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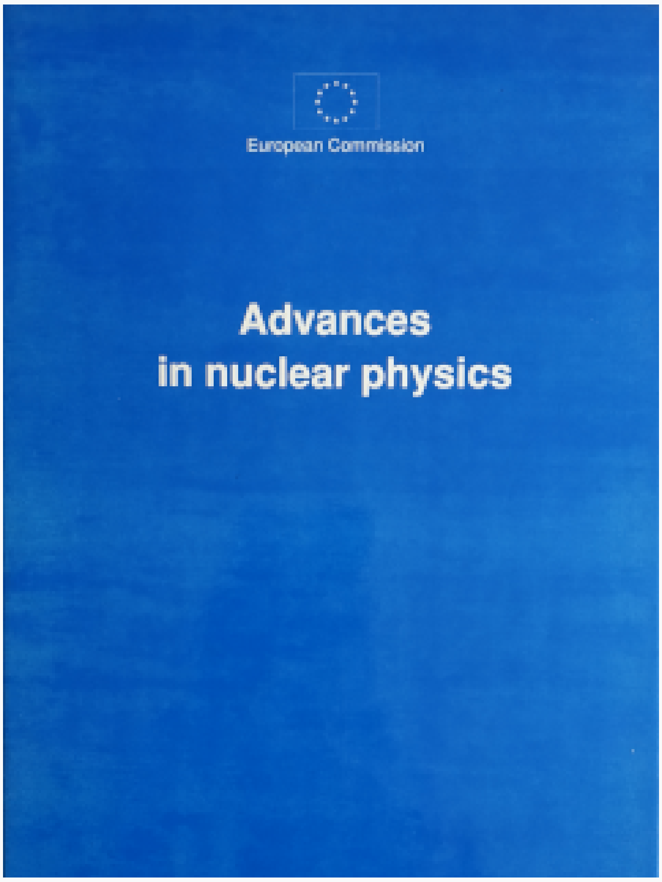

Indoor Radon Measurement in Patras Region Using Activated Carbon

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INDOOR RADON MEASUREMENT
IN PATRAS REGION
USING ACTIVATED CARBON

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SUMMARY

Measurements of Rn concentration in air indoors in Patras area, Greece, have been carried out and are presented in this paper.
The method used is based on George method using activated Carbon which adsorbs Rn and a NaI (Tl) γ-ray detector.
The method determines the γ-ray activity of the Rn decay products.
The Rn level in (pCi/l) and the total error are presented for different geological areas in the region.

I. Description of the project

To determine Rn, a 3X3 NaI (Tl) detector was used to measure the γ-rays emitted by its products Pb-214 and Bi-214. The total radioactivity from the γ-rays of the radon decay products is determined from the absorption peaks of ^{214}Pb (0.242, 0.294 and 0.352 MeV) and of ^{214}Bi (0.609 MeV).

Radon is collected through a charcoal canister of 4 inch diameter containing approximately 100gr of activated charcoal.
The canister is kept sealed prior to this indoors exposure to ensure only radon, from the room being tested, is absorbed in the charcoal. Radon gas emits only α particles which cannot penetrate this canister. Hence, this technique does not count directly radon. It measures it indirectly through Rn daughters, as mentioned above.

To calculate the radon exposure level one needs the following information :

ETIM = Exposure time in hours
DTIM = Time from end of exposure till count time in hours
IWT = Initial weight of canister in grams
FWT = Weight of canister after exposure in grams
BKD = Background of counting system regions of interest
CTS = sample counts in regions of interest
EFF = Detector efficiency for Radon spectrum's regions of interest

NWT = FWT-IWT net weight

The correct calibration coefficient (COEFF) is selected through a table using net weight (NWT) and exposure time (ETIM).

LEVEL = RAD / 1.15 , where

LEVEL is the Radon level in pCi/Liter

RAD = (CTS - BKD)/(EFF * 600 * DEC * COEFF * ETIM) (1)

where

DEC = EXP (-0.0076 * MTIM)

MTIM = (0.5 * ETIM) + DTIM

The system itself, i.e. NaI crystal, a photomultiplier and a canister were placed inside a Pb shield of 10cm thickness.

The system was tested and calibrated. Then the Rn spectrum's regions of interest around the desired γ-peaks (^{214}Pb, 0.242, 0.294 and 0.352 MeV and ^{214}Bi, 0.609 MeV) were set up. The charcoal canisters were exposure open to the room air for 72 hours.

An empirical calibration factor (CF) was calculated by

$$CF = \frac{N}{E.Ts.DF.Rn} \quad . \qquad (2)$$

Several buildings were chosen within Patras larger area, as seen in the map attached herewith.
The samples were kept in a closed room to minimise air draft. The rooms tested were under the earth surface and also in ground floor. A great variation in the measurements was noticed.
The finding are shown in the tables which follow.

