Faculty of Physics, Laboratory of Nuclear Physics and Technology

Measurement of radon and its progeny concentration in air

Kalina Mamont-Cieśla[1], Magdalena Piekarz[1], Zuzanna Podgórska[1], Jan Pluta[2], Dariusz Aksamit[1,2] (translation)

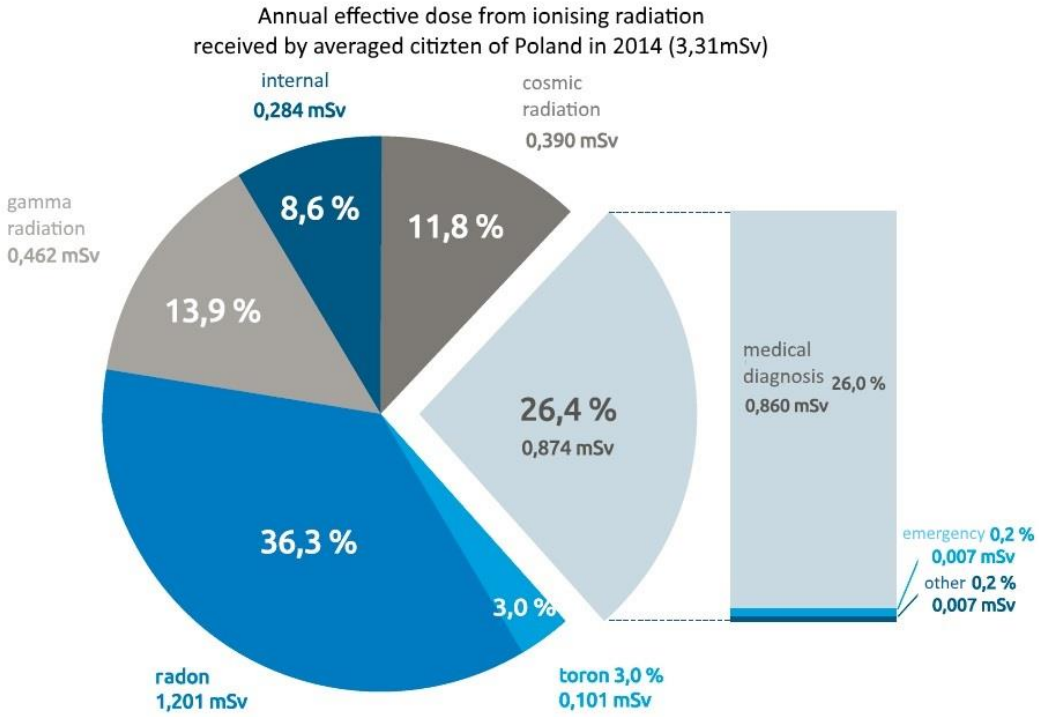
---

[1] Central Laboratory for Radiological Protection, [2] Faculty of Physics, WUT

version 1.0, 13.09.2015

Radon is a naturally occurring radioactive noble gas, few times heavier than the air. Two main radioisotopes are Rn-222 ("radon", $T_{1/2}$=3,8 days) and Rn-220 ("toron", $T_{1/2}$=56s), a decay products of radium Ra-226 and Ra-224 respectively.

It is the main source of annual radiation dose received by average citizen of Poland, as depicted in the Figure 1, taken from annual report of Polish Atomic Agency President:



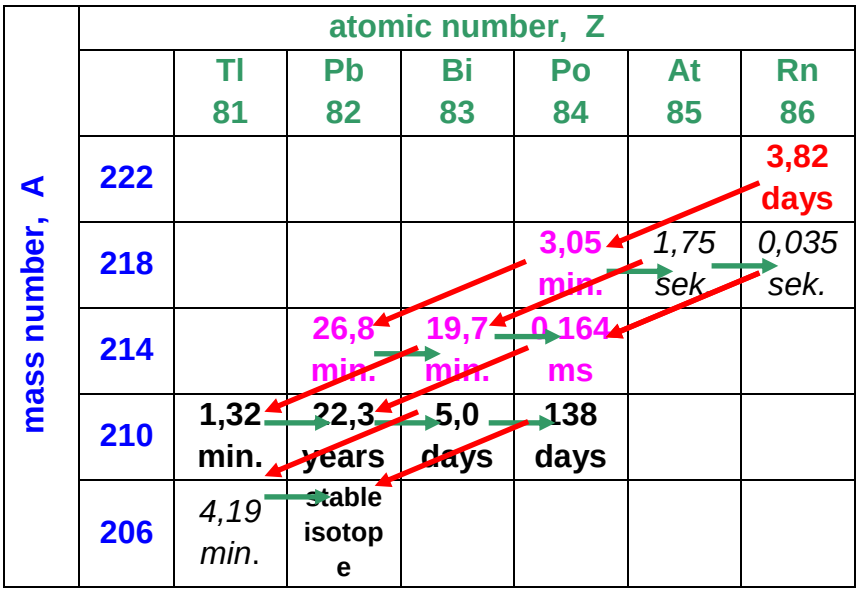
Such big contribution is a result of radon decay scheme. Firstly, radon and its progeny decays through alpha (and beta) decay, so weighting factor for biological damage is 20 times bigger than for gamma with this same energy. Secondly, as a gas radon is inhaled with atmospheric air during normal breathing, so we have internal contamination, mainly in respiratory track.

Purpose of this exercise is to gain knowledge about radon and its progeny: origin of radon and its place in the decay schemes, pathways responsible for indoor radon concentration, learn the ways to measure radon concentration, perform calculation of radon concentration in laboratory using measurements of its progeny collected on the filter and the calculation for effective dose caused by this amount radon.

