Département de Physique
Université de Fribourg (Suisse)

External background radiation in the Fribourg (Switzerland) urban area

THESE

présentée à la Faculté des Sciences de l'Université de Fribourg (Suisse) pour l'obtention du grade de *Doctor rerum naturalium*

Mathieu Boucher

du

Canada

numéro de la thèse 1599

Imprimerie St-Paul, Fribourg
2008

Acceptée par la Faculté des Sciences de l'Université de Fribourg (Suisse) sur la proposition du Dr. Jost Eikenberg et du Prof. Dr. Jean-Claude Dousse.

Fribourg, le 9 avril, 2008

Le directeur de thèse :	Le Doyen :
Prof. Dr. Hansruedi Völkle	Prof. Dr. Titus JENNY

Contents

Abstract

We are constantly exposed to ionizing radiation of different type. Most of the radiation exposure comes from natural sources. External background γ radiation originates from two different sources, terrestrial and cosmic. Terrestrial radiation originates from two different background, natural and artificial or "man-made" isotopes. The artificial radiation contributes very little to the total absorbed dose.

External background γ radiation has been thoroughly studied in the Swiss fields and meadows, by the *Environmental Radioactivity Section*, since the 1960's. A data base of more than thousand measurement have been performed outdoors. In the early stages, dose rate measurements were performed by an ionisation chamber, and compared to NaI spectrometry measurements. With the development of high purity germanium crystals, $HPGe$ spectrometers have replace the NaI in field measurements.

The objective of this work is to systematically survey the external background γ radiation in an urban area. Therefore, various indoor and outdoor measurements were carried out in the Fribourg (Switzerland) urban area, to investigate the average equivalent dose rate and its variation. We want to evaluate the increase of terrestrial contribution and the decrease of cosmic radiation in the vicinity of buildings.

Measurements sites were chosen regarding various parameters. For outdoor measurements, we tried to cover most of the urban territory, measuring on different soil types.

Many different construction materials have been used for the structure of buildings, influencing both the terrestrial and the cosmic background radiation, when being indoors. Therefore, measurements were carried in buildings made of different materials. Furthermore, measurements were made on many different stories, to evaluate the cosmic absorption by the building structure.

Résumé

Nous sommes constamment exposés à des rayonnements ionisants de multiples sources. La majorité de l'exposition est de provenance naturelle. La composante terrestre et cosmique forment le rayonnement de fond γ externe. Deux types de rayonnement composent la partie terrestre, le rayonnement naturel et artificiel. Le rayonnement artificiel ne contribue que très peu à la dose totale absorbée.

Le rayonnement de fond γ externe fut étudié en profondeur dna les prés et champs Suisse, par la *Section de la surveillance de la radioactivité*, depuis les années 1960. Plus de mille mesures extérieures furent effectuées. Dans les premières années, des mesures de débit de dose, faites avec une chambre à ionisation, étaient comparées avec des measures de spectrométrie NaI. Depuis le développement de cristaux germanium de très haute pureté, les spectromètres au germanium ont remplacé les NaI dans les mesures de terrains.

Dans ce travail, nous souhaitions étudié le bruit de fond γ externe dans un environnement urbain. Pour ce faire, de multiple mesures, à l'extérieur et à l'intérieur, furent effectuées à Fribourg (Suisse) afin d'évaluer le débit de dose moyen et ses variations. Nous souhaitions déterminer l'augmentation de la composante terrestre et la diminution de la composante cosmique autour et dans différents bâtiments.

Différents paramètres étaient étudiés dans le choix des sites de mesures. À l'extérieur, nous avons essayé de couvrir au mieux l'espace urbain, en mesurant sur différents types de sol.

À Fribourg, différents types de matériaux sont utilisés dans la construction des bâtiments, qui ont une influence directe sur le rayonnement de fond terrestre et cosmique. C'est pourquoi, à l'intérieur, nous avons mesuré le bruit de fond γ dans des construction de différents matériaux. De plus, dans la mesure du possible, nous avons mesuré sur différents étages, nous permettant de déterminer l'absorption du rayonnement cosmique par la structure.

Chapter 1

Introduction to Radiation Protection

We are constantly exposed to ionizing radiation of different types, arising from a multitude of sources. As shown in Fig. 1.1, most of the exposure comes from natural radiation. Radon and its affiliates, cosmic, and terrestrial radiation represents about two third of the total exposure.

Since the 1950's, the *Environmental Radioactivity Section*of the Swiss Federal Office of Public Health, measures and evaluates radioactivity and radionuclide over the Swiss territory. In the 1960's, § 2.2.1, a first census of natural radioactivity was made in Switzerland on natural ground and environment. The measurement sites were chosen mainly on geological criteria. Since then, the monitoring of radioactivity focused on the surveillance of the effects of atomic bomb testing and the Chernobyl catastrophe and on the surroundings of the nuclear power plants, research centers, like *CERN*[1] and *PSI*, and on hospitals and industries using radioactive products.

Different instruments are used for the surveillance of the environment. In particular, *In Situ* spectrometry allows direct outdoor measurements (see § 2.2). Such measurements are used by the *Environmental Radioactivity Section*, ensuring a full coverage of radioactivity in the environment over the whole Swiss territory, mainly in fields, meadows, and rural environment. All the measurements are made outdoors.

At the *Environmental Radioactivity Section*, we developed a project that would census natural radioactivity and its components in an urban environment. This project, described in details, focuses on the average exposure to terrestrial and cosmic components and their variations in a standard urban population, both indoor and outdoor. From the UNSCEAR report 2000, people living in urban environment spend roughly 80% of their days indoor and 20% outdoor [28]. For the time spent indoors, UNSCEAR reports that roughly 20% of the cosmic radiation is absorbed and there is a roughly 40% increase in the terrestrial radiation due to building structure. Therefore, the total exposure to radiation in an urban environment is

$$\begin{matrix} \text{cosmic} \\ \text{terrestrial} \end{matrix} \Rightarrow \begin{pmatrix} 80\%_{\text{in}} \cdot 80\% + 20\%_{\text{out}} \cdot 100\% \\ 80\%_{\text{in}} \cdot 140\% + 20\%_{\text{out}} \cdot 100\% \end{pmatrix} \cdot D_{\text{out}} = \begin{pmatrix} 0.84 \\ 1.32 \end{pmatrix} \cdot D_{\text{out}} \qquad (1.1)$$

With this project, we wished to measure the effect of urban environment on the total absorbed γ radiation dose, excluding the irradiation by the body's own natural and artificial

[1]All acronyms and abbreviation are given in Appendix B, at page 213

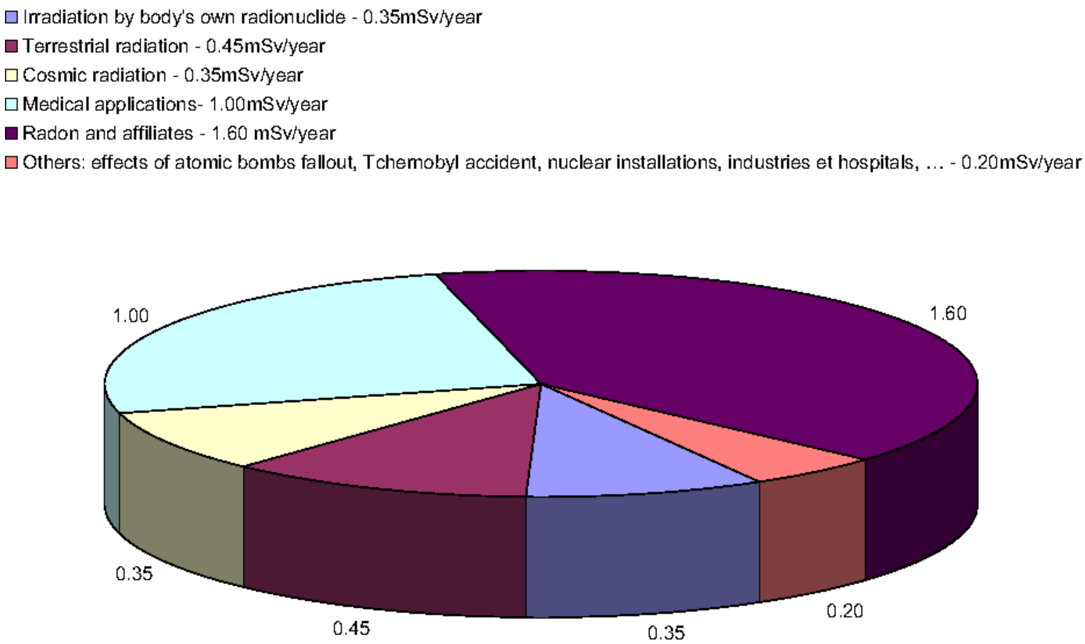


Figure 1.1: Total exposure to the Different types of irradiation, measured in milli Sievert (mSv). The values in this figure are taken from page A-13 of the annual report [26] of the *Environmental Radioactivity Section* of the Swiss Federal Office of Public Health.

radionuclide and the effects of radon and its affiliates. We wished to evaluate the total external dose absorbed from the ionizing radiation, terrestrial and cosmic contribution. *In Situ* spectrometry was used to measure natural radioactivity in different areas of a populated region. Outdoor measurements were done on different public areas, depending on parameters like the type of ground and the elevation of the site. Indoor measurements were done in buildings of various types, with different construction materials, and on various stories.

We have decided to do this project in **Fribourg** (Switzerland) for multiple reasons. Fribourg offers a very wide range of different construction types, from the middle ages to current day. The city is built over roughly 200 m of vertical variation.

Chapter 2

Indoor – Outdoor measurements

Different projects were developed over the years to evaluate the total average exposure of the population to radiation. Some studies focused mainly on outdoor measurements, while others tried to evaluate the influence of man-made alterations to the background rate.

I will here try to summarize a selection of different projects that studied or are still working in the field of environmental radiation monitoring. The projects presented were chosen for their dried applicability or methodological impact on this project.

2.1 Radiation Monitoring in Switzerland

In 1956, in Switzerland, two federal commission were founded for protection against radiations and for monitoring of environments radioactivity, called the CFSR or KUeR and the CFR or EKS. In 2001, they fused to formed the CPR or KSR [12].

In 2004, this commission evaluated the average irradiated dose to the population, published by the Swiss Federal Office for Public Health, given in Fig. 1.1. For natural external radiation, shown in Table 2.1, two components are considered in their evaluation: cosmic radiation contribution and terrestrial radiation contribution.

Table 2.1: Values published by KSR – CPR [12].

KSR Publication	**Air Kerma** (K_a in $\frac{\text{mGy}}{\text{yr}}$)	**Equivalent dose rate** (E in $\frac{\text{mSv}}{\text{yr}}$)	**Ambient dose rate** ($H^*(10)$ in $\frac{\text{mSv}}{\text{yr}}$)
Terrestrial radiation	0.35	0.26	0.42
Indoor terrestrial radiation	0.46	0.35	0.55
Cosmic radiation (ionising and neutronic component)		0.45	0.73
Indoor cosmic radiation		0.38	0.61
Total		**0.71**	**1.15**
Total indoor		**0.73**	**1.16**

The contribution of cosmic radiation to the external total dose has two components: ionizing radiation and neutron radiation. Primary and secondary cosmic radiation increases with altitude, due to its partial absorption by the Earth's atmosphere, and with latitude, due to its deflection by the Earth's magnetic field, as described in §§ 3.6–4.4.3. The federal commission evaluates the contribution of the ionizing component of the cosmic radiation to the total external absorbed dose[1] to be

$$E_c(z) = \left(33\frac{\text{nSv}}{\text{h}}\right) e^{\frac{z}{2.5\,\text{km}}} \tag{2.1}$$

where z represents the altitude in km, for $0 \leq z \leq 2$ km. The neutron component of the cosmic radiation to the total external absorbed dose evaluates to

$$E_n(z) = \left(7.5\frac{\text{nSv}}{\text{h}}\right) e^{\frac{z}{1.2\,\text{km}}} \tag{2.2}$$

where z again represents the altitude in km, for $0 \leq z \leq 2$ km.

2.2 Outdoor radiation

2.2.1 Radiosurveillance Census in Switzerland of 1961

In the summer of 1961, the Swiss federal office of public health, in collaboration with the Radiological Institute at Freiburg University, in Germany, and the Swiss committee for atomic fuels, carried out a series of measurements throughout Switzerland [35]. The objective was to evaluate the amount of natural radiation emitted from different soils.

Measurements were to be carried out so that the whole of Switzerland would be covered as systematically and uniformly as possible. The measurement procedure was accomplished in four stages, dividing the country into four regions, as shown in Table 2.2. Approximately 250 measurements were carried out in the whole campaign. The process took roughly four months to be accomplished.

The measuring sites were chosen mainly on geological criteria. Measurements were done for as many different conditions as possible. The project's purpose was to link the different geological regions of Switzerland with the amount of natural radiation emitted and absorbed. Therefore, some measurements were made in urban areas, but most were carried in the country side. The results were given by soil composition of the sites.

Measurements were made with a NaI scintillation counter and an ionisation chamber, made of a 25 l air chamber at atmospheric pressure, with an intense electric field. The ionisation chamber measured a total absorbed dose, without distinguishing between terrestrial and cosmic components. The NaI scintillation counter detected the terrestrial contribution to the total background γ radiation. The comparison between the two resulted in a fair approximation of the terrestrial and cosmic contribution to the total dose absorbed.

Halm, Herbst and Mastrocola [35] chose the summer of 1961, which was between two atomic bomb testing periods. They suggested that the nuclear waste from the previous bomb testing had no more effect on the environmental radiation. Therefore, the results of their measurements seems to over-estimate the external background γ radiation.

[1] Sv – Sievert defined in Chap. 4

Table 2.2: Results from the census made in 1961 [35], over the Swiss territory.

Region (**Herbst, Halm and al. 1961**)	**Number of Measurements**	**Dose rate** (D in $\frac{\text{mr}}{\text{h}}$)	**Equivalent dose rate** (E in $\frac{\text{mSv}}{\text{yr}}$)	**ambient dose rate** ($H^*(10)$ in $\frac{\text{mSv}}{\text{yr}}$)
Jura, North Jura	9	68	0.45	0.72
Central Switzerland	17	70	0.46	0.74
Prealps and north lime alps	13	77	0.51	0.81
Non cristalline east alps	4	102	0.67	1.07
Cristalline Graubünden and Vallis	6	115	0.76	1.21
Tessin and Bergell	12	154	1.01	1.62
Average terrestrial radiation	**61**	**76.1**	**0.50**	**0.80**
Indoor terrestrial radiation		91	0.60	0.96
Average cosmic radiation		38.4	0.25	0.40
Indoor cosmic radiation		31	0.20	0.33
Total		**114.5**	**0.75**	**1.20**
Total indoor		**122**	**0.80**	**1.28**

2.2.2 NADAM network

The Automatic Dose Alarm and Monitoring Network (NADAM) consists of 58 stations located at MeteoSwiss sites throughout Switzerland. Geiger-Müller devices transmit the measured ambient dose rate, together with data on local rainfall at ten-minute intervals to the NEOC, based in Zürich. If the threshold value of $1\frac{\text{mSv}}{\text{h}}$ is exceeded, the alarm is raised immediately. The NADAM data are evaluated daily at the NEOC and enable external radiation to be monitored over a large area [40].

Table 2.3: Results obtained by the NADAM network over yearly period.

Year	**Equivalent dose rate** mSv/yr
2001	1.01 ± 0.22
2002	1.03 ± 0.22
2003	1.02 ± 0.22
2004	1.03 ± 0.22
2005	1.03 ± 0.22
2006	1.05 ± 0.22

The yearly average results obtained from the 58 stations of the NADAM network are given in Table 2.3. Different factors can explain the over-estimated values ($\approx 20\%$) obtained with this network :

- the sensitivity of the probes ranges over six orders of magnitude (from 50×10^{-9}Sv/h $\rightarrow$ 50×10^{-3} Sv/h). The results obtained normally are at the lower end of the probe range, therefore the uncertainties increase.
- the unknown internal activity of the probes can increases the results.
- several monitors are located at high mountain stations, where the results obtained are higher (as expected from Eq. 2.1).

The NADAM network probes are being changed gradually. The new probes should reduce the uncertainties in the results.

2.2.3 In Situ spectrometry

Few methods are used for monitoring radioactivity in the environment, like laboratory γ ray spectrometry, exposure rate measurement, NADAM, dose rate measurement and field γ ray spectrometry. Of these methods, I will give a more complete description of field γ ray spectrometry, also known as *In Situ* spectrometry. Field γ ray spectrometry was developed in Switzerland in the mid 1980's (1985). More than a thousand field measurements have been performed up to this day.

In fields and meadows, the field γ ray spectrometry measurements brings a complete overview of the radionuclide and their concentration. The *In Situ* method gives a mean value of the radioactivity concentration over roughly 50 m^2 [5]. In addition, the measurements are faster than the other methods and the results can be shown directly while measuring or shortly after.

In Situ spectrometry, for environmental radiation monitoring, consists in measuring incident γ rays at a fixed height above ground level, with a portable γ ray detector. The detector is normally set at 1 m above ground level [27]. The incident γ rays are detected with a portable spectrometer made of an intrinsic high purity germanium (HPGe) crystal of coaxial type. The incoming γ radiation deposits its energy in the HPGe crystal, allowing the identification of the radionuclide present in the soil. The concentration of these radionuclide are calculated from the flux of γ rays into the detector's crystal, see § 4.4. The *In Situ* spectrometry is a technique to evaluate the terrestrial contribution to the total background γ radiation.

To have a complete overview of the surroundings, a parallel measurement is done with a high pressure ionisation chamber. The *Environmental Radioactivity Section* uses a "General Electric – Reuter-Stokes" ionisation chamber, see § 5.1.6 for specifications of this device. This instrument records the dose rate exposure during the field γ ray spectrometry measurements, terrestrial and cosmic radiation indistinctly. The terrestrial component, from γ ray spectrometry, added to the calculated cosmic contribution is compared with results of dose rate measurements.

In Situ spectrometry has become a very common method for environmental radioactivity monitoring. The work of C. Murith [5] has helped the *environmental radioactivity monitoring section* develop a more complete overview of radioactivity distribution over the Swiss' territory.

2.2.4 Radiation doses from external sources

Rybach, Bächler, Bucher and Schwarz [20] compared and analyzed the radiation exposure of the Swiss population to environmental sources, from aeroradiometry measurements and data collected from field measurements. Due to landscape variations, the population in Switzerland is not distributed uniformly over the territory: very few people live in the high mountain regions. Therefore, a comparison is made between the average dose rate over the territory and the average dose rate per capita. Both cosmic and terrestrial contributions are considered in the comparison.

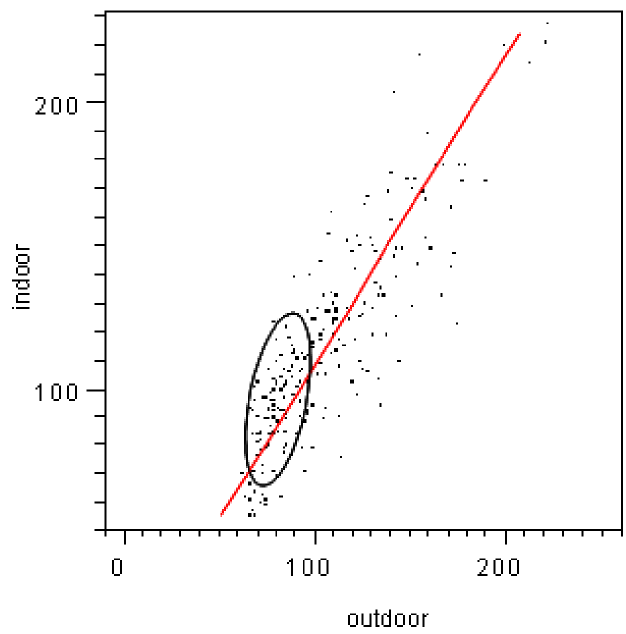


Figure 2.1: Comparison between indoor and outdoor measurements, made by Johner and Völkle [17].

The ionizing cosmic component of the total external exposure was calculated for land parcels of 2km×2km, from a digital terrain model of the Switzerland. The calculations were performed with the formula considered by the federal commission for radiation protection and monitoring [12]. The 2 km × 2 km mapping of the terrestrial contribution to the total external exposure is made from airborne γ radiation spectrometry, *In Situ* γ radiation spectrometry, and from selected data sets from other surveys. [20].

From their measurements, Rybach *et al.* measured an outdoor average external dose rate of $147\frac{\mathrm{nSv}}{\mathrm{h}} = 1.29\frac{\mathrm{mSv}}{\mathrm{yr}}$ over the Swiss territory. The average dose rate absorbed by the Swiss population is $108\frac{nSv}{h} = 95\frac{mSv}{yr}$ per capita [20].

2.3 Indoor measurements

In Switzerland, like in many countries, environmental radioactivity monitoring focused essentially on outdoor measurements. On the Swiss' territory, most of the monitoring was done around nuclear power plants, research centers and industries that use radioactive products. A great deal of efforts over the whole Swiss territory was put into monitoring the effects of the atomic bomb testing fallout and the repercussion of the Chernobyl catastrophe. Very few indoor measurements have been performed in Switzerland.

From Máduar and Hiromoto [24], man-made alteration of the natural environment can increase radiation exposure of the public. The materials used to built houses and buildings contain natural radioactivity. Therefore, exposure to natural radiation inside buildings can be altered by the structure itself. From Máduar and Hiromoto's computation, thickness of the walls, material density, size of the area (rooms) are parameters that can influence the total indoor exposure to radiation by up to 20% or more.

UNSCEAR [28] reports an increase of the terrestrial component when being indoor. Even though indoor surveys are not as complete as outdoor, UNSCEAR reports an increase of 40% of the terrestrial component when being indoor (see in Eq. 1.1). The building structure absorbs an average of 20% of the cosmic contribution to the total external background γ radiation.

Clouvas, Xanthos and Antonopoulos-Domis [3] did extended surveys of indoor and outdoor terrestrial γ radiation in Greece. The surveys were conducted in all Greek provinces and in 41 towns of the Greek mainland. From *In Situ* γ spectrometry, they were able to measure the influence of buildings on the total exposure to radiation from the Uranium and Thorium decay series, ^{40}K and ^{137}Cs. From these surveys, they tried to map a complete indoor and outdoor γ radiation of Greek urban areas.

Measurements were made to evaluate the natural radiation in Switzerland [17]. These measurements were performed to evaluate the influence of construction on the terrestrial and cosmic contribution to the total external dose exposure. The data were acquired with a plastic scintillator and an ionisation chamber. Figures 2.2 show the results obtain for measurements performed outdoor and indoor over different areas of Switzerland. The indoor dose rate is average at $(103 \pm 2)\frac{\mathrm{nSv}}{\mathrm{h}}$ compared to the outdoor average dose rate of $(89 \pm 2)\frac{\mathrm{nSv}}{\mathrm{h}}$. Figure 2.1 compares measurements made indoor and outdoor. Results of measurements made over the Swiss territory, given in Table 2.5, show the dose rate weighted by the number of inhabitants of the region.

From the work of Johner and Völkle [17], the terrestrial component of indoor radiation exposure varies within a room. Simulations have been performed to evaluate the local dose rate with a building. Figure 2.3 shows that the total exposure to radiation as it varies within one building, depending on the closeness of walls, as well as, the geometry and the structure of the rooms. Radionuclide concentration of the building material plays an important role in the total indoor exposure.

Nuccetelli, Bolzan, Grisanti and Risica [6] combined results from *In Situ* measurements with computational estimates from room models to evaluate the indoor exposition to terrestrial γ radiation. From a measured indoor specific dose rate, their method evaluates the activity concentration in the walls of the room (Eq. 2.3), for the ^{238}U and ^{232}Th decay series and for ^{40}K, yielding:

$$D_\gamma = 0.876 C_{^{238}U} + 1.130 C_{^{232}Th} + 0.076 C_{^{40}K} \tag{2.3}$$

for different concentration of radioactive materials: $C_{^{238}U}$, $C_{^{232}Th}$, $C_{^{40}K}$

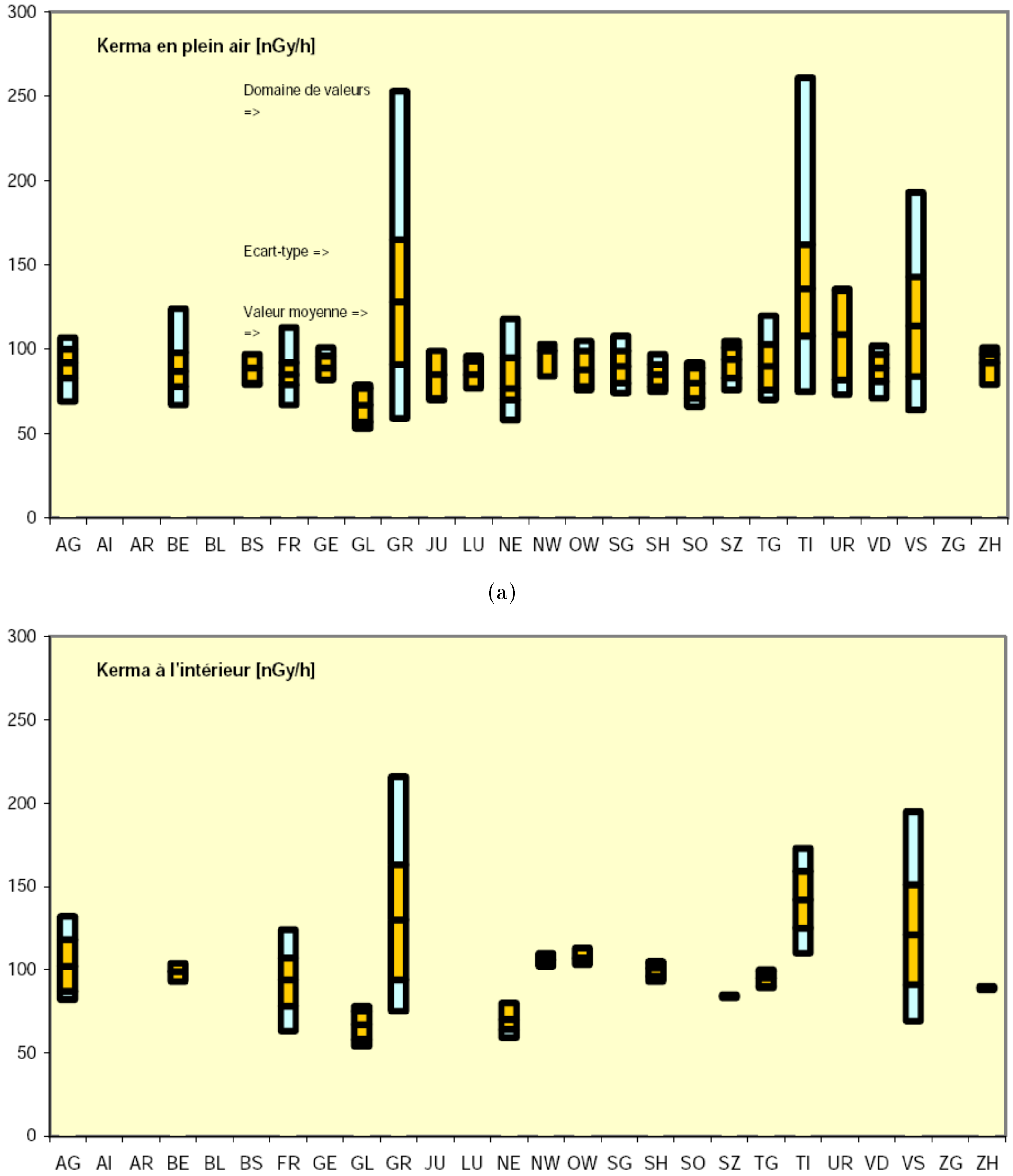
Papastefanou, Manolopoulou, and Charalambous [7] studied radioactivity in various building materials used in Greece. Through different models, they evaluated the indoor exposure to terrestrial γ radiation. The dose rate exposure is calculated (Eq. 2.4) for ^{232}Th and ^{238}U series and for ^{40}K concentration in the walls, via

$$D_\gamma = 0.887 C_{^{238}U} + 1.17 C_{^{232}Th} + 0.080 C_{^{40}K} \tag{2.4}$$

Monte Carlo simulations were performed at the IRA, to evaluate the influence of construction materials on the indoor γ radiation exposure [21]. Table 2.4 compares the results obtained from these simulations with the results from previous studies.

2.4 Our project

At the *Environmental Radioactivity Section*, we developed a project to measure and evaluate the total external background γ radiation in an urban environment, both outdoor



(a)

(b)

Figure 2.2: (a) Outdoor Kerma rate measurements, performed with an ionisation chamber: average value, standard deviation and range of values [12]. (b) Indoor Kerma rate measurements, performed with an ionisation chamber: average value, standard deviation and range of values [12].

and indoor. The terrestrial and cosmic component average and standard deviation, were evaluated.

Outdoor measurements were made with a portable HPGe detector cooled with liquid nitrogen and a high pressure ionisation chamber (GM – Reuter-Stokes). Indoor measure-

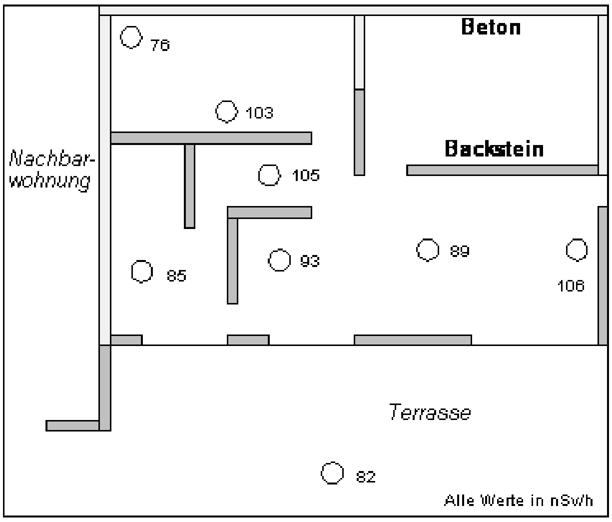


Figure 2.3: Results of simulation evaluating the indoor dose rate [17].

Table 2.4: The influence of the concentration of radioactive materials on the total absorbed dose.

Method	**Room dimensions**	^{238}U**-Series**	^{232}Th**-Series**	^{40}K
Nuccetelli [6] Papastefanou [7]	$5 \times 4 \times 2.8m$; $20cm$ wall thickness; concrete density $2.32g/cm^3$	0.876 0.89	1.13 1.2	0.076 0.08
This work	$5 \times 5 \times 3m$; $20cm$ wall thickness; concrete density $2.32g/cm^3$; -10% for windows	0.75	0.97	0.069

ments were made with a portable HPGe detector cooled with a sterling motor (ORTEC – DETECTIVE) and a high pressure ionisation chamber.

Measurements were carried in the whole of the urban area, covering as much of the territory as possible. Outdoor measurements were chosen by the geographical situation (the altitude) and the type of soil of the site. Indoor measurements were chosen by the geographical situation (the altitude), the structure and the age of the buildings and the height above ground level or the number of stories of the building. Since the city of Fribourg is built in a region with about 200 m of altitude change, the geological situation made it possible to evaluate the cosmic contribution to the total background γ radiation (see § 3.9). For both indoor and outdoor measurements, the type of material or soil changed the terrestrial contribution to the total background γ radiation, see § 4.4. The amount of stories allowed an indirect measurement of the cosmic attenuation due to absorption by the structure of the buildings.

Table 2.5: Dose rate measurements covering Switzerland made by Johner and Völkle [17].