II. Errors in measurements

The level of radon is calculated following the different equations described in & 1. Equation (1) has a form which it is possible to deduce the errors in measurements:

RAD = (CTS - BKD)/(EFF * 600 * DEC * COEFF * ETIM) (3)

All the variables being independent, we can apply the partial by-products:

$$\delta\, RAD = (\partial\, RAD/\partial\, CTS) * \delta\, CTS + (\partial\, RAD/\partial\, BKD) * \delta\, BKD$$
$$+ (\partial\, RAD/\partial\, EFF) * \delta\, EFF + (\partial\, RAD/\partial\, DEC) * \delta\, DEC$$
$$+ (\partial\, RAD/\partial\, ETIM) * \delta\, ETIM \qquad (4)$$

$$\partial\, RAD/\partial\, CTS = 1/(EFF * 600 * DEC * COEFF * ETIM)$$

$$\partial\, RAD/\partial\, BKD = -1/(EFF * 600 * DEC * COEFF * ETIM)$$

$$\partial\, RAD/\partial\, EFF = (CTS - BKD)/(EFF^2 * 600 * DEC * COEFF * ETIM)$$

$$\partial\, RAD/\partial\, DEC = (CTS - BKD)/(EFF * 600 * DEC^2 * COEFF * ETIM)$$

$$\partial\, RAD/\partial\, ETIM = (CTS - BKD)/(EFF * 600 * DEC * COEFF * ETIM^2)$$

$\delta\, CTS = \sqrt{(CTS)}$
$\delta\, BKD = \sqrt{(BKD)}$

The efficiency is calculated by means of counting the number of CPM emitted by a reference sample (Ra-226), the result unit being CPM/pCi or CPM/Bq.
So EFF is the result of the count of the reference sample divided by its activity.

$d\, EFF = \sqrt{(Counts)}/Activity$ (for the source of reference)

$d\, DEC = (d\, MTIM/MTIM) * |-0{,}0076|$

d ETIM is function of the user.

The above formulae make the error determination related to each measurement possible (3).
Errors in the calculations are shown in table 2 which follows.

Discussion

The method gives a relative low figure for the estimated error. That gives a good level of reliability.
It is clear from the results shown in table I that, buildings of concrete heavy structure give a much higher Rn concentration indoors. On the other hand limestone geological areas present a high concentration in Rn compared to old quaternary deposits.

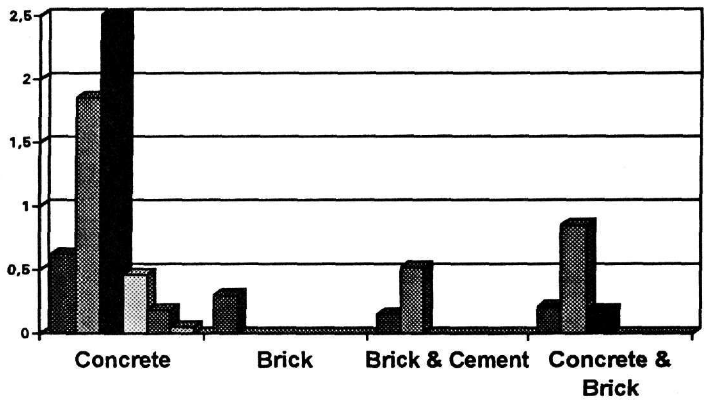
Table 1: Results

Canister #	Soil	Building	Radon Level (pCi/l)	Radon Level (Bq/m^3)
01	Quaternary	Concrete	0,62	0,0167
02	Limestone	Concrete	1,85	0,0500
03	Quaternary	Brick & Cement	0,15	0,0041
04	Quaternary	Brick & Cement	0,52	0,0141
05	Limestone	Concrete	2,50	0,0676
06	Quaternary	Concrete	0,46	0,0121
07	Quaternary	Concrete	0,18	0,0049
08	Quaternary	Brick	0,30	0,0081
09	Weatherings	Concrete & Brick	0,21	0,0057
10	Weatherings	Concrete	0,05	0,0014
11	Quaternary	Concrete & Brick	0,85	0,0229
12	Quaternary	Concrete & Brick	0,18	0,0049

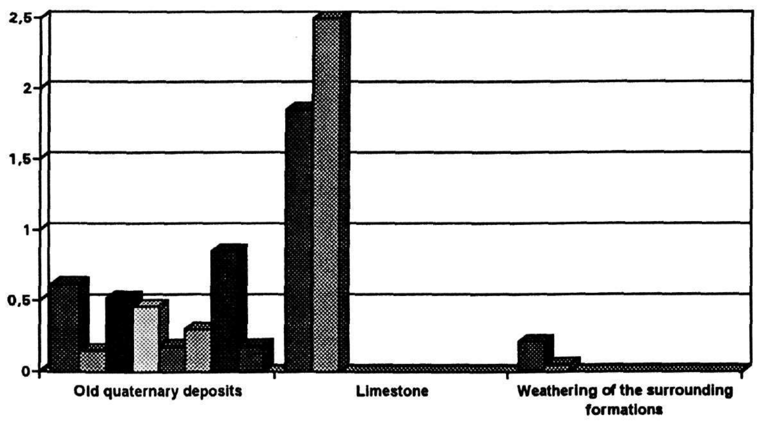
Table 2: Errors in measurement

Canister #	Radon Level (pCi/l)	Radon Level (Bq/m^3)
01	0,62 ± 0,50	0,0167 ± 0,0014
02	1,85 ± 0,38	0,0500 ± 0,0102
03	0,15 ± 0,03	0,0041 ± 0,0008
04	0,52 ± 0,10	0,0141 ± 0,0027
05	2,50 ± 0,60	0,0676 ± 0,0162
06	0,46 ± 0,08	0,0124 ± 0,022
07	0,18 ± 0,02	0,0049 ± 0,0005
08	0,30 ± 0,05	0,0081 ± 0,0014
09	0,21 ± 0,03	0,0057 ± 0,0008
10	0,05 ± 0,007	0,0014 ± 0,0002
11	0,74 ± 0,12	0,0229 ± 0,0032
12	0,18 ± 0,03	0,0049 ± 0,0008

Radon level of different buildings (pCi/l)



Radon level following different geological areas (pCi/l)



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Cable Connections for Indoor-Radon-Level-Measurement with Multichannel-Analyzer Canberra Series 35 Plus