THE MEASUREMENT OF THE NATURAL RADIATION BACKGROUND IN A SALT MINE

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The Unirea Salt Mine is situated at a depth of 208 meters beneath the surface of the earth that corresponds to a water-equivalent thickness of about 560 meters. It has a remarkable stability of microenvironment, characterized by a constant temperature over the year of 12.5 ±0.5 ºC and a relative humidity of 60-65 %.

In order to set up a calibration laboratory in this mine, for the measuring systems dedicated to the dosimetric measurements and environment, the natural radiation background had to be measured.

The measurements were made using two different dosimetric systems: An electronic type, consisting from two ratemeters: an Eberline FH 40 GL 10 and an AUTOMESS 6150 dose ratemeter with external scintillation probes; A TLD dosimetric system SD-TL type, which consists of the TL laboratory reader-analyze, 770 A type and thermoluminescent detectors by LiF:Mg, Cu, P. The results obtained with the two systems are in good agreement.

Key words: low level background, natural radiation, dosimetric system, ambient dose equivalent.

INTRODUCTION

The measurement of the absorbed dose or of the integral ambient dose equivalent, and their rates, at the level of natural radiation background is a basic aspect of the dosimetry of the environment. In this case, an important problem to be solved in the calibration of the dosimetric measuring systems, is the low level of the measuring range, which has to include the values corresponding to the natural radiation background (50÷100) nSv·h⁻¹. At the same time, the measurement of the radioactive content of some special environment samples becomes more and more important, mainly when ultrapure materials are to be selected for special applications.
In order to reach the adequate conditions to perform such calibrations, an ultralow level background laboratory is necessary. So, the “Horia Hulubei National Institute R&D for Physics and Nuclear Engineering” (IFIN-HH) decided to develop an ultralow level radiation background in the former Unirea salt mine, located in the town Slanic, at a distance of about 100 km from Bucharest.

The Unirea Salt Mine is located at a depth of 208 meters beneath the surface of the earth; taking into account the geological structure of the soil in the area of the mine, it was found that this depth corresponds to a water equivalent thickness of about 560 m [1]. On the other hand, due to the very pure salt walls, the underground radon content is much lowered; a small quantity of atmospheric radon can enter in the inside air through the lift case.

The salt mine is characterized also by a remarkable stability of the microclimate: a constant temperature, measured over several years, of 12.5±0.5°C and constant relative humidity, measured in the same conditions, of 60-65%. Of course, in order to set up a calibration laboratory in this mine, the first step was to perform accurate measurements of the absorbed dose and of the integral ambient dose equivalent and their rates, corresponding to the natural background in a hall where the new laboratory is located.

MATERIALS AND METHODS

In order to perform accurate measurements of integral ambient dose equivalent $H_{(10)}^*$ expressed in mSv and of the rate $H_{(10)}^*$, expressed in nSv h$^{-1}$, in the area were the laboratory was located, two different dosimetric system were chosen:

a) Two electronic dose ratemeters, with external scintillation probes; b) One TLD dosimetric system, SD-TL type.

Description:

a) As for electronic dose ratemeter, we used many instruments and finally we have selected two of them:

– an Eberline FH 40 GL 10 dose ratemeter, with the external probe FHZ 5023E. This probe has a large scintillation NaI detector of 3x3 inch. We calibrated it in terms of absorbed dose per impulse, with a value of the calibration factor of: $F = (0.17±0.03)$ nGy·imp$^{-1}$. The energy dependence of the response instrument in the ratemeter mode, is of maxim ±30% for the whole measured energy range. The conversion of units from absorbed dose, Gy, to ambient equivalent dose, Sv, was done by considering a conversion factor $f = 1$ Sv/Gy. It was used only for preliminary measurements.