Canton	inhabitants ×1000	Equivalent dose rate		Dose × inhabitants
		nSv/h	mSv/yr	
ZH	1179	85.5	0.75	883.05
BE	958	80.9	0.71	678.92
LU	326	77.9	0.68	222.46
UR	34	126.7	1.11	37.74
SZ	112	96.2	0.84	94.38
OW	29	87	0.76	22.10
NW	33	93.1	0.82	26.91
GL	39	71.8	0.63	24.53
ZG	86	75.6	0.66	56.95
FR	214	77.9	0.68	146.03
SO	232	71.8	0.63	145.92
BS	199	100	0.88	174.32
BL	233	100	0.88	204.11
SH	72	84.7	0.74	53.42
AR	52	96.9	0.85	44.14
AI	14	82.4	0.72	10.11
SG	428	83.2	0.73	311.94
GR	174	126.7	1.11	193.12
AG	508	93.1	0.82	414.30
TG	209	89.1	0.78	163.13
TI	282	131.3	1.15	324.35
VD	602	81.7	0.72	430.85
VS	250	116	1.02	254.04
NE	164	74.8	0.66	107.46
GE	379	82.4	0.72	273.57
JU	66	85.5	0.75	49.43
CH	**6874**			**5347.30**
Weighted average				**0.78**

Chapter 3

What is radioactivity

3.1 A brief history

Knowledge of matter and its components has greatly improved since John Dalton (1803) proposed some postulates to describe the atom. He was the first to postulate that matter is composed of atoms, by suggesting that atoms are the smallest possible components of matter.

In 1897, J.J. Thomson discovered the electrical properties of the electron. He thought that the negatively charged electrons were dispersed in the atoms, like plums are put in the English plum pudding. The rest of the atom had to be positively charged, since matter is electrically neutral. His theory of matter states that atoms are put closely together to form matter.

In 1895, Wilhelm Roentgen noticed mysterious fluorescence emitted from a glass Hittorf-Crookes tube while studying cathode rays. These mysterious invisible rays had the ability to penetrate opaque black paper. Roentgen called them X rays.

Soon after Roentgen's discovery, Henri Becquerel began investigating more closely these new mysterious rays. He chose to work with potassium uranyl sulfate. He found that uranium marked photographic paper, even when wrapped in black paper, and thus discovered spontaneous emission of radiation by matter. Later, he proved that the radiation emitted by uranium is similar to X radiation.

Following Becquerel's discovery, Marie and Pierre Curie made intensive investigation of the newly found radioactive material. They discovered that not only uranium spontaneously disintegrated, but that, a panoply of different elements can disintegrate in this manner.

Even though Marie Curie first introduced the term "radioactivity", Ernest Rutherford can be considered as the father of modern nuclear physics. From his studies, he explained many concepts of the atom and the newly found phenomenon of radioactivity. He discovered that radioactive material not only emitted electromagnetic rays, but also particles, that he named and characterized as the alpha, α, and the beta, β, particles, see § 3.3.

In 1911, Ernest Rutherford and two of his student, Hans Geiger and Ernst Marsden, made an experiment which proved wrong Thomson's theory of matter [1]. They bombarded a thin gold foil with a beam of α particles, represented in Fig. 3.1(a). From Thomson's theory of matter, the α particles would be deflected uniformly on the screen. Rutherford

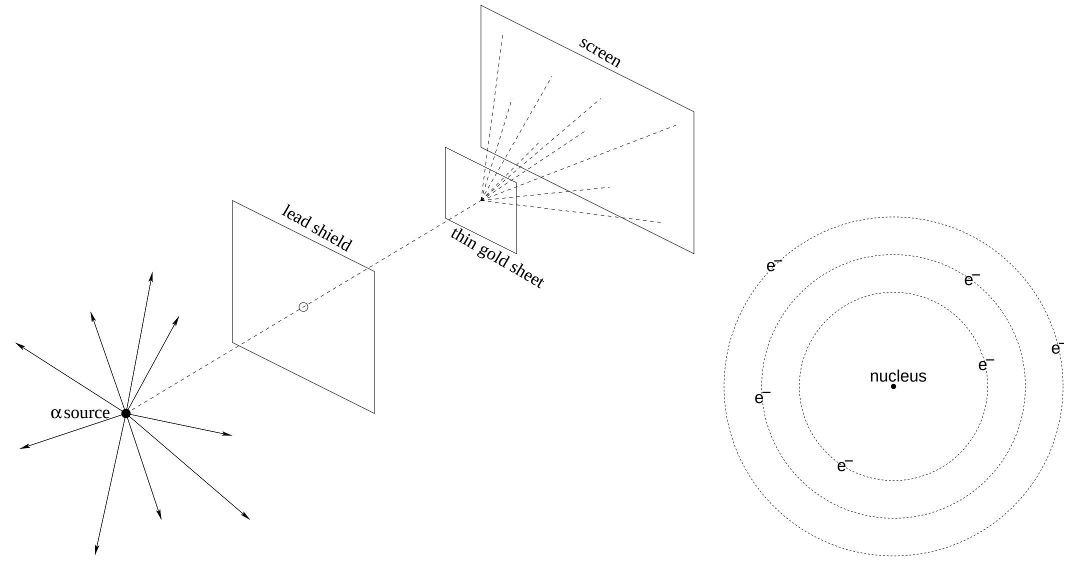


Figure 3.1: (a) Diagram of Ernest Rutherford's setup which lead to the planetary atomic model. For this setup, Rutherford used radium as the α emitter. (b) Diagram of Niels Bohr atomic model. In this model, the electrons orbits are predefined to a certain energy state.

noticed that most of the particles passed through the gold foil without any deflection, while some were deflected at different angles and some even bounced back. There is a difference between the Thomson's expected scattering cross section and Rutherford's experiment. From these observations, Rutherford suggested a new atomic model, where the positive charges, holding most of the atomic mass, are compacted into a very small nucleus with the electrons orbiting around, like a planetary system. The positively charged α particles are deflected by the positive nucleus, through Coulomb electric repulsion. They are more and more deflected, the closer they pass from the nucleus, to the point where they are pushed back from a direct hit with the nucleus.

From Rutherford's experiment, Niels Bohr proposed an atomic model that dropped the two major defects of the planetary model: that it could not explain why atoms emit electromagnetic waves of certain frequencies only, and why a moving charged particle, like the orbiting electrons, does not continuously radiate electromagnetic energy. In Bohr's atomic model, the classical theory of electromagnetic emission does not stand, and the electrons rotate around the nucleus on fixed predefined orbits, represented in Fig. 3.1(b).

J.J. Thomson, in his "plum-pudding" theory of matter, evaluated an atomic radius, from material density, atomic weight and Avogadro's number, to be $R_{\text{atom}} \sim 10^{-10}$ m. Rutherford's experiment suggested the nuclear size to be $R_{\text{nucleus}} \sim 10^{-15}$ m, later consisistant with Bohr's calculations. More than 99.95% of the atomic mass is found in a very small nucleus of 10^{-5} times less than the size of an atom.

$$\frac{R_{\text{nucleus}}}{R_{\text{atom}}} = \frac{10^{-15}\ \text{m}}{10^{-10}\ \text{m}} = 10^{-5} \tag{3.1}$$

The full development of modern Quantum Mechanics was born at that time leading to the theory used today. Through their work, and followed by others, we can now understand atomic and subatomic behaviours. They generated the discovery of the different nucleons: which are the particles that forms nuclei, to a list of isotopes: which are elements with a different mass number but with the same atomic number.

3.2 What is radioactivity

Radioactivity is the property of some atomic nuclei to spontaneously disintegrate. Emission of highly energetic particles (α and β radiation) or electromagnetic radiation (γ radiation) are the key signature of nuclei disintegration.

Since the discovery of radioactivity, knowledge of the atom and the nucleus has developed greatly. A good explaination of the disintegration process of a nucleus, with the emission of radiation or particles exists. The disintegration process of an unstable nucleus is stochastic. Therefore, a system of many nuclei must be considered.

In a system of many unstable nuclei, the average lifetime, τ, equals to the inverse of the decay rate, λ. The average number of disintegration or activity of the system, dN, per time interval, dt, can be found from the mean lifetime of a nucleus and the number of unstable nuclei in the system, N, via

$$dN = \lambda N dt \tag{3.2}$$

3.2.1 Nuclear mass

Very precise measurement of nuclear mass is important to understand nuclear phenomenona. It would take much effort to enumerate all the methods for this purpose, only one example of *nuclear mass spectrometry* will be given here.

The *Bainbridge nuclear mass spectrometer* gives a very accurate measurement of a nuclei's mass. The technique is shown in Fig. 3.2. A beam of ionized isotopes is produced and accelerated to a fixed momentum $\vec{p}$. The isotopes pass through a velocity filter, which consist of a combination of an electric and a magnetic field. While in the combined fields, calle a "wien filter", the particle is subjected to both Coulomb and Lorentz forces.

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B} \tag{3.3}$$

By choice of $\vec{E}$ and $\vec{B}$, the forces can be made to cancel and the only particles which will not be deviated have $v = \frac{E}{B}$. Slits or other collimaters can be used to select the undeviated atoms, which will be localized around some speed $v \pm \Delta v$. In the magentic field, only the Lorentz force applies, and circular motion results:

$$\begin{aligned} F_L &= m\frac{v^2}{R} \\ q\cancel{v}B &= \frac{m\cancelto{v}{v^2}}{R} \\ \frac{m}{R} &= \frac{qB}{v} \end{aligned} \tag{3.4}$$

$$\text{and } \frac{dm}{dR} = \frac{qB^2}{E} = 0.1\frac{\mathrm{U}}{\mathrm{mm}} \begin{cases} B = 1\ \mathrm{T} \\ E = 10\frac{\mathrm{kV}}{\mathrm{mm}} \\ q = 1\ \mathrm{e} \end{cases} \tag{3.5}$$

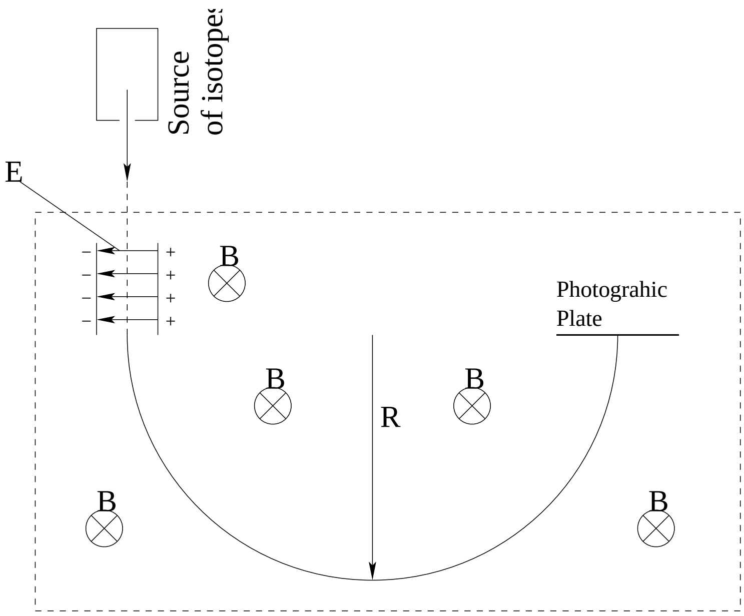


Figure 3.2: A representation of the *Bainbridge* nuclear mass spectrometer.

Sub mm resolution of the separation of where the ions arrive on the photographic plate give very high mass resolution measurements.

3.2.2 Mass defect

The very accurate measurements of nuclear mass, outlined above, brought to light the "missing" mass of a nucleus, the so-called mass defect. The total mass of all free nucleons is greater than the mass of the nucleus. This phenomenon is easily illustrated by looking at the ^{12}C atom. The nucleus of that atom is composed of 6 protons and 6 neutrons. The total mass of the free particles is

$$\begin{aligned} m_{tot} &= 6m_p + 6m_n \\ m_{tot} &= 6(1.6726 \times 10^{-27}\,\text{kg}) + 6(1.6750 \times 10^{-27}\,\text{kg}) + 6(9.109 \times 10^{-31}\,\text{kg}) \\ m_{tot} &= 2.00911 \times 10^{-26}\,\text{kg} \end{aligned} \tag{3.6}$$

The mass of the ^{12}C nucleus is

$$m_{^{12}C} = 12.01115\,\text{u}\frac{1.660 \times 10^{-27}\,\text{kg}}{1\,\text{u}} = 1.99385 \times 10^{-26}\,\text{kg} \tag{3.7}$$

which is different from the mass of the total free nucleons by

$$\Delta m = m_{tot} - m_{^{12}C} = 1.526 \times 10^{-28}\,\text{kg} \tag{3.8}$$

Where is the mass? Did the mass disappeared for good? How do nucleons bind to each other? These are some of the questions one can ask. To answer these questions, we must look deep inside the nucleus and study the interactions between nucleons.

The strong nuclear interaction is the force that binds the nucleons together. This interaction acts on nucleons that get close enough to each other, independent on their mass, their size, their structure, or their electrical charge. When the distance between particles is less than a few femtometers ($\mathrm{fm} = 10^{-15}$ m), this nuclear interaction develops a strong attraction between the particles. Beyond these few fm, the repulsive Coulomb interaction between charge particles takes over.

Since the strong interaction is attractive, the energy level of each nucleon is therefore lowered by the binding process. From the theory of relativity, the negative binding energy between the nucleons generates a decrease in the total mass,

$$\Delta E = \Delta m c^2 \tag{3.9}$$

The binding energy of a nucleus depends on the number of nucleons it contains. From Fig. 3.3, one can see that the binding energy per nucleon increases rapidly for nuclei with few nucleons. The binding energy saturates for nuclei with ~ 60 nucleons. At the saturation point, the energy per nucleon is ~ 8.7MeV, where MeV represent *mega-electron-volt* (1 MeV $= 1.602 \times 10^{-13}$ J). For heavier nuclei, the energy per nucleon decreases almost constantly. The very short range of the strong nuclear interaction (~ 2 fm) and the Coulomb interaction between protons are greatly responsible for the decrease in the binding energy. For heavy nucleus, the strong nuclear interaction decreases due to the size of the core, which is bigger than the interaction range. Furthermore, the Coulomb interaction increases between protons, destabilizing the core.

There are several different models and theories explaining nuclear behavior. Each model explains certain behaviors in certain circumstances. No one model can explain all the behaviors of nuclei.

The "liquid drop" model explains quite well the stability and the binding energy of nuclei. This model approximates the nucleus to be sphere with uniform interior density, like a drop of liquid [34]. In 1935, a German physicist, Carl von Weizsäcker, used that model to formulated a semi-empirical equation giving the binding energy of a nucleus.

$$E_{Z,A} = f_0(Z,A) + f_1(Z,A) + f_2(Z,A) + f_3(Z,A) + f_4(Z,A) + f_5(Z,A) \tag{3.10}$$

The first term represents the *mass of the constituent* of the atom

$$f_0(Z,A) = (m_p Z + m_n(A-Z))\, c^2 \tag{3.11}$$

This term is the sum of the mass of the protons ($m_p Z$) and the neutrons ($m_n(A-Z)$) in the core. The remaining terms correct the mass of the nucleus due to the various effect of a liquid drop.

In this model, the nucleus is supposed to be spherical. The binding energy per nucleon is imagined to be constant. Therefore, the binding energy of the whole core increases by the *volume* term

$$f_1(Z,A) = -c_1 A \tag{3.12}$$

where $c_1 = 15.5 \frac{\mathrm{MeV}}{c^2}$

The nucleons near the surface of the nucleus are have fewer neighbors, therefore, their binding energy is reduced by the *surface* term

$$f_2(Z,A) = +c_2 A^{\frac{2}{3}} \tag{3.13}$$

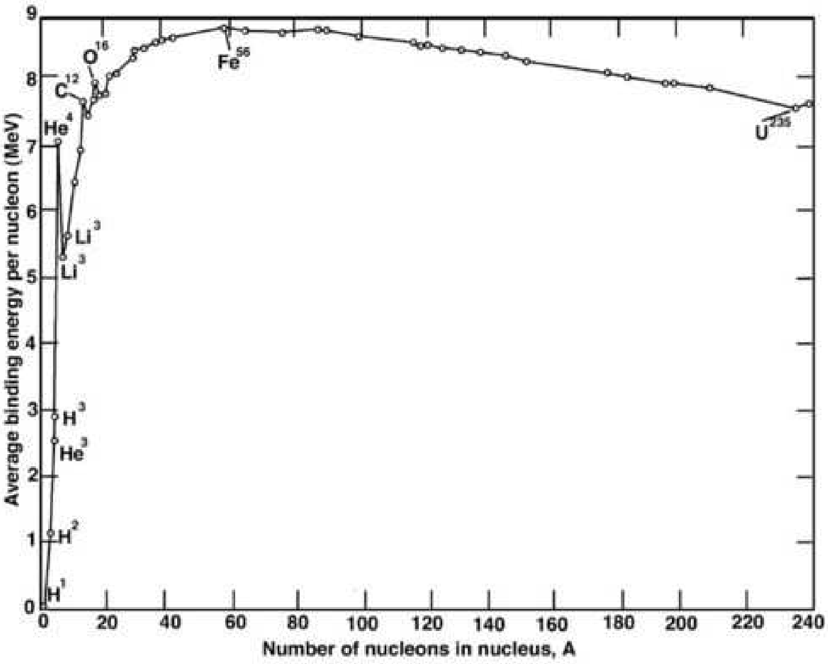


Figure 3.3: Standard graph of average binding energy per nucleon for different nuclei. The figure is from [30].

where $c_2 = 16.8 \frac{\mathrm{MeV}}{c^2}$

The repulsive *Coulomb* interaction between the positively charged protons reduces the total binding energy of the nucleus

$$f_3(Z, A) = +c_3 \frac{Z^2}{A^{\frac{1}{3}}} \tag{3.14}$$

where $c_3 = 0.715 \frac{\mathrm{MeV}}{c^2}$

Since nuclei do not always have the same amount of protons and neutrons, an interaction arising from this *asymmetry* term reduces again the total binding energy of the nucleus

$$f_4(Z, A) = +c_4 \frac{\left(Z - \frac{A}{2}\right)^2}{A} \tag{3.15}$$

where $c_4 = 23 \frac{\mathrm{MeV}}{c^2}$. This term is zero for $Z = N = (A - Z)$.

The last term influencing this semi-empirical formula arises from the tendency of nuclei to have even/odd Z and even/odd N, called *pairing*

$$f_5(Z, A) = \begin{cases} -c_5 A^{\frac{1}{2}} & \text{if even } Z \text{, even } N \\ 0 & \begin{cases} \text{if even } Z \text{, odd } N \\ \text{or odd } Z \text{, even } N \end{cases} \\ +c_5 A^{\frac{1}{2}} & \text{if odd } Z \text{, odd } N \end{cases} \tag{3.16}$$

where $c_5 = 11.3 \frac{\mathrm{MeV}}{c^2}$

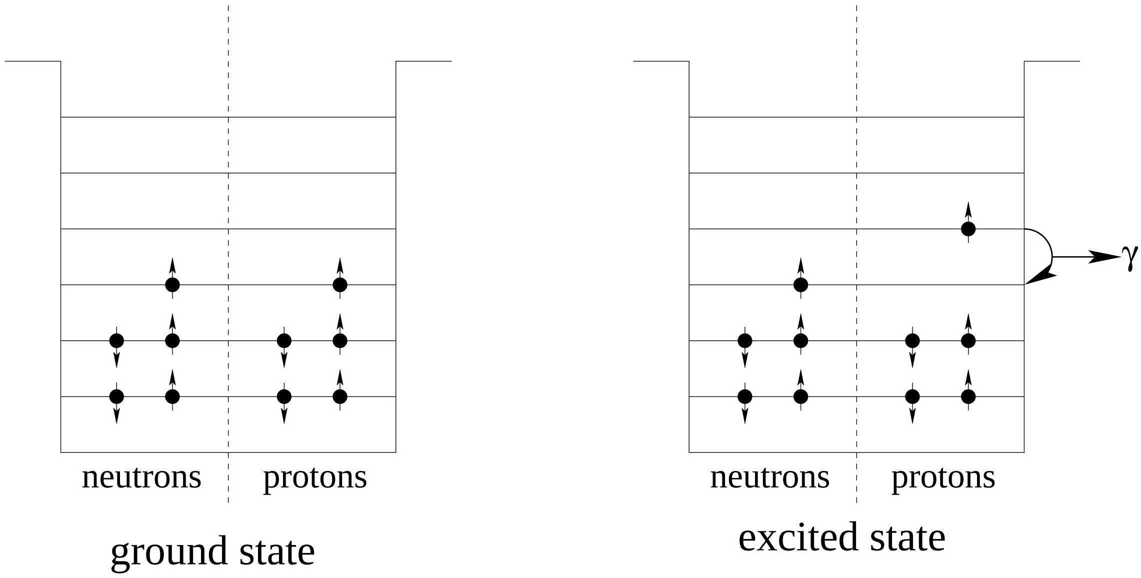


Figure 3.4: A schematic representation of the energy filling of a nucleus. In the ground state, the nucleons fill the lower energy state in first.

3.3 Nuclear structure

The complex arrangement and interactions between bound nucleons set discrete energy levels for a nucleus. The energy level of the whole nucleus depends on the energy state of each nucleon. Figure 3.4 schematically represent the filling of nucleons in a nucleus, according to the limitation of Pauli's exclusion principle, as formulated in the shell model.

In quantum mechanics, a set of four quantum numbers is given to every particle, including nucleons. These quantum numbers define the quantum state of the particle. Table 3.1 gives a short description of these quantum numbers.

Pauli's exclusion principle states that "in a multiparticle system there can never be more than one particle in the same quantum state". The fundamental difference between

Table 3.1: The quantum numbers that enumerate the quantum state of each particle.

symbol	name	possible values
n	principal quantum number corresponds to the main energy level of the particle	any integer possible starting from 1
l	azimuthal quantum number angular momentum quantum number corresponds to the sub-level state of the particle	any integer from 0 to $n-1$
m_l	magnetic quantum number	any integer from $-l$ to $+l$
m_s	spin quantum number	$= \pm\frac{1}{2}$

protons and neutrons makes Pauli's principle striking. Once again the Pauli principle is quite obvious for protons (neutrons) in different energy levels. From this exclusion principle, there can be two protons (neutrons) with the same quantum numbers n, l and m_l represented by each line in Fig. 3.4. These particles must have a different spin quantum number m_s.

Nuclear instability

The stability of a nucleus lies essentially in the binding energy between nucleons. The binding energy is found to be the sum of the attractive nuclear strong interaction and the repulsive Coulomb interaction. Since the nuclear strong interaction has a very short range of action, a bigger and heavier core will be less stable. Therefore, the stability of a particular nucleus decreases with increasing neutrons in the core. Unstable nuclei will decay to a more stable state following different modes.

Independent of the mode, unstable nuclei will decay with the emission of highly energetic particles, which allows the remaining nucleons to bind more tightly in the core (see Fig. 3.3). However, the emission of particles can leave the nucleons of the newly formed isotopes in excited states (see Fig. 3.4). The nucleons will eventually cascade to their ground state, following Pauli's exclusion principle, via the emission of highly energetic electromagnetic radiation, called γ rays.

An element is called "radioactive" if nuclei are either unstable or in an excited state. The emission of particles or electromagnetic radiation to deexcite or stabilize the core is called "radioactivity" or "radioactive decay".

3.4 Alpha and Beta decay

It is not the purpose of this work to give a complete theoretical explanation of α and β decay. Therefore, I will limit the discussion on the simple process of both decay modes, without giving too many theoretical explanations on why the decay happens.

Alpha decay

The α decay occurs when an unstable nucleus – called "parent nucleus" – decays into its "daughter nucleus" by the emission of an α particle, composed of two protons and two neutrons. The emission of the α particle is spontaneous and transforms the nucleus ${}^{A}_{Z}X$ into ${}^{A-4}_{Z-2}X$. The α decay occurs when a heavy nucleus breaks into two parts, due to the strong repulsive Coulomb interaction between protons. Figure 3.5 gives a schematic situation of an α decay.

The mass of the parent nucleus is greater than the sum of the mass of both the daughter nucleus and the α particle (Eq. 3.17). The remaining mass is transformed into kinetic energy for the particles. From the momentum conservation law, and since the α particle is very light compare to the daughter nucleus, most of the energy available from this decay is carried away by the α particle as kinetic energy.

$$m_{Z,A} > m_{Z-2,A-4} + m_\alpha \tag{3.17}$$

$$K_\alpha = \left[m_{Z,A} - (m_{Z-2,A-4} + m_\alpha)\right] c^2 \tag{3.18}$$

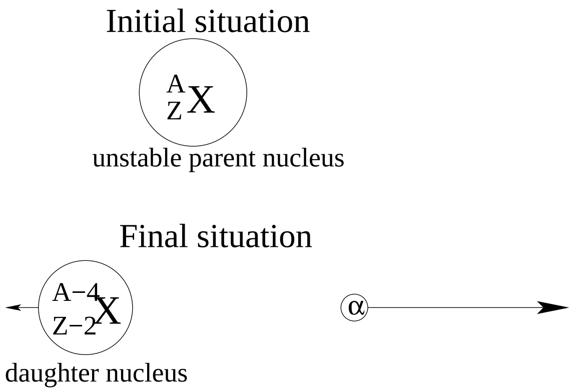


Figure 3.5: A representation of a parent nucleus decaying into a daughter nucleus, following the α decay.

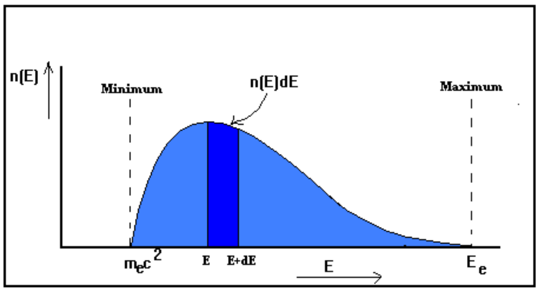


Figure 3.6: A beta decay energy spectrum. $n(E)dE$ is the proportion of beta particles with energy between E and $E + dE$ [36].
.

Beta decay

The β decay occurs when a parent nucleus decays into a daughter nucleus by the emission or absorption of a β particle, i.e., an electron (e^-) or a positron (e^+). Table 3.2 shows the three different β decay schemes possible: the emission of an electron (β^-) by the nucleus ${}^A_Z X \Rightarrow {}^A_{Z+1} X$, the capture of an electron (β^+) by the nucleus ${}^A_Z X \Rightarrow {}^A_{Z-1} X$ and the emission of a positron (β^+) by the nucleus ${}^A_Z X \Rightarrow {}^A_{Z-1} X$. The light unstable nucleus will follow this decay mode, due to the decreasing strong nuclear interaction. Like for the α decay mode, the parent nuclear mass is greater than the sum of the mass of the daughter nucleus and the electron/positron.

The energy made available from this decay is carried away partly by the β particle. From lepton number conservation, an anti-neutrino or neutrino ($\overline{\nu}$ or ν) is created in the β decay process. The electronic neutrino (ν_e) and antineutrino ($\overline{\nu}_e$) are expected to have very little mass ($\leq 2\frac{\text{meV}}{c^2}$), no electrical charge and a spin $s = \frac{1}{2}$. These properties are essential for electric charge conservation, angular momentum conservation, and energy conservation. Therefore, the neutrino can carry away some of the energy made available from the decay, leaving the rest for the β particle as kinetic energy, as shown in Fig. 3.6. Since the β particle and the neutrino's mass are extremely small compared to the daughter nucleus, the nuclear recoil is negligible.

3.5 Gamma radiation

When a parent nucleus disintegrates via α or β decay, the daughter nucleus is often left in an excited state (Fig. 3.4). The excited nucleons undergo a series of cascades to the ground state. Each transition releases a precise amount of energy, normally emitted as a photon.

Table 3.2: The different cases of β decay. The decay will happen spontaneously if the equation is energetically favorable.

β^-	e^- emission	$n \rightarrow p^+ + e^- + \overline{\nu}_e$	$E = [m_{Z,A} - (m_{Z+1,A} + m)]\, c^2$
β^+	e^- capture	$p^+ + e^- \rightarrow n + \nu_e$	$E = [(m_{Z,A} + m) - m_{Z-1,A}]\, c^2 < 1.022\,\text{MeV}$
β^+	e^+ emission	$p^+ \rightarrow n + e^+ + \nu_e$	$E = [m_{Z,A} - (m_{Z-1,A} + m)]\, c^2 > 1.022\,\text{MeV}$

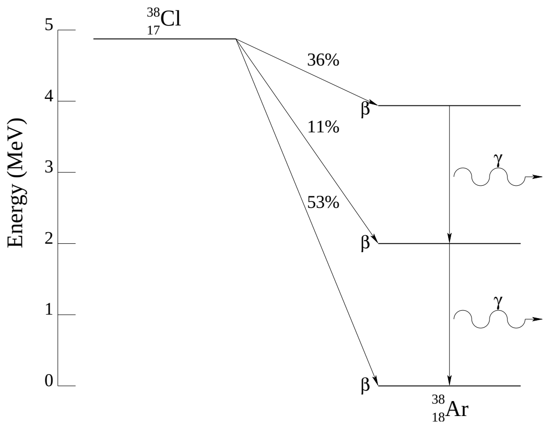


Figure 3.7: Schematic representation of the radioactive decay of $^{38}_{17}Cl$ into $^{38}_{18}Ar$. Three decay routes are possible for this disintegration, with its probability.

For each transition, a photon is emitted of frequency equal to the energy difference divided by Planck's constant ($h = 6.626 \times 10^{-34}$ J $\cdot$ sec):

$$\nu = \frac{E}{h} \tag{3.19}$$

This type of deexcitation is called γ radiation. Figure 3.7 represents schematically the decay process of the $^{38}_{17}Cl$ nucleus. In this example, the β decay can happen along three different possibilities. The nucleus has 53% chance of emitting a β^- particle with up to roughly 5MeV of kinetic energy. In this case, the daughter nucleus is into the ground state. The other scenarios, the parent nucleus β^- decays into an excited state of the daughter nucleus. In these cases, γ radiation will be emitted when the nucleus cascades to the ground state.

Not all transitions are allowed. The transition between two states will occur only if the "selection rules" of quantum numbers are satisfied

$$\Delta l = \pm 1 \tag{3.20}$$

$$\Delta j = 0, \pm 1 \tag{3.21}$$

where j is the total angular momentum quantum number.

Decay rate

Independent on the decay mode and the particle emitted, a radioactive nucleus has a certain probability per unit time to decay, called the "decay rate" λ. In a system with many nuclei, the amount of decays recorded per second represents the decay rate, called the "activity" of the system. The activity of a system of many nuclei is measured in "Becquerel" (Bq), representing the number of disintegration per second. In this system, the probability per time interval that any of the excited nuclei decays is $N\lambda dt$, where N is the number of excited nuclei in the system. Therefore, the average change in number of decaying nuclei is

$$dN = -N\lambda dt \tag{3.22}$$

where the minus sign indicates the decreasing amount of excited nuclei in the system. From this equation, the number of excited nuclei $N(t)$ remaining in the system after time t is given by Eq. 3.23. In this equation $N(0)$ is the initial activity of the system.

$$N(t) = N(0)e^{-\lambda t} \tag{3.23}$$

From the decay rate, we can deduce the average time an excited nucleus survives, called the "lifetime" τ. Since the decay rate gives the probability per second to decay, the lifetime is therefore the inverse of λ:

$$\tau = \frac{1}{\lambda}. \tag{3.24}$$

One of the standards often used in nuclear physics is the "half-life" $T_{\frac{1}{2}}$ of the system. The half-life represents the time needed for half of the excited or unstable nucleus to deexcite or disintegrate. From Eq. 3.23, the half-life, proper for each type of nuclei, is given by:

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \ln(2)\tau \approx 0.693\tau \tag{3.25}$$

3.6 Cosmic radiation

Soon after the discovery of radioactivity, by Becquerel, physicists began to study and evaluate radiation high in the atmosphere. In 1910, Albert Gockel made measurements of ionizing radiation on board a hot air balloon. He discovered an increase in ionizing radiation with increasing altitude. A few years later, in 1912, Viktor Hess made further measurements and discovered that part of the ionizing radiation to which we are exposed daily comes from outer space. Viktor Hess won the Nobel prize 1936 for his discovery of cosmic radiation [9].

