into account the attachment of radon progeny to aerosol particles, wall deposition and removal by ventilation. This finding results from the model that the unattached fraction of radon progeny can vary from approximately 90% to less than 1%, and the normalized potential alpha energy (PAE) to the energy at equilibrium with radon varied from a few per cents to approximately 70% depending on the concentration of air suspended aerosols and on ventilation rate. Measurements in radon chambers [13, 14, 17] confirm the generally predicted concentrations from the model, although in some cases some discrepancies appeared. Wide variation of the unattached fraction of radon progeny $f = A_u/(A_u + A_a)$ and the unattached fraction of potential alpha energy $f_{PAE} = PAE_u/(PAE_u + PAE_a)$ are confirmed by A_u, A_a – the unattached and attached activity of radon progeny, and PAE_u, PAE_a – the unattached and attached potential alpha energy. Another parameter describing the influence of radon progeny on potential alpha energy concentration is the equilibrium ratio PAE: $e_p = (0.1065A_1 + 0.5154A_2 + 0.379A_3)/A_o$, where A_1, A_2, A_3 are the ^{218}Po, ^{214}Pb, ^{214}B(^{214}Po) concentrations, respectively, and A_o – radon concentration. Knowing the equilibrium ratio, PAE can be determined from measurements of radon concentration in dwellings.

To measure the PAE and radon progeny concentration in air, a number of instruments and methods were developed [3, 6]. The available methods of measurements are based on deposition of the progeny on an air filter and measurement of alpha radiation from the progeny. A one count method [15] employs 5–10 min pumping air through a filter and after a break of a few minutes the total alpha radiation is counted within 5–10 min with a scintillation counter. The PAE is proportional to the count rate and inversely proportional to the detection efficiency, sampling time and a conversion factor depending on the measurement parameters. In the two count method [11], air is filtered within 5 min through a filter and then alpha radiation is measured with a semiconductor detector at two time intervals lasting 3 min each. The first counting interval starts 1 min after the end of pumping, the second – 7 min after the end of pumping. ^{218}Po concentration is calculated from the relation: $^{218}\mathrm{Po} = k_1(n_1 - n_2)/(\varepsilon\eta\nu)$ and $\mathrm{PAE} = k_2 n_2$. Where k_1, k_2 – calibration coefficients; n_1, n_2 – number of counts at intervals 1 and 2; ε – detection efficiency; η – air filter deposition efficiency of radon progeny; ν – air flow rate. Concentration measurement is loaded with an error, resulting from the processing method, depending on the ratio between the radon progeny ^{218}Po: ^{214}Pb: ^{214}Bi and varies in the range +13% to –12% for ^{218}Po and in the range +11% to –9.5% for PAE, when the ratio varies from 1:1:1 to 1:0:0. The three-interval method [18] employs a 5 min deposition of radon progeny on an air filter at a flow rate of 10 $\mathrm{dm^3 \cdot min^{-1}}$ followed by the measurement of total alpha activity in three-intervals 2–5 min, 6–20 min and 21–30 min after the end of deposition. The progeny concentration is calculated from equations of the type $C_i = (k_{1i}n_1 + k_{2i}n_2 + k_{3i}n_3)/(v\varepsilon)$ with $k_{1i}...k_{3i}$ – proportionality coefficients; n_1–n_3 – count number at intervals 2–5 min, 6–20 min, 21–30 min, respectively; v – air flow rate; ε – detection efficiency; i = 1–3 for ^{218}Po, ^{214} Pb, ^{214}Po, respectively.

Radon progeny exists in air as the unattached fraction forming clusters of 1–10 nm in diameter, and the attached fraction where the diameters depend on the diameter of aerosols suspended in air. Measurements of the attached and unattached radon progeny are done by deposition of radon progeny on an "open face" filter and deposition on another filter with a wire screen, or diffusion battery, filtering the unattached progeny [1, 2, 4, 19]. The unattached progeny fraction is the difference of activity deposited on both filters. A portable radon/radon progeny monitor for measurement of attached and unattached radon progeny has been developed [16].

A radon mining radiometer RGR for the measurement of radon progeny in air was investigated in a radon chamber at varying, controlled concentration of suspended aerosols. The aim of the investigations was to check how the indication of radon progeny concentration varies with aerosol concentration. Apart from the radon concentration, the count rate from radiometer detector against time was measured that permitted signal processing by other methods. The investigated RGR radiometer operates on the principle of measurement of total alpha activity of radon daughters deposited on a glass fiber air filter at two time intervals [5, 11]. The aim of the experiment was also to see how the errors of radon progeny measurements depend on data processing. So, count rates from the detector of the radiometer against time were used for the three-interval and Principal Component Regression methods of signal processing.

