NATURAL RADIOACTIVITY CONTENT
AND RADON EXHALATION RATE
MEASUREMENTS OF ZEOLITES
FOR Project ZEOGYP-BOARD

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RESEARCH ACTIVITIES ON NATURAL RADIOACTIVITY (I)

Gamma spectroscopic determination of natural radionuclides ($^{238}\text{U}$, $^{226}\text{Ra}$, $^{210}\text{Pb}$, $^{232}\text{Th}$, $^{40}\text{K}$ etc) in:

- Soil (more than 2000 surface soil samples have been collected and analysed over Greece and Yugoslavia - Kosovo).
- Lignites and ashes produced in Lignite-fired Power Plants (more than 500 samples).
- Building materials (more than 200 samples).
- Foodstuff.
RESEARCH ACTIVITIES ON NATURAL RADIOACTIVITY (II)

1. Radon ($^{222}\text{Rn}$) exhalation measurements from:
   - raw building materials
   - building structures
2. Radon barrier materials testing.
3. Thoron ($^{220}\text{Rn}$) exhalation rate determination from building materials (under development).
4. Radon concentration measurement instruments calibration.
GAMMA SPECTROSCOPY LAB
SAMPLE PREPARATION
SAMPLE MEASUREMENT IN XtRa Ge DETECTOR
Spectrum: FM331B
Collect time: 171947 s
Detector: LeGe
# ZEOLITE NATURAL RADIOACTIVITY CONTENT RESULTS (I)

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>$^{226}$Ra (Bq kg$^{-1}$)</th>
<th>$^{232}$Th (Bq kg$^{-1}$)</th>
<th>$^{40}$K (Bq kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKL-1</td>
<td>40 ± 2</td>
<td>59 ± 3</td>
<td>918 ± 38</td>
</tr>
<tr>
<td>MET-1</td>
<td>80 ± 4</td>
<td>104 ± 5</td>
<td>944 ± 41</td>
</tr>
<tr>
<td>2P</td>
<td>121 ± 6</td>
<td>205 ± 10</td>
<td>2010 ± 80</td>
</tr>
<tr>
<td>3C</td>
<td>124 ± 6</td>
<td>195 ± 10</td>
<td>2500 ± 125</td>
</tr>
<tr>
<td>PEN-1</td>
<td>85 ± 4</td>
<td>122 ± 6</td>
<td>473 ± 19</td>
</tr>
<tr>
<td>Sample Code/Grain size (mm)</td>
<td>Radioactivity Content Bq kg⁻¹</td>
<td></td>
<td></td>
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<tr>
<td>----------------------------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$^{226}\text{Ra}$</td>
<td>$^{232}\text{Th}$</td>
<td>$^{40}\text{K}$</td>
</tr>
<tr>
<td>2P/0.9-1.2</td>
<td>122 ± 5</td>
<td>197 ± 8</td>
<td>2016 ± 84</td>
</tr>
<tr>
<td>PET-1/0.7-1.6</td>
<td>154 ± 6</td>
<td>108 ± 5</td>
<td>1117 ± 50</td>
</tr>
<tr>
<td>PET-1/0-0.2</td>
<td>160 ± 7</td>
<td>117 ± 5</td>
<td>1202 ± 52</td>
</tr>
</tbody>
</table>
RADON EXHALATION MEASUREMENT METHOD USED

✓ ENCLOSE THE SAMPLE IN A CONTAINER
   (RADON CHAMBER)