"Cosmic radiation" is the name given to the particles coming from different parts of the Universe and reaching the Earth. These particles are of very high energy, ranging from eV $\rightarrow 10^{19}$ eV [16]. Cosmic rays are mainly composed of protons and α particles. Heavier atomic nuclei, in similar abundance as on Earth, make up only a smal part of cosmic rays. Electrons, γ radiation and neutrinos are only a fraction of the cosmic particles that reach the Earth.

The origins of cosmic radiation is not yet well understood. There is discussions between different theories on the definite origins of cosmic rays. Particles forming cosmic radiation originate from at least three different sources:

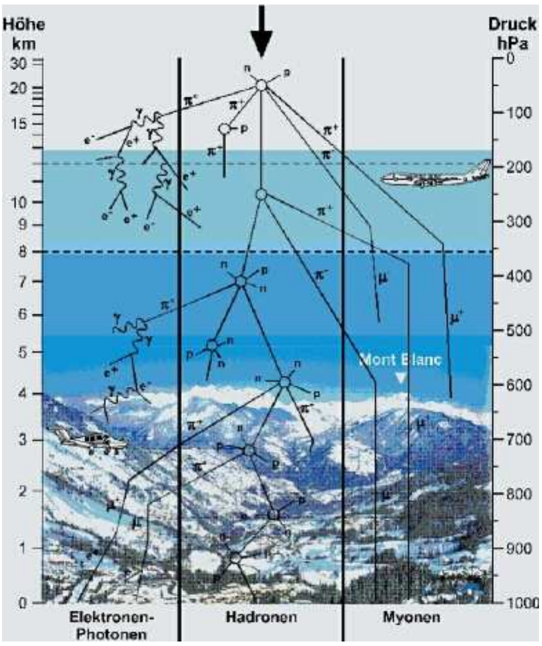


Figure 3.8: A scheme showing secondary cosmic radiation. The process shown represents the different possible disintegration of the particles [38].

1. Galactic Cosmic Rays come from outside the Solar system, but from within the Milky Way.

2. Anomalous Cosmic Rays come from outside our galaxy.

3. Solar Energetic Particles arise from the sun and are kept relatively near the solar system, guided under the local magnetic fields.

Independent on their origin, when reaching our planet, we distinguish between "primary" and "secondary" cosmic radiation. Primary cosmic radiation is that originating from outer space: solar, galactic or anomalous rays combined. Protons constitute $\sim 90\%$ of the total flux, α particles for $\sim 10\%$ and about 1% for the remainder of the particles presents [16]. The two main components of the primary radiation are positively charged particles, which interact with the Earth's magnetic field. Therefore, a greater proportion of the radiation will enter the atmosphere near the poles of the planet. When penetrating the atmosphere, the highly energetics particles collide with ncueli of the air. Their collisions with the atmospheric atoms produces series of radioactive nuclei found in the high atmosphere, like ^3H, ^7Be, ^{26}Al, ^{32}Si, ^{39}Ar and ^{85}Kr. The rest of the energy from the collisions will create secondary cosmic radiation, shown in Fig. 3.8, showering the Earth's surface.

When interacting with the Earth's atmosphere, primary cosmic radiation will create either electrons/photons, hadrons, or muons/pions/neutrinos. Most of these create secondary particles which have a very short life, e.g. pion τ_π = 26 ns, muon $\tau_\mu = 2.2\mu$s. Very few reach the Earth's surface before disintegrating. The protons created will interact very shortly after their creation with other particles of the atmosphere. Therefore, highly energetic γ and neutronic radiation composes most of the secondary cosmic radiation we are exposed to daily.

The intensity of both type of cosmic radiation tends to increase with altitude. A maximum intensity is reached at above 15 km about sea level. Below that altitude, the particles created are either absorbed gradually by the Earth's increasingly dense atmosphere or have disintegrated into daughter particles. Near sea level, the cosmic radiation is composed mostly of muons ($\mu^{\pm}$), electrons (e^{-}), neutrinos (ν) and γ radiation, decreasing with altitude. Being dependent on the altitude, the intensity of the cosmic rays can be expressed as follows,

$$I = I_0 e^{\frac{P_0 - P}{L}}, \tag{3.26}$$

where I is the intensity at atmospheric pressure P, I_0 is the intensity at pressure P_0 and L is an attenuation coefficient. The attenuation coefficient is generally expressed in $\mathrm{g/cm^2}$ and depends on the type of particle. The relation between the air pressure and the altitude is

$$P = P_0 e^{-\frac{H_0 - H}{8000\,\mathrm{m}}} \tag{3.27}$$

3.7 Terrestrial radiation

Different radioactive isotopes decay following different modes, as mentioned earlier. Some of these isotopes are present in the Earth's crust (i.e. long-lived primordial isotopes, Rb-87, K-40, U-238, Th-232, and their decay chain isotopes). The radiation emitted by these isotopes is called "terrestrial radiation". In the term terrestrial radiation, we include the isotopes that are present in the Earth's crust since its formation, called "natural radiation". "Artificial radiation" comes from the man made isotopes released in nature, such as $Pu{-}239$ and $Cs - 137$, through the different process mentioned in Chap. 1.

Natural radioactivity has been present in the Earth since the beginning of our planet. All the isotopes present in the Earth's crust, stable or not, have an extraterrestrial origin. Lighter elements, from hydrogen (H) to iron (Fe) in the periodic table of elements (Fig. 3.3) were formed in the different life stages of stars : main and post-main sequence, through thermonuclear fusion. Incidents like novas and supernovas are most probably the answer to the existence of elements heavier than iron in our planet.

In natural terrestrial radiation, we distinguish two different types of elements. On one side, our planet contains radioactive isotopes that disintegrate, via α or β decay, into stable elements. Table 3.3 gives a short list of some of these single occurring isotopes. On the other side, some radioactive series of elements are present in the Earth. Parent nuclei decay into unstable daughter nuclei, which decay again into unstable nuclei, which eventually decay into stable nuclei. Three decay series are found in nature, which are the thorium-232 series (^{232}Th)(Fig. 3.11), the uranium-238 series (^{238}U)(Fig. 3.10), and the uranium-235 series (^{235}U))Fig. 3.9).

From the three decay series, one can deduce a recurrent pattern that takes the form of $4n$ for the ^{232}Th series, $4n + 2$ for the ^{238}U series and $4n + 3$ for the ^{235}U series, where n is an integer. From this recurrence pattern, there seems to be the series $4n + 1$ missing in the natural radiation. In fact, this series, with ^{237}Np as parent nucleus, was present in nature at the formation of the Earth. Due to the short half-life of 2.25×10^6 yr, this series completely decayed, and is not found naturally anymore.

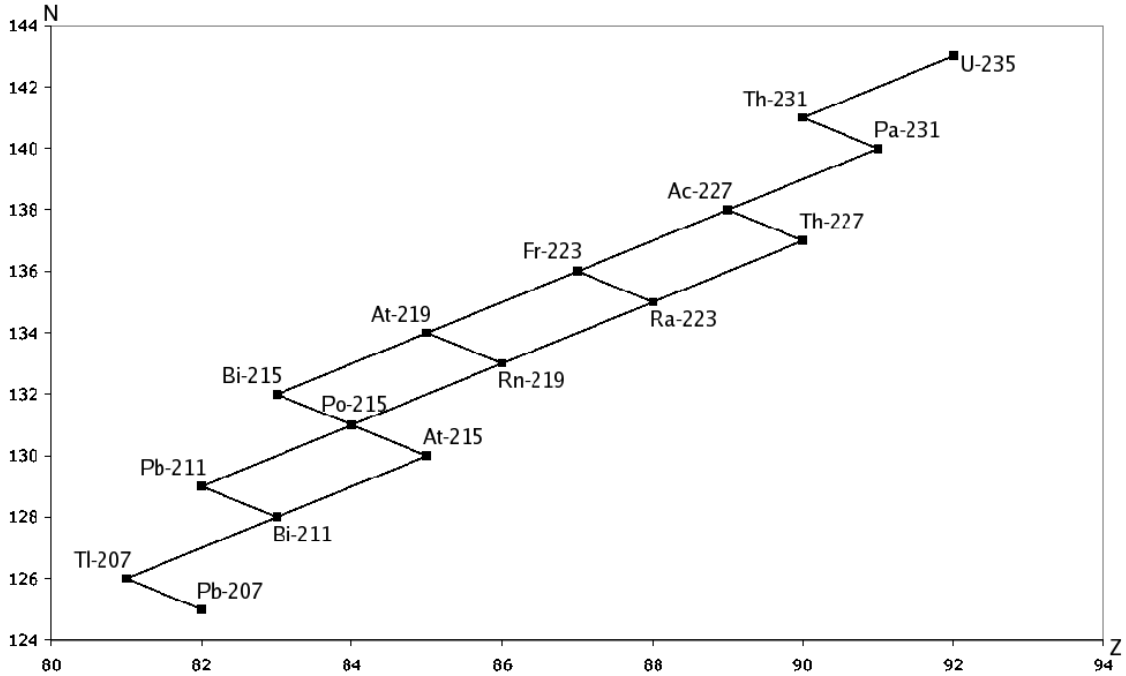


Figure 3.9: A scheme of the decay series of uranium-235 (^{235}U) and its daughter nuclei. The graph is viewed from top to bottom. An α decay is represented by a change to the left. A β^- decay is represented by a change to the right. For more information concerning the decay series see Table 3.4.

Table 3.3: Some single occurring radioisotopes found in natural terrestrial radiation [16].

Radioisotope	Half-life	Principal decay mode	Energy (MeV)	Intensity
^{40}K	1.26×10^9 yr	β^-	1.311	89%
		β^+/EC	1.505	11% for EC
^{87}Rb	4.88×10^{10} yr	β^-	0.283	100%
^{115}In	4.4×10^{14} yr	β^-	0.495	100%
^{123}Te	$> 5.3 \times 10^{16}$ yr	EC	0.053	100%
^{138}La	1.06×10^{11} yr	β^-	0.21	80%
		γ with EC	$(0.81, 1.43)$	70%
^{142}Ce	$> 1.6 \times 10^{17}$ yr	β^-		
^{144}Nd	2.1×10^{15}	α	1.83	100%
^{147}Sm	1.06×10^{11} yr	α	2.23	100%
^{148}Sm	7×10^{15} yr	α	1.96	100%
^{146}Sm	1.03×10^8 yr	α	2.50	100%
^{176}Lu	3.73×10^{10} yr	β^-	1.192	100%
^{187}Re	4.2×10^{10} yr	β^-	0.00266	100%

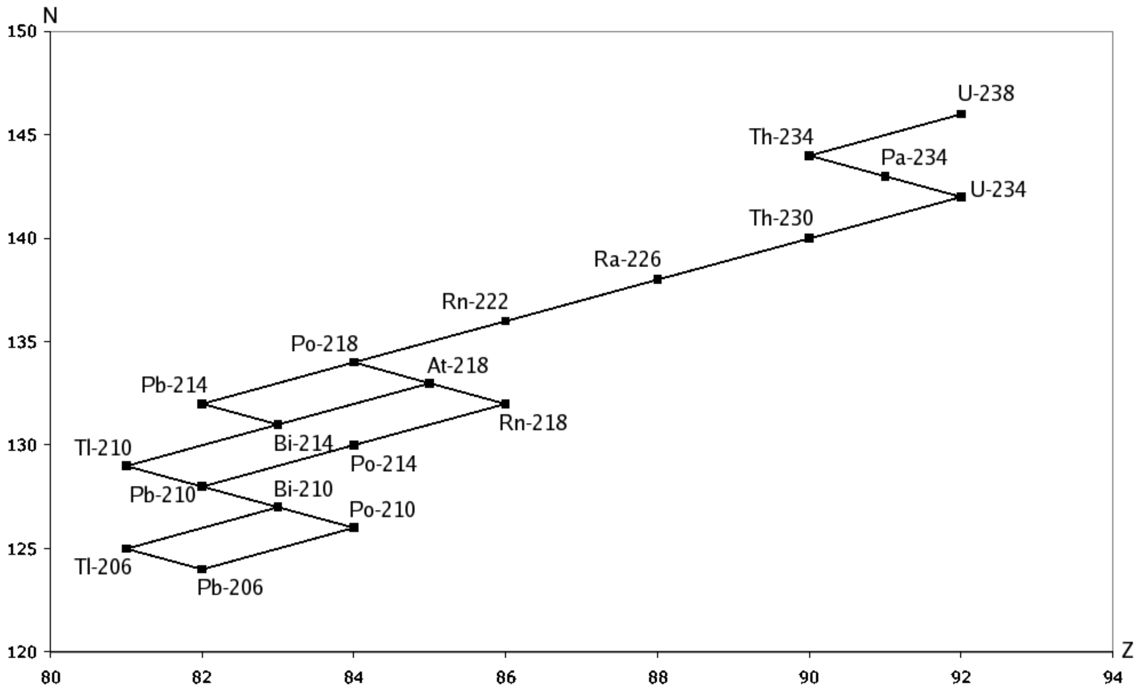


Figure 3.10: A scheme of the decay series of uranium-238 (^{238}U) and its daughter nuclei. The graph is viewed from top to bottom. An α decay is represented by a change to the left. A β^- decay is represented by a change to the right. For more information concerning the decay series see Table 3.4.

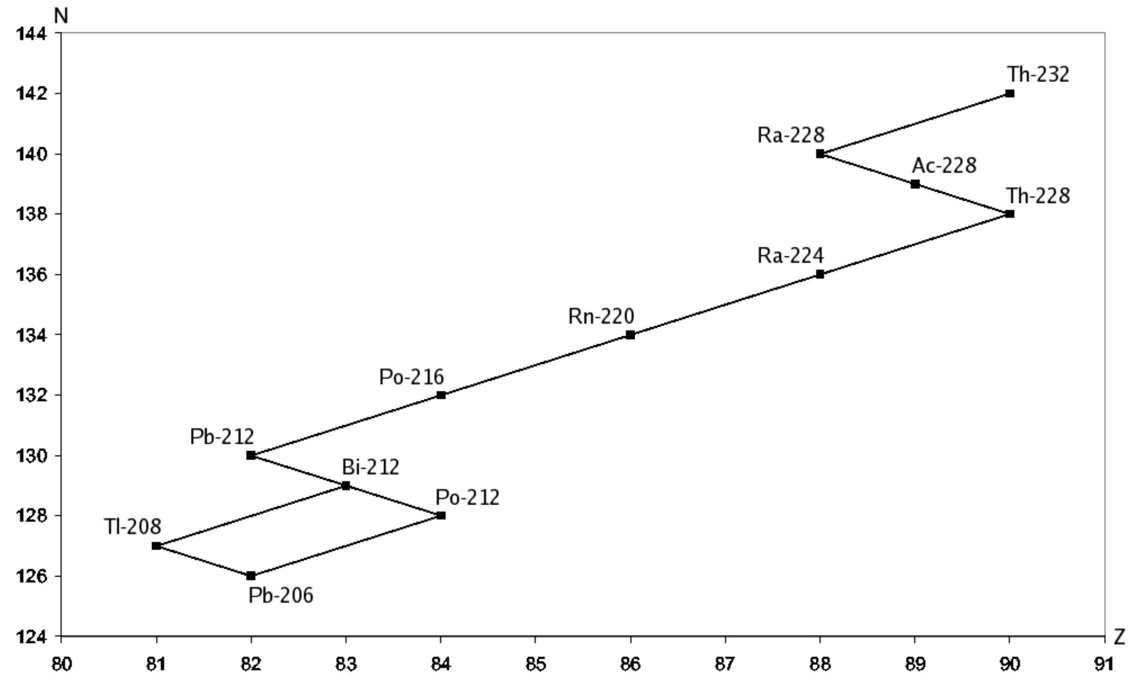


Figure 3.11: A scheme of the decay series of thorium-232 (^{232}Th) and its daughter nuclei. The graph is viewed from top to bottom. An α decay is represented by a change to the left. A β^- decay is represented by a change to the right. For more information concerning the decay series see Table 3.4.

Table 3.4: Information concerning the different natural decay series and their daughter nuclei [16].

$U-235$ series				$U-238$ series				$Th-232$ series			
Isotope	$T_{\frac{1}{2}}$	decay mode	Energy (MeV)	Isotope	$T_{\frac{1}{2}}$	decay mode	Energy (MeV)	Isotope	$T_{\frac{1}{2}}$	decay mode	Energy (MeV)
$U-235$	7.04×10^8 yr	α	4.6793	$U-238$	4.47×10^9 yr	α	4.0395	$Th-232$	1.40×10^{10} yr	α	4.081
$Th-231$	1.063 d	β^-	0.390	$Th-234$	24.10 d	β^-	0.273	$Ra-228$	5.76 yr	β^-	0.046
$Pa-231$	3.25×10^4 yr	α	5.148	$Pa-234$	6.69 h	β^-	2.197	$Ac-228$	6.15 h	β^-	2.127
$Ac-227$	21.77 yr	β^-	98.60	$U-234$	2.455×10^6 yr	α	4.856	$Th-228$	1.913 yr	α	5.520
		α	1.40	$Th-230$	7.54×10^4 yr	α	4.771	$Ra-224$	3.66 d	α	5.789
$Th-227$	18.72 d	α	6.146	$Ra-226$	1599 yr	α	4.870	$Rn-220$	55.6 sec	α	6.404
$Fr-223$	22.0 min	β^-	1.149	$Rn-222$	3.823 d	α	5.590	$Po-216$	0.145 sec	α	6.906
		α	0.006	$Po-218$	3.04 min	β^-		$Pb-212$	10.64 h	β^-	0.574
$Ra-223$	11.43 d	α	5.979			α	6.114	$Bi-212$	1.009 h	β^-	2.254
$At-219$	50 sec	α	6.390	$At-218$	1.6 sec	β^-				α	
$Rn-219$	3.96 sec	α	6.946			α	6.883	$Po-212$	0.298μ s	α	8.953
$Bi-215$	7.7 min	β^-	2.3	$Pb-214$	26.9 min	β^-	1.0	$Tl-208$	3.053 min	β^-	5.001
$Po-215$	1.780 ms	β^-		$Rn-218$	35 ms	α	7.267	$Pb-206$			
		α	7.526	$Bi-214$	19.7 min	β^-	3.27				
$At-215$	0.10 ms	α	8.178	$Po-214$	163.7μ s	α	7.833				
$Pb-211$	36.1 min	β^-	1.37	$Tl-210$	1.30 min	β^-	5.48				
$Bi-211$	2.14 min	α	6.279	$Pb-210$	22.6 yr	β^-	0.0635				
$Tl-207$	4.77 min	β^-	1.423	$Bi-210$	5.01 d	β^-	1.163				
$Pb-207$						α					
				$Po-210$	138.4 d	α	5.407				
				$Tl-206$	4.20 min	β^-	1.533				
				$Pb-206$							

3.8 gamma rays and their interaction with matter

The disintegration of radioactive isotopes, via α or β^- decay, often leaves the daughter nucleus into an excited state. From § 3.5, the daughter nucleus undergoes a cascade to the ground state with the emission of γ radiation. The cascade occur via one or multiple steps, with each step emitting γ radiation. The energy of the γ ray or rays emitted gives precious information on the excited state of the nucleus.

The purpose of this work is to evaluate the total exposure to radiation of a population in an urban area. Therefore, to evaluate the total exposure of a population, we need to get information on the type and the amount of radioactive elements presents in the urban environment. We will get this information through counting the number and fluence of incoming γ rays seen by a detector (Chap. 5). For this reason, I give a description of the interaction of γ radiation with matter.

A γ ray is a photon, that travels through free space in a straight line. The energy carried by this photon is proportional to its frequency (ν) or inversely proportional its wavelength (λ).

$$E = h\nu = \frac{hc}{\lambda} \tag{3.28}$$

where h is Planck's constant and c is the speed of light in vaccuum.

We chose to measure γ radiation to evaluate the total exposure to radiation instead of α or β radiation. Multiple reasons explains this choice. Firstly, γ radiation's penetrating power is greater than α, which are themselves absorbed in the first few layers of air, or β, which are absorbed in the first layers of dense matter. Therefore, γ radiation allows field measurement to survey a greater area. Secondly, due to the penetrating power of γ radiation, the detection instruments can be much smaller than for α or β rays. Field measurements becomes easier, especially indoor measurement, with smaller instruments. Finally, γ are indicators of the nuclei present, and can indicate whether α or β decay preceeded the γ emission.

When γ rays encounter matter, interaction with the atoms can happen through three different process. Photoelectric effect, § 3.8.1, Compton effect, § 3.8.2, and pair production, § 3.8.3 are the different possible interaction of γ radiation with matter.

3.8.1 Photoelectric Effect

The photoelectric effect is a process whereby electrons are extracted from their atom, after absorbing a photon. The energy of the photon is completely transferred to the electron, Fig. 3.12. The electrons can either be ejected from the surface of the material, like the surface of a metal, or interact with electrons from other atoms in the structure. After the electron has been extracted, the ionized atom is left in an excited state. The excited atom will relax to the ground state by the cascade of outer-shell electron and the emission of X-ray photons or by the emission of an Auger electron.

To extract an electron from the attractive electric potential of the atom, the photon must carry a minimum of energy. Otherwise, the atom is simply excited before relaxing to the ground state. The minimum energy required to extract an electron from an atom is called the "work function" and is $W = h\nu_0$ (h is Planck's constant $= 6.6262 \times 10^{-34}$ J $\cdot$ s). The value of the work function depends on the nature of the atom.

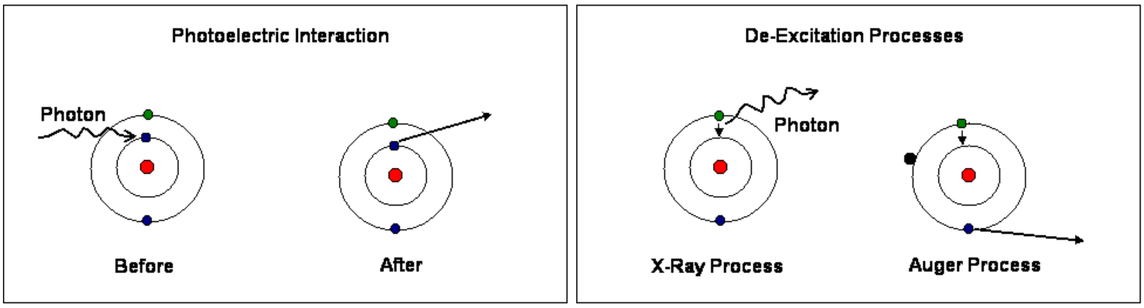


Figure 3.12: The photoelectric process is the ejection of an inner-shell electron, after the absorption of a photon. The atom is left into an excited state. The de-excitation process can happen either by the cascade of the outer-shell electron or the emission of an Auger electron [25].

The excess energy of the incident photon, if any, is carried away by the photoelectron as kinetic energy, given by

$$K_{e^-} = h\nu - W \tag{3.29}$$

In the photoelectric effect, the photons interact with electrons from the first layer (L) of atoms. Figures 3.12 gives a schematic representation of the photoelectric and de-excitation process.

3.8.2 Compton Effect

The Compton effect is an interaction between an incoming photon and an orbiting valence electron of the material. Part of the photon's energy is transferred to the electron, which is subsequently ejected from the atom. The scattered photon carries the remaining energy. The new photon can interact many times with different valence electrons of different atoms. Each interaction would eject the electron and create a new photon with less energy than the previous. The collision of the two particles, as shown in Fig. 3.13, follows the law of momentum conservation Eq. 3.30, which indicates the direction of the electron, but also of the new photon.

The electron will be ejected from this collision with a kinetic energy equals to the difference between the energy of the two photons, minus the work function needed to extract the electron from the atom:

$$\vec{p_\gamma} + \vec{p_e} = \vec{p_{\gamma'}} + \vec{p_{e'}} \tag{3.30}$$

$$K_{e^-} = (E_\gamma - E_{\gamma'}) - W = h\nu - h\nu' - W \tag{3.31}$$

3.8.3 Pair production

Pair production is a process where by an incoming photon creates a pair of particles (electron and positron). For this process to happen, represented schematically in Fig. 3.14, the photon needs to encounter a nucleus. The photon looses its energy, $h\nu$, to create a pair

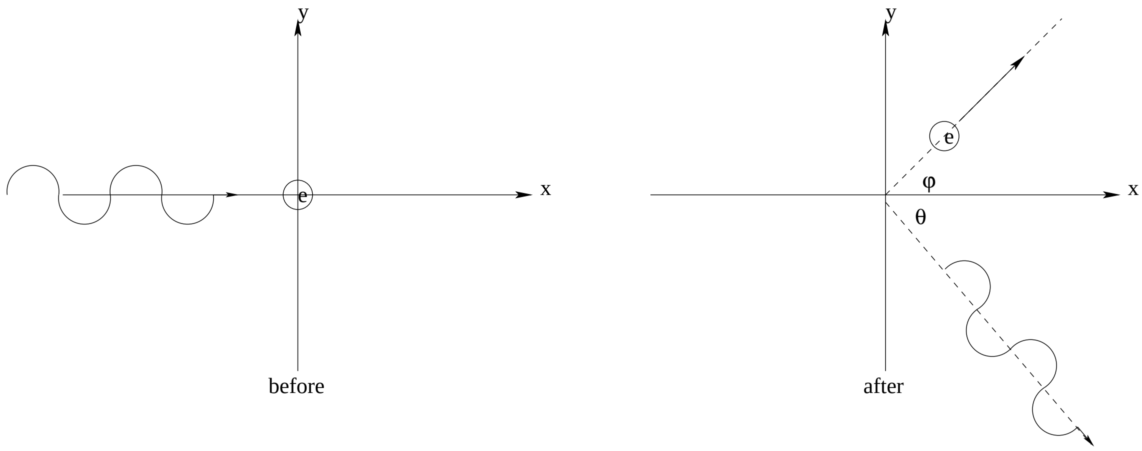


Figure 3.13: A schematic representation of the Compton effect. The energy and the direction of the electron and photon are given by the laws of conservation of energy and momentum.

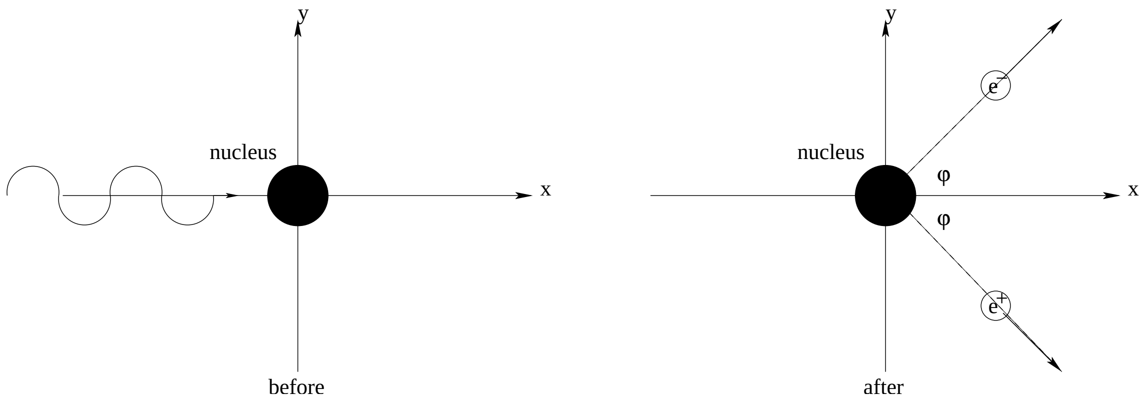


Figure 3.14: A scheme of the pair production process. An electron (e^-) and a positron (e^+) are created in the process. The kinetic energy that they carry depends on the energy of the incoming photon.

of electron-positron, $\gamma \rightarrow e^+ + e^-$. From the law of conservation of energy, the particles are created with kinetic energies given in Eq. 3.32. Since the positron has exactly the same properties as the electron, except for the electrical charge, their rest mass energy is the same. The creation of these particles must occur in the vicinity of a nucleus, for the conservation of momentum, therefore, from the Coulomb potential of the nucleus, the positron will have a slightly higher kinetic energy.

$$h\nu = E_{e^-} + E_{e^+} = \left(m_0c^2 + K_{e^-}\right) + \left(m_0c^2 + K_{e^+}\right) = K_{e^-} + K_{e^+} + 2m_0c^2 \qquad (3.32)$$

The inverse process, pair annihilation, happens when a positron comes close enough to an electron. Both being at rest, the particles annihilate, and their rest masses are turned into energy, $e^- + e^+ \rightarrow \gamma\gamma$. From the law of conservation of momentum, a pair of photon have to be created. Each photon carries away the energy liberated from the annihilation : $h\nu = m_0c^2 = 0.511\,\text{MeV}$

3.8.4 Cross section

An incident photon, or any other particle, travelling through a slab of material has a certain probability of interacting with the atoms. The probability of interaction is called the "cross section". As a matter of fact, each type of interaction process, photoelectric, Compton, and pair production, have a different probability of happening in the material.

The probability that a photon will interact with the material through the photoelectric effect is a function of the type of material and the energy of the incident photon. Equation 3.33 gives the cross section (τ) for the photoelectric effect. In this equation n and m range from 2 to 5, depending upon the γ [10]. From this equation, we can deduce that the probability of photoelectric effect increases with larger Z.

$$\tau_{PE} \sim \frac{Z^n}{E^m} \text{ for } n \sim 4...5 \text{ and } m \sim 2 \tag{3.33}$$

The cross section for the Compton effect decreases for higher energy photons. At low energy, from 100 keV to $\sim$ 10 MeV, the Compton effect represents the essential absorption mechanism. The cross section for the Compton effect is proportional to the type of material (Z) and inversely proportional to the energy of the incident photon (E),

$$\tau_C \sim \frac{Z}{E}. \tag{3.34}$$

For pair production, the energy of the incident photon has to be at least $2m_0c^2 = 2(0.511\,\text{MeV}) = 1.022\,\text{MeV}$. Above that energy threshold, the probability for the event is proportional to the type of material (Z^2) and to the natural log of the energy ($ln(E)$),

$$\tau_{PP} \sim Z^2 \ln(E). \tag{3.35}$$

In § 5.1, the different instruments used in environmental radiation monitoring will be explained. At this moment, one must remember that the higher the Z of the material, the greater the chance of creating the photoelectric.

Of the three interactions possible, only in the photoelectric effect is the photon's energy totally transferred to the ejected electron. Determining the energy of this electron boils directly to knowing the energy of the incoming photon. A technique, called *spectrometry*, consists in evaluating the energy of the electron ejected from photoelectric effect, through the collision it makes with atoms of matter.

3.9 Cosmic rays and their interaction with matter

Cosmic rays reaching our planet are mostly secondary in nature. The energy of these particles range from a few keV up to $\sim$ 20 GeV depending on the primary particle. The techniques to detect these particles can vary from one particle to the other and depends on the energy range in which we are interested. In the field of environmental radiation monitoring, we are interested in the energy deposited by these particles when passing through different material.

3.10 Environmental radiation

γ radiation spectrometry

In γ spectrometry, the energy for incoming γ radiation is detected; allowing the identification of radionuclide. Only the photoelectric effect absorbs all the energy of γ radiation. The material density of a spectrometer increases the probability of photoelectric effect. Furthermore, only in semiconductive material, th photoelectron can put valence electrons in the conduction band. Therefore, γ spectrometers are made from semiconductive material with a high density, and high Z.

dose rate measurements

Dose rate measurements, on the other hand, evaluates the total energy left by incoming γ radiation. Any process, photoelectric and Compton effects, that releases energy to the device ($\Delta E/$ kg) will be considered for the dose rate measurement. Therefore, dose rate measurements are made from material with lower density and Z.