Measuring arrangement

Measurements of radon progeny concentration were carried out in a radon chamber in the arrangement shown in Fig. 1. Volume of the radon chamber was 0.8 $\mathrm{m^3}$. Volume of the sealed radon source chamber was 5 $\mathrm{dm^3}$ at a radon concentration approximately of 10 $\mathrm{Bq/cm^3}$. ^{222}Rn in the radon source chamber was produced by disintegration of an open ^{226}Ra source. Radon from the radon source was forced to enter into the radon chamber in a closed loop by an air pump and when the valves of the radon chamber and the radon source RV and V were open. The same RV valves of the radon chamber allowed to take air samples from the radon chamber to a radon concentration gauge LC. Aerosol concentration in the radon chamber was measured by an LAS-X aerosol spectrometer. The RGR radiometer measured the total decay product concentrations deposited on the glass fiber air filter (no separate measurement of unattached radon daughters were performed). Air flow of the RGR was 2 $\mathrm{dm^3/min}$ within 5 min (10 $\mathrm{dm^3}$ sample). Cigarette smoke served as aerosols in the radon chamber which was equipped with a window and rubber sleeves, (not shown in Fig. 1), allowing for observation and manipulation the RGR radiometer.

The aerosol concentration was measured with the LAS-X aerosol spectrometer in differential mode. An example of aerosol spectrum from the cigarette smoke employed during the measurements is shown in Fig. 2. It can be noticed that the maximum aerosol diameter does not exceed 0.6–0.7 μm. LAS-X measurements were carried out at an air flow rate of 2 $\mathrm{cm^3/s}$ and 1 $\mathrm{cm^3/s}$ for high aerosol concentration.

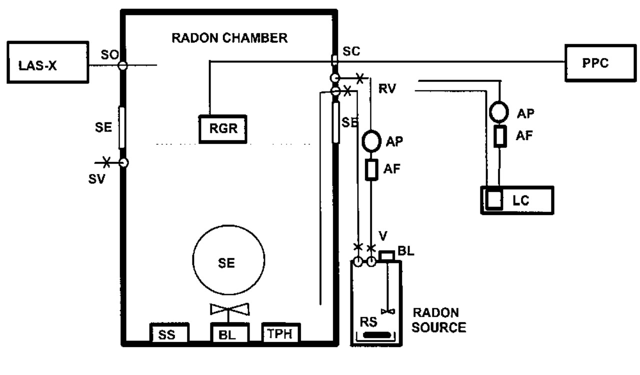

Fig. 1. Block diagram of the measuring arrangement. LAS-X – aerosol spectrometer (Grimm, Labortechnik GmbH, Germany); RGR – mining radiometer type RGR-30 (Institute of Nuclear Chemistry and Technology, Poland); RS – open ^{226}Ra source; LC – radon concentration gauge; PPC – programmable pulse counter; AP – air pump; AF – air filter; SE – sealed entrance opening; SO – sealed opening allowing to connect the aerosol spectrometer; SC – sealed connector; SV – valve with rubber sealing allowing to introduce radon into the radon chamber with a medical syringe; RV – radon chamber valves allowing to introduce radon from the radon source; V – radon source valve; SS – smoke (aerosol) source; BL – blower; TPH – temperature, pressure, humidity gauges.

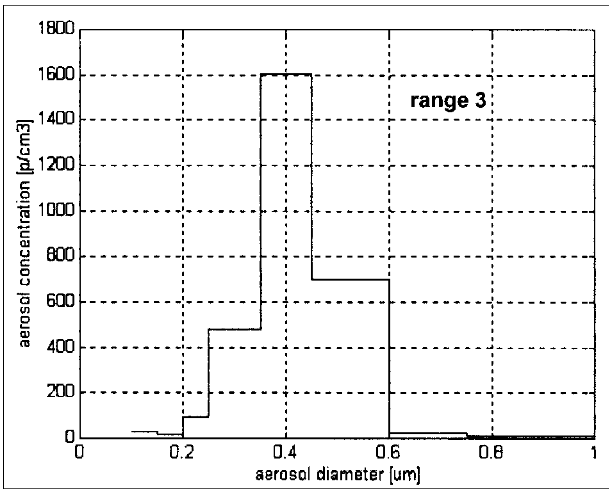

Fig. 2. Differential spectrum of diameters of cigarette smoke aerosols.