1. Basic information and quantities:

One should read this script, before exercise. For ambitious students [1] K. Mamont-Cieśla - *„Radon - promieniotwórczy gaz w środowisku człowieka”* is recommended, available on the web site of Laboratory www.lfit.pw.edu.pl or other in English.

Below radon Rn-222 and its decay chain is presented:



The most important decay product of Rn-222 are alpha-emitting radioisotopes:

- polonium ^{218}Po ($T_{1/2}$=3,05 minutes),
- polonium ^{214}Po ($T_{1/2}=1{,}64\cdot10^{-4}$ seconds)

and beta-emitting:

- lead ^{214}Pb ($T_{1/2}$=26,8 minutes)
- bismuth ^{214}Bi ($T_{1/2}$=19,7 minutes).

Main dose received from radon is due to exposure to its progeny. For this reason quantity “PAEC” was introduce, meaning summed total energy of all decay products per mother nuclei, given in J/m^3. Term “potential” refers to “ability” of atom to further decays.

As radon half-life is much longer than its progeny, it is possible to obtain balance between mother and daughter nuclei. For Rn-222 it is obtained after 3 hours. For full balance sum of PAEC progeny gives a value of 0,18 Bq per 1 nJ.

Due to ability of progeny to adhese to objects (so-called palate-out phenomena) ratio of balance – F – could vary from 0 (all products are removed from air) to 1(no product removal). Typically value at home is 0,4.

To obtain effective dose one can use formula $E=PAEC\cdot DCF\cdot t$, where DCF – dose conversion factor, recommended by ICRP Publication 103 as 2,46 Sv/(J·h·m^{-3}), t – time of exposure in hours.

For now there are no regulations in Poland for legal radon concentration. Average is 50Bq/m^3. World Health Organization, recommends to assure concentration below 300 Bq/m^3 in living houses, what corresponds with effective dose of about 10 mSv/year.

2. Measurements:

2.1 Purpose and measurement idea

Purpose of our measurement is to assess radon concentration in air at laboratory using indirect method, through measurement of Potential Alpha Energy Concentration – PAEC – of radon progeny.

Idea lies on the relations between radon concentration in air and PAEC of short-lived progeny, given by formula below:

$$C_{Rn} = E_{\alpha} \cdot 0{,}18/F$$

where:

- C_{Rn} – radon concentration in air [Bq/m^3]
- E_{α} – PAEC, Potential Alpha Energy Concentration [nJ/m^3]
- 0,18 – calculation coefficient [Bq/nJ] from PAEC (E_{α}) to radon concentration (C_{Rn}). Coefficient is equal to radon concentration at unit of PAEC with radioactive balance ratio F=1.
- F – real radioactive balance ratio in studied air

2.2 Measurement equipment:

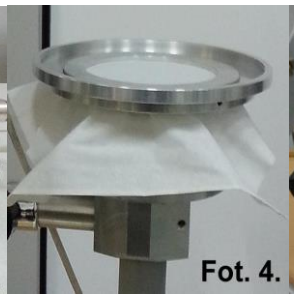
Measurement equipment consist of following items:

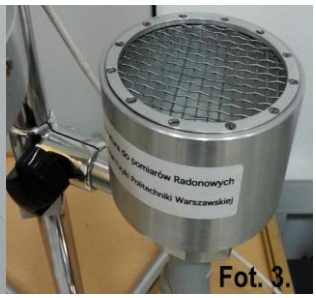
- Set for pumping the air though a paper filter (1 in the Fot.1), with vacuum cleaner as a pomp (2) and thin tissues as filters (3)
- Scintillating probe type SSA-1P for alpha radiation measurement (4). Product datasheet: http://www.polon-alfa.pl/produkty/aparatura-dozymetryczna/sondy/sonda-scyntylacyjna
- Universal radiometer type RUM-1 (5, and Fot.2). Instruction of RUM-1 is the lab.

Fot. 1.

Part (1) is a metal container with grid on the top (Fot.3.). Filter should be mounted from above and held by metal ring as in Fot.4. Pipe from pump is to be mounted from below.

Set should be mounted as in Fot.1 before proceeding further.





2.3 Conducting measurements:

1. **Turn on RUM-1:** following attached instruction. (Warning: it is not allowed to connect or disconnect probe with meter on! One should firstly connect the probe, secondly turn on the device). Supply voltage should be 804 V.
2. **Background measurement:** put a new filter below detector (Fot.5). Set measurement time for 100s. Write down value and its uncertainty
3. **Measurement PAEC of radon progeny**: Mount filter, turn on pomp for 15 minutes. Then turn off the pomp, put filter under scintillating probe tightly. 30 seconds after turning off the pump run 100 second long measurement with RUM-1.
4. **Measurment of number of counts in function of time of collection of radon progeny on a filter:** repeat the measurement described in p. 3 for time of air flow of 10 and 5 minutes. Time of data collection should be set to 100 secunds.

5. **Investigation of decay time of radon progeny** for the filter through which air was passed for 15 minutes. Perform measurements after: 10, 20, 30, 40, etc. minutes. They do not necessarily have the same intervals. Use the time to complete the laboratory classes and collect data for the largest possible number of measuring points.
6. **Measurement of the alpha energy concentration of radon decay products outside the building and at different heights above ground level. (Optional measurement, to be agreed with the lecturer.)**

7. Measurements of radon concentration in soil air
   Details will be given during exercise.
   Perform one background measurement (n_0) and three after pumping (n_1, n_2, n_3) and put into equation:

$$^{222}\text{Rn (kBq/m}^3\text{)} = -0{,}1396n_0 - 0{,}082n_1 + 0{,}1356n_2 + 0{,}086n_3$$