Chapter 4

Radiation Protection Standards

4.1 History of Radiation Protection

Soon after the discovery of X-rays and radium, the potential dangers of exposure to radiation were recognized. In 1928, the ISR founded the *International X-ray and Radium Protection Committee.* This committee was restructured, in 1950, to better account for the total exposure to radiation, especially from sources outside the medical area. The committee changed its name to the ICRP, which still exist today. From their web site [39], the mission of the commission is "an independent Registered Charity, established to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation."

The ICRP is composed of a main commission and five standing committees. The main commission is composed of 12 members and a chairman. The five committees: Radiation effects, Doses from radiation exposure, Protection in medicine, Application of ICRP recommendations, and Protection of non-human environment, each including $12-20$ members.

The results from Chap 6 are presented following ICRP's recommendations.

4.2 Radiation Protection Units

The exposure time to direct radiation flux before reddening of the skin occured was the first attempt to qualify safe limits while working with ionizing radiation. The experts from the field of radiation protection soon realized that this first attempt gave very little details on the danger of the exposure.

In the 1930's, the "Roentgen" (symbol R) appeared in the field of radiation protection. This is the first unit that tries to measure the effect of exposure to radiation. The "Roentgen" is define as the amount of radiation required to liberate positive and negative charges of one electrostatic unit of charge in $1cm^3$ of air at standard temperature and pressure [30]. The process and energy required to ionized molecules or atoms can vary considerably from one matter to the other. A measure with this unit gives no detail on the type of radiation exposure. Therefore, new standards had to be developed that evaluate the exposition to radiation with greater precision.

For this purpose, the "rad" unit tried to fill the gap of the roentgen. A "rad" stands for radiation absorbed aose. In the international system of units, the "rad" is no longer used.

Table 4.1: Different units used in the field of environmental radiation protection. Some of the units evaluate activity of radioactive materials, while others take in consideration the effect of radiation on different matter.

unit name	**unit size**	
curie	activity of radioactive elements	$1\ \mathrm{Ci} = \frac{\text{disintegration of 1g of }^{226}\text{Ra}}{1\,\text{sec}}$
becquerel	activity of radioactive elements	$1\ \mathrm{Bq} = \frac{\text{1disintegration}}{1\,\text{sec}}$
roentgen	$\frac{\text{charges}}{\text{air volume}}$	$\mathrm{R} = \frac{\mathrm{C}}{\mathrm{m}^3}$ or $\frac{\mathrm{C}}{\mathrm{kg}}$
gray or rad (in the U.S.)	$\frac{\text{energy}}{\text{mass of matter}}$	$1\ \mathrm{Gy} = \frac{1\,\mathrm{J}}{1\,\mathrm{kg}}$
Sievert	$\frac{\text{energy}}{\text{mass of tissue or organ}}$	$1\ \mathrm{Sv} = \frac{1\,\mathrm{J}}{1\,\text{kg of organ}}$

The United States is the only country that still uses the “rad” as an absorbed dose unit, which represents $1\frac{\mathrm{erg}}{\mathrm{g}}$.

The “Gray” (symbol Gy) has replaced the “rad” in the international system of units. The “Gray” is defined as the energy deposited by radiation in matter, where $1\frac{\mathrm{J}}{\mathrm{kg}}$. The Gray makes no difference between the different types radiation or matter in which the energy is deposited.

In the field of nuclear physics, some units are used essentially to measure the amount of radioactivity in matter. The “Curie” (symbol Ci) is a unit that represents the amount of disintegration per second of a standard source. $1Ci$ is define as the activity of $1g$ of radium isotope (^{226}Ra). The scale of this unit is enormous, and no longer used as a standard unit.

$$1\ \mathrm{Ci} = 3.7 \times 10^{10}\ \mathrm{Bq} \tag{4.1}$$

For the latter reason, a second activity unit has been defined. The “Becquerel” (symbol Bq) is now used in the international system of units, and represents one disintegration per second.

The activity of radioactive matter plays an important role in the exposure to radiation. It is important firstly because it gives an indication on the amount of particles (radiation) flowing through the body, but also because when coupled to the type of radiation, the amount of energy deposited can be evaluated. Table 4.2 gives an overview of the different physical values used when calculating exposure to a direct flux of particles.

By knowing the geometrical situation and the activity (in Bq) of matter, we are able to determine the flux of radiation flowing through a body. This can help determine the total energy transferred (E_{tr}) by radiation flowing into a unit mass (dm) of matter, see Eq. 4.2. This proportion is defined as the “KERMA” (symbol K). The KERMA represents the total kinetic energy liberated by the incoming radiation in a reference material. The KERMA is measured in Gy. The KERMA makes it difficult to evaluate the danger of human exposure to radiation, since it does not take into account the exposure time or the

Table 4.2: Different physical values when exposed to a direct flux of particle [13]

Size	Definition	Meaning of size
number of particles	$N = \int \frac{dN}{dt} dt$	This represents the total number of particles flowing through a body
particle flux (ϕ)	$\frac{\dot{N}}{A} = \frac{1}{A}\frac{dN}{dt}$ $(\frac{1}{\text{cm}^2 \cdot \text{sec}})$	This represents the number of particles per second flowing through a surface.
Radiant Energy (ψ)	$R = \int \frac{dN}{dE} E \cdot dE$	This represents the energy carried by the total amount of particles.
Energy flux (Ψ)	$\frac{\dot{R}}{A} = \frac{1}{A}\frac{dR}{dt}$ $(\frac{\text{MeV}}{\text{cm}^2 \cdot \text{sec}})$	This represents the amount of energy carried through a body per second.

type of radiation.

$$K_a = \frac{dE_{tr}}{dm}. \tag{4.2}$$

Incoming radiation interacts with matter through the energy transmitted to its component, see § 3.8. Therefore, the "absorbed dose" (symbol D) is the energy actually transmitted (E) by the flux of particles to the material per unit mass (dm). The "absorbed dose" is also measured in Gy. One Gray represents the absorption of one joule by one kilogram of matter:

$$D = \frac{dE}{dm} \tag{4.3}$$

In radiation protection, it is not only important to know the total amount of energy absorbed by a body, but the time scale that the energy was absorbed. The same dose can be fatal if absorbed over a short period of time, and be insignificant over a long time scale. Therefore, a new value has to be introduce called the "absorbed dose rate" or just the "dose rate" (symbol $\dot{D}$), which represent the total dose absorbed by a body over the absorption period:

$$\dot{D} = \frac{dD}{dt} \tag{4.4}$$

Both the absorbed dose and the dose rate evaluate the energy transmitted by the incoming radiation, without considering the type of radiation or the details of the material irradiated. In radiation protection, we normally want to evaluate the danger resulting from radiation exposure. The exposition danger will be different with different types of radiation. Therefore, the "equivalent dose" (symbol H_T) is the absorbed dose weighted by the radiation factor, since different radiation type penetrate and interact differently with matter. In this equation, $\omega_R = 1...20$ is the radiation weighting factor and $D_{T,R}$ is the mean absorbed dose in a tissue or an organ T.

$$H_T = \sum_R \omega_R D_{T,R} \tag{4.5}$$

On top of weighting the radiation type, a standard that considers the type of tissue or organ irradiated is called the "effective dose" (symbol E). The effective dose is the equivalent dose with a tissue or organ weighting factor, given by $\omega_T = 0.01...1$ in Eq. 4.6. The equivalent dose and the effective dose are both measured in "Sievert" (symbol Sv). A Sievert is the energy transmitted by the incoming radiation to the tissue or organ by unit mass ($1\ \mathrm{Sv} = \frac{1\ \mathrm{J}}{1\ \mathrm{kg}}$) including all weighting factors. The weighting factors have no associated units, they represents the sensitivity of the tissue or organ to differing radiation types. The values for the radiation weighting factor are given in Table 4.3 and the tissue weighting factors are given in Table 4.4.

$$E = \sum_T \omega_T H_T = \sum_T \sum_R \omega_R D_{T,R} \tag{4.6}$$

Similarly to the dose rate, it is often more important to know the absorbed dose per time interval, than the total amount radiation absorbed. The "equivalent dose rate" (Eq. 4.7) and the "effective dose rate" (Eq. 4.8) are simply the dose absorbed by a tissue or an organ per unit time.

$$\dot{H}_T = \frac{dH_T}{dt} \tag{4.7}$$

$$\dot{E} = \frac{dE}{dt} \tag{4.8}$$

Many parameters have to be considered for a precise evaluation of the equivalent dose and the effective dose. The type of incoming radiation, the energy of the particles, the isotropy or anisotropy of the radiation beam, the tissues or the organs irradiated and the irradiation time period all play a role in the precise evaluation of the standard. The multitude of parameters can change from situation to situation making it very difficult to standardize their precise evaluation. Therefore, the ICRU created a unit called the "ambient dose equivalent" ($H^*(10)$) which represents the equivalent dose measured in a sphere with tissue equivalent weighting factor $\omega_T = 1$ at $10mm$ in depth in the oriented parallel incoming radiation beam, like shown in Fig. 4.1. For non-penetrating radiation, the ambient equivalent dose can measured at $0.07mm$ ($H^*(0.07)$) in depth of the ICRU sphere. The ambient equivalent dose, like the equivalent dose and the effective dose, is measured in Sievert.

4.3 Limits in Radiation Protection

The field of radiation protection was developed to evaluate the danger of exposure of human beings to different types of ionizing radiation. The ICRP, since its creation, fixes dose limit restrictions and reviews the limits periodically (given in Table 4.5). Switzerland follows ICRP recommendations, in its "Swiss Radiation Protection Ordinance". The last revision made to the Swiss Radiation Protection Ordinance was edited in 2000, by the Federal Chancellery.

Switzerland also has some limits for concentrations of radioactive material in air and water and consumer goods which are given in the "limits on protection against radiation"(art. 102) [11] and on consumer goods in the "limits on foreign substances and components" [8].

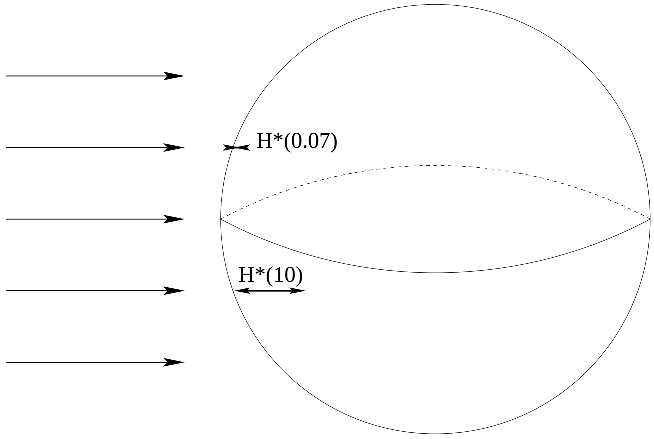


Figure 4.1: Schematic representation of the ICRU sphere. The ambient dose equivalent is shown for $H^*(10)$ and for $H^*(0.07)$.

Table 4.3: Radiation weighting factors [28]. These values are being revised by the ICRP. Their values can change shortly after this work is done.

Type of radiation	Energy range	Radiation weighting factor ω_R
Photons, electrons, muons	All energies	1
Neutrons	< 10 keV	5
	> 20 MeV	5
Protons	> 2 MeV	5
Neutrons	$10 - 100$ keV	10
	$2 - 20$ MeV	10
Neutrons	$0.1 - 2$ MeV	$5 - 20$
α particles, fission fragments, heavy nuclei	All energies	20

4.4 Environmental Radiation Dose

In radiation protection, to evaluate the total exposition to radiation, we define three types of incoming radiation. We differentiate these sources based on their origins: terrestrial, artificial, and cosmic radiation.

4.4.1 In-depth Terrestrial Radiation Contribution

Terrestrial radiation (see § 3.7) is generated by all the radioactive elements present in the Earth's crust, since its formation. The radiation originates from single occurring isotopes, see Table 3.3, or from one of the three decay schemes, see Table 3.4. The equivalent dose and the effective dose are evaluated from the amount of incoming radiation per surface area.

The isotopes contributing to terrestrial radiation have been present in the Earth's crust since the formation of the world. Therefore, to evaluate the contribution of terrestrial radiation, we assume that the distribution of these isotopes is homogeneous. The distribution is assumed homogeneous indepth as well as radially. Figure 4.2 gives a schematic repre-

Table 4.4: Tissue and organ weighting factors [28]. These values are currently being revised by the ICRP, and their values may change in 2008 when the latest review is released.

Tissue or organ	weighting factor ω_T
bone surface	0.01
breast	0.05
colon	0.12
gonads	0.20
liver	0.05
lungs	0.12
oesophagus	0.05
red bone marrow	0.12
skin	0.01
stomach	0.12
thyroid	0.05
urinary bladder	0.05
remainder	0.05

sentation of the flux of particles Φ_E coming from a volume unit dV. The soil contains an activity A (in $\frac{\text{Bq}}{\text{kg}}$) of particles with energy E_i (in J) of intensity I_i

$$\Psi_E = \sum_i E_i I_i \int_V \frac{A}{4\pi(r'+r)^2} e^{-\mu_{\text{ssoil}} r} e^{-\mu_{\text{sair}} r'} dV \tag{4.9}$$

where μ_{ssoil} and μ_{sair} are the absorption coefficient of the soil and of the air, respectively, which varies for γ rays of different energies. Since the integration is done over the whole area, the flux of incoming radiation becomes

$$\Psi_E = \sum_i E_i I_i \int_{\phi=0}^{\frac{\pi}{2}} \int_{\theta=0}^{2\pi} \int_{r=0}^{\infty} \frac{A}{4\pi\cancel{(r'+r)^2}} e^{-\mu_{\text{ssoil}} r} e^{-\mu_{\text{sair}} r'} \cancel{(r'+r)^2} \sin\phi dr d\theta d\phi \tag{4.10}$$

where ϕ is the axial angle and θ is the radial angle. When integrating this equation, the flux of radiation through a dV, becomes

$$\Psi_E = \frac{A}{2\mu_{\text{ssoil}}} \sum_i E_i I_i \int_{\phi=0}^{\frac{\pi}{2}} e^{-\frac{\mu_{\text{sair}}}{\cos\phi}} \sin\phi d\phi \tag{4.11}$$

From this result, we can evaluate the contribution of the terrestrial radiation to the total absorbed dose rate

$$\dot{D} = \sum_i E_i \Phi_E \cdot f \tag{4.12}$$

where, in the air

$$f = \frac{\mu_{\text{aair}}}{\rho}[cm^{-1}] \cdot 1.602 \times 10^{-13} \frac{J}{MeV} \cdot 1000 \frac{g}{kg} \cdot 3600 \frac{s}{h} \tag{4.13}$$

is the absorption factor (in $[\frac{\text{J}}{\text{kg}}]$) of the radiation in the body.

Table 4.5: Effective dose limits recommended by the ICRP (publication 60 from 1990) per person per year [28]. These recommendation are made for effective dose when exposed to radiation coming from artificial sources, apart from medical exposure to radiation, radon, and cosmic radiation.

Maximum constraint Effective dose (mSv/year/person)	Situation to which it applies	
100	In emergency situations, for workers, other than for saving life or preventing serious injury or preventing catastrophic circumstances, and for public evacuation and relocation : and for high level of controllable existing exposures (art. 21).	professionally exposed
20	For situations where there is direct or indirect benefit for exposed individuals, who receive information and training, and monitoring and assessment (art. 35).	
5	In Switzerland, the “radiation protection schedule” precise for situations where there is direct or indirect benefit for exposed individuals **between 16 and 18 years of age**, who receive information and training, and monitoring and assessment (art. 36).	
1	For individuals exposed in normal situations (art. 37).	general public

4.4.2 Surface Artificial Radiation Contribution

Nuclear power plants, research centers, nuclear bomb testing, hospitals and industries use radioactive material for different reasons. Nuclear catastrophes, like Chernobyl, nuclear accidents, or any other incident that releases radioactive isotopes into nature is called “artificial radiation”. Two cases scenarios are used to evaluate its contribution to the total absorbed dose: 1) freshly deposited isotopes, most of whos components are still on the ground surface, and 2) isotopes deposited a certain while ago, having more or less penetrated the soil.

Surface deposition

Firstly, in the case of a fresh deposition on an area, we assume that the isotopes are still on the first soil layers. The contribution to the total absorbed dose comes from a “surface deposition”. Figure 4.3 gives a schematic representation of a surface deposition. The energy flux Ψ_E passing through a body’s surface element dS, for a soil containing a surface deposition activity A (in $\frac{\mathrm{Bq}}{\mathrm{m}^2}$) of isotopes emitting rays at energy E_i (in J) of intensity I_i.

$$\Psi_E = \sum_i E_i I_i \int_S \frac{A}{4\pi r^2} e^{-\mu_{s\mathrm{air}} r} dS \tag{4.14}$$

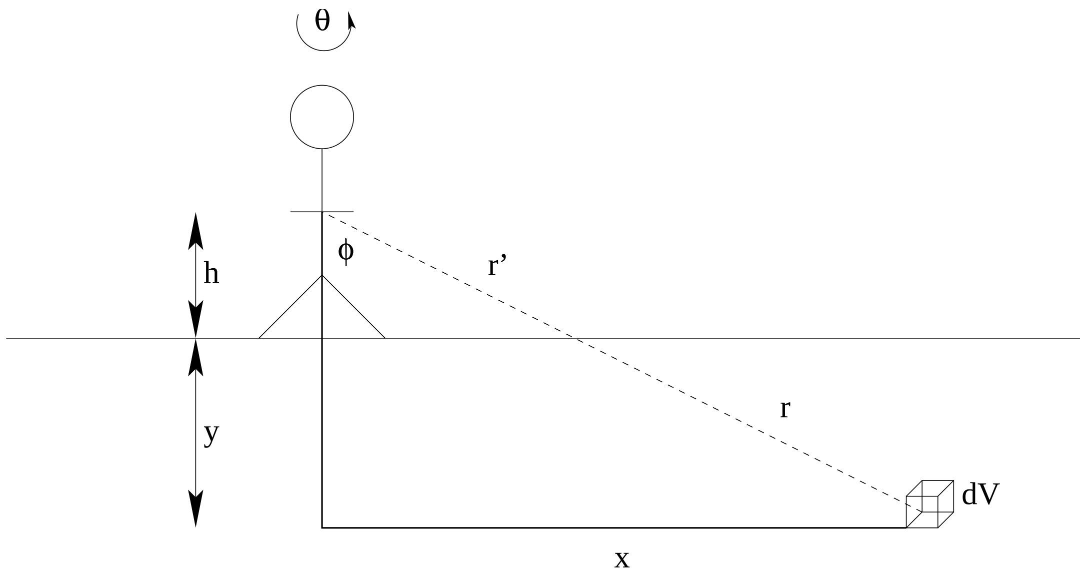


Figure 4.2: Schematic representation of the contribution of terrestrial radiation. The incoming flux of particles starts from a volume unit dV. The dotted line represents the trajectory of an incoming γ ray has not been absorbed over the distance $r + r'$ in the soil or in the air.

where $\mu_{s\text{air}}$ is the absorption coefficient in the air. After the integration, the energy flux becomes

$$\Psi_E = \sum_i E_i I_i \int_{\theta=0}^{2\pi} \int_{r=0}^{\infty} \frac{A}{4\pi r^2} e^{-\mu_{s\text{air}} r} r dr d\theta \tag{4.15}$$

where θ is the radial angle.

$$\Psi_E = \frac{A}{2} \sum_i E_i I_i \int_{r=0}^{\infty} \frac{e^{\mu_{s\text{air}} r}}{r} dr \tag{4.16}$$

From the energy flux passing through a body's surface element, we can evaluate the contribution of artificial radiation deposited on a soil surface to the total absorbed dose rate $\dot{D}$

$$\dot{D} \sim \frac{d\Psi_E}{dt} \tag{4.17}$$

Penetrated deposition

In the case when the deposition happened a while ago, the contribution to the total absorbed dose can be evaluated similarly as for the normal terrestrial contribution, with the assumption of uniformly penetrated isotopes if the time $t >> 1$. Otherwise, from the ICRU report [27], the isotopes' distribution follows an exponential penetrating law in depth, see Eq. 4.18. In fact, when isotopes are deposited on a surface, they encrust into the soil. The type of soil, the type of isotopes, and the weather are some of the parameters influencing

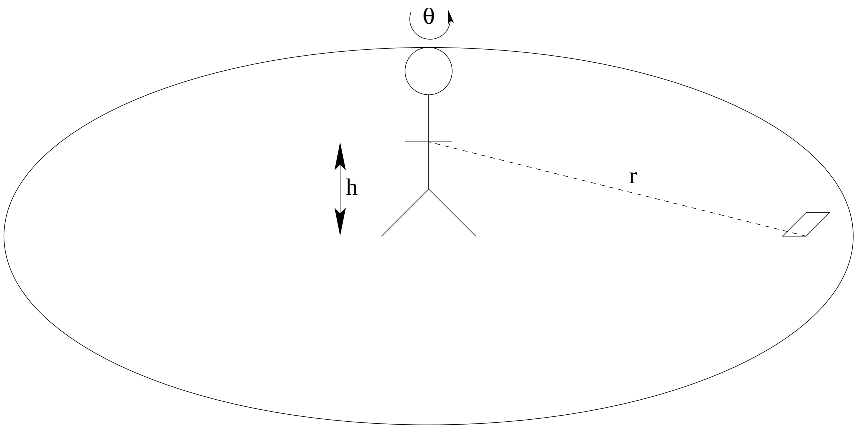


Figure 4.3: Schematic representation of the contribution of surface deposition. The incoming flux of particles starts from a volume unit dS. The dotted line represents the trajectory of an incoming particle that has not been absorbed by the air.

the absorption of isotopes by the surface. The activity distribution of the soil A depends the surface activity A_0 and a relaxation mass per unit area ρ. The energy flux and the total absorbed dose rate for such a distribution can be found in Eq. 4.19 and 4.20

$$A(r) = A_0 e^{-\frac{r}{\rho}} \tag{4.18}$$

$$\Psi = \frac{A(t)}{2\mu_{\text{ssoil}}} \sum_i E_i I_i \int_{\phi=0}^{\frac{\pi}{2}} e^{-\frac{\mu_{\text{sair}}}{\cos\phi}} \sin\phi d\phi \tag{4.19}$$

$$\dot{D} = \Psi_E \cdot f \tag{4.20}$$

where f is the same as for the indepth case (see Eq. 4.13).

4.4.3 Cosmic Radiation Contribution

Cosmic radiation (cf. § 3.9) is defined as a flux of particles or radiation coming from outer space. This radiation originates from astronomical events like novas, supernovas, solar flares and solar wind. The Earth's atmosphere, therefore, is constantly bombarded by the primarily particles (essentially protons and α particles). The collisions of these particles with the atmosphere's nucleus generates secondary cosmic radiation, composed mainly of muons, electrons, neutrons and highly energetic γ rays (Fig. 3.8). After the creation of secondary radiation, these particles cascade toward the Earth's surface.

The Earth's atmosphere acts as a shield against cosmic radiation. The greater the layer of atmosphere, absorbs more and more cosmic radiation, increasing the shield. Therefore, cosmic radiation increases with altitude.

The Earth's magnetic field deflects the lower energy primary cosmic particles toward the magnetic poles. More particles enter the poles increasing the intensity of the cosmic radiation. This increase at the poles implies a variation in cosmic radiation intensity as a function of the geographical emplacement. From Bouville and Lowder [2], “the flux density and dose rate is about 10% lower at geomagnetic equator than at high latitude.”

Cosmic particles interact with nuclei. The greater the density of nuclei, the greater the attenuation of the cosmic flux. Up to here, we have only considered natural variations of the cosmic flux. The structure of the buildings create an extra shield to cosmic particles. One of the objectives of this work is to evaluate the importance of construction materials in shielding cosmic radiation.

In addition to spatial variations, their are five temporal parameters that influence the intensity of cosmic radiation. Since the amount of air plays a key role for the collisions with cosmic particles, barometric pressure fluctuations will affect the cosmic flux by a very small amount. Secondly, seasonal variations affect slightly the atmosphere's thickness. This parameter has no net effect over the yearly absorbed dose from cosmic radiation. Disturbance in the Earth's magnetic field varying the trajectories of primary cosmic particles, have a negligible affect on the total absorbed dose from cosmic radiation. The last temporal parameter affecting the cosmic flux is the 11 years cycle of solar activity. This mean variation can vary the total absorbed dose from cosmic radiation by 10% [2].

We have differentiate between charged and neutral particles to evaluate the equivalent dose absorbed from cosmic radiation. This difference has to be considered because of the weighting factor with tissues and organs. Charged particles (muons and electrons) have a radiation weighting factor of $\omega_R = 1$. For outdoor exposure, Bouville and Lowder [2] evaluate the tissue weighting factor $\omega_T = 1$. The mean equivalent dose absorbed for charged cosmic particles (H_c) over yearly period in function of the altitude (z) is given in Eq. 4.21. The mean equivalent dose absorbed for cosmic neutrons (H_n) over yearly period as a function of the altitude (z) is given in Eq. 4.22.

$$H_c = (45.87\frac{\mu\,\mathrm{Sv}}{\mathrm{yr}})e^{-\frac{z}{0.6\,\mathrm{km}}} + 177.731e^{\frac{z}{2.2\,\mathrm{km}}} \tag{4.21}$$

$$H_n = \begin{cases} (20\frac{\mu\,\mathrm{Sv}}{\mathrm{yr}})e^{\frac{z}{0.962\,\mathrm{km}}} & \text{for } z < 2km \\ (39.6\frac{\mu\,\mathrm{Sv}}{\mathrm{yr}})e^{\frac{z}{1.432\,\mathrm{km}}} & \text{for } z > 2km \end{cases} \tag{4.22}$$

4.5 Choice of units

The ICRU [27] reports that the equivalent dose rate ($\dot{H}$) or the effective dose rate ($\dot{E}$) are the best standards evaluating radiation exposure, since they take into account the type of radiation and the body part exposed. The ambient dose equivalent ($H^*(10)$) is the standard used in the CPR [12]. External background exposure supposes that the whole body is irradiated by γ radiation of different energies. To convert the measured air KERMA into ambient dose equivalent, the *Environmental Radioactivity Section* follows Table 4.6, from the calibration laboratory of the radiation protection department of PSI.

The results of this work will be given as the ambient dose rate ($H^*(10)$). The ionisation chamber is calibrated in this standard, a calibration made at the PSI, Switzerland. From the terrestrial γ radiation energy, a conversion is possible from the fluent rate to the ambient dose rate, as shown in Table 4.6. Cosmic exposure is given in equivalent dose

Table 4.6: Estimation of the ambient equivalent dose rate $H^*(10)$ conversion factors from air KERMA rate as function of γ radiation energy. Conversion factors used by the *Environmental Radioactivity Section.*

Energy (MeV)	$H^*(10)/K_a$ $\frac{\mathrm{Sv}}{\mathrm{Gy}}$	Energy (MeV)	$H^*(10)/K_a$ $\frac{\mathrm{Sv}}{\mathrm{Gy}}$
0.01	0.008	0.015	0.26
0.02	0.61	0.03	1.10
0.04	1.47	0.05	1.67
0.06	1.74	0.08	1.72
0.10	1.65	0.15	1.49
0.20	1.40	0.30	1.31
0.40	1.26	0.50	1.23
0.60	1.21	0.80	1.19
1.00	1.17	1.50	1.15
2.00	1.14	3.00	1.13
4.00	1.12	5.00	1.11
10.00	1.10		

rate [12]. Cosmic radiation covers an energy range from a few keV to many GeV, in a continuous manner. The conversion of cosmic radiation exposure will be assumed to be roughly equals

$$E_{\text{cosmic radiation}} \approx H^*(10)_{\text{cosmic radiation}}. \tag{4.23}$$

Chapter 5

Instruments and Devices

In environmental radiation protection the standards described in Chap. 4 are realized instruments which measure the incoming flux of one of the radiation types: α, β or γ. Very few instruments can measure all types of radiation at once. The purpose of this work is to evaluate the total absorbed dose from γ radiation, in an urban area. To do so, incoming γ radiation must be measured in various environments, both indoor and outdoor.

Due to their penetrating capacity, γ radiation are the primary contributors to the absorbed dose. Since α and β radiation are stopped quickly by the first layers of material, their contribution to the total absorbed dose is insignificant as long as the radioactive substance is not incorporated in the human body, by inhalation, drinking water or consumer goods. Therefore, this discussion to γ radiation measuring instruments.

By measuring γ rays, the detection of most of the natural and artificial radioactive isotopes distributed in the environment is possible. Many radioactive isotopes, following emission of α or β radiation, will be left in an excited state which cascades to the ground state by the emission of γ radiation. The energy of the emitted γ are unique to the specific isotope, and allow unambiguous identification of the source nucleus.

5.1 Environmental Radiation Monitoring

For environmental radiation monitoring, several techniques have been developed and their combined used yields a full overview of the environment. Firstly, "laboratory monitoring" consist of measuring the activity of samples of various sources (goods, soil, air, water, ...) taken from natural environment. In Switzerland, the samples are taken from regions all over the country, giving a overview of the whole territory. The samples are brought to the laboratories to be measured on appropriate instruments, after adequate sampling preparation. This technique offers the advantage of having the samples in the laboratory, which they can be measured for a long periods of time, increasing therefore the quality of the results. But measuring samples in laboratories has some inconveniences. Samples taken from a field or a meadow, for example, do not necessarily give a correct overview of the isotopes distribution, especially in the case where the isotopes are not distributed homogeneously in or on the ground. Secondly, it takes longer compared to other techniques, to obtain results from a laboratory measurements, due to the length of the measurement, but also due to time lost from the moment the samples are collected and prepared to the moment they are measured. In the case of a nuclear incident or catastrophe for example, the laboratory based sampling method is not prompt enough.

A second technique used in environmental radiation monitoring is called *In Situ* measurement. This technique consists of measuring the incoming radiation with instruments directly situated in the field, meadow or site of interest, giving immediate results. To do so, instruments were developed which are portable and robust. The online measurement is one of the great advantage of this technique, very useful in the case of a nuclear incident or catastrophe. In the case of non-homogeneous ground or non-homogeneous surface deposition, such as found after a nuclear accident, *In Situ* measurements give an average overview of the activity of the soil, of $\sim 20m$ radius for in-depth distribution and $\sim 1'500m$ radius for surface distribution [21]. Due to γ radiation absorption by soil and air, 95% of the incoming γ rays originate from this $\sim 20m$ radius surface surrounding the measurement instrument.

Instruments have been developed specifically for measurements of incoming γ radiation. Whether laboratory or *In Situ* measurements, the γ spectrometer developed are fundamentally similar. *In Situ* instruments are designed for robustness and portability, where laboratory instruments are made for more precise results, and often include lead shielding to eliminate background radiation.

For *In Situ* measurements, two types of instruments are used. Instruments measuring the incoming terrestrial γ radiation and instruments measuring the total background γ radiation dose, including the cosmic contribution, are generally used in parallel. The instruments used in environmental radiation protection are: Geiger-Müller counter, scintillation counter, germanium spectrometer and ionization chamber.

5.1.1 Geiger-Muller counter

In 1908, at the very beginning of understanding radioactive phenomenons, Hans Geiger, in collaboration with Ernest Rutherford, developed an instrument able to detect α particles. Twenty years later, with a Ph.D. student (Walther Müller) Geiger improved the counter so it could detect all types of radiation [30].

