

## A LABORATORY FOR NUCLEAR TEST BAN MEASUREMENTS

***F. Steger, M. Schwaiger and C. Schmitzer***

Radiation Protection, Division for Health Physics  
Austrian Research Centers Seibersdorf, A-2444 Seibersdorf, Austria

*Abstract: The Protocol of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) calls for Radionuclide Laboratories certified by the Technical Secretariat to support the international monitoring system (IMS) for verification of the Treaty [1]. Therefore a Radionuclide Laboratory at the Austrian Research Centers Seibersdorf (RL3) was installed.*

*To achieve the demanded minimum detection limit of  $5 \mu\text{Bq}/\text{m}^3$  for Ba-140 (537 keV), the RL3 was constructed as a low level laboratory. The background of a high-purity Germanium detection system (HP-Ge) has been reduced by developing an active and passive detector shielding. The entire system is encapsulated in an iron-castle and placed into a fall-out shelter. The influence of radon was reduced by the installation of an air-conditioning system.*

*The final count rate, achieved over the energy interval from 40 keV to 2700 keV, amounts to 0.18 cps. The reduction factor, compared with the outdoor count rate, is approximately to  $10^3$ . Hence, the demanded detection limit for Ba-140 will be achieved by using a minimum measurement time of 24 hours.*

*Keywords: radionuclide laboratory, background-reduction, shielding modules*

### 1 INTRODUCTION

In the year of 1996 the Comprehensive Nuclear-Test-Ban Treaty (CTBT) was signed to achieve an end on nuclear testing. In order to verify compliance with this treaty, a verification regime and a international monitoring system (IMS) were established. This international monitoring system comprises facilities for seismological monitoring, radionuclide monitoring, hydroacoustic monitoring and infrasound monitoring. The radionuclide monitoring system consists of radionuclide stations, for the measurement of radionuclides in air filter samples, and of radionuclide laboratories to support the radionuclide monitoring stations. Hence for radionuclide laboratories it is necessary, hereinafter referred to as RLs, to provide high level analysis to find conclusive evidence about the presence of radionuclides in the samples. [2] Therefore a minimum detection limit of  $5 \mu\text{Bq}/\text{m}^3$  for Ba-140 (537 keV), for a sampled air-volume of  $12000 \text{ m}^3$  per filter sample, is given by the Technical Secretariat of the CTBT as a minimum technical requirement.

For the Radionuclide Laboratory RL3 at the Austrian Research Centers Seibersdorf, an passive and active shielding was developed to reduce the background noise and to increase the sensitivity of the detection system.