Measurements were carried out in the following way. The investigated RGR radiometer was placed together with a lit cigarette inside the radon chamber, a portion of radon was introduced into the chamber and the air inside the chamber was mixed with a blower. Air sample from the radon chamber was taken, in a closed loop, into the Lucas cell of the radon concentration gauge, and the chamber was left for a time longer than 3 h until radiation equilibrium was reached. After that period, the RGR monitor was switched on and the measurement of radon progeny and alpha potential energy concentration was made. Aerosol concentration was measured. Readings of temperature, air pressure and humidity were taken. Additionally, count rate of the RGR detector against time was measured with a programmable pulse counter within a period of 30 min. To enable measurement of count rate against time, standard RGR-30 was modified so that pulses from the detector that are fed to a microprocessor for processing were also fed to the programmable pulse counter. Radon concentration was varied by introducing various amounts of radon into the radon chamber from the radon source. Similarly, the aerosol concentration was changed by a smoldering shorter or longer piece of cigarette. A series of 21 such measurements were made. During measurements, the aerosol concentration varied from 40 to 12,000 p/cm^3, and that of radon in the range 840 to 14,300 Bq·m^{-3}. Radon progeny and potential alpha energy concentration indicated by the RGR-30 radiometer used in the experiment are given by the equations [5]:

$$
\begin{aligned}
&{}^{218}\mathrm{Po} = 2.19(\mathrm{N}_1 - \mathrm{N}_2)\ \mathrm{k} && [\mathrm{Bq \cdot m^{-3}}]\\
&{}^{214}\mathrm{Pb} = 0.55\ \mathrm{N}_2\ \mathrm{k} && [\mathrm{Bq \cdot m^{-3}}]\\
&{}^{214}\mathrm{Bi} = (1.1\ \mathrm{N}_2 - \mathrm{N}_1)\ \mathrm{k} && [\mathrm{Bq \cdot m^{-3}}]\\
&E = 3.2 \times 10^{-3}\ \mathrm{N}_2\ \mathrm{k} && [\mu\mathrm{J \cdot m^{-3}}]
\end{aligned} \tag{1}
$$

where: N_1 is the count number at a time interval of 6 to 9 min since the start of sampling; N_2 – is the count number at a time interval of 12 to 15 min since the start of sampling; k – is the calibration coefficient. The total RGR measuring cycle, including pumping air through the filter, lasted 15 min. Alpha activity was measured by a semiconductor detector. Results of measurements are presented in Figs. 3 and 4.

Influence of aerosol concentration on gauge indication

To investigate the influence of aerosol concentration on the indication of RGR monitor, the ratio of radon daughters

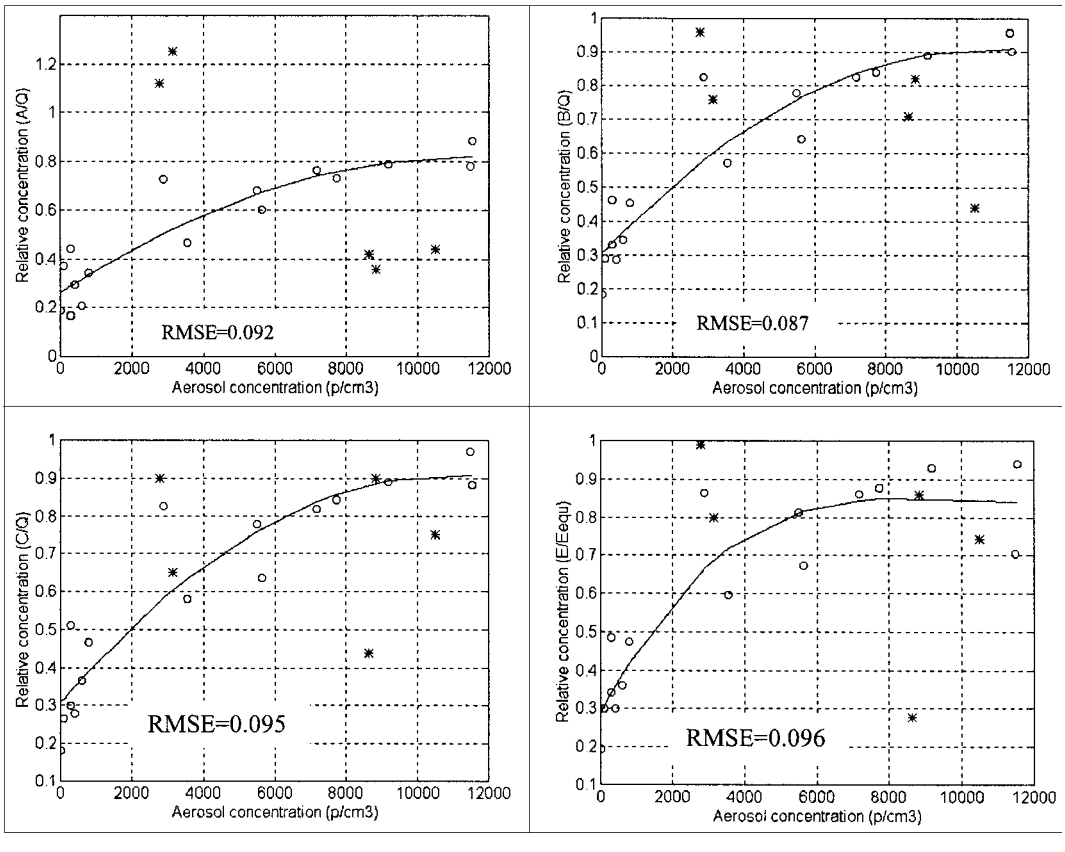

Fig. 3. Relative concentration of ^{218}Po (A/Q), ^{214}Pb (B/Q), ^{214}Bi (C/Q) and alpha potential energy (E/E_{equ}) against aerosol concentration. A, B, C, Q – measured ^{218}Po, ^{214}Pb, ^{214}Bi, and radon concentration in (Bq·m^{-3}); E_{equ} – computed alpha potential energy at radiation equilibrium when concentration of ^{218}Po = ^{214}Pb = ^{214}Bi is equal to ^{222}Rn concentration; o – measured values taken for computation of regression curves (continuous line); * – rejected measurements in regression curves computation.