A Geiger-Müller counter is a device able to detect ionizing radiation. Generally this device is used to detect α or β particles, but also γ radiation provided it undergoes a charge creation interaction within the apparatus. The Geiger-Müller counter consist of a device chamber, generally in a cylindrical shape, filled with noble gas, where an intense electric field is maintained. When ionizing particles passes through the device, interactions can occur between the particles and the atoms of the gas and of the walls of the device, creating electron-ion pairs in the chamber. Under the intense electric field created by the high voltage, the electrons drift toward the cathode. Through multiple collisions, the energy acquired by the drifting electrons can ionize atoms or molecules of the gas, generating a discharge. A small electrical impulse is produce in the device when the electrons reach the cathode.

The Geiger-Müller counter can only detect the presence of radioactivity. Under the intense electric field, the number of electrons liberated in the discharge is not proportional to the energy of the incoming radiation. Therefore, the device cannot differentiate between the types of radiation or their energies. For this reason, the Geiger-Müller counter is used currently only to detect the presence of radioactive sources, such as surface contamination.

Once the contamination has been detected, other instruments can can be used to make a more detailed overview of the situation, in which the type, concentration and distribution of radionuclide can be found. The low cost and the ease of use makes the Geiger-Müller device useful in contamination cases, to have a rapid overview of the situation.

5.1.2 Scintillation Counter

Environmental radiation monitoring cannot evaluate the danger of exposure to radiation by only detecting the presence of radioactivity. It is necessary to have more information on the type of radionuclide: on the energy of the incoming rays and on the radiation dose. Detectors, like scintillation counters, have been developed for this purpose.

Scintillation counters detects incoming γ radiation by emitting low energy photons (usually in the visible range) generated by the Compton, photoelectric and pair production. Different types of scintillation counters can be found: organic scintillators (solids, liquids, or gas), inorganic scintillators (like NaI or CsI crystals for example) and inert elements scintillators (liquid or gas). The scintillation produced is different for these types of scintillators. I will explain the scintillation process of inorganic scintillators, since γ spectroscopy for radioprotection uses almost exclusively the NaI type scintillator [18].

The scintillation process is produced by the interaction of a γ ray with the atoms of the crystal. γ radiation generates Compton, photoelectric or pair production. The subsequent charged particles excite surroundings atoms, creating electron/hole pairs. The recombination of the electron/hole pairs make visible light. To increase the probabilities of reunification of electrons and holes, impurities are added to the crystal, called "activator". Thallium activator is generally added to NaI scintillator ($NaI(Tl)$). The electrons, put in the conduction band will drift in the crystal until interacting with activator. The electrons can yield their energy, exciting the activator's atoms. The activator will emit photons (normally in the visible range) when returning to ground state.

The number of photons generated by the crystal is proportional to the energy of the incoming γ radiation. These photons are collected by a photomultiplier tube (PMT). A PMT is a device sensitive to light, that multiplies the incoming impulse, by $10^5 \rightarrow 10^7$ times. The incoming photons detected by the crystal are amplified and turned into an electrical impulse by the PMT.

Scintillation counters are sensitive to γ radiation ranging from a few keV up to many MeV. The number of photons created in the scintillator is proportional to the energy of the incoming γ radiation. The experimental counting efficiency of a detector is defined as the fraction of particles detected out of the total incident particles flux (I_γ in rays/sec) passing through the crystal

$$\eta = \frac{\text{count}/\sec}{I_\gamma} \cdot 100\% \tag{5.1}$$

given in %. The theoretical efficiency of a detector is found from the number of electrons freed by a γ radiation

$$\Delta n = \frac{\sqrt{n}}{n} \tag{5.2}$$

where n is the number of γ rays detected

$$n = \frac{E_\gamma}{e_\gamma} \cdot \epsilon_L \cdot \epsilon_s \cdot \epsilon_c \tag{5.3}$$

where E_γ is the energy of the incoming γ radiation, e_γ is the energy needed to create an electron/hole pair in the conduction band, ϵ_L is the probability of having a photon transfer ($\sim 10\%$), ϵ_s is the probability of electron collection ($\sim 50\%$) and ϵ_c is the efficiency of the PM ($\sim 20\%$). The counting efficiency of a scintillation counter depends greatly on the size and the geometry of the crystal. The probability of interaction with the crystal increases with the size of the crystal. A quite bulky scintillation counter can, therefore, reach a high counting efficiency.

Most scintillation counters have quite a poor energy (peak) resolution

$$\frac{\Delta E_\gamma}{E_\gamma} = 5 \rightarrow 15\% \tag{5.4}$$

This poor energy resolution makes it difficult to obtain field measurements in which it is important to differentiate the energy of incoming γ radiation, in order to evaluate the danger of exposure. However, scintillation counters give very accurate measures of overall dose rate.

5.1.3 Semiconductor Detector

Semiconductor detectors were developed to improve the poor energy resolution of scintillation counters, and generally have $\Rightarrow \frac{\Delta E_\gamma}{E_\gamma} = 0.1 \rightarrow 1\%$, instead of the $5 \rightarrow 15\%$ efficiency of a scintillation counter.

Basic Properties

These detectors are made from semiconductor crystalline structures of silicon or germanium. A semiconductor is an insulator in which some charge carriers are mobile [19]. In a metal, Fig. 5.1, all the electrons from the valence band are in the conduction band. In an insulator, the valence electrons are unable to cross the energy gap to be propelled into the conduction band. In a semiconductor, the energy band is sufficiently narrow for some electrons to cross, with the help of ionizing radiation in particular. The energy band decreases with increasing crystal temperature. Therefore, semiconductor detectors are plunged into liquid nitrogen, at $77K$, in which the conduction band is empty, since thermally excited valence band electrons have insufficient energy to access the conduction band.

When γ radiation passes through the crystal, three interactions are possible: Compton effect, photoelectric effect, and pair production, see § 3.8. The only process where all the energy of the γ ray is directly transferred to the electron is the photoelectric effect. Through photoelectric effect, the γ ray interaction forms an electron-hole pair, where the electron released is called the "primary electron". The electron will be ejected with a kinetic energy equals to the excess energy binding the electrons to the atom

$$K_e = h\nu - W \tag{5.5}$$

The primary electron will interact, loosing part of its kinetic energy, with valence electrons of neighbor atoms, creating secondary electrons. The number of electrons released from

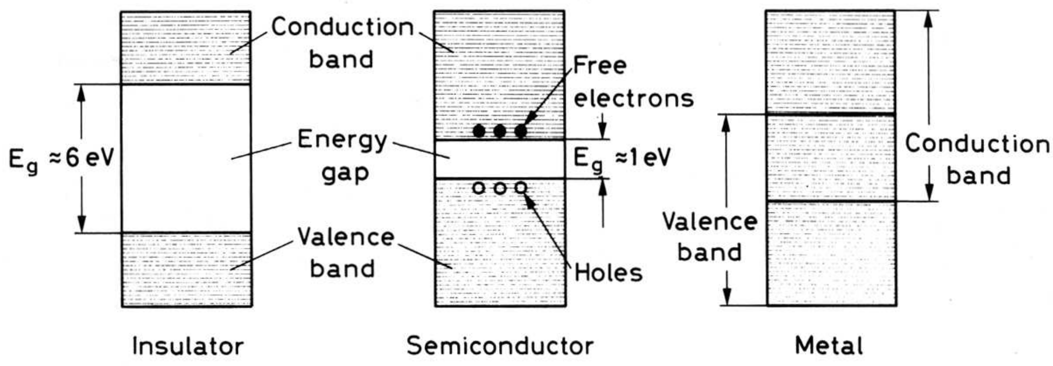


Figure 5.1: Energy band structure.

this process is proportional to the energy of the incoming γ radiation. Under intense electric field, the primary and secondary electrons will drift toward the cathode and the holes toward the anode, creating an electrical impulse.

The energy required to create an electron-hole pair in silicon or germanium ($W \sim 3eV$) is ten times less than the energy required to ionize a gas ($\sim 30eV$) [18]. Therefore semiconductor detectors have much better energy resolution than ionisation chambers, see § 5.1.6.

Increasing the probability of photoelectric effect increases the full energy efficiency of the semiconductor detector. We know from § 3.8.4, the photoelectric cross section is greater for crystals with

$$Z >> 1. \tag{5.6}$$

Therefore, the photoelectric effect becomes predominant for crystal of germanium, with a high Z and high density.

Doped Semiconductors ($GeLi$)

In a pure semiconductor, the number of holes (p) is equal to the number of free electrons (n), as in the case in a high purity germanium crystal ($HPGe$). Changing this equilibrium, via impurities, affects greatly the electrical properties of the crystal. These impurities, shown in Fig. 5.2, are atoms with one electron more (N_+) or less (N_-) in their valence orbits. Some impurities, like arsenic or antimony, can be incorporated into in the crystal lattice. While others, like lithium, will not take the place of a normal atom, but will position themselves in the interstices of the lattice. The electrical properties of a lithium drifted germanium crystal are similar to a high purity germanium. To stop lithium from drifting, the crystal was cooled down to liquid nitrogen temperature. The first fabrication techniques could not make the $HPGe$ pure enough, therefore $Ge(Li)$ crystals were often produced and such detectors must always be maintained at low temperatures. Currently, purification techniques are such that almost only $HPGe$ crystals are produced, and detectors based on such crystals need only be cooled for operation.

An n-type semiconductor is made by adding atoms with one extra valence electron. This unattached electron is in a discrete energy level, very close to the conduction gap.

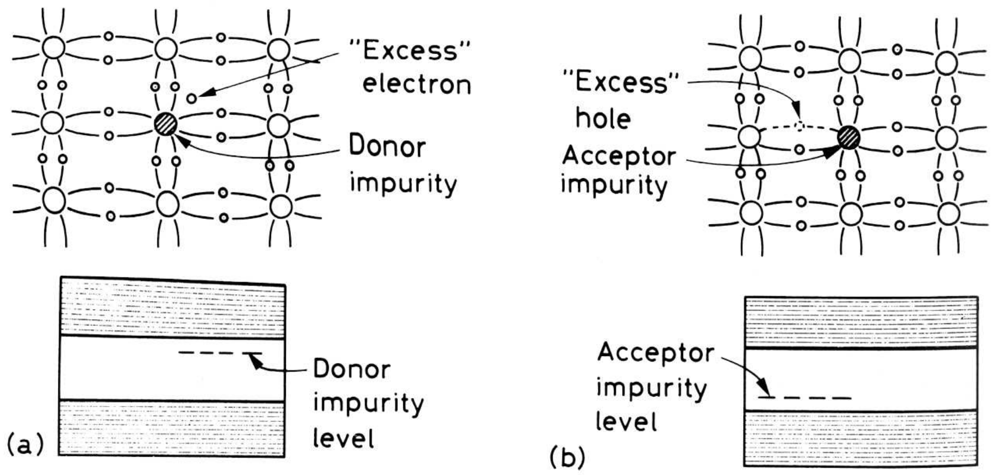


Figure 5.2: (a) The n-type semiconductor is produced by adding impurities with excess electrons. (b) The p-type semiconductor is produced by adding impurity with missing electrons.

This extra electron will be able to fill the holes created and lower the hole concentration. The electrical impulse produced in this type of semiconductor is due to the movement the electrons.

The *p*-type semiconductors are made by adding atoms with one electron less in the outer shell, creating a surpopulation of holes in the crystal. By having too many holes to fill, the electrical impulse produced is due to the movement of holes.

np Junction

When placed together, *n*-type and *p*-type semiconductors transfer holes and electrons to each other creating a depletion zone (Fig. 5.3), at the interface of the materials. By the migration of the electrons and holes, zones that were originally neutral end up with accumulated charges on each side of the junction, creating an electric field.

If radiation penetrates in this region, it will create electron-hole pairs by ionisation, and the created charge will be immediately pushed aside by the electric field. By connecting each side of the depletion zone to an electric circuit makes it possible to collect the proportional impulse coming out of the depletion zone.

Normally, the internal electric field created is too weak to give a complete and rapdi charge collection. Furthermore, the depletion zone created is of a size that it could stop only low energy particles. By adding external voltage, such that the holes and the electrons are moved away from the junction, the depletion zone is widened, giving more sensitivity to the detector. In addition, this high voltage bias helps achieve complete charge collection, yielding better energy resolution.

With increasing crystal temperature, the valence electrons are thermally excited from the valence band to the conductivity band. In the presence of a strong electric field, these conductive electrons will migrate to the cathode of the detector, masking the electrical impulse from an incoming γ radiation. To avoid unnecessary increase of impulse in the

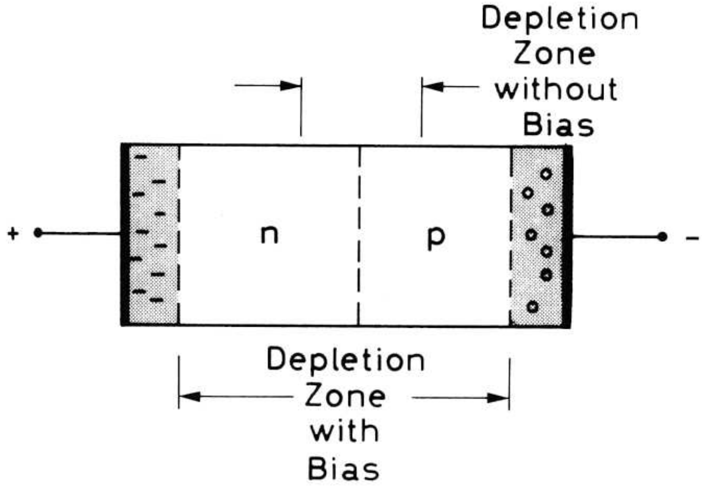


Figure 5.3: The np junction with inverse voltage of a *HPGe* crystal.

detector and to keep most of the electrons in the valence state, the crystal is kept at liquid nitrogen temperature ($\sim 77K$). The energy gap (E_g) between the conductivity band and the valence band decreases with increasing temperature from the absolute zero energy gap (E_0). The energy gap depends on the crystal potential [19]. To obtain optimal conditions, the crystal is plunged into liquid nitrogen. At 77 K, the energy gap of germanium atoms is $0.75eV$ [18].

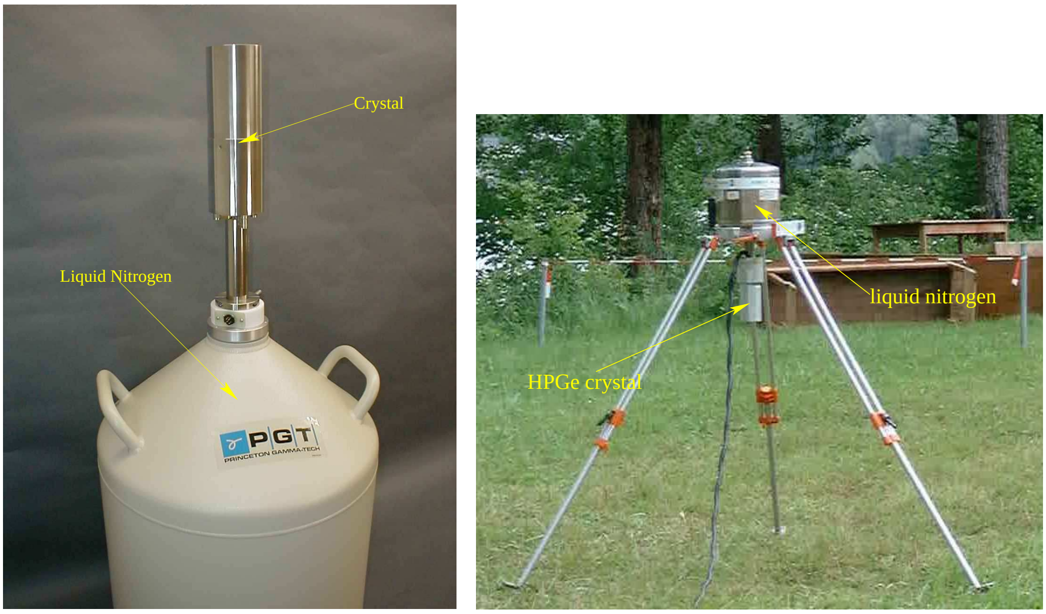
High purity germanium detectors (*HPGe*) are used in the laboratories of the environmental radiation monitoring section, see Fig. 5.4(a). For *In Situ* measurements, for security reasons, only *HPGe* crystals are used. Since these instruments are portable, some mishaps can happened during manipulation, which could cause heating of the crystal. *HPGe* crystals can be warmed and cooled again without consequences to the quality of the crystal, while lithium will drifted in *Ge*(*Li*) crystal, when heated, which would ruin the quality of the crystal.

5.1.4 EGPC *In Situ* detectors

Two devices from *EG&G Ortec*, the *EGPC* detectors, were used for the *In Situ* measurements reported in this work.

These instruments and devices are developed for outdoor measurements. The terrestrial background γ radiation is measured with high purity germanium detectors (*HPGe*), see Fig. 5.4(b).

The environmental radiation monitoring section uses two of these devices for terrestrial background γ radiation measurements. The instruments specifications are given in Table 5.1. The efficiencies of 20% and 30% refers to the relative efficiency of an NaI crystal scintillator of $7.6cm$ height $\times$ $7.6cm$ diameter ($3'' \times 3''$) for the $1.33MeV$ γ radiation of ^{60}Co and for a source-detector distance of $25cm$ [27].



(a) (b)

Figure 5.4: (a) Germanium detector found in laboratories. The crystal is normally shielded from outside radiation with a lead cast around the crystal, of $5 \rightarrow 10cm$ thick. (b) *In Situ* instrument able to measure on the field. Shielding is not wanted for this type of instrument.

5.1.5 ORTEC-DETECTIVE

Indoor and outdoor γ radiation measurements are needed to evaluate the total absorbed dose in an urban area. For outdoor *In Situ* measurement, $HPGe$ portable detectors cooled by liquid nitrogen, Fig. 5.4(b), can be used. The size, cumbersom tripod shape and heavy electronics of the portable detectors makes indoor measurements difficult. To ease the indoor measurements, a detector developed by ORTEC which main purpose is portable nuclide identificator, was used. Several tests were needed to evaluate the ability of the ORTEC-DETECTIVE to serve as an *In Situ* instrument for indoor measurements. This instrument uses a $HPGe$ crystal detector, with all-in electronics and a crystal cooled by a Stirling engine, Fig. 5.6(a).

The detector developed by ORTEC has a internal, coaxial, $50mm$ diameter$\times 30mm$ deep p-type nominal $HPGe$ crystal, Fig. 5.5(a). The crystal is cooled by a low-power, hymatic, dual-piston Stirling cooler. The vibrations of the Stirling cooler and the surrounding electronic noise from the equipment are digitally processed by the incorporated ORTEC's Low Frequency Rejector (LFR) Filter. The ORTEC-DETECTIVE is an all-in detector of $37.3cm$ length $\times$ $16cm$ width $\times$ $32cm$ height and weighs $10.39kg$ including handle, Ge detector end cap and shock absorbers. The ORTEC-DETECTIVE is shipped with a docking station, for charging purposes, integrating a $Cs-137$ calibration source, used by to reset the energy scale. All the technical data are taken from the *Administrator's manual* [31].

The shape, size, and weight of this ORTEC-DETECTIVE makes it relatively easy to use for indoor measurements. This detector was developed to be fully autonomous for up to three hours, and can last $\sim 15h$ with the external battery belt. Once the detector is

Table 5.1: Specifications of the EGPC detectors at the environmental radiation monitoring section.

Specifications	**EGPC 20**	**EGPC 30**
Type	P-type Ge	N-type Ge
Cryostat	4.5 l	2.3 l
Autonomy	90 h	50 h
Heating	3 d	3 d
Cooling	8 h	8 h
Size $D \times L$(mm)	53×48	56×58
L/D	~ 0.9	~ 1.0
Detector's cap	5 mm	5 mm
Cap's thickness AI	500μ m	500μ m
Dead layer	500μ m	$< 500\mu$ m
amplifier polarity	negative	positive
HV	$+4'000$ V	$-4'000$ V
Efficiency	20%	30%
Resolution	1.9 keV	1.9 keV
Peak/Compton	52	52

cooled, a battery ensures the operation of the system. The whole measurement process can be operated either directly from the integrated operator keypad, Fig. 5.6(b), or from a PC connected to the detector, via a USB port. The detector is put on a docking station to be recharged, where the spectrum can be calibrated and stabilized with a cesium-137 (^{137}Cs) source.

Stirling engine

A Stirling engine is a closed-cycle piston heat engine. On the contrary to open-cycle internal combustion engines, the working gas is permanently contained in the cylinder of the Stirling engine [30]. An example of a Stirling engine is shown in Fig. 5.7. In this example, two pistons are connected to the same crankshaft. The power piston fits tightly in the cylinder, while the displacement piston is used to displace the working gas. The four cycle of this engine are :

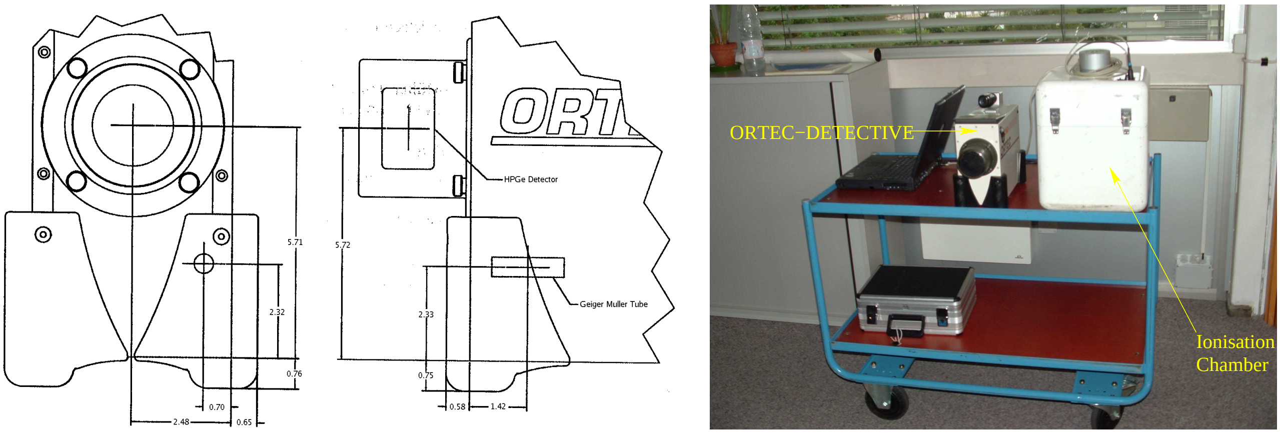
1. The power piston compresses the gas, heats following the gas law

$$\frac{p_1 \cdot V_1}{T_1} = n \cdot R = \frac{p_2 \cdot V_2}{T_2} \tag{5.7}$$

   Meanwhile, the displacement piston moved most of the heated gas to the heat exchanger.

2. Under the increased gas pressure, the power piston is pushed along the cylinder, a movement called the **power stroke**.

3. The gas temperature decreases, while the displacement piston moves it to the cool end of the cylinder



(a) (b)

Figure 5.5: (a)*HPGe*-Based Portable Nuclide Identifier. The overall dimensions of this detector, with the handle and the shock absorbers is $37.3cmL \times 16cmW \times 32cmH$ and weighs $10.39kg$. (b) Indoor measurement setup, with the ORTEC-DETECTIVE and an ionisation chamber.

4. Under the momentum of the fly wheel, the power piston can compress the cooled gas, while the displacement piston moves the gas to the hot end of the cylinder.

The *HPGe* crystal of the ORTEC-DETECTIVE, connected to the cold end of the Stirling engine's cylinder, is kept at working temperature.

5.1.6 Ionisation Chamber

An ionisation chamber is a gas filled instrument designed to measure ionizing radiation. Two electrodes, kept at high voltage, create an intense electric field in the gas chamber. Incoming radiation interacts with atoms of the gas creating electron-ion pairs. Under the intense electric field, the electrons drift toward the cathode, gaining sufficient energy between collisions to ionize the gas [18]. The number of initial electrons generated from such collisions is proportional to the energy of the incoming radiation, see Fig. 5.8(b). The drifting electrons are collected by the cathode, creating an electrical impulse proportional to the energy of the incoming radiation. Ionisation chambers measure the total amount of energy deposited in the device over a certain period of time, giving, therefore, a measurement for the total background γ radiation.

In the field of environmental radiation monitoring, ionisation chamber are used in parallel with other instruments, like *HPGe In Situ* instrument, to be able to differentiate the terrestrial and the cosmic contribution to the total absorbed dose (Fig. 5.8(a)). Figure 5.9 illustrates the field measurements process. *HPGe* instruments are detectors able to differentiate the energy of the incoming γ radiation, allowing, therefore, radionuclide identification. The identification enables the evaluation of the terrestrial contribution to the total absorbed dose. Indoor measurements are performed using the ORTEC-DETECTIVE portable instrument. The total absorbed dose is calculated by adding the cosmic contribution, calculated from the altitude of the site. This total absorbed dose is compared with

(a) (b)

Figure 5.6: (a) ORTEC-DETECTIVE Portable Nuclide Identifier. (b) The integrated operator keypad is located on top of the apparatus, next to the handle.

the absorbed dose measured by the ionisation chamber.

$$H_{\text{ionisation}} \leftrightarrow H_{\text{cosmic}} + H_{\text{terrestrial}} \tag{5.8}$$

Where the result from the ionisation is compared to the sum of the calculated cosmic and the measured terrestrial component of the ambient dose.

$$\Delta_{\text{R \& S}} = \frac{H_{\text{R \& S}} - H_{\textit{In Situ}}}{H_{\text{R \& S}}} \cdot 100\% \tag{5.9}$$

General Electric – Reuter-Stokes RSS131

The Environmental Radioactivity Section uses a **Ge Reuter-Stokes RSS131** ionisation chamber for dose rate measurements. This instrument consists of a $25cm$ diameter stainless-steel sphere with $2.37\ \text{g} \cdot \text{cm}^{-2}$ wall thickness. The spherical chamber is filled with ultrapure argon at 2.5 MPa pressure. A 5 cm diameter hollow sphere, set in the center of the device, acts as the collecting electrode, kept at high voltage of ~ 396 V [23]. The ion current is collected with a temperature compensated electrometer consisting of a MOSFET and an operational amplifier using 100% feddback gromd the amplifier output to the FET [23]. From the U.S. Department of Energy [23], the chamber allows a complete charge collection of the total background radiation, terrestrial and cosmic contribution together, in fields up to 10μ Gy/h. Factory calibration of this instrument is performed with a certified sealed 37 MBq ^{226}Ra source traceable to the NIST, using shadow shield technique [14].

The Swiss Inspection Service, based at PSI, verified the Reuter-Stokes calibration in 2005. The ionisation chamber was put in a reference radiation field, generated by ^{137}Cs, and the $H^{*}(10)$ values measured were compared to the factory calibration. A variation of 4% was found from the factory calibration [33].

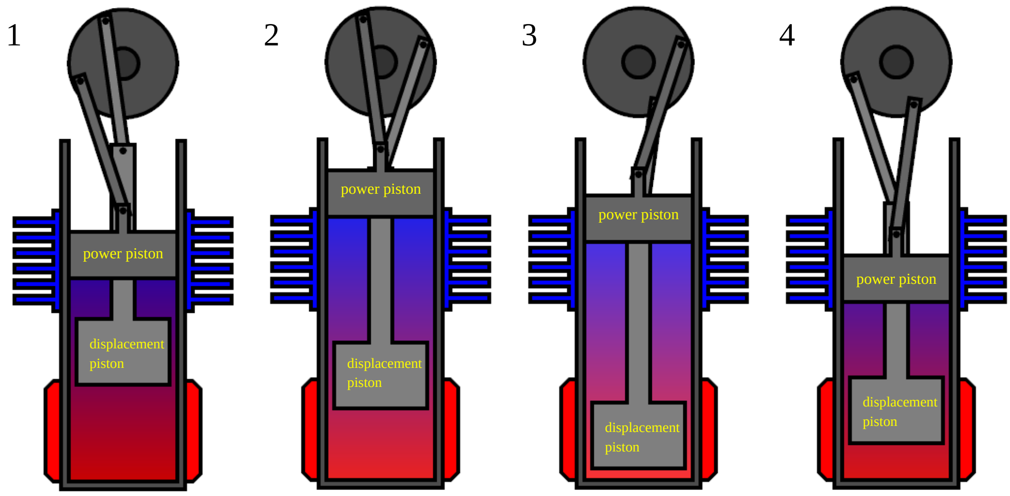


Figure 5.7: The four cycles of a β Stirling engine [30].

5.2 Environmental Radiation in an Urban Area

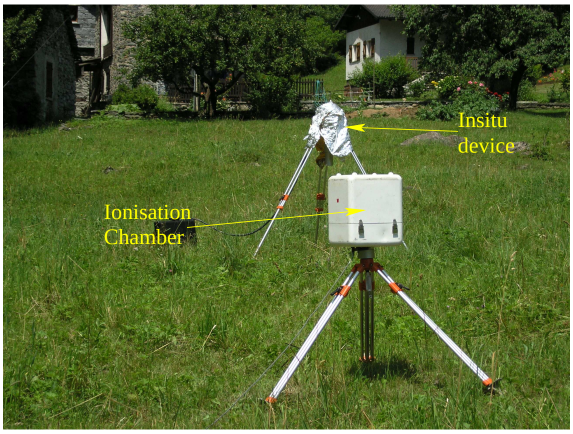
In order to evaluate the total absorbed dose in an urban area, indoor and outdoor measurements have to be performed. Outdoor measurements were made in different points of the area. The radionuclide concentration and the topography of the ground surface are the major influence of the natural radioactivity. Other parameters like the altitude of the site and the type and geometry of the structures in the close environment were also taken into consideration. For outdoor measurements, *In Situ* portable *HPGe* detector was used in parallel with an *GE Reuter-Stokes* ionisation chamber (Fig. 5.8(a)).

Indoor measurements were made in different buildings and dwellings over the area. The structure, the height or number of stories and the emplacement or altitude of the buildings in the area were some of the influencing parameters of natural radiation. For indoor measurements, the ORTEC-DETECTIVE portable detector was used in parallel with an *GE Reuter-Stokes* ionisation chamber (Fig. 5.5(b)).

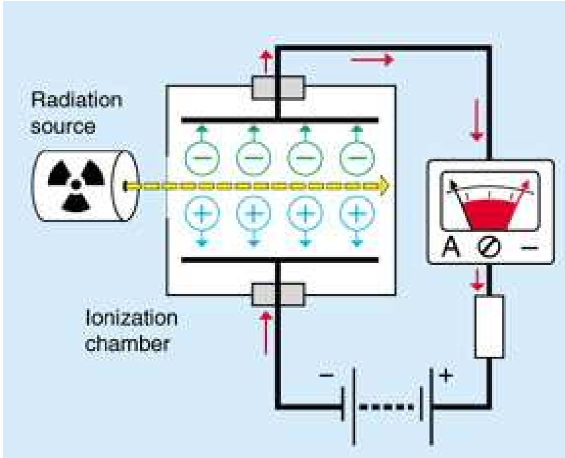
5.3 Instruments Calibration

To evaluate the measurements of natural radiation in an urban area, instruments and devices have to be calibrated. The calibrations carried out also clarified the instrument's response to incoming radiation. The instrument response to radiation depends greatly on the type of device, on the size, geometry and composition of the detector material and on the type and energy of the incoming radiation. Different parameters were to be checked: the efficiency of the detector, the FWHM energy resolution and the angular response.

Firstly, the detector efficiency for γ radiation of different energies was determined. The efficiency of a detector is given by the probability of detecting an incoming γ radiation. Experimentally, the ratio of particles detected per second (n) on the calculated flux of particles ($\Phi = [\frac{\gamma}{\mathrm{cm}^2 \cdot \mathrm{sec}}]$) through the crystal gives the detector efficiency (ϵ), $\epsilon = \frac{n}{\phi}$. Different calibrated radioactive sources were placed at 1m in front of the detector, Fig. 5.11, and the count rates measured.