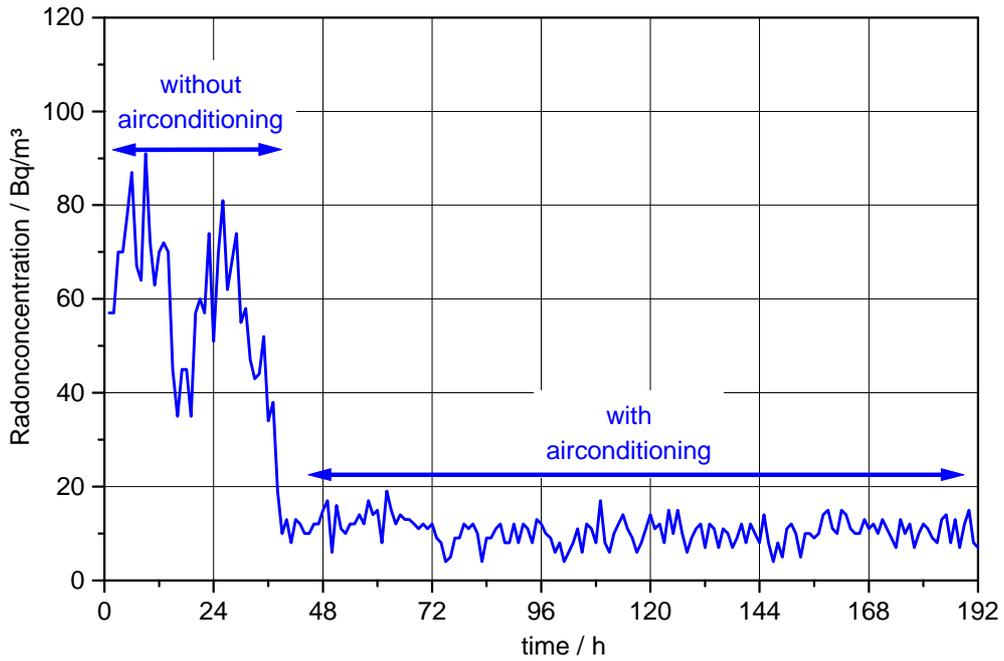
### 2 THE CONSTRUCTION

The particular measurement system of the RL3 is composed of a HP-Ge detector and special passive and active shielding modules. The effectiveness of all taken measures concerning the shielding was verified by detection of background spectra within the different shielding modules. [3]

#### 2.1 Outer shielding

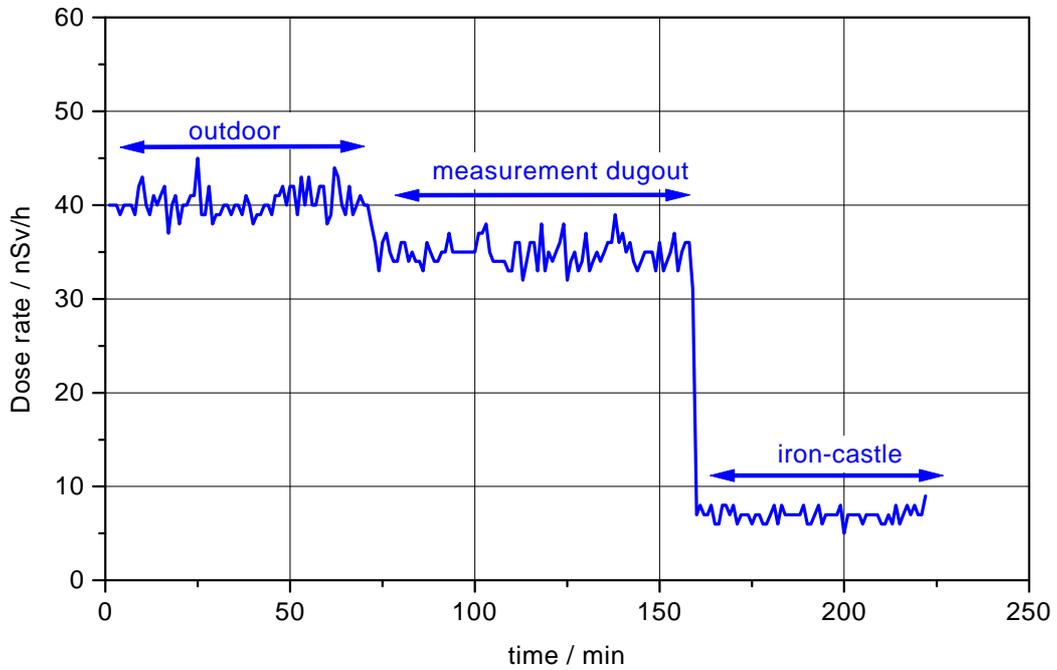
The detection system is surrounded by two separate outer shields. The first outer shield consists of concrete walls of an old fall-out shelter, with a thickness of 30 cm. To avoid an high radon concentration, the room is equipped with an air conditioning system. The range of the Rn-222 background amounts to less than  $20 \text{ Bq}/\text{m}^3$  and is shown, over the measurement time, in figure 1.

Further, within this first outer shield an iron-castle, using 5 cm thick cast steel is placed as a second outer shield. The inner dimensions amount to 2 m x 3 m and to 2.5 m height. Possible contamination of the steel was proved by gamma-spectrometric measurements and after an adequate measurement time no Co-60, no Cs-137 and no Ir-192 were counted.



**Figure 1.** Rn-222 concentration, measured in the measurement dugout with and without air conditioning, over a measurement period of eight days.

The total dose rate, measured within the different outer shielding modules, is shown in figure 2.



**Figure 2.** Dose rate measurement in comparison of various measurement sites, i.e. outdoor, in the measurement dugout and in the iron-castle.