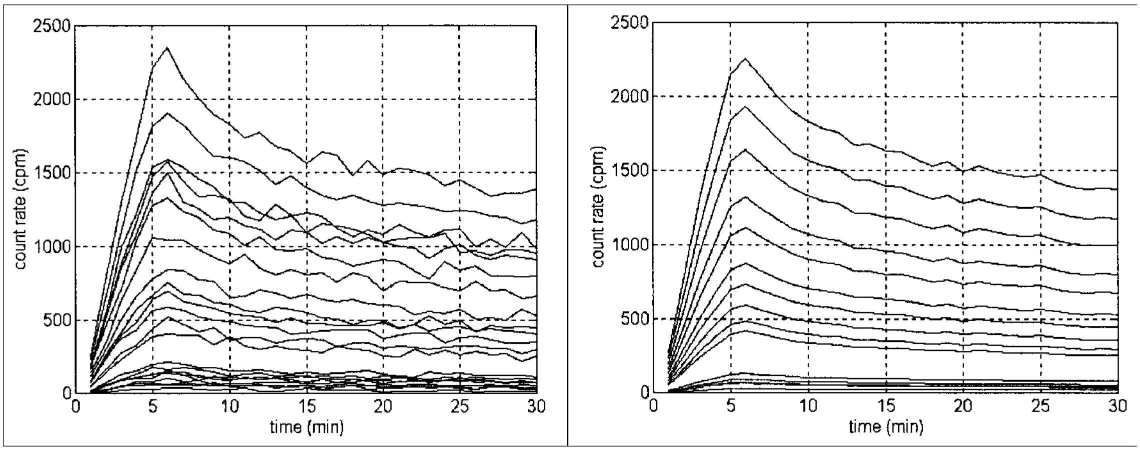

Fig. 4. Measured 1 min count rates from the RGR radiometer (left) and PCR processed count rates against time (right).

concentration to the radon concentration in the radon chamber was calculated and such ratios against aerosol concentration are shown in Fig. 3. In the case of potential alpha energy, the ratio of measured energy E to the energy at equilibrium state E_{equ} is shown in Fig. 3. The equilibrium potential alpha energy was computed from the relation:

$$\text{PAE} = \frac{A}{\lambda_A} E_A + \frac{B}{\lambda_B} E_B + \frac{C}{\lambda_C} E_C \tag{2}$$

A, B, C – activity of ^{218}Po, ^{214}Pb, ^{214}Bi; λ_A, λ_B, λ_C – decay constants of A, B, C; E_A, E_B, E_C – energy of alpha radiation related to A, B, C.

When the radon progeny concentration ^{218}Po = ^{14}Pb = ^{214}Bi is equal to the radon concentration Q. Five measurements that seriously differed from the regression curve for A/Q concentration were rejected and were not taken neither for computation of regression curves nor for root mean square error (RMSE) calculation. The RMSE of measured concentrations in respect to regression line is given in Fig. 3. Large dispersion of measured points in respect to the regression curves, seen in Fig. 3, can be explained by random errors of count numbers due to statistics of radiation decay. This is especially significant when the radon progeny concentration is proportional to the difference of counts at two time intervals N_1–N_2. Other reasons for the dispersion is the air flow rate instability and errors of measurement of aerosol concentration. Regression curve $y = a_o + a_1x + a_2x^2$ describes the concentration A/Q, B/Q, C/Q and the curve: $y = a_o + a_1x + a_2x^2 + a_3x^3$ describes the E/E_{equ}, where: y is calculated concentration and x measured concentration.

It can be seen from Fig. 3 that the indication of radon progeny monitor depends considerably on aerosol concentration. The radon progeny normalized to radon concentration increases from approximately 0.3 at an aerosol concentration of 40 p/cm^3 and reaches a "saturation" level at about 8,000–9,000 p/cm^3. Indication of radon progeny concentration is three times lower, at very low aerosol concentration, in respect to the indication at the "saturation" level. In respect to mines, where aerosol concentration generally is high, this phenomenon has little effect on indication of the radon progeny monitor. In case the monitor is used in places with low concentration of air suspended aerosols, the aerosol concentration should be measured and appropriate correction considered.