(a)



(b)

Figure 5.8: (a) Picture of a measurement setup for the *GE Reuter-Stokes* ionisation chamber. (b) General purpose of an ionisation chamber [29].

Secondly, the energy resolution of each detector was evaluated. When a γ ray of energy E makes a photoelectric effect with the semi-conductor crystal, it creates a certain number of electron-hole pairs (n_e). The mean number of electron-holes created depends on the energy of the interacting particle and on the forbidden energy gap of the semi-conductor (W):

$$n_e = \frac{E}{W} \tag{5.10}$$

where W is the energy necessary to produce an electron-hole pair, for *Ge* detectors is typically $\sim 3.0eV$ [22]. The theoretical energy resolution of a detector becomes

$$\frac{\Delta n_e}{n_e} = \frac{\sqrt{n_e}}{n_e} = \sqrt{\frac{W}{E}} \tag{5.11}$$

assuming that this is the greatest contribution to the width of the peak in the γ spectrum. With many data collected and plotted, the peak can be represented or fitted by a Gaussian function, Fig. 5.10, centered on the energy of the incoming γ rays (E_0), see Eq. 5.12, where σ represents the standard deviation. An expression called the FWHM represents the width of the independent variable ($E_2 - E_1$) at which the dependent variable is half its maximum value, shown in Eq. 5.13.

$$\begin{aligned} f(E) &= f_0 e^{-\frac{(E-E_0)^2}{2\sigma^2}} \\ \text{and: } f_0 &= \frac{1}{\sigma\sqrt{2\pi}} \end{aligned} \tag{5.12}$$

$$\begin{aligned} FWHM_{\text{experimental}} &= 2\left(\sqrt{2\ln(2)}\sigma\right) \\ FWHM_{\text{theoretical}} &\simeq 2.36\sqrt{\frac{W}{E}} \text{ with: } \sigma \geq \sqrt{\frac{W}{E}} \end{aligned} \tag{5.13}$$

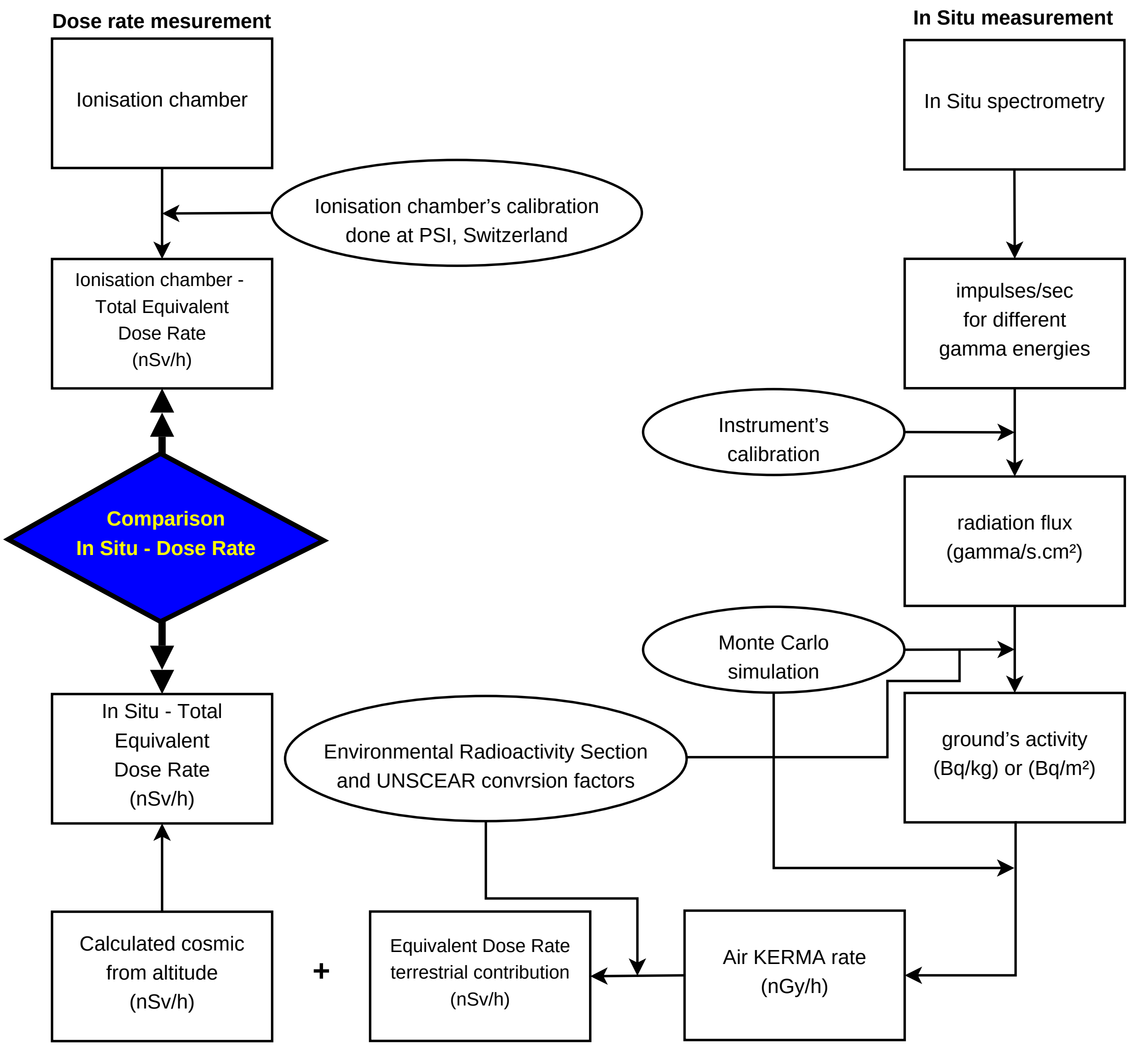


Figure 5.9: Field measurement illustration. Comparison between measurement made with *In Situ* spectrometer and dose rate chamber.

Thirdly, the angular response of a detector is evaluated. In environmental radiation monitoring, for *In Situ* measurements, radioactive isotopes are assumed to be distributed homogeneously in the ground. The same assumption applies for the evaluation of radiation background in an urban area, indoor and outdoor. Therefore, incoming γ radiation passing through the detector come from almost all directions. To make wise evaluation of the absorbed dose, the angular response of the detector to incoming radiation must be known, by which is meant the efficiency of the detector when irradiated from different angles compared to the efficiency when irradiated from the front.

ORTEC-DETECTIVE calibration

The efficiency and FWHM of the ORTEC-DETECTIVE detector are shown in Table 5.3. The experimental efficiency is given by the ratio $\epsilon = \frac{n}{\phi}$. An empirical approximation [32],

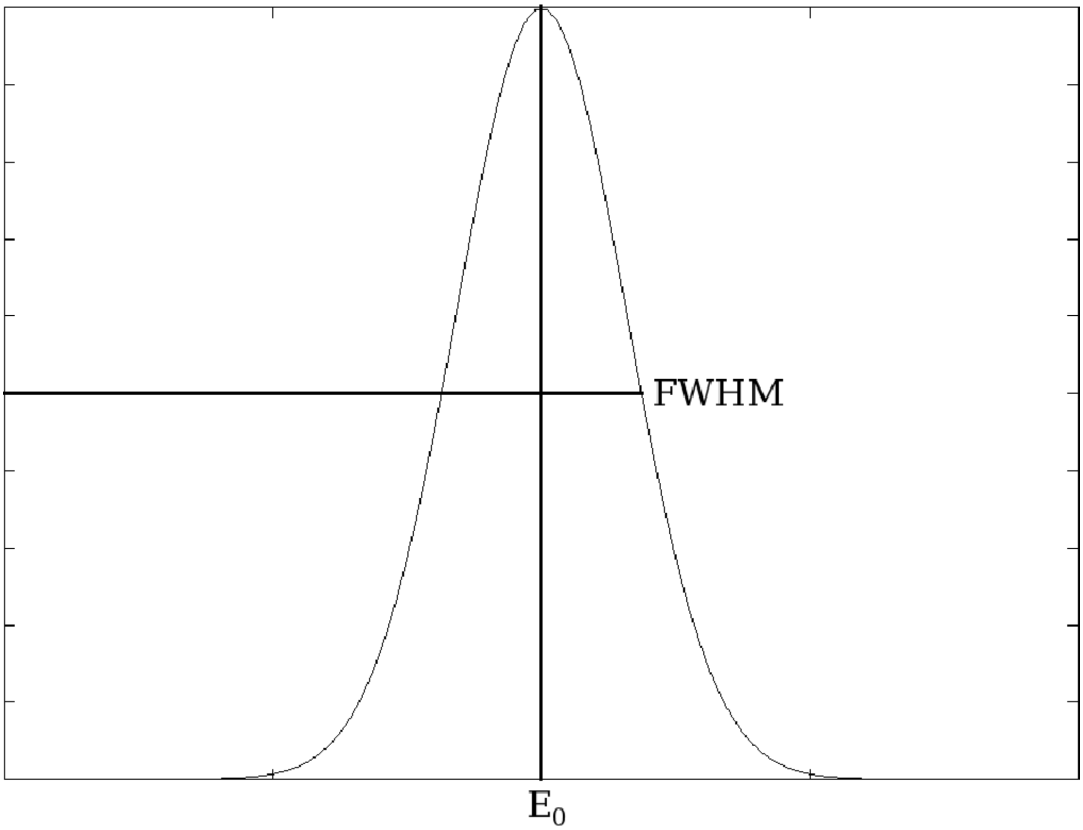


Figure 5.10: A Gaussian function centered on E_0.

see Eq. 5.14, can explain the general response of a detector to incoming γ radiation of different energies. This empirical approximation is called the "fitted efficiency" in Table 5.3. Parameters α, β, γ and δ of the Winiger empirical efficiency curve model, see Eq. 5.14, the experimental measurements, see Table 5.2, and the graph in Fig. 5.12. The FWHM is given in Table 5.3 and in Fig. 5.13 for the ORTEC-DETECTIVE instrument.

$$\epsilon = \left(\frac{\epsilon_0}{2}\right)\left[\left(\frac{E}{E_0}\right)^{\alpha} + \left(\frac{E}{E_0}\right)^{\beta}\right]\left(1 - e^{\gamma E}\right)^{\delta} \tag{5.14}$$

Uncertainties appear in any measurements and are commonly characterized as two specific types. The first type, **systematic uncertainties**, are due in uncertainties due to the general manipulation of the instruments and experiments. Four systematic uncertainties appeared in the calibration of the ORTEC-DETECTIVE instrument: uncertainty on the distance between the radioactive source and the detector crystal ($\Delta\epsilon_{\text{distance}} < 1\%$), uncertainty of the activity of the radioactive sources [15] ($\Delta\epsilon_{\text{activity}} = 3\%$), uncertainty in the alignment of the detecor's crystal to the incoming γ radiation ($\Delta\epsilon_{\text{alignment}} < 1\%$), and uncertainty on the values of the fit from Winiger's Eq. [32] ($\Delta\epsilon_{\text{fit}} = 1 \rightarrow 2\%$). For each γ ray measured, a slight deviation can occur in the instrument. This deviation is the second type of uncertainty, **statistical uncertainty** ($\Delta\epsilon_{\text{stat}}$). The statistical uncertainty decreases with increasing statistic like in Eq. 5.15, where N is the number of measured

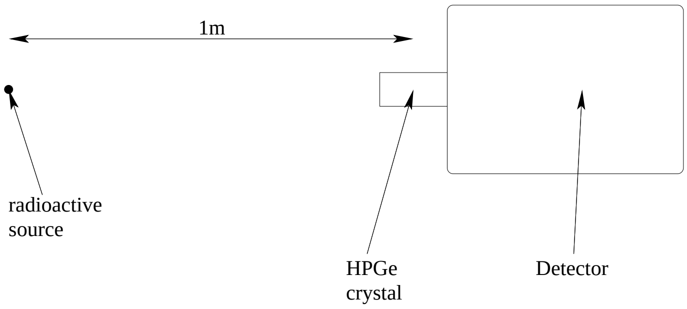


Figure 5.11: A schematic view of efficiency calibration measurements using sources of known activity.

Table 5.2: Parameters from Winiger's empirical approximation [32] for the *HPGe* detectors used at the *Environmental Radioactivity Section.*

	α	β	α	δ
ORTEC-DETECTIVE				
calibration geometry	-1.33	-0.71	-0.032	16.43
indoor geometry	-1.09	-0.17	-0.035	18.00
In Situ geometry	-0.95	0.0326	-0.03	14.62
EGPC-20	-1.22	-0.54	-0.026	12.39
EGPC-30	-1.02	-0.64	-0.045	62.16

γ rays of a certain energy. By convention, 2σ is used as the confidence interval, which represent the region surrounding the central value which contains 95% of the measured values.

$$\Delta\epsilon_{\text{stat}} = 2\sigma \tag{5.15}$$

The uncertainty on a measurements is the sum of the two types of uncertainties, systematic and statistical, see Eq. 5.16. From calibration measurements, the statistical uncertainty is much greater than the sum of the systematic uncertainties.

$$\Delta\epsilon_{\text{total}} = \sqrt{(\Delta\epsilon_{\text{stat}})^2 + (\Delta\epsilon_{\text{distance}})^2 + (\Delta\epsilon_{\text{activity}})^2 + (\Delta\epsilon_{\text{alignment}})^2 + (\Delta\epsilon_{\text{fit}})^2} \tag{5.16}$$

The last calibration performed on the ORTEC-DETECTIVE is the "angular efficiency". This calibration evaluates the efficiency of the detector to incoming γ radiation of different energies from various angles. Figure 5.14 shows the angular response of the detector, viewed from the top. Figure 5.15 shows the angular response of the detector, viewed from the side. As expected, γ radiation coming from behind the detector is mostly absorbed by the structure never reaching the detector. Figure 5.16 shows the axial angular response of the detector, viewed from the front. The axial angular response is almost isotropic, except when the radiation comes from the handle side.

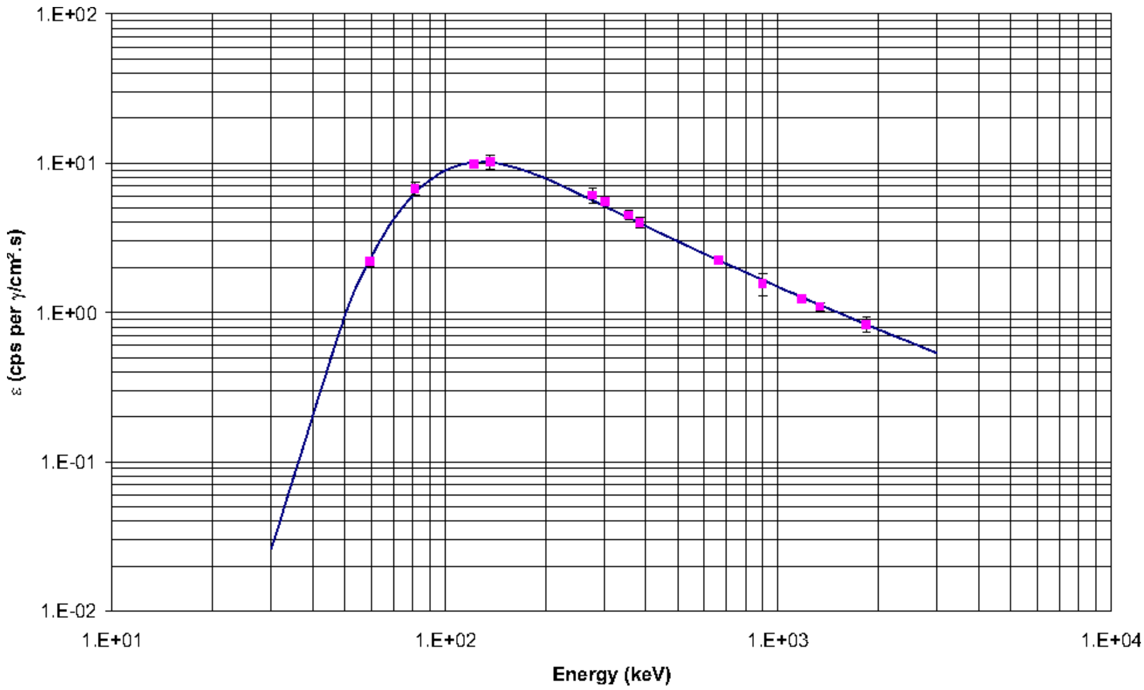


Figure 5.12: A graphical representation of the ORTEC-DETECTIVE efficiency, in cps/$\frac{\gamma}{\text{cm}^2\cdot\text{sec}}$. The dots mark the experimental results from the radioactive sources. The solid line represents the fit using Eq. 5.14.

EGPC detector calibration

EGPC detectors are instruments used by the environmental radiation monitoring section for *In Situ* measurements. EGPC are $HPGe$ crystal detectors, cooled with liquid nitrogen, Fig. 5.4(b). The crystals have a relative efficiency of 20% and 30% of an NaI scintillator of $3'' \times 3''(7.6cm \times 7.6cm)$. The experimental efficiency and FWHM for these two detectors are shown in Table 5.3. An empirical approximation, Eq. 5.14, can be fitted for these two detectors, shown in Fig. 5.17. For *In Situ* measurements, the incoming γ radiation is coming from the ground, between $+90°$ and $-90°$. There is almost no γ radiation passing through the structure of the detector. Furthermore, the cylindrical shape (length $\simeq$ diameter) of the crystals allows a better uniformity in the measurements of incoming γ radiation from different angles. It is not necessary to evaluate the angular efficiency of these detectors.

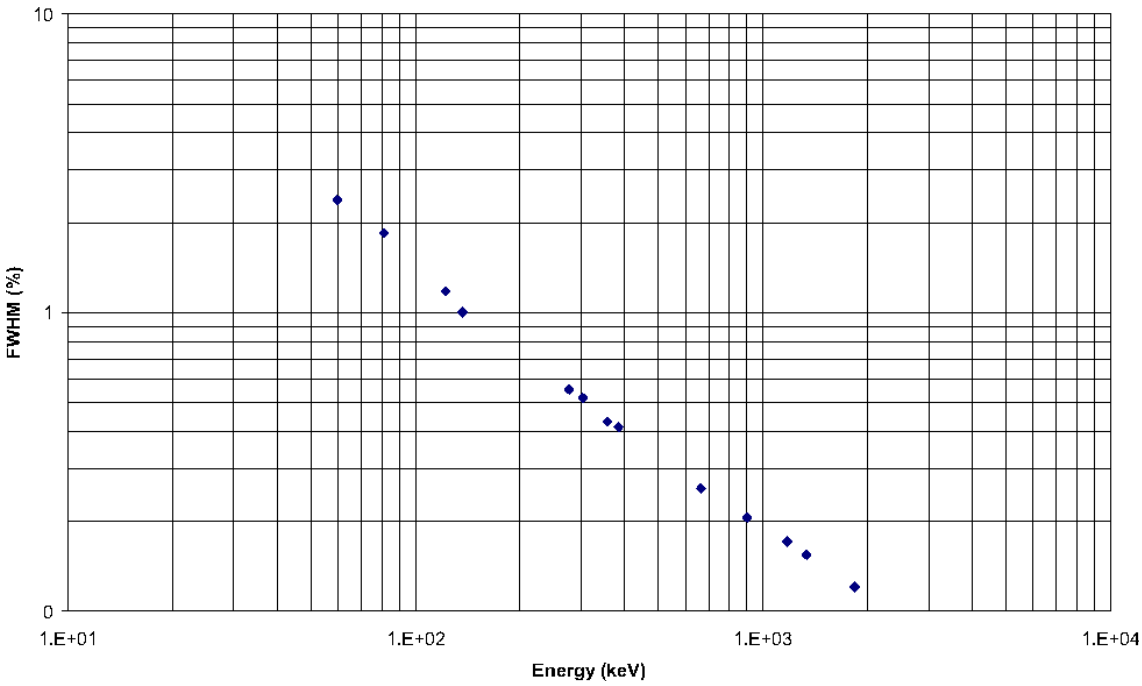
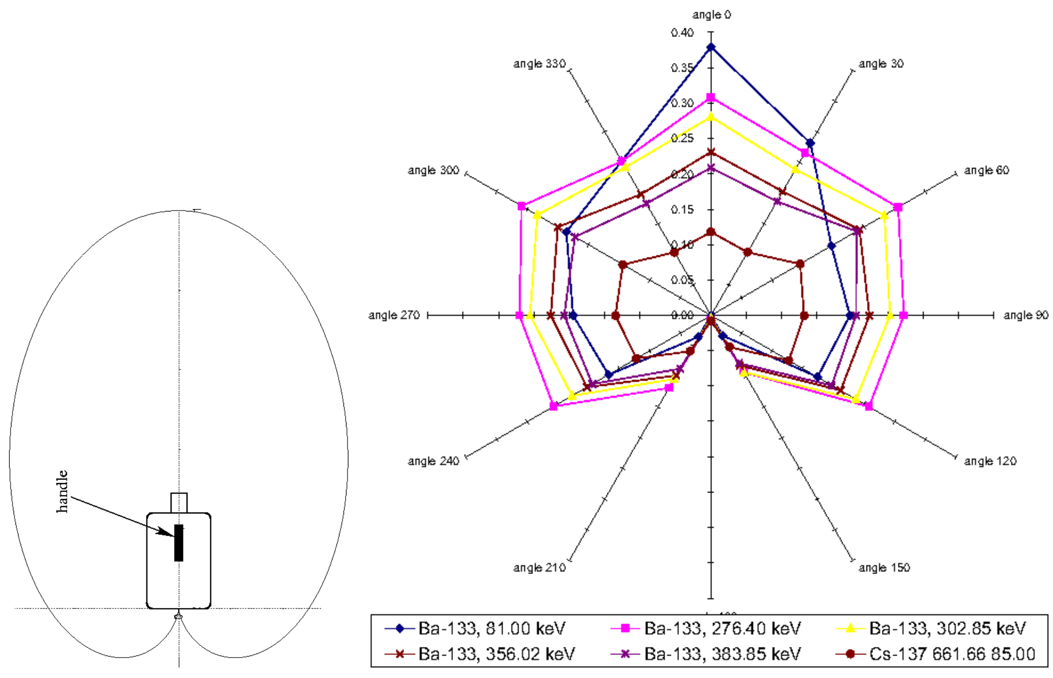
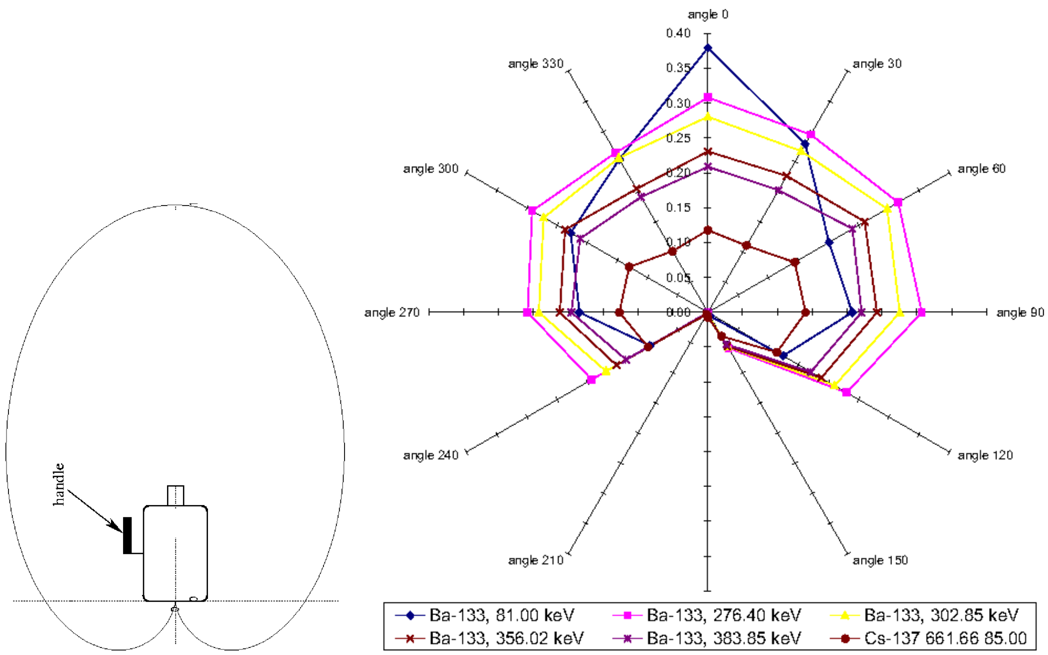


Figure 5.13: ORTEC-DETECTIVE FWHM as function of the energy of incoming γ radiation.



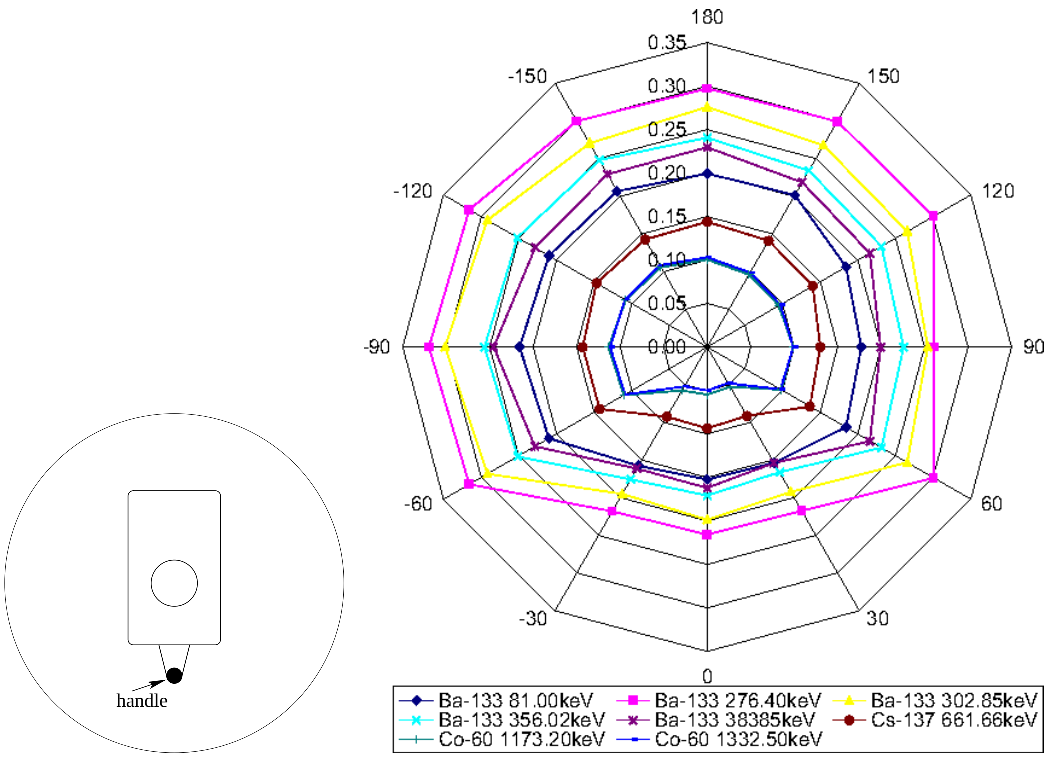
(a) (b)

Figure 5.14: (a) A schematic overview of the angular response of the ORTEC-DETECTIVE. The detector is viewed from the top. (b) Experimental results of the angular response for different energies.



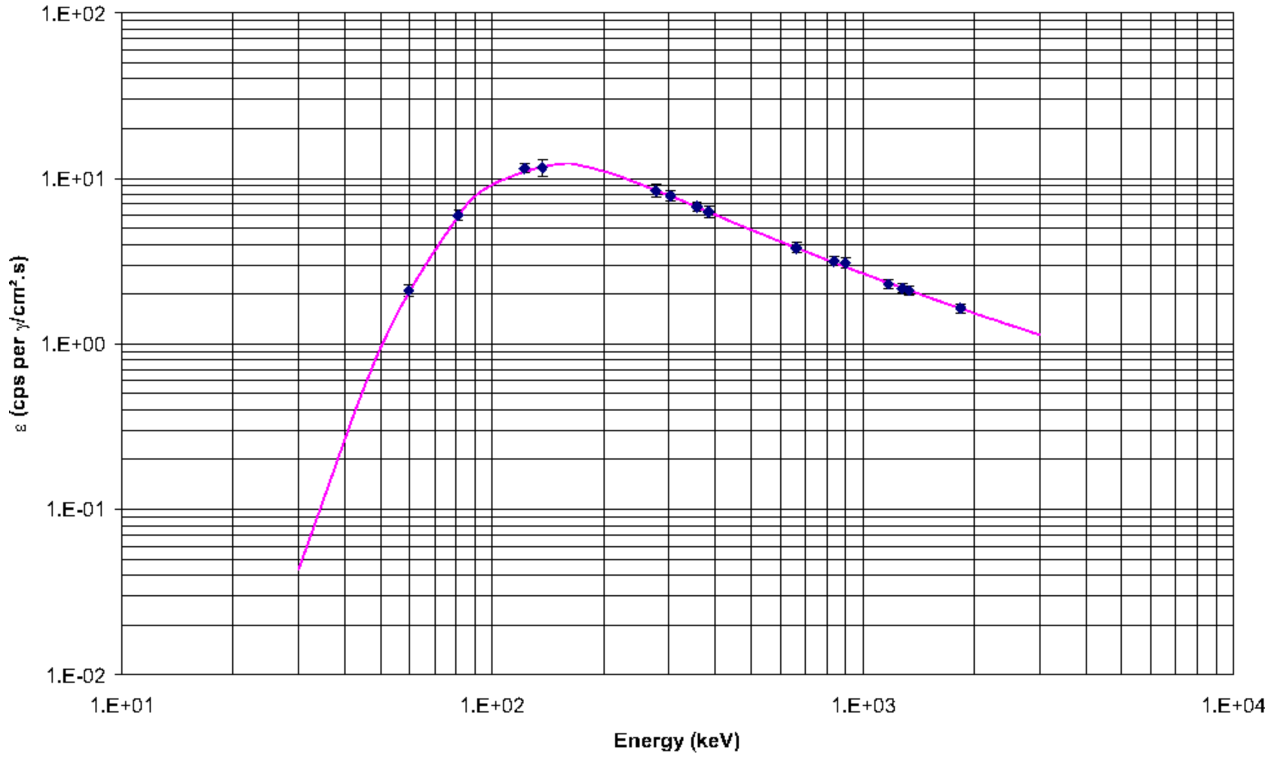
(a) (b)

Figure 5.15: (a) A schematic overview of the angular response of the ORTEC-DETECTIVE. The detector is viewed from the side. (b) Experimental results of the angular response for different energies.