## 2.2 Passive Detector shielding

The outer casing of the detector is built on a 50 mm thick lead plate to avoid background radiation from the underground. The passive detector shield consists of 130 mm thick lead with a purity less than 130 Bq/kg of Pb-210. Additionally, 10 cm thick boron-endowed paraffins were used to slow down and to capture neutrons. The inner casing of the detector chamber consists further of 15 mm lead plates with a purity less than 20 Bq/kg of Pb-210 (figure 3, left photograph). Additionally, 4 mm thick high purity electrolytic copper was used to reduce x-rays, bremsstrahlung and possible  $\alpha$ -rays from the inside of the lead shielding (figure 3, right photograph).



**Figure 3.** Passive detector shielding (left photograph: the outer casing with lead and boron-endowed paraffins; right photograph: the inner casing with lead and high purity electrolytic copper)

## 2.3 Active detector shielding

The active shielding of the detector is based on a veto-shield consisting of six units of plastic scintillators. Five units have an area of approximately 1 m<sup>2</sup>, and one unit of approximately 0.2 m<sup>2</sup> (shown in figure 4). Each one is assembly wrapped in reflection foil and in light tight vinyl. Every plastic scintillator is equipped with a photomultiplier (six pieces). The detector unit operates as a radiosensitive anticoincidence measurement facility:

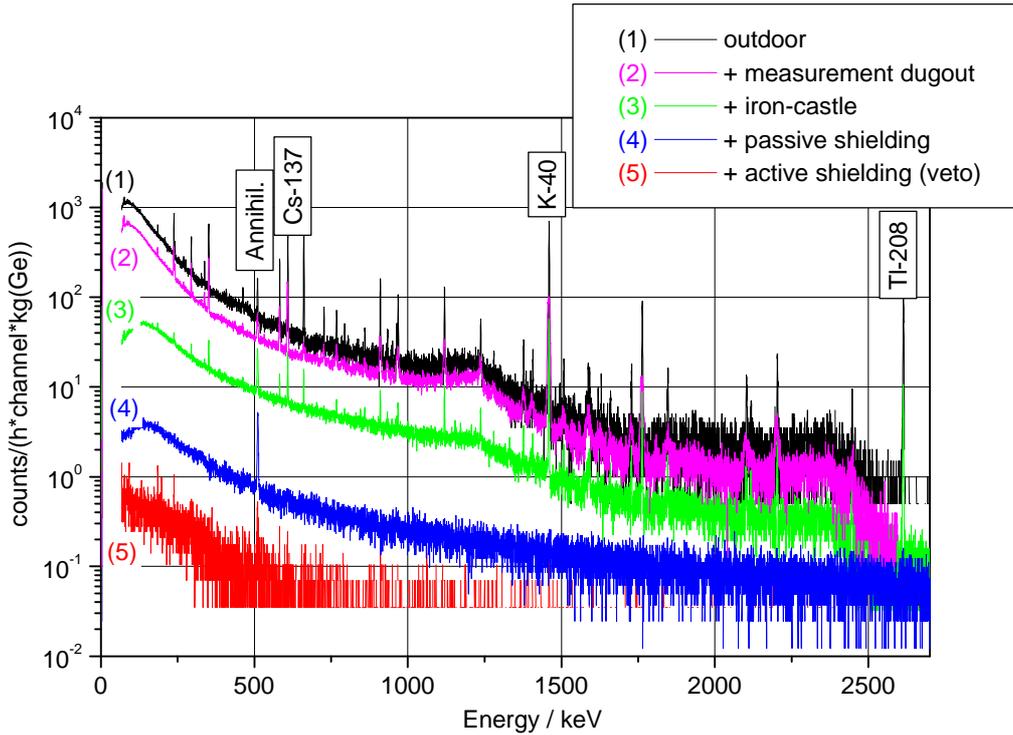


**Figure 4.** Active detector shielding with veto-sensors (black plates) with opened (left photograph) and closed (right photograph) measurement chamber.

### 3 MEASUREMENT RESULTS

The background spectra by using the different shielding modules are shown in figure 5. The minimum detection limits can be calculated. [5] The minimum detection limit amounts for the activity for the Ba-140 to 33 mBq and for the Cs-137 to 9.8 mBq by using a 24 hours measurement periode and filter-geometry with a diameter of 6 cm and hight of 2 cm. The sample was positioned directly at the detector surface.