It can also be seen from Fig. 3 that the regression curve A/Q is by 14% lower than the B/Q and C/Q curves. This means that the indication of relative concentration of ^{218}Po against aerosol concentration is lower than the concentration of ^{214}Pb and ^{214}Bi. From the physical point of view such a situation is impossible. This can only be explained by an error of calibration of the RGR radiometer. Regression curve of potential alpha energy normalized to the energy when all the radon progeny is at radiation equilibrium and varies from 0.3 to 0.85 at high aerosol concentration.

Environmental Measurement Laboratory and Lawrence Berkeley Laboratory measured the unattached fraction and equilibrium factor in a room at high concentration of cigarette smoke [14]. The measured PAE equilibrium ratio was 0.82 that reasonably well coincides with the value 0.85 shown in Fig. 3 at high aerosol concentration.

Three-interval data processing

Three-interval data processing, from the mathematical point of view, is a very promising method. Set of three equations can be written for three count numbers n_1, n_2, n_3 registered at three counting intervals t_1, t_2, t_3 permitting to calculate three unknown variables of ^{218}Po, ^{214}Pb, ^{214}Bi concentration. The set of equations has the form:

$$\begin{aligned} n_1 &= (k_{11}A\varepsilon_1 + k_{12}B\varepsilon_2 + k_{13}C\varepsilon_2)\nu \quad [c/t_1] \\ n_2 &= (k_{21}A\varepsilon_1 + k_{22}B\varepsilon_2 + k_{23}C\varepsilon_2)\nu \quad [c/t_2] \\ n_3 &= (k_{31}A\varepsilon_2 + k_{32}B\varepsilon_2 + k_{33}C\varepsilon_2)\nu \quad [c/t_3] \end{aligned} \tag{3}$$

For a 5 min radon progeny deposition time, the coefficients k_{11}...k_{33} describe how many times higher is the activity present in the selected time interval when an activity of 1 Bq/min is continuously deposited within 5 min on the air filter. A, B, C – radon progeny concentrations of ^{218}Po, ^{214}Pb, ^{214}Bi, respectively; ε_1 – registration efficiency for ^{218}Po including alpha detection efficiency, air filter deposition efficiency and radon progeny loses on the way to the air filter due to plate out effect to the walls of air duct; ε_2 – registration efficiency for ^{214}Pb and ^{214}Bi; ν – air flow rate (dm^3·min^{-1}). The coefficients k_{11}...k_{33} are calculated from simulating computations for decay series of radon progeny when only ^{218}Po or only ^{214}Pb or only ^{214}Bi are deposited on the air filter. Simulated alpha activity of the radon progeny deposited on the air filter is shown in Fig. 5. Alpha activity in Fig. 5 was computed on the assumption of constant rate deposition of radon progeny on the air filter. Introducing numeric values for ε_1, ε_2 and $k_{11}...k_{33}$ coefficients then solving the set of such equations, the achieved relations allow to compute radon progeny concentration in the form:

$$\begin{aligned} A &= (n_1a_1 + n_2a_2 + n_3a_3)/v \quad [\mathrm{Bq{\cdot}m^{-3}}] \\ B &= (n_1b_1 + n_2b_2 + n_3b_3)/v \quad [\mathrm{Bq{\cdot}m^{-3}}] \\ C &= (n_1c_1 + n_2c_2 + n_3c_3)/v \quad [\mathrm{Bq{\cdot}m^{-3}}] \end{aligned} \tag{4}$$

where: $n_1...n_3$ – are the count numbers at time intervals $t_1...t_3$ determined from count rates shown in Fig. 4, by summing count rates at the time interval of interest, $a_1...a_3$, $b_1...b_3$, $c_1...c_3$ are constant coefficients. Potential alpha energy (PAE) is computed from eq. (2). Simulated computations showed that the 15 min RGR-30 measuring cycle gives unsatisfactory measured results in the three-interval data processing model because of large random errors. The measuring cycle has to be prolonged to at least 30 min in order to reduce random errors. Three-time-interval processing ensures lower systematic (model) errors of measurements than two-interval processing, but the random error due to counting statistics is higher as three count numbers loaded with random errors are involved in computations (propagation of errors). It was found from simulations that, for a selected 30 min measuring cycle including 5 min radon progeny deposition on the air filter, the lowest random errors due to pulse counting statistics are achieved for counting intervals t_1 = 1–7 min, t_2 = 8–20 min and t_3 = 21–30 min from the start of deposition of the radon progeny on the air filter [8, 9]. The same 16 measurements that were used for computation of regression curves in Fig. 3 were used for data processing according to eq. (4). A Matlab program was used for simulations and computations of radon progeny concentrations.