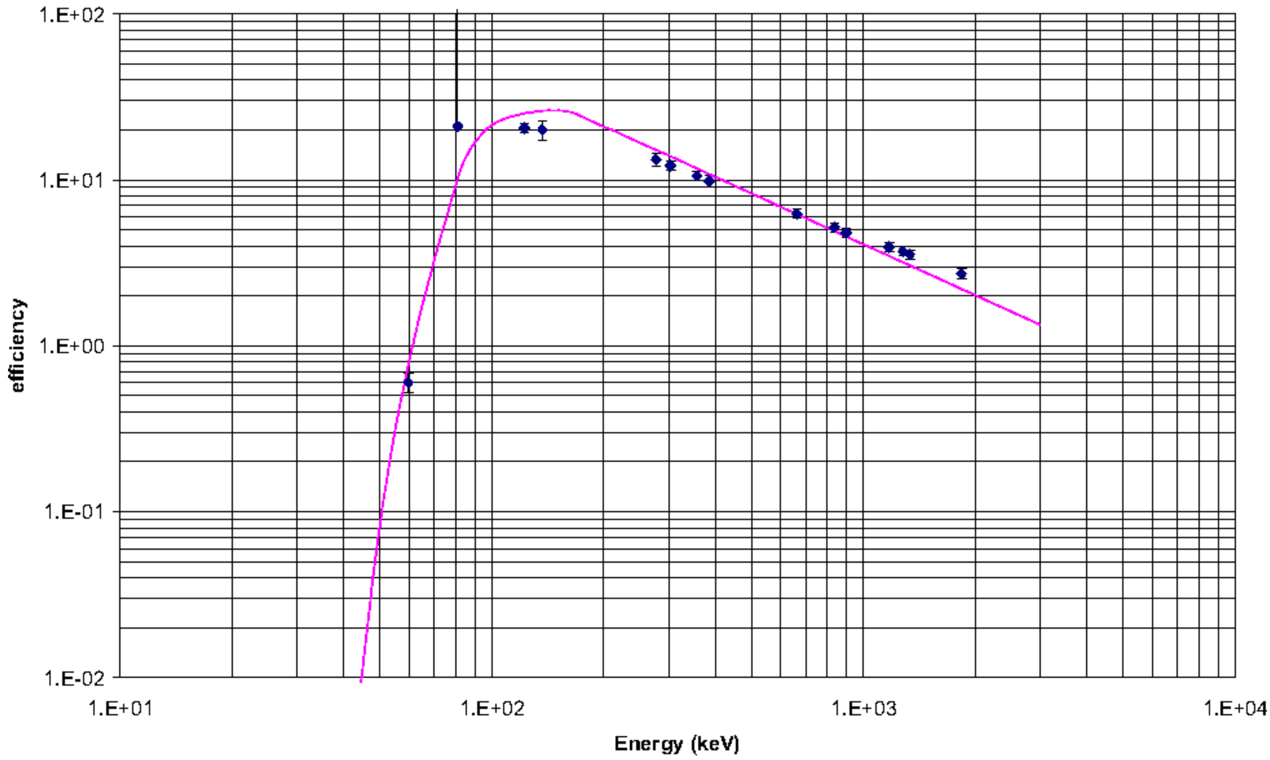


(a) (b)

Figure 5.16: (a) A schematic overview of the axial angular response of the ORTEC-DETECTIVE. The detector is viewed from the front. (b) Experimental results of the angular response for different energies.



(a)



(b)

Figure 5.17: Graphical representations of the EGPC detector efficiencies. The dots mark the experimental results measured with the radioactive sources. The solid line represents the fitted efficiency using Eq. 5.14.(a) Efficiency for the EGPC-20 detector, with a crystal of 20% relative efficiency. (b) Efficiency for the EGPC-30 detector, with a crystal of 30% relative efficiency.

Table 5.3: Experimental and fitted efficiency for the ORTEC-DTECTIVE and the EGPC detectors (20% and 30%). Different γ emitting sources have been set $1m$ in front of the detector. The uncertainty is the sum of the uncertainties evaluated for theses measurements, given in Eq. 5.16.

			ORTEC-DETECTIVE			EGPC 20			EGPC 30			
Nuclide	**Energy** (keV)	**Intensity** (%)	efficiency (ϵ) exp	fit	**FWHM** (in %) exp	efficiency (ϵ) exp	fit	**FWHM** (in %) exp	efficiency (ϵ) exp	fit	**FWHM** (in %) exp	**FWHM** (in %) theo
Am-241	59.54	35.9	0.11 ± 0.02	0.1149	2.38	0.117 ± 0.005	0.117	2.27	0.023 ± 0.004	0.023	1.78	0.70
Ba-133	81.00	34.06	0.35 ± 0.06	.3171	1.85	0.33 ± 0.04	0.328	1.72	0.8 ± 0.8	0.282	1.1	0.60
	276.4	7.16	0.31 ± 0.6	0.2853	0.55	0.47 ± 0.06	0.471	0.54	0.50 ± 0.06	0.496	0.4	0.33
	302.85	18.33	0.28 ± 0.5	0.2585	0.52	0.44 ± 0.05	0.433	0.5	0.46 ± 0.05	0.458	0.37	0.31
	356.02	62.05	0.23 ± 0.03	0.2171	0.43	0.37 ± 0.04	0.372	0.44	0.40 ± 0.04	0.399	0.33	0.29
	383.85	8.94	0.20 ± 0.03	0.2003	0.41	0.35 ± 0.04	0.347	0.41	0.37 ± 0.04	0.374	0.3	0.28
Cs-137	661.66	85.0	0.15 ± 0.01	0.1134	0.26	0.21 ± 0.02	0.211	0.28	0.24 ± 0.02	0.236	0.21	0.21
Na-22	1274.54	99.94				0.12 ± 0.01	0.121	0.17	0.14 ± 0.02	0.138	0.14	0.15
Mn-54	834.81	99.98				0.18 ± 0.02	0.172	0.22	0.20 ± 0.02	0.195	0.18	0.19
Co-57	122.06	85.6	0.50 ± 0.5	0.5119	1.18	0.64 ± 0.06	0.634	1.11	0.78 ± 0.08	0.786	0.78	0.50
	136.47	10.68	0.52 ± 0.08	0.0508	1.00	0.6 ± 0.1	0.669	1.00	0.8 ± 0.1	0.804	0.71	0.47
Co-60	1173.2	99.85	0.063 ± 0.007	0.0643	0.17	0.13 ± 0.02	0.13	0.18	0.15 ± 0.02	0.148	0.14	0.16
	1332.5	99.98	0.056 ± 0.007	0.0569	0.15	0.12 ± 0.01	0.117	0.16	0.14 ± 0.01	0.133	0.13	0.15
Y-88	898.04	94.00	0.08 ± 0.2	0.0835	0.21	0.17 ± 0.03	0.162	0.22	0.18 ± 0.02	0.184	0.17	0.18
	1836.1	99.33	0.042 ± 0.006	0.421	0.12	0.091 ± 0.009	0.091	1.33	0.10 ± 0.01	0.103	1.09	0.13

5.4 Monte Carlo Simulations

Monte Carlo simulations are computational representations of physical or mathematical phenomena using random or pseudo-random parameters. The random nature of the parameters give stochastic results.

5.4.1 Monte Carlo efficiency simulation for ORTEC-DETECTIVE

In the preceding sections, the experimental results obtained for the efficiency, FWHM, and angular response were presented. They were obtained from measuring incoming γ radiation from different radioactive sources placed at (1 ± 0.01) m from the detector's crystal. The fitted efficiency parameters (α, β, γ and δ) are scaled for the best fit of the experimental results.

Monte Carlo simulations have been performed in order to verify and support the experimental results obtained for the ORTEC-DETECTIVE instrument. The simulations were developed and performed at the IRA in Lausanne, Switzerland. The simulations were made using GEANT4 simulation program [37].

Part of the simulations done at the IRA were aimed at evaluating the ORTEC– DETECTIVE's efficiency. The simulated γ rays, chosen over a wide energy range, were emitted in random direction from the source placed 1 m from the detector. From geometrical parameters, such as the probability of a γ ray passing through the detector crystal, and the internal parameters of the crystal, such as the size, shape, and dead layer, the detector efficiency could be evaluated. The simulated γ radiation chose at energy intervals of 10 keV with an activity of 1 Bq [21]. Figure 5.18 shows that the results obtained via the Monte Carlo simulation are in good agreement with the experimental efficiency obtained in §5.3, with the difference less than $\pm 10\%$.

5.4.2 Monte Carlo simulations for *In Situ* measurements

To evaluate the background γ radiation in an urban area, measurements were performed in various places, both indoor and outdoor. For both types of measurements, the contribution of the surroundings, like the size, shape and type of wall for indoor measurements, greatly influence the background terrestrial radiation.

For outdoor *In Situ* measurements, a flat ground parcel of 20 m radius and 30 cm deep is considered. The detector was pointed downwards in the center of the parcel, the crystal held at 1 m above ground level. Figure 5.19 sketches the situation. The ground density is fixed at $1.1 \frac{\mathrm{g}}{\mathrm{cm}^3}$, with element distributions presented in Table 5.4 [21]. The distribution of isotopes is supposed to be homogeneous in the soil. The results of this simulation are shown in Fig. 5.20.

Because of the assumption of homogeneous distribution of elements, we limited the size of parcel to 20 m radius and 30 cm deep, since 95% of the terrestrial radiation passing through the detector originates from that value. Most of the γ rays originating from outside this parcel are absorbed either by the soil or the air. The soil absorption coefficient is much greater than the air, as shown in Fig. 5.22. On the other hand, if the isotopes distribution is assumed to be on the surface of the soil, such as for a fresh deposition, then γ radiation passing through the crystal would be coming from up to a $1'500$ m radius [21].

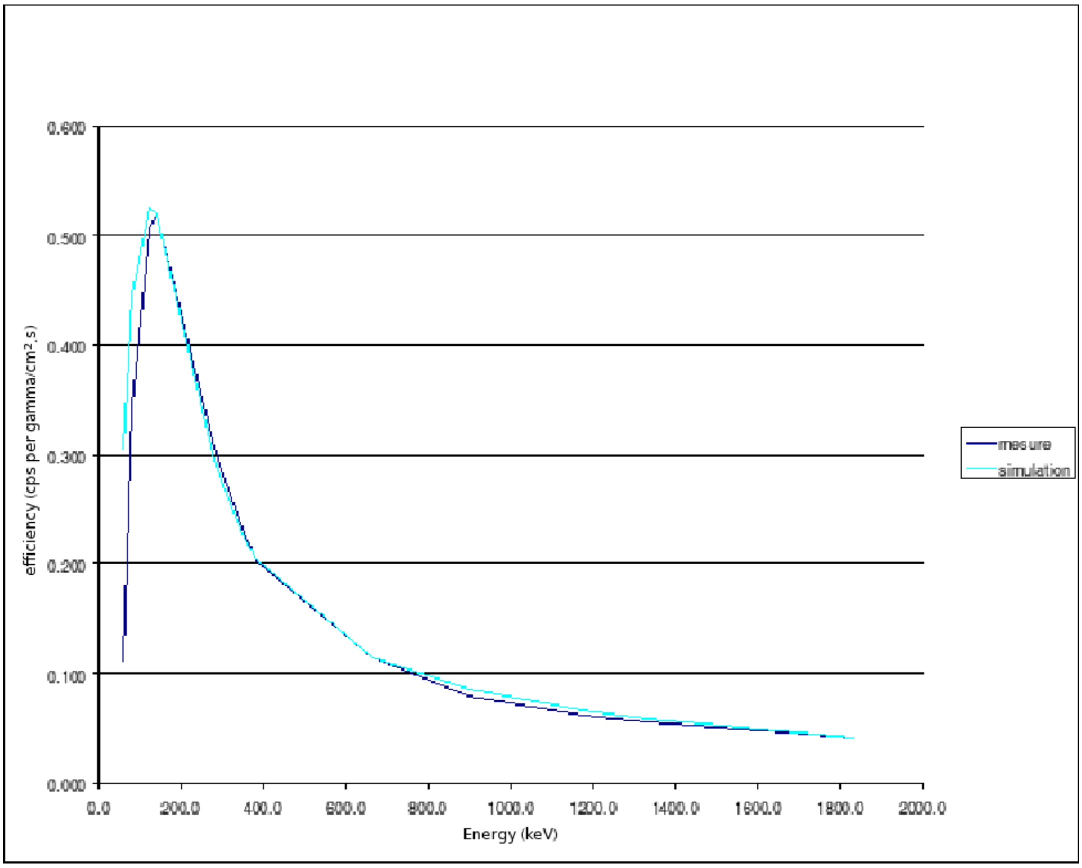


Figure 5.18: Comparison between the experimental and the Monte Carlo simulation values for the efficiency of the ORTEC-DETECTIVE portable detector. Results from the Monte Carlo simulation are in good agreement with the calibration results obtained for the ORTEC-DETECTIVE device. The efficiency is given in $\frac{\text{cps}}{\gamma/\,\text{cm}^2\cdot\text{sec}}$.

Winiger's approximation (Eq. 5.14) fits the Monte Carlo results for outdoor *In Situ* geometry shown in Fig 5.21. The parameter values for this fit are given in Table 5.2.

5.4.3 Monte Carlo simulations for indoor measurements

For measurements inside buildings and dwellings, a rectangular parallelepiped room of 5 m $\times$ 5 m $\times$ 3 m high with 20 cm thick concrete walls was considered. The detector was pointed downwards in the middle of the room, the crystal held at 1 m above floor level. Figure 5.23 represents the situation schematically. The concrete density was fixed to $2.3\frac{\text{g}}{\text{cm}^3}$, with the element distribution presented in Table 5.4. The distribution of isotopes is supposed to be homogeneous in the concrete. The results of this simulation are shown in Fig. 5.24.

For indoor measurements, the γ rays passing through the crystal come from every point in the room. The ones from the back are partially absorbed by the structure of the detector. Therefore, the efficiency of the spectrometer has to be corrected for the unseen radiation unlike the outdoor case where the angular efficiency does not affect the results.

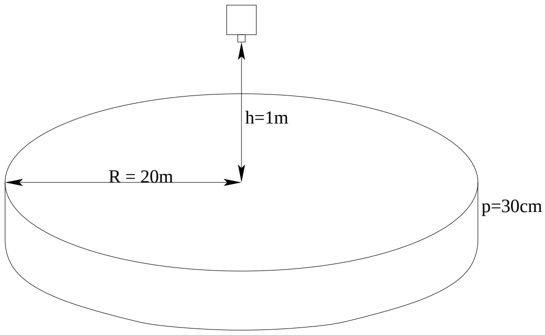


Figure 5.19: Schematic situation overview of Monte Carlo *In Situ* simulations for *In Situ* measurements.

Table 5.4: Element distribution taken for the Monte Carlo *In Situ* simulation [21]. The distribution is given in %.

elements	Al	C	Ca	Fe	H	K	Mg	Na	O	Si	Ti
ground	5.7	1.8	5.6	3.6	1.5	2.1	1.1	0.6	53.6	24.2	0.2
concrete	3.4	0.1	4.4	1.4	1.0	1.3	0.2	1.6	52.9	33.7	

Winiger's approximation (Eq. 5.14) fits the Monte Carlo results for indoor geometry shown in Fig 5.5. The parameter values for this fit are given in Table 5.2.

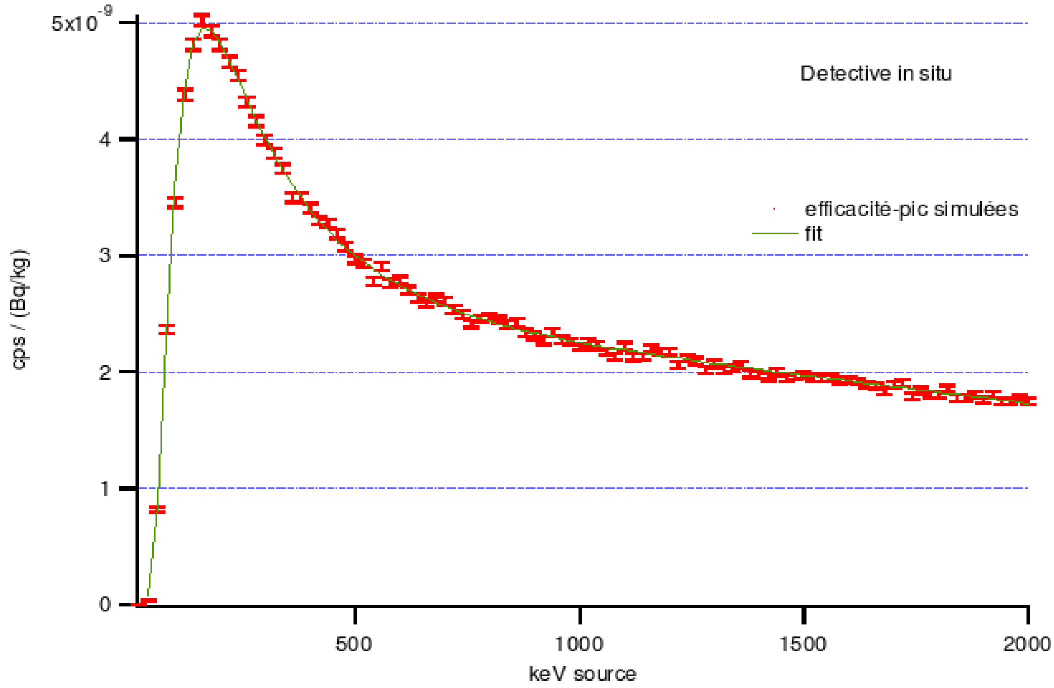


Figure 5.20: Monte Carlo simulation evaluating the efficiency of the ORTEC-DETECTIVE spectrometer for *In Situ* geometry [21].

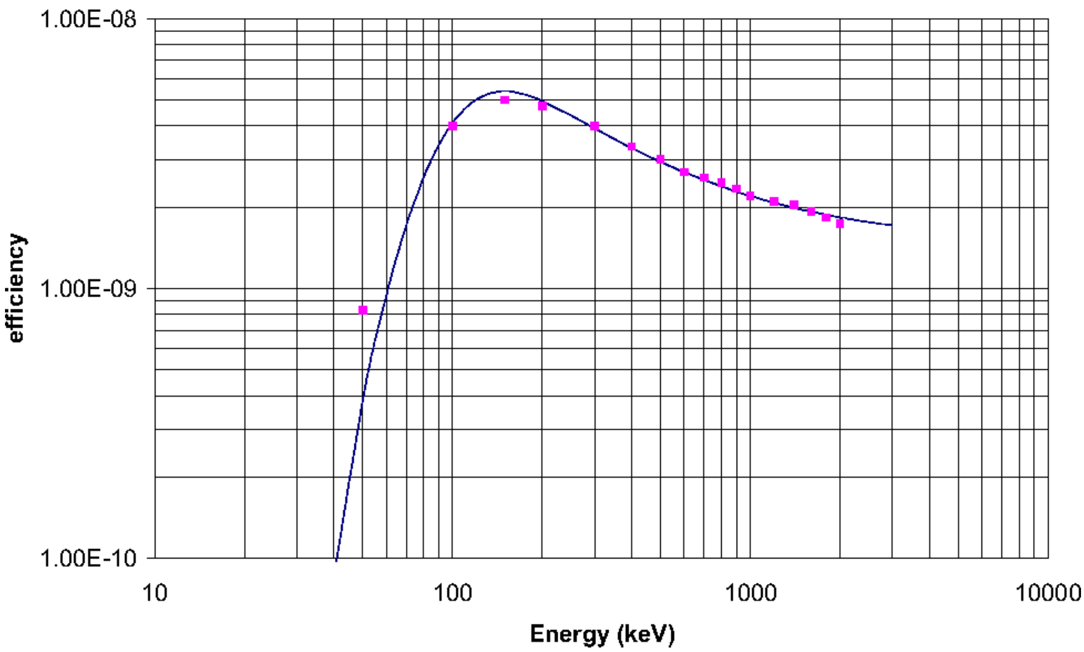


Figure 5.21: Fitting the results obtained with Monte Carlo simulations for outdoor *In Situ* geometry to Winiger's approximation Eq. 5.14.

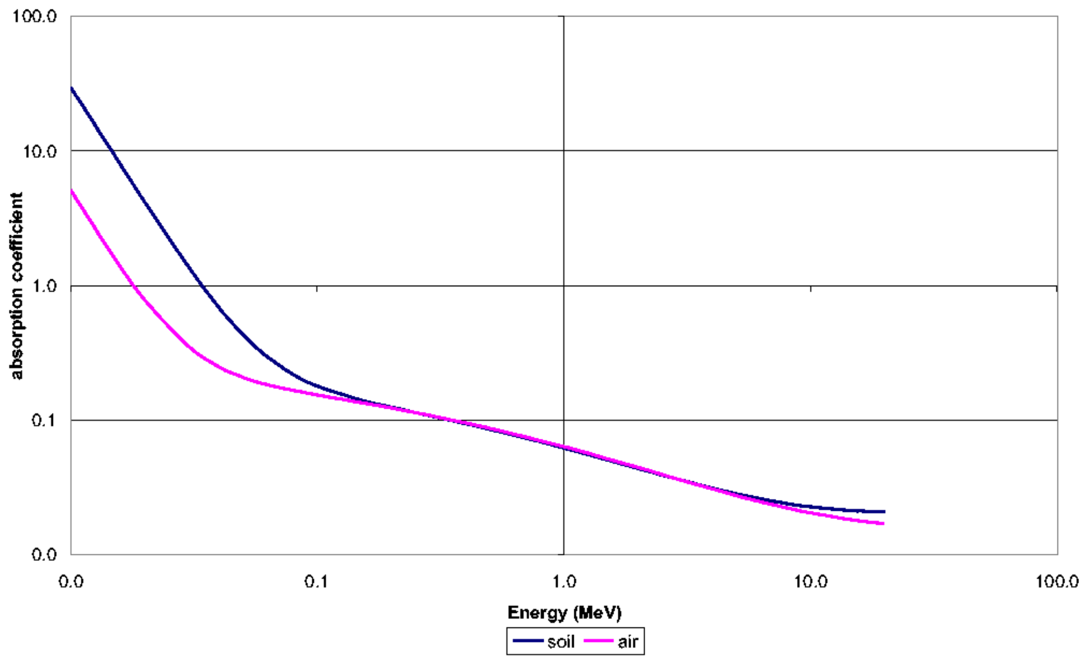


Figure 5.22: γ radiation absorption coefficient ($\frac{\mu_s}{\rho}$ in $\frac{\mathrm{cm}^2}{\mathrm{g}}$) in air and soil. Data are taken from the National Institute of Standards and Technology's website [41].

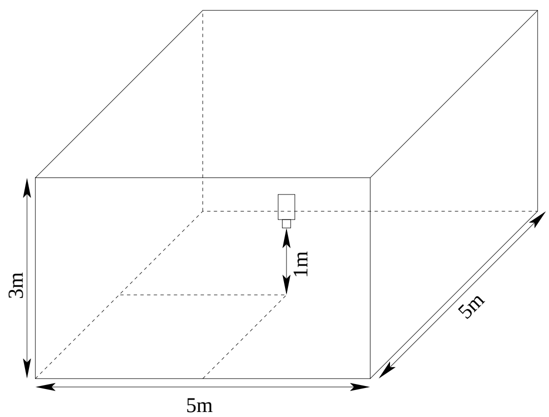


Figure 5.23: Schematic situation overview of Monte Carlo *In Situ* simulations for indoor measurements.

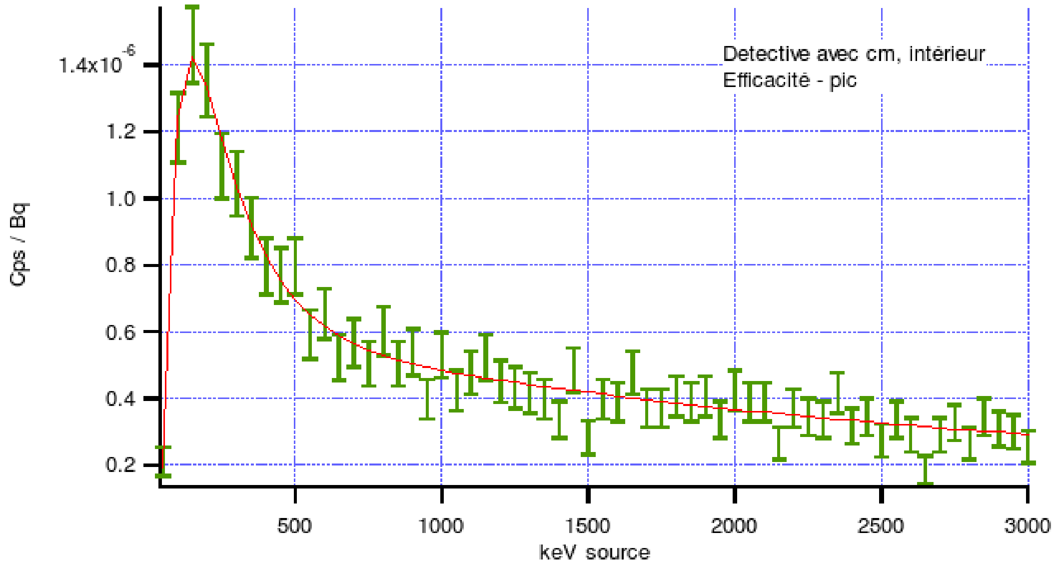


Figure 5.24: Monte Carlo simulation evaluating the efficiency of the ORTEC-DETECTIVE spectrometer indoor geometry [21].

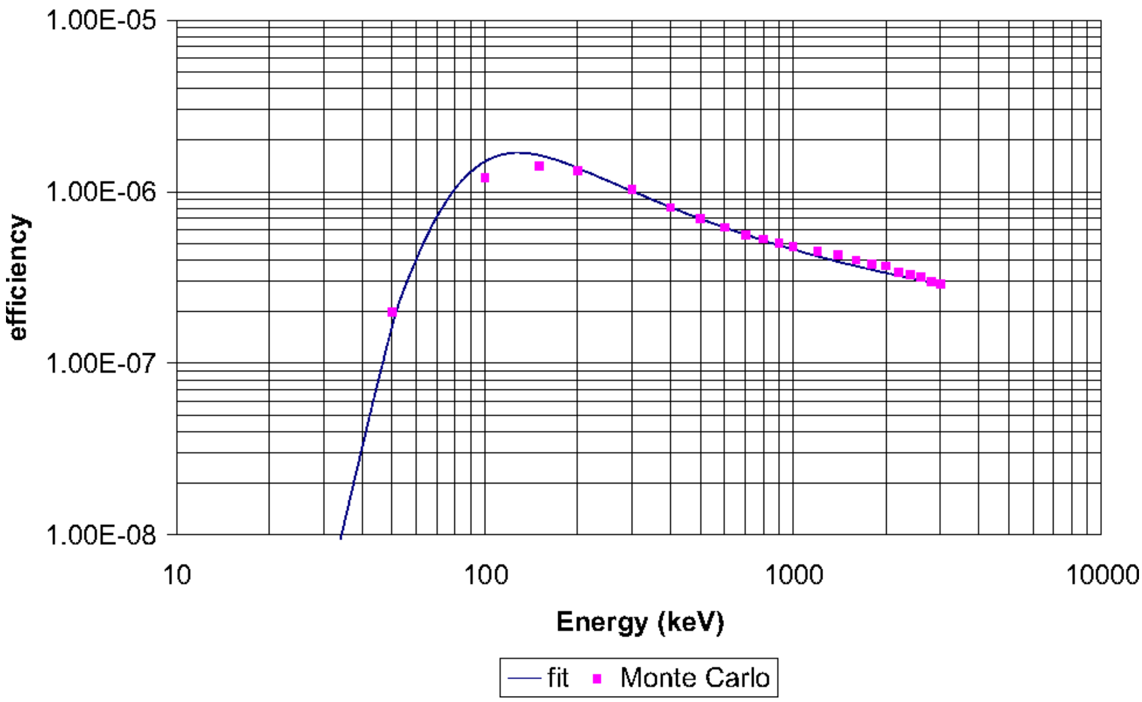


Table 5.5: Fitting the results obtained with Monte Carlo simulations for indoor geometry to Winiger's approximation Eq. 5.14.

Chapter 6

Results

In the preceding chapters, the different theories, standards and equipment needed to understand the experimental setup of this work were explained. The text should have brought sufficient details to grab the meaning of the results obtained in the different measurements. The propose of this work was to measure and evaluate the different components of the background γ radiation and its variations in an urban area, when subjected to man-made alteration of the environment.

The data presented in this chapter are the results of 124 measurements made throughout Fribourg's urban area, both indoors and outdoors. They are intended to evaluate the ionizing external dose, from natural and artificial sources, excluding internal doses from the body's own radionuclide and from radon and its affiliates.

The results of the external ambient dose rate are given in $\frac{\mathrm{mSv}}{\mathrm{yr}}$. The conversion factors between the KERMA rate and the ambient dose equivalent rate are given in Table 4.6 (page 45).

6.1 Experimental location

To evaluate the exposure to background γ radiation in urban surroundings, *In Situ* and γ dose rate measurements were carried out on different sites, in Fribourg city. As mentioned in § 2.4, we chose Fribourg city since it offers a wide variety of constructions and dwellings dating from the middle ages to modern times, Fribourg is built on roughly 200m of altitude change.

Various parameters intervened in the choice of sites. For outdoor measurements, the sites were chosen regarding altitude, the type of ground: natural soil, cobblestone or asphalted road, and the surroundings, like the proximity of buildings. For indoor measurements, the sites were chosen with respect to the type of buildings or dwellings which were representative of certain age period, the building materials, their location in the city and the height of the building (number of stories).

outdoor measurements

The altitude of the site influences the cosmic contribution of the total background γ radiation. As mentioned in § 3.9, primary cosmic radiation is deviated by the Earth's magnetic field and secondary radiation is partly absorbed by the Earth's atmosphere. Therefore,

Table 6.1: Range of values of the calculated cosmic component in Fribourg's urban area. The indoor neutronic component is very hard to evaluate. The interaction of neutron of high energy with matter is not yet determined.

height range	ionizing component		neutronic component	
	outdoor	indoor	outdoor	indoor
(m)	(mSv/ yr)	(mSv/ yr)	(mSv/ yr)	(mSv/ yr)
500	0.34	0.28	0.088	unknown
700	0.38	0.32	0.105	unknown

the total amount of cosmic rays increases with latitude and decreases with altitude. The equivalent dose rate $\dot{E}_c$ (in $\frac{nSv}{h}$), § 4.2, produced by the ionizing component of cosmic radiation in Switzerland [12] can be approximated by

$$\dot{E}_c = \frac{E_c}{t} \approx \left(0.286 \frac{\mathrm{mSv}}{\mathrm{yr}}\right) \cdot e^{\frac{z}{2.5\,\mathrm{km}}} \tag{6.1}$$

as a function of the altitude z (in km) for $0 \leq z \leq 2$ km. The calculated ambient dose equivalent rate for the ionizing component of cosmic radiation is for outdoor measurements only. When measuring indoors, part of this cosmic radiation is absorbed by the structure of the building. The altitude and unevenness of the urban area is needed to evaluate the total background γ radiation. In Fribourg, measurements were performed at different altitude, covering most of the ~ 200 m altitude change of the city.

Cosmic radiation reaching the Earth' surface is also compose of non-ionizing neutronic radiation. The equivalent dose rate (E_n) due to this neutronic cosmic radiation can be approximated by

$$E_n \approx \left(0.061 \frac{\mathrm{mSv}}{\mathrm{yr}}\right) \cdot e^{\frac{z}{1.2\,\mathrm{km}}} \tag{6.2}$$

as a function of the altitude z (in km) [12]. Table 6.1 gives the range of values for Fribourg's urban area.

The type of ground surface greatly influences the terrestrial contribution of the total background γ radiation, due to the concentration of natural radionuclide from the uranium and thorium decay series and from potassium (^{40}K). Different ground or soil will have various isotope composition. Firstly, this difference in composition can influence the concentration of radioactive isotopes. Secondly, different radioactive isotopes emit γ rays at different energies, changing the contribution to the total absorbed dose rate. Finally, the soil partly absorbs the radiation. For example, a slab of soil 23 cm thick absorbs up to 95% of the γ rays at 600 keV. In Fribourg, measurements were performed on few ground types of different construction types: natural ground (grass and exposed soil), cobblestone roads, sidewalks, and bituminous or asphalted roads and sidewalks.