Further, the detection limit for the activity concentration for a sampled air-volume of 12000m<sup>3</sup> amouts for the Ba-140 to 2.7 μBq/m<sup>3</sup> (table1) and for the Cs-137 to 0.8 μBq/m<sup>3</sup>. The results are summerized in table 1.



**Figure 5.** Recorded background spectra within the various shielding modules compared to an outdoor measurement.

**Table 1.** Counts and suppression ratio within the various shielding modules for the total energy range, the Ba-140 and the Cs-137 and the detection limit for the Ba-140 and the Cs-137

shielding module	energy intervall 40 keV – 2700 keV		Ba – 140 537 keV			Cs – 137 662 keV		
	count rate [cph]	suppres. ratio [-]	count rate [cph]	suppres. ratio [-]	detection limit [mBq]	count rate [cph]	suppres. ratio [-]	detection limit [mBq]
Outdoor (1)	632316	1	1029	1	849	4749	1	563
+ measurement dugout (2)	373182	1.7	662	1.5	682	561	8.5	194
+ iron castle (3)	50865	12.4	160	6.4	336	171	28.0	108
+ passive shielding (4)	4325	146	12.5	82.3	96	10.1	470	27
+ active shielding (veto) (5)	658	962	1.28	804	33	1.18	4025	9.8

## 4 CONCLUSION

The background of the HP-Ge detection system is reduced by a factor of 962 for the total energy range, by a factor of 804 for BA-140 and by a factor of 4025 for Cs-137. Hence the sensitivity of the detection system is increased remarkably and is comparable with the achieved sensitivity of ultra low level installation in Europe (table 2). [4]

**Table 2.** Comparison of the background radiation of different low-level laboratories in Europe

	overground without veto	overground with veto	underground
Laboratory	count rate [cps]	count rate [cps]	count rate [cps]
RL3, ARCS	1.2	0.18	-
GSF, Germany	1.03	-	-
University of Freiburg	1.06	0.42	-
Technical University of Garching	2.38		0.24 (15 m w.e.)
Physikalisch Technische Bundesanstalt Braunschweig	1.06		0.012 (850 m underground)

The final count rate, achieved over the energy interval from 40 keV to 2700 keV, amounts to 0.18 cps. The reduction factor, comparing with the outdoor counting rate, is approximately  $10^3$ . Hence, the demanded detection limit of  $5 \mu\text{Bq/m}^3$  for Ba-140 (537 keV) will be achieved by using a measurement time of 24 hours.

The Radionuclide Laboratory RL3 at the Austrian Research Centers Seibersdorf meets the technical requirements and will get certified by the Technical Secretariat of the CTBTO during the next months. From thence it will serve the international monitoring system for verification of the Comprehensive Nuclear Test Ban Treaty (CTBT).

## REFERENCES

- [1] CTBTO: *Comprehensive Nuclear-Test-Ban Treaty (CTBT) and Text of the establishment of a Preparatory Commission for the Comprehensive Test-Ban-Treaty Organisation: Resolution CTBT/MSS/RES/1 at a meeting of States Signatories convened by the Secretary-General of the United Nations in his capacity as depositary of the Treaty*. 1996, November 19.
- [2] CTBT/PTS/INF.96: *Certification of IMS Radionuclide Laboratories*, Draft: 29 January 1999
- [3] Heusser, G.: *Background in ionizing radiation detection illustrated by Ge-Spectrometry; Low-Level Measurements of Radioactivity in the Environment. Techniques and Applications*; Editors: M. Garcia-Leon & R. Garcia-Tenorio: Proceedings of the third international summer school. Huelva, Spain, September 20 – October 2, 1993
- [4] Wahl W.: *1st Report from „FZS Low-Level Spectrometer“ First Measurements and Evaluation of Data*. ISuS Institution für Spektrometrie und Strahlenschutz D-83722 Schliersee, Germany, March 15 2000
- [5] analogical to [2]: Calculation of the MDA, 12.3, page 27

**AUTHORS:** Dr. Ferdinand STEGER, DI Dr. Martina SCHWAIGER and DI Dr. Christian SCHMITZER, Radiation Protection, Division for Health Physics, Austrian Research Centers Seibersdorf A-2444 Seibersdorf, Austria, Phone: +43 2254 780 2500, Fax: +43 2254 780 2502  
E-mail: firstname.name@arcs.ac.at