The computed radon progeny and PAE concentration against the measured concentration, for the same registration efficiency of ^{218}Po and the remaining radon progeny $\varepsilon_1 = \varepsilon_2 = 0.2$, are shown in Fig. 6. As can be seen, in the three-interval model of data processing, the indication for ^{218}Po is lower (slope of regression line S_A = 0.90) than the

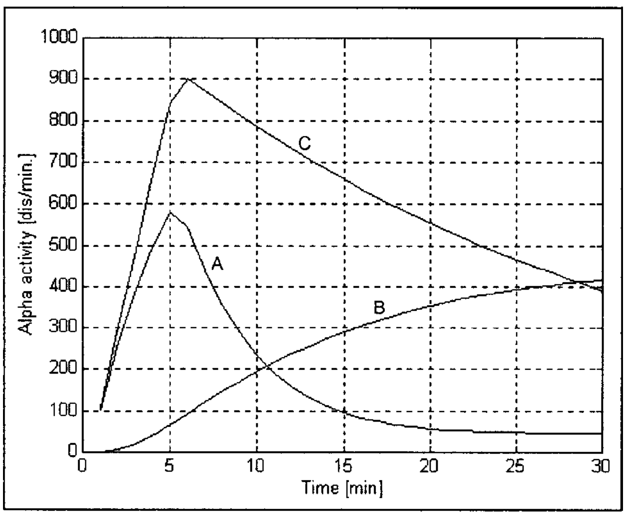

Fig. 5. Simulated alpha activity deposited on an air filter when a 200 Bq·min^{-1} activity is continuously deposited within 5 min. A – only ^{218}Po is deposited; B – only ^{214}Pb is deposited; C – only ^{214}Bi is deposited.

indication for ^{214}Pb and ^{214}Bi (S_B = 1.08, S_C = 0.97) which, from the physical point of view, is impossible. Lower indication for ^{218}Po can be explained by the fact that the real registration efficiency for each radon progeny is not the same. The registration efficiency ε, apart from the detection efficiency of incident radiation on the detector, also includes a decrease of a number of radon progeny particles due to attachment to the walls of air duct on its way to the air filter, and additionally by loses of radon progeny that are not deposited on the air filter and pass through it or are deeply deposited in the filter and are not detected. All these effects are especially important for ^{218}Po which contains a much higher unattached fraction than ^{214}Pb and ^{214}Bi has lower alpha radiation energy and higher deposition loses on the air filter. The slope of regression lines for each radon progeny in Fig. 6 shows how much indications of three-interval data processing differ from the two-interval data processing employed in the RGR radiometer.

To improve ^{218}Po indication of three-interval data processing model, other values for ε_1 were taken and the measured data were processed. For $\varepsilon_1 = 0.153$ and $\varepsilon_2 = 0.2$ data processing gives: the slope of regression lines for ^{218}Po, ^{214}Pb, ^{214}Bi, S = 1.15, 1.01, 1.01, respectively and for PAE S_E = 1.01. The three-interval data processing model confirms also that the indication of the RGR-30 for ^{218}Po should be higher by 15%, which well agrees with 14% resulting from regression curves for the RGR-30 shown in Fig. 3. The mean value of PAE measured by the RGR-30 and from three-interval data processing for 16 measurements, in both cases, is 24.1 μJ·m^{-3}. The registration coefficients ε_1 and ε_2 were set to obtain equality of PAE for the RGR-30 and three-interval model.

Principal component data processing

Principal component repression data processing (PCR) applied to raw results of measurements by the RGR radiometer removes a considerable part of random fluctuations on measured count rate and, consequently, decreases measuring random errors [10, 12]. The effect of removal of random fluctuations is illustrated in Fig. 4 where the measured count rate against time and PCR processed count rates are shown. The 16 measurements used in three-interval data processing were taken for PCR processing. Count rates against time in the form of a matrix **X** (16 row, 30 columns), radon progeny concentrations of ^{218}Po, ^{214}Pb, ^{214}Bi in the form of matrix **Y** (16 rows, 3 columns) were PCR processed employing Matlab functions. As a result of PCR processing, the matrix of regression coefficients **B'** (30 rows, 3 columns) is achieved and the estimated radon progeny concentration of A_{est}, B_{est}, C_{est} (^{218}Po, ^{214}Pb, ^{214}Bi) is computed from the relation:

$$\mathbf{Y}_{est} = \mathbf{X}\mathbf{B}'. \tag{5}$$

The potential alpha energy was computed from eq. (2) replacing A by A_{est}, B by B_{est}, C by C_{est}. The results of PCR processing and computation are shown in Fig. 7. The slope of regression lines is close to unity and is: 1.01, 0.99, 0.99 and 0.99 for ^{218}Po, ^{214}Pb, ^{214}Bi and PAE, respectively. The RMSE for ^{218}Po, ^{214}Pb, ^{214}Bi and PAE is 360 Bq·m^{-3}, 95 Bq·m^{-3}, 181 Bq·m^{-3} and 4.23 μJ·m^{-3}. The RMSE of PCR processing for radon progeny is considerably lower than the RMSE for the three-interval processing amounting to 469 Bq·m^{-3}, 507 Bq·m^{-3}, 285 Bq·m^{-3} and 4.35 μJ·m^{-3} for ^{218}Po, ^{214}Pb, ^{214}Bi and PAE, correspondingly (Fig. 6). The RMSE for PAE computed from the PCR processed progeny concentration is quite high due to one measurement deviating largely from the regression curve and is comparable to that of the three-interval processing model. Rejecting the highly deviating measurement, the RMSE = 0.087 μJ·m^{-3} is achieved.