– a thermo AUTOMESS 6150, with the external probe 6150 AD-6/H having also a scintillation detector.
This instrument, metrologically certified by its producer, has the following characteristics, according to the technical specification:

- **Measuring range (digital):** 0.01 µSv·h⁻¹ ÷ 9.99 mSv·h⁻¹, with a declared uncertainty of 10%.
- **Energy range:** 60 keV - 1.3 MeV; energy dependence of the response in this range: ±30%.

The reported results were obtained with this instrument.

b) The TLD dosimetric system, SD-TL type, consists of TL reader-analyzer, model RA-94 and the thermoluminescent dosemeters with commercial thermoluminescent detectors type LiF:Mg,Cu,P, known as GR 200A. The dosimeter for environmental monitoring, designed and made in our laboratory, consists of a plastic cylindrical container with the external dimensions: Φ = 50 mm and h = 9 mm. Each dosimeter is provided with three detectors. A detailed description of the system and its dosimetrical characteristics is given in the paper [2].

### MEASUREMENT CONDITIONS

The electronic dose ratemeters measuring directly the dose equivalent rate $\dot{H}_{(10)}^*$ were used in several pre-established significant locations inside the laboratory. The TLD system is calibrated in units of dose equivalent, $H_{(10)}^*$. The dose equivalent rate is calculated as the ratio of dose equivalent, mSv, and exposure time, h. In our case, two series of exposure, for periods of 39 d and 93 d were performed. In the case of the TL dosemeters, when processing the measured values, we took into account their irradiation during the transportation from Bucharest to the salt mine, and an appropriate correction was done. The reported values are the means obtained from the two exposition intervals.

For the purpose of the comparison of measurements and the establishment of consistence of results, the locations for the two types of measurements, electronic ratemeters and TLD system, were the same.

### RESULTS

Table 1 represents the measured values of the ambient equivalent dose rate [nSv·h⁻¹], obtained with the two systems, respectively the electronic AUTOMESS 6150 and the TLD system SD-TL, in four representative locations and their comparison. These points were selected as the most representative from a large number of measurements areas of the mine.
Table 1
Mean ambient equivalent dose rate values, measured with the two systems and their comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean ambient equivalent dose rate [nSv·h⁻¹], AUTOMESS 6150 system</th>
<th>Mean ambient equivalent dose rate [nSv·h⁻¹], TLD, SD-TL system</th>
<th>Difference, (AUTOMESS-TLD), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.17±0.42</td>
<td>1.49±0.41</td>
<td>-27</td>
</tr>
<tr>
<td>2</td>
<td>2.22±0.42</td>
<td>2.15±0.82</td>
<td>+3</td>
</tr>
<tr>
<td>3</td>
<td>1.87±0.57</td>
<td>1.55±0.30</td>
<td>+17</td>
</tr>
<tr>
<td>4</td>
<td>2.56±0.55</td>
<td>2.14±0.32</td>
<td>+16</td>
</tr>
</tbody>
</table>

The reported uncertainties were calculated from the instruments’ calibration factor uncertainties, respectively 10% and 7.5% and additional uncertainties: nonlinearity outside the certified interval, statistical uncertainty, etc.

DISCUSSION

Such as it can be seen from the Table 1, two conclusions can be drawn:
1. The levels of background inside the underground laboratory are about 25–50 times less than the usual ground level, (50 -100) nSv h⁻¹. The explanation is that the cosmic radiation is strongly attenuated by the rocks. The registered values are due to the residual content of radioactive elements existent in rocks, whose influence is also reduced by the existence of thick pure salt walls surrounding the laboratory. The influence of salt purity over the influence of ²²⁶Ra - ²²²Rn decay chain and of ⁴⁰K was reported in [3], by using classical chemical analyses methods, [4] and Neutron Activation Analysis.
2. The results obtained with two independent and different as operating principle dosimetric systems are in agreement within their measurement uncertainties.

CONCLUSIONS

– The low level of background in an underground laboratory was systematically studied, in order to characterize the environmental dose of the new laboratory.
– Two independent systems, an electronic and a TLD one were used. Their operating principles are different, but the results are in good agreement, what demonstrates the consistence of measurements.

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