✓ FOLLOW UP THE RADON CONCENTRATION GROWTH INSIDE THE CONTAINER
THE NTUA RADON CHAMBERS

*Designed and constructed in Greece by the NTUA Nuclear Engineering Laboratory*

- Radon chamber 1.8 m³
- Radon chamber 8.5 m³

Made of stainless steel, Air-tight and Radon-tight

Computer controlled environmental conditions

(Temperature 12-45 °C,
Humidity 15 –95% non-condensing)
THE 8.5 m³ RADON CHAMBER

FRONT SIDE VIEW
LENGTH: 2.4m,
 WIDTH: 1.7m,
HEIGHT: 2.1m

DOOR:
1.1m HIGH,
0.6m WIDE
THE 1.8 m³ RADON CHAMBER USED FOR THIS PROJECT

FRONT
SIDE VIEW
LENGTH: 1.2m,
WIDTH: 1.0m,
HEIGHT: 1.5m
DOOR: 1.1m HIGH,
0.6m WIDE
QUASI-CONTINUOUS RADON CONCENTRATION MONITORING
MATHEMATICALLY EXPRESSED...

\[ C = C_o \exp(-\lambda t) + E[1-\exp(-\lambda t)](\lambda V)^{-1} \]  \( \text{(1)} \)

- \( C \) Radon concentration (Bqm\(^{-3}\)) in the container at growth time \( t(\text{h}) \)
- \( E \) exhalation rate (Bqh\(^{-1}\))
- \( \lambda \) Radon decay constant (h\(^{-1}\))
- \( C_o \) initial Radon concentration (Bqm\(^{-3}\)) in the container at time \( t(0\text{h}) \) – i.e. the background
THE EQUATION IS VALID IF... (I)

- There is **no leakage** of Radon out of the container.
- The activity concentration in the container air is low compared to the activity concentration in the pore air of the sample – i.e. no **back-diffusion** effects.
TYPICAL RADON EXHALATION CURVE

Typical Radon Exhalation Rate Plot (Sample 2P)
# ZEOLITE RADON EXHALATION RATE RESULTS (ss=1)

<table>
<thead>
<tr>
<th>Sample Code/Grain size (mm)</th>
<th>Radon Exhalation Rate $\mu$Bqkg$^{-1}$s$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2P/ 0.9-1.2</td>
<td>115 ± 20</td>
</tr>
<tr>
<td>PET-1/ 0.7-1.6</td>
<td>80 ± 3</td>
</tr>
<tr>
<td>PET-1/ 0-0.2</td>
<td>100 ± 8</td>
</tr>
</tbody>
</table>
SHORT DISCUSSION (I)

- The $^{226}$Ra content of the zeolites examined (40-160) lies within the $^{226}$Ra content range of European building materials, i.e. 4 - 4000 Bq kg$^{-1}$

- The Radon exhalation rate of the zeolites examined (80-115) lies within the range of Greek black cement or fly ashes, i.e. 10 – 110 µBq kg$^{-1}$s$^{-1}$ but it is much lower than that of internationally reported values
The $^{232}\text{Th}$ content of the zeolites examined lies within the $^{232}\text{Th}$ content range of European building materials, i.e. 0 - 540 Bq kg$^{-1}$.

The Thoron exhalation rate of the zeolites should be further measured, since the experiments already conducted showed measurable Thoron concentrations. (Thoron exhalation measurement methods are currently under development).
The $^{40}$K content of the zeolites examined lies within the $^{40}$K content range of European building materials, i.e. 25 - 2354 Bq kg$^{-1}$. The respective range for Greek building materials is 1 – 1158 Bq kg$^{-1}$. 
SHORT DISCUSSION (IV)

Assuming the worst case scenario that boards are constructed exclusively of zeolites with the highest natural radionuclide concentrations measured, then such a building material would result to an “activity concentration index I” equal to:

\[
I = \frac{^{226}\text{Ra content}}{300} + \frac{^{232}\text{Th content}}{200} + \frac{^{40}\text{K content}}{3000} = 2.8
\]
If such a board is used in bulk amounts then it results to a dose higher than the dose criterion of 1mSva⁻¹.

If such a board is used superficially then it results to a dose lower than the dose criterion of 1mSva⁻¹.

The dose due to natural radioactivity from every source has been world-wide calculated to 2mSva⁻¹.
CONCLUSION

It is advisable to sample and measure radiologically important parameters in gypsum boards containing zeolite.