The PCR processing method quite well fits to the processed values of radon progeny concentration to the measured values (slope of regression lines close to unity) and removes a considerable part or random error due to statistics of count number fluctuation, but also due to other random errors. It is worth of mention that the PCR method is unable to check if the processed ^{218}Po concentration is correct from the physical point of view.

Conclusions

The data obtained for the RGR radiometer show that the ratio of radon progeny to radon concentration in the radon chamber varied from approximately 0.3 to 0.9 when the concentration of air suspended aerosols varied from 40 to 8,000 p/cm^3. At an aerosol concentration higher than 8,000 p/cm^3 a "saturation" of regression curve is reached, the ratio of radon progeny to radon concentration changes very little and can be considered constant. This means that the indications of radon progeny depend considerably on the air suspended aerosol concentration and should be taken into account when the measurements are carried out at aerosol concentration lower than 8,000 p/cm^3. The measurements were carried out at about constant relative humidity, using one type of aerosols from cigarette smoke. With a different ambient relative humidity or different aerosol diameter, the aerosol concentration can change the "saturation" level. The RGR mining radiometer is designed for operation in mines where high aerosol concentration is observed. In such a case, the radon progeny concentration indicated by the RGR monitor is correct.

Three-interval data processing model and Principal Component Regression model were used for processing measured data. The three-interval data processing method eliminates systematic errors connected with the manner of data processing. To keep low random errors due to pulse counting statistics, the method requires at least a 30 min long measuring cycle. Two registration coefficiencies of radon progeny are needed. One for ^{218}Po registration, the other for ^{214}Po. If only one registration efficiency is used the concentration of ^{218}Po is incorrect, it is too low. The equations for calculation of radon progeny concentration are derived on the assumption of continuous constant rate of deposition of radon progeny on an air filter during measuring cycle. This in practice may not be true and can lead to errors.

The PCR data processing removes fluctuations of any origin from the measured data such as count rate fluctu-

