# Feasibility of *in situ* radon monitoring using common GM counters

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## Introduction

Radon ($^{222}$Rn) is an intermediate product in the $^{238}$U decay chain:

$$\ldots\ ^{222}Rn \xrightarrow{\alpha,3.8d}\ ^{218}Po \xrightarrow{\alpha,3.1m}\ ^{214}Pb \xrightarrow{\beta,27m}\ ^{214}Bi \xrightarrow{\beta,20m}\ ^{214}Po \xrightarrow{\alpha,164\mu s} \ldots \quad (1)$$

Being a noble gas, radon (together with its short-lived progeny, Rn+) is the main natural factor for spreading out radioactivity in the environment. Its large-scale monitoring is of scientific interest in two different fields: assessment of the human health radiation risk, and/or investigation of some natural phenomena related to radon exhalation and its propagation in the Earth's crust and atmosphere.

Alpha-detectors, usually used for Rn+ are relatively expensive and are not well suited for field work (being sensitive to ambient air humidity).

We suggest using standard GM counters sensitive to β/γ radiation of $^{214}$Pb and $^{214}$Bi. Their performance as Rn+ detectors is evaluated by long term measurements of the background radiation in uninhabited dwelling rooms in parallel with a classical radon alpha-particles detector.

## Experimental

Two detectors in parallel were used:

- a reference radon monitor RD200M[1] (pulse ion chamber, active volume 200 cm$^3$, factory calibrated with 10% uncertainty);
- a standard GM counter SBM-20[2] (wall thickness of 50µm SS), and
- additional sensors for the temperature, pressure and humidity.

Data was reported every 10min to the Internet platform meter.ac[3].

## Results

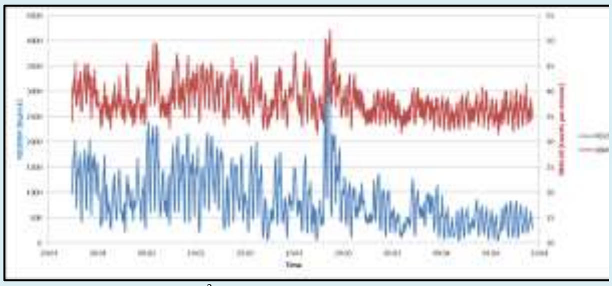
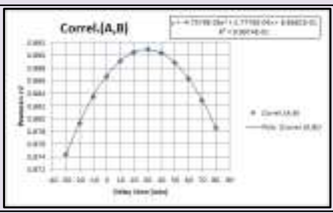


Fig.1 Data, RD200M [Bq/m$^3$] and SBM-20 [cpm] for 3 months observation time

## Data analysis and discussion

Basic assumption: *the temporal variations of the background radiation are due entirely to the Rn levels variations, for the given experimental conditions (isolated room, fixed detectors and surrounding).*

Due to the $^{222}$Rn decay scheme, SBM-20 signal (β) delays relative to the α-rays detected by RD200M. The delay time is determined by maximization of the (α, β) correlation function: $t_d$=29.2min, i.e. 3 steps 10min each.




If this basic assumption is true then the Rn volume concentration reported by RD200M, $A(t_i)$ has to be virtually a linear function of the registered β/γ count rate in detector B at the moment $t_{i+3}$:

$$A(t_i) \approx F(t_i) = BG + b*B(t_{i+3}), \quad i=0...n-1. \quad (2)$$

The coefficient *b* evaluates the SBM-20 efficiency and *BG=const(t)* is a measure for the non-Rn+ background component in the two detectors.

A least-squares solution of (2) yields the 'best' values of the parameters:

BG=-4694.82±0.67, b=143.95±0.02. (3)

The very high value of the correlation coefficient after optimization ($r^2$*(A,F)=0.895*) supports the validity of the basic assumption for the persistency of the non-Rn+ background throughout the observation period.

In order to check the real performance of this calibration, the least-squares approximation (2) was reapplied to observations in the first two months only and the resulting optimal coefficients (*BG, b*) were then used to extrapolate the model forward to the next observations. Results are shown on Fig.3:

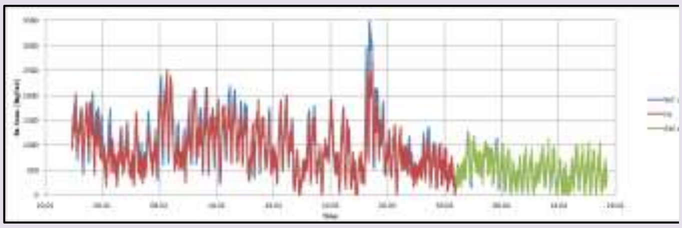


*Fig.3. a) Reference data for the whole period (Ref.data), its approximation for the first two months (Fit) and evaluated data (GM only) for the third month*

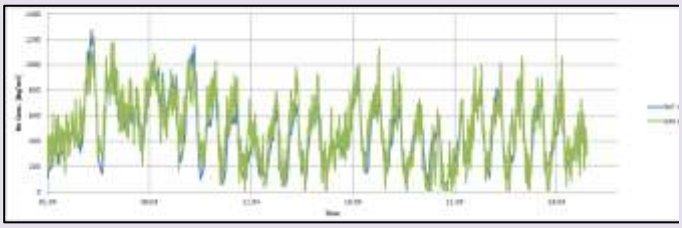


*Fig.3.b) Reference and evaluated data for the third month in a larger scale*

The correlation coefficients for the Fig.3a data are: $r^2$*(Ref.data,Fit)=0.876*, $r^2$*(Ref.data,GM)=0.831*. A certain decrease of the correlation is to be expected; nevertheless it remains rather high which confirms the adequacy of the linear model used here. If (2) is solved for B(t) using the optimal coefficients (3):

$$B(t_{i+3}) \approx A(t_i)/143.95 + 32.61, \quad (4)$$

i.e., the non-Rn+ background of SBM-20 is $BG_{SBM-20} = 32.6\ cpm$ and its sensitivity to Rn+ is $Sens_{SBM-20} = 144 Bq/m^3\ /cpm$. It is only twice worse than the RD200M sensitivity as declared by the producer ($Sens_{RD200M} = 74 Bq/m^3/cpm$)[2]. The main limitation to use GM counters for Rn monitoring remains, however, its high β/γ background (*32.6cpm* in our case which is equivalent to *4700Bq/m$^3$* Rn concentration). If the non-Rn+ contribution from the detector surrounding is not steadily constant then a GM counter could not be used as a radon-only monitor. So, the applicability of GM for radon monitoring is limited to long-term observations at a fixed position in a non-disturbed site.

## Conclusion

The main advantages of GM based radiation detectors are their low cost, robustness and humidity resistance which greatly facilitates the development of dense networks for radon monitoring in the nature. The main drawback of the GM counters is their sensitivity to non-Rn+ components of the local radiation field which deteriorates their signal-to-nose ratio. The results obtained in the present work suggest that GM counters can be successfully used for long-term Rn+ monitoring in a stationary ambience (e.g. underground, in soil gas or in waters).

## References:

[1]. https://www.radonshop.com/ftlab-radon-gas-sensor-rd200m-detektor
[2]. https://www.gstube.com/data/2398/
[3]. https://meter.ac/