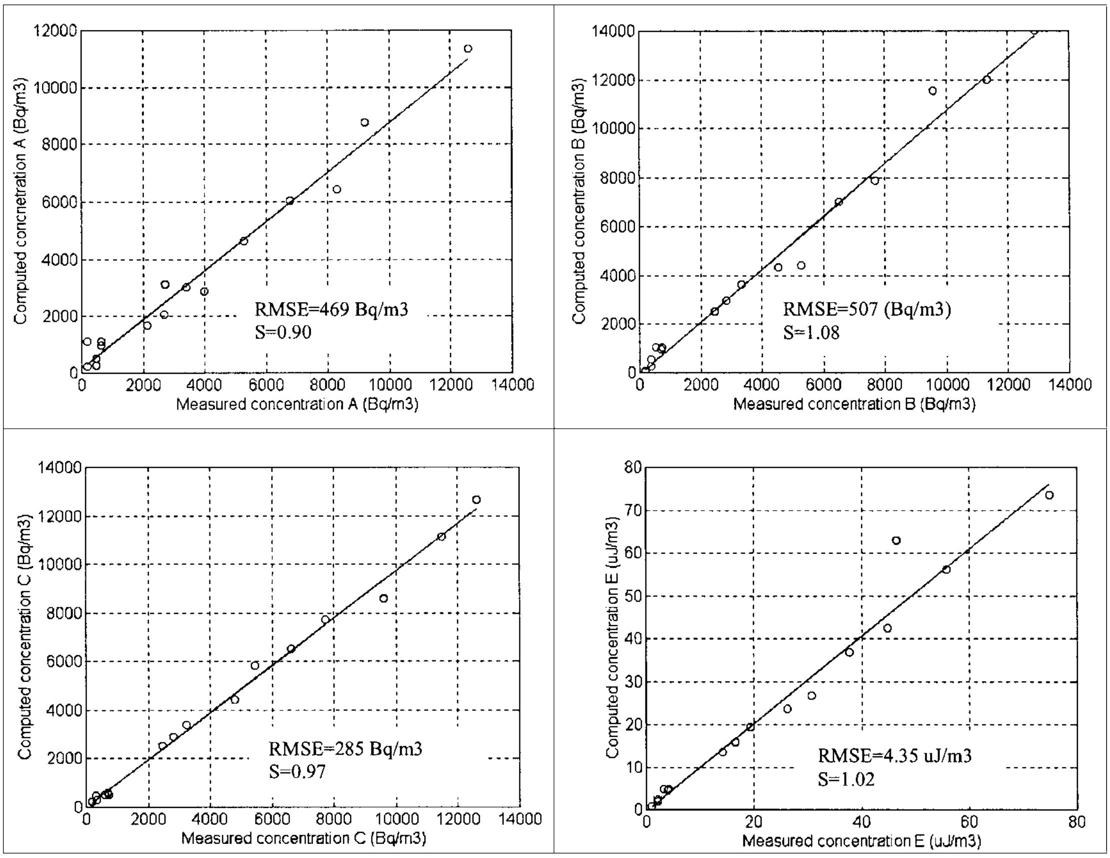

Fig. 6. Radon progeny and potential alpha energy concentration computed from the three-interval data processing model against measured concentration at $\varepsilon_1 = \varepsilon_2 = 0.2$. RMSE – root mean square error; S – slope of regression line; A, B, C, E – ^{218}Po, ^{214}Pb, ^{214}Bi, PAE concentration.

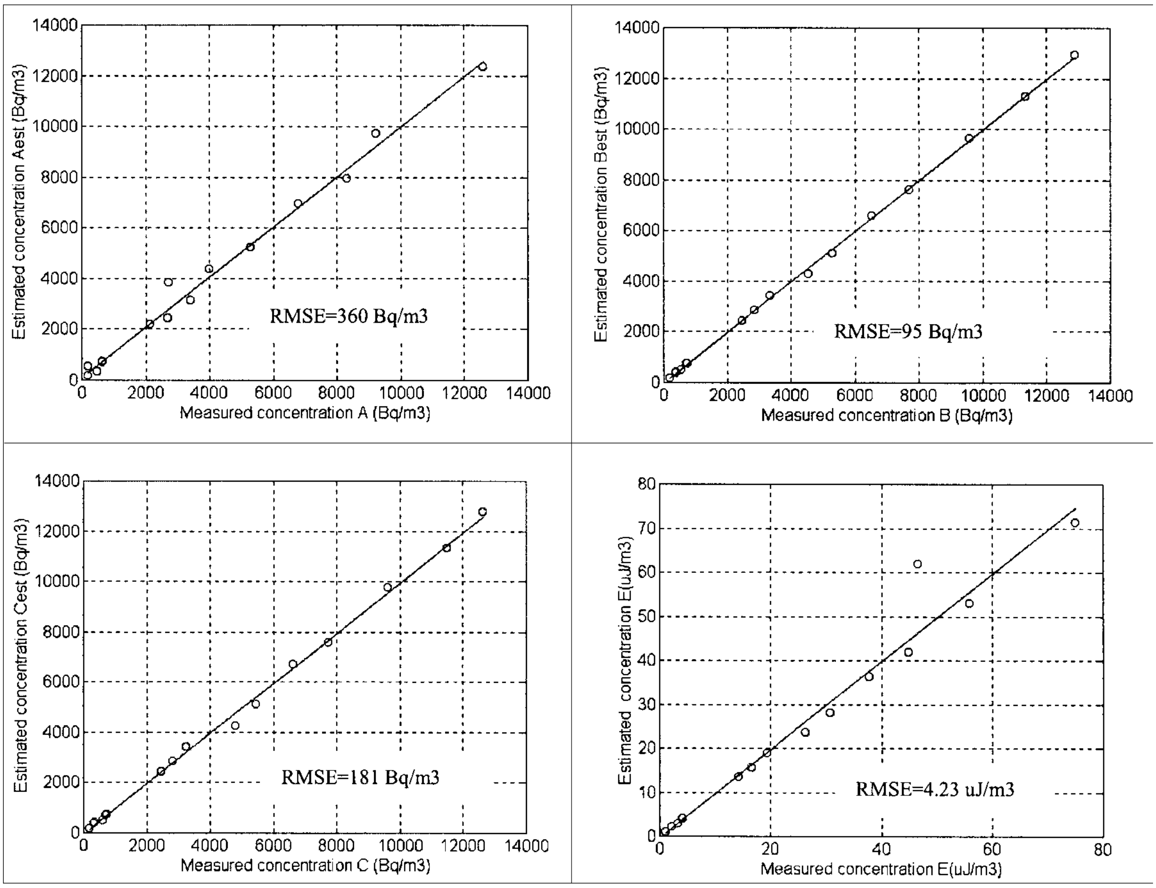

Fig. 7. PCR estimated A_{est}, B_{est}, C_{est} and PAE_{est} concentration against measured concentration A, B, C, E of radon progeny.

ations, deposition rate fluctuations etc., and makes fit to reference samples. The PCR processing of measured count rates against time during the 30 min measuring cycle showed that Root Mean Square Error on radon progeny was considerably lower than in the case of three-interval data processing. Thus, the application of the PCR processing model can improve both the accuracy and the lower detection limit of radon progeny concentration.

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