Finally, the surroundings can influence the terrestrial contribution of the total background γ radiation. Objects, like buildings, over-passes, and bridges, surrounding the measurement site can either increase or reduce the background radiation. Therefore the terrestrial component of the background γ radiation changes whether the surrounding was

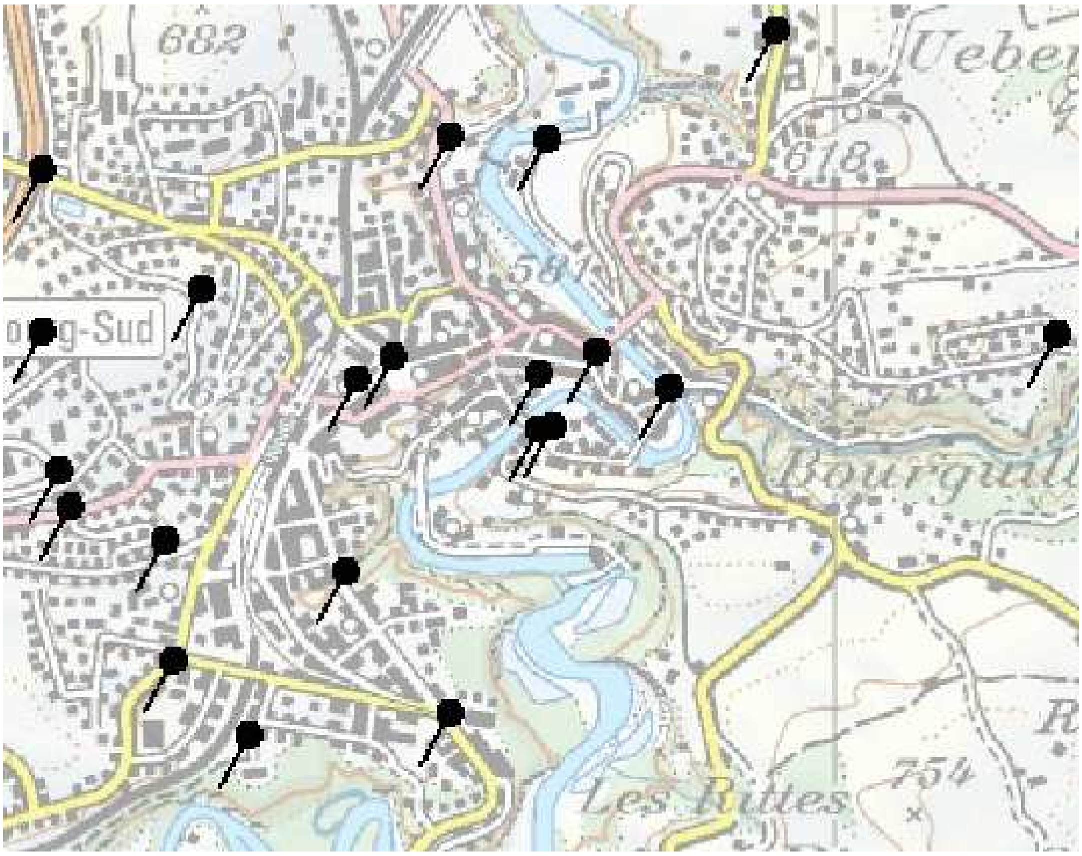


Figure 6.1: Map of Fribourg with the 21 outdoor measurement sites chosen for this project.

a wide open park or a small side street with many buildings close to each other. In some cases, the detectors were set in a clearing, while in other cases, very little space is left between the detectors and the walls of the constructions.

Figure 6.1 shows the different outdoor measurement sites chosen for this project.

indoor measurements

The building construction type influences the total background γ radiation: by either absorbing radiation coming from outdoors and/or by contributing from the radionuclide contained in the construction materials. The results will differ whether the measurement was done in a house, an indoor parking garage, a small building or a tall one. From individual houses to tall buildings, Fribourg offers a wide range of different constructions.

Cosmic radiation is partly absorbed by matter it crosses. The Earth's atmosphere, therefore, absorbs some of the cosmic radiation. When measuring indoor, the structure of the building also absorbs part of it, decreasing even more its dose rate. Each story absorbs more and more cosmic radiation. So, the number of stories, more than the height of a building, plays a role in diminishing the cosmic component of the total background γ radiation.

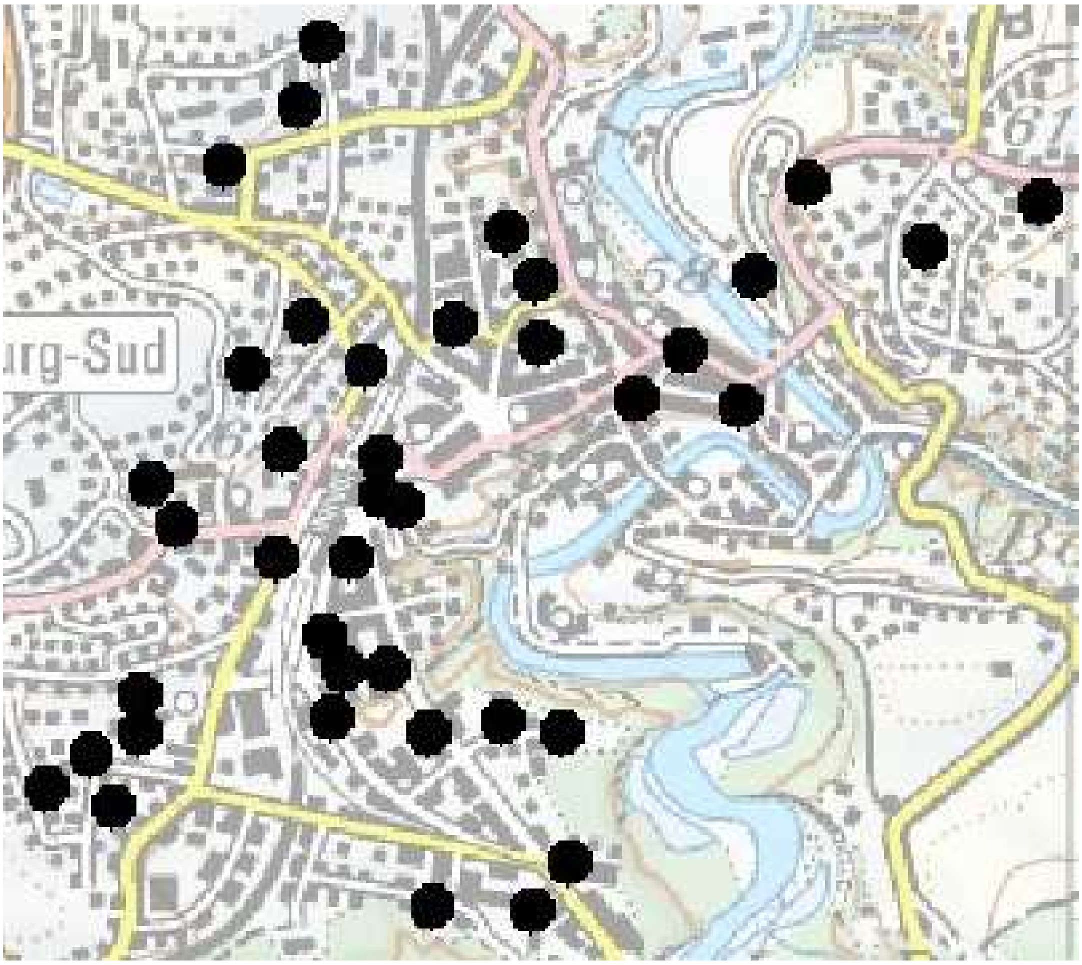


Figure 6.2: Map of Fribourg with the 103 indoor measurement sites chosen for this project. Measurements were performed on different stories of each indoor site.

Figure 6.2 shows the different indoor measurement sites chosen for this project. Whenever possible, measurement were carried on several different stories of the buildings.

6.1.1 Instruments for different sites

Measurements were performed with two instruments in parallel: a γ spectrometer, for the terrestrial component, and an ionisation chamber, for the total γ background dose rate. The outdoor terrestrial component was measured with an *In Situ* portable γ spectrometer, with the crystal facing downward. A dose rate measurement was also carried out with an ionisation chamber, Fig. 5.8(a) (page 59).

Due space constraints inside buildings, the instrument setup changed for indoor measurements: the ORTEC-DETECTIVE (§ 5.1.5) with the crystal set horizontally, measured the terrestrial contribution to the total background γ radiation. A dose rate measurement was carried out in parallel using an ionisation chamber. The two instruments were set closely together on a mobile carriage, mounted on soft rubber wheels, to ease movement

Table 6.2: Concentration of radioactive elements in cobblestone and granite.

	element concentration	
	cobblestone [12]	granite [17]
^{238}U	$20 \leftrightarrow 25 \frac{\mathrm{Bq}}{\mathrm{kg}}$	$25 \leftrightarrow 70 \frac{\mathrm{Bq}}{\mathrm{kg}}$
^{232}Th	$20 \leftrightarrow 25 \frac{\mathrm{Bq}}{\mathrm{kg}}$	$35 \leftrightarrow 70 \frac{\mathrm{Bq}}{\mathrm{kg}}$
^{40}K	$200 \leftrightarrow 600 \frac{\mathrm{Bq}}{\mathrm{kg}}$	$700 \leftrightarrow 1400 \frac{\mathrm{Bq}}{\mathrm{kg}}$

and prevent damage (Fig. 5.5(b)).

For both indoor and outdoor measurements, the instruments were set at 1 m above ground or floor level according to the recommendations from ICRU Report 53 [27].

6.2 Results

outdoor measurements

From Halm, Herbst and Mastrocola [35], different types of soil contribute differently to the γ dose rate. In 1962, measurements were made outdoors throughout Switzerland, on different geological ground type (§ 2.2.1). Ground types chosen for this census were outside of any urban surroundings and not altered by mankind.

Four different types of ground surface were surveyed in the Fribourg area: grass, asphalt, gravel, and coblestone. They give noticeable different terrestrial contributions to the total absorbed dose (Fig. 6.3).

The highest terrestrial contribution to the total dose was noticed on **cobblestone** surfaces. Measurements were made on this ground surface at location: in the upper and lower part of *Planche Supérieure*, and *Place Jean-François-Reyff* in front of the wooden bridge. Cobblestone places are found mostly in the lower part of the urban area, which are also the oldest. The material used for these cobblestone surfaces contain a greater concentration of radioactive elements, increasing the terrestrial contribution, Table 6.2.

Outdoor measurements made on **asphalt** surfaces have noticeable variations of terrestrial contribution, ranging from $(25 \pm 2) \frac{\mathrm{nSv}}{\mathrm{h}}$ to $(68 \pm 3) \frac{\mathrm{nSv}}{\mathrm{h}}$. From a conversation with Mr. Dominique Ding, civil engineer at Fribourg's municipal administration, different materials and material concentrations are mixed to asphalt, changing the hardness and rigidity of the surface. The material and material concentration influence greatly the terrestrial contribution nearby.

The lowest terrestrial contribution to the total absorbed dose was noticed on natural **gravel** surfaces, with values from $(19 \pm 3) \frac{\mathrm{nSv}}{\mathrm{h}}$ to $(27 \pm 3) \frac{\mathrm{nSv}}{\mathrm{h}}$.

For total background γ radiation, terrestrial and cosmic contribution, parallel dose rate measurements were performed with an ionisation chamber, i.e., the cosmic contribution, calculated from the altitude of the site, is added to the terrestrial contribution, from *In Situ* measurements, and compared to the dose rate measurement, from the ionisation chamber. Figure 6.4 compares this *In Situ* total background γ radiation, with an average of $(85 \pm 8) \frac{\mathrm{nSv}}{\mathrm{h}}$, to the *Reuter-Stokes* dose rate measurement, with an average of $(98 \pm 3) \frac{\mathrm{nSv}}{\mathrm{h}}$.

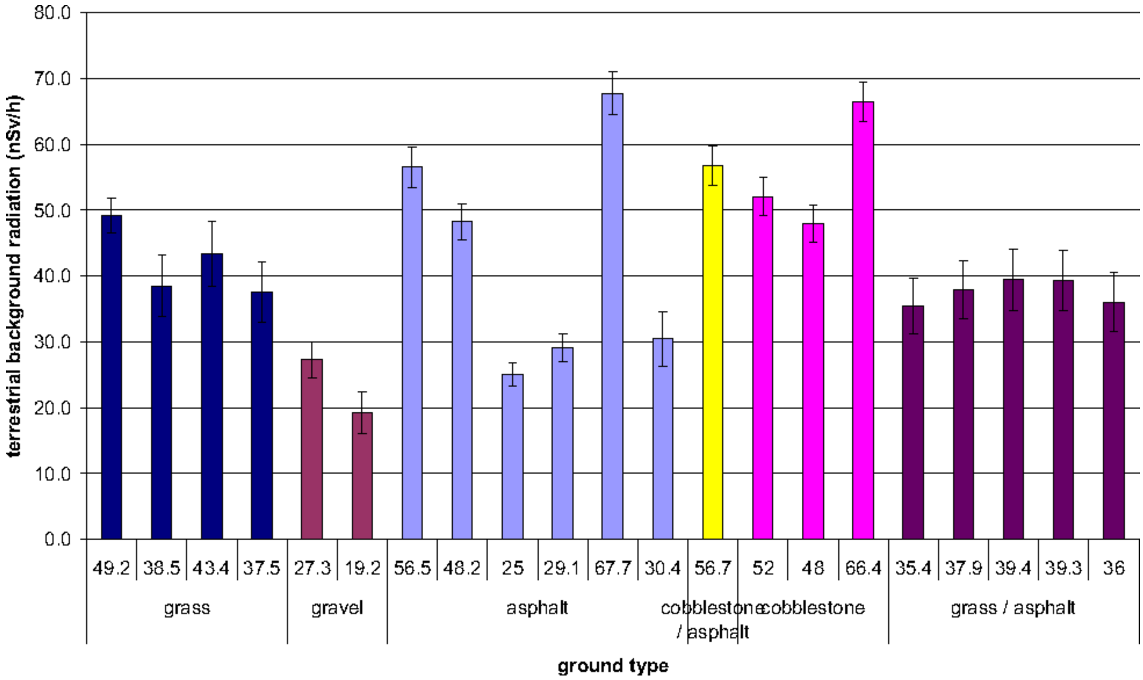


Figure 6.3: Outdoor terrestrial contribution to the total absorbed dose, for the different ground surfaces found in the Fribourg urban area. The terrestrial component was evaluated from *In Situ* measurements.

indoor measurements

Variations were noticed in the terrestrial contribution due to the absorption of radiation by the walls and from the added contribution by the materials used in the construction of buildings, Fig. 6.5. I received help from Mr. Jean-Pierre Aeby, construction inspector at Fribourg's municipal administration. Mr. Aeby allowed measurements to be performed in multiple buildings of the town. He helped in identifying the different material construction of all indoor measurements. In addition to Mr. Aeby's help, R. Bollin's book [4] give further details on the construction material used for some building the Fribourg.

The highest values, from Table 6.3, were found being inside buildings made of **molasse**.

Table 6.3: Values for the terrestrial contribution, when measuring indoor. This component variation depends greatly on the building material.

building material	**Minimal** (nSv/h)	**Average** (nSv/h)	**Maximal** (nSv/h)
concrete	22 ± 4	47	77 ± 6
masonry/molasse	51 ± 5	70	81 ± 7
masonry/rough-cast	28 ± 6	64	83 ± 4
metal frontage curtain	35 ± 6	51	79 ± 10
molasse	45 ± 5	67	95 ± 7

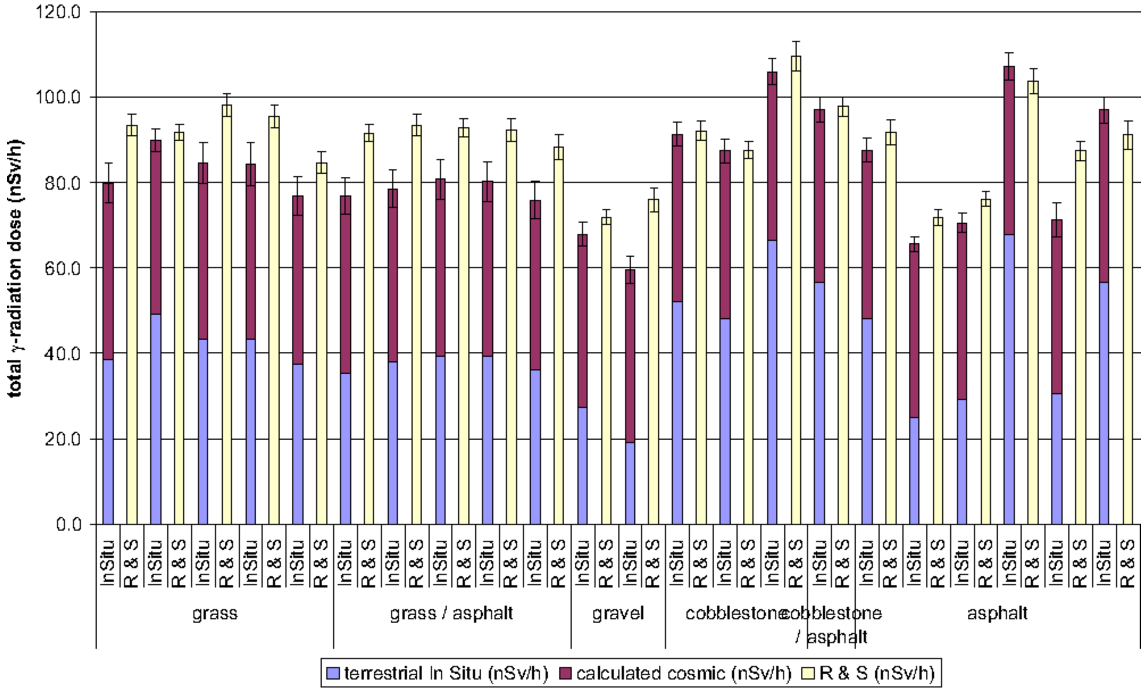


Figure 6.4: Comparison between the sum of the measured terrestrial with the calculated cosmic contribution and the measured total absorbed dose, for outdoor measurements. Outdoor measurements show little difference between *In Situ* and dose rate measurements: (*In Situ* + calculated cosmic) $\xleftrightarrow{\sim\pm5\%}$ (ionisation chamber's measurement).

The thickness of the walls of these buildings and the higher concentration of radioactive isotopes, like ^{40}K and the decay chains of ^{238}U and ^{232}Th, can explain these higher values.

Great variations were observed when measuring in construction of **concrete** and **masonry/molasse**, with values ranging over 55 nSv/h. Different materials added to the construction greatly influences the concentration of radioactive isotopes, thereby influencing the terrestrial contribution to the total background radiation.

When indoors, the building structure partly absorbs the cosmic radiation. Cosmic radiation contribution can be found by subtracting the terrestrial contribution, measured by the ORTEC-DETECTIVE, from the total radiation, measured by the ionisation chamber. The absorption of cosmic radiation by the structure can be found by comparing the cosmic radiation measured indoors, to the cosmic radiation evaluated outdoors at the same altitude

$$\text{absorption in } \% = \frac{\text{indoor cosmic} - \text{outdoor cosmic}}{\text{outdoor cosmic}} \simeq -17\% \tag{6.3}$$

Figure 6.6 shows the variation of the total absorbed dose, when measured indoors as a function of number of floors absorbing, compared to an outdoor *In Situ* measurement at the same altitude. Figure 6.7 shows the average amount of cosmic radiation absorbed by the structure of the building. As predicted, more and more cosmic radiation was absorbed when measuring near the ground floor, with the whole structure of the building on top. Cosmic radiation absorption seems to increases for the first 5 → 7 floors on top,

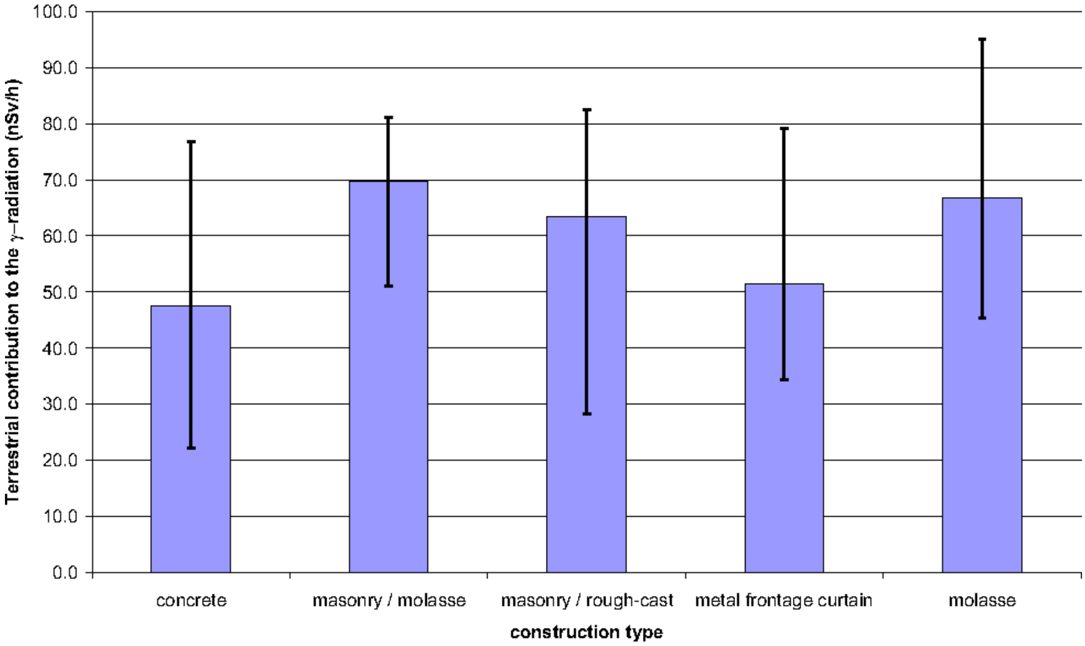


Figure 6.5: The average indoor terrestrial contribution from the different construction types. The uncertainty bar shows the maximal deviation to the average value.

Table 6.4: The average absorption of cosmic radiation (in %) per floor of building, for indoor measurements.

	concrete	masonry / molasse	masonry / rough-cast	metal front curtain	molasse
$\frac{\text{Average cosmic absorption}}{\text{floor}}$	1.6%	0.7%	1.3%	1.2%	−2.5%

to become constant afterwards. The angular dependence of cosmic radiation could explain this situation. Cosmic radiation coming from straight above is absorbed by the successive stories it crosses. Only a certain proportion of the residual cosmic radiation is absorbed by the walls of building. The average absorption (in %) per floor is shown in Table 6.4. **Concrete** is the construction material which absorbs most cosmic rays, whereas **molasse** is the construction material which absorbs the least cosmic rays from the materials tested. In fact, molasse construction have a negative average cosmic radiation absorption. This can be explained from the very small cosmic absorption by this construction material($\sim -2.5\%$).

Indoor – outdoor difference

From Máduar and Hiromoto [24], man-made alteration can increase terrestrial radiation exposure by 20% or more. Many measurements were made indoors and outdoors to evaluate the increase of terrestrial contribution to the background γ radiation exposure. From more than 100 indoor and 22 outdoor measurements, a noticeable average increase of

$$\frac{(\text{indoor terrestrial}) - (\text{outdoor terrestrial})}{(\text{outdoor terrestrial})} \simeq +16\% \tag{6.4}$$

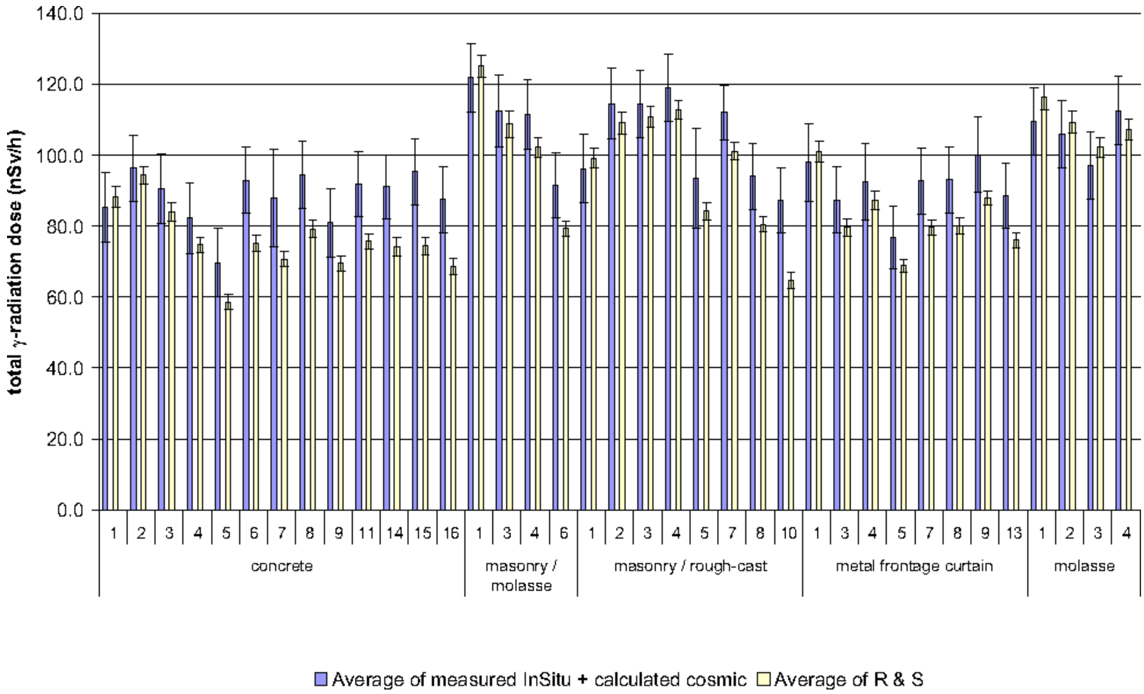


Figure 6.6: The total absorbed dose from indoor measurements. The *In Situ* contribution was measured from γ spectrometer. The cosmic contribution was calculated from the altitude. *R & S* was the dose rate value measured by the ionisation chamber.

of the terrestrial contribution was found when measuring indoors, with measured average terrestrial radiation exposures of $(56 \pm 6)\frac{\text{nSv}}{\text{h}}$ indoors and of $(48 \pm 3)\frac{\text{nSv}}{\text{h}}$ outdoors. Since cosmic radiation is partly absorbed by the structure of the buildings, decrease in the cosmic contribution to the total radiation exposure of

$$\frac{(\text{indoor cosmic}) - (\text{outdoor cosmic})}{(\text{outdoor cosmic})} \simeq -17\% \tag{6.5}$$

was noticeable when measuring indoors. The increase of terrestrial and the decrease of cosmic contribution leaves the total exposure to ionizing background radiation, only strenght changed:

$$\frac{(\text{indoor total}) - (\text{outdoor total})}{(\text{outdoor total})} \simeq +2\% \tag{6.6}$$

with an average of $(91 \pm 3)\frac{\text{nSv}}{\text{h}}$ for indoor and $(89 \pm 2)\frac{\text{nSv}}{\text{h}}$ for outdoor measurements, a difference consistant with zero. Measurements performed by Johner and Völkle [17] showed an increases of $\sim +10\%$ in Switzerland and of $\sim 11\%$ in Fribourg, when measuring indoors.

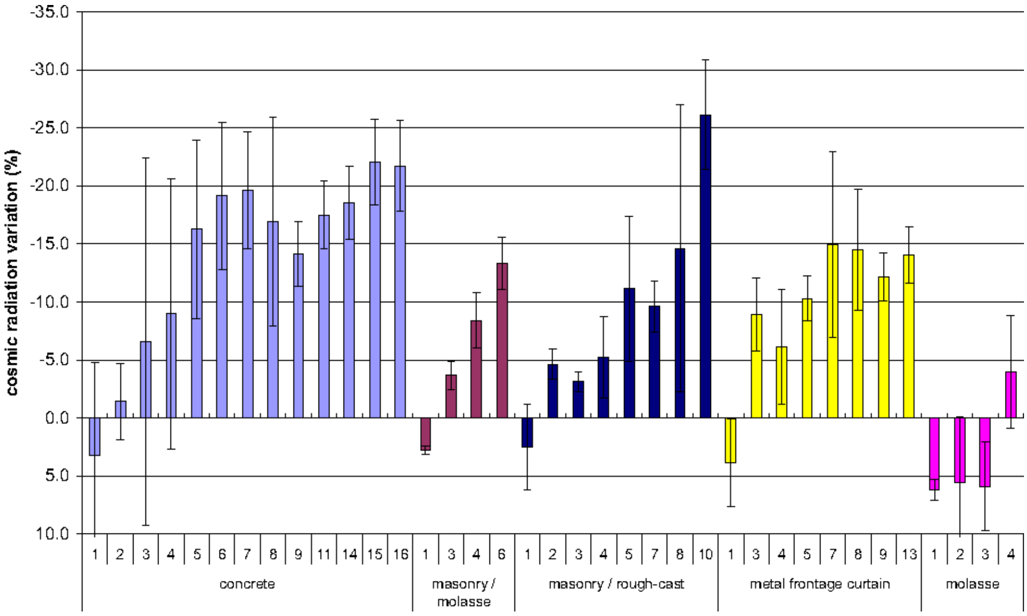


Figure 6.7: Cosmic radiation absorption by the structure of the buildings, when measuring indoors. The x value represents the number of stories absorbing cosmic γ radiation.

Chapter 7

Conclusion

The purpose of this work was to measure and evaluate the total background γ radiation, from external sources, in an urban area. From the results obtained and presented in Chap. 6, the terrestrial and cosmic components average doses and deviations were found.

7.1 Results comparison

Terrestrial contribution

The population of Fribourg, Switzerland, is exposed to an average terrestrial contribution to the external background dose shown in Table 7.1. Considering that $\sim 20\%$ of the time is spent outdoors [27], Table 7.2 compares the results obtained in this work for terrestrial contribution to the external background dose to the results from the CPR [12].

Ionizing component

The total external background γ radiation is composed of a ionizing cosmic contribution, which is partly absorbed by building structure when indoors. For outdoor measurements, in the Fribourg urban area, an average ionizing cosmic radiation of $40.2\,\frac{\text{mSv}}{\text{h}}$ was measured for altitude of 597 m(a.s.l.) of average measuring height. Indoor measurements have been performed at an average altitude of 640m(a.s.l.) for an average ionizing cosmic contribution of $34.8\,\frac{\text{mSv}}{\text{h}}$. Considering that $\sim 80\%$ of our time is spent indoors, Table 7.3 compares the

Table 7.1: Terrestrial contribution values obtained from measurements done in Fribourg urban region.

	indoor measurements		outdoor measurements	
	terrestrial $\frac{\text{mSv}}{\text{yr}}$	total background $\frac{\text{mSv}}{\text{yr}}$	terrestrial $\frac{\text{mSv}}{\text{yr}}$	total background $\frac{\text{mSv}}{\text{yr}}$
minimal value	0.19	0.44	0.22	0.63
average value	0.49	0.79	0.42	0.79
maximum value	0.83	1.10	0.10	0.96

Table 7.2: Results compared for the KERMA in the air (K_a), the effective dose (E) and the ambient dose ($H^*(10)$) to the CPR [12] and to Johner and Völkle [17], for terrestrial contribution to the total external background γ radiation.

	$K_a \rightarrow$ Air KERMA (mGy/ yr)		$80\% t_{\text{indoor}} + 20\% t_{\text{outdoor}}$	
	indoor	outdoor	E (mSv/ yr)	$H^*(10)$ (mSv/ yr)
This work	0.41	0.36	0.30	0.48
Switzerland [12]	0.49	0.35	0.35	0.55
Fribourg [12]	0.45	0.32	0.32	0.51
Fribourg [17]	0.33	0.27	0.24	0.39

Table 7.3: Results compared to the CPR's [12] effective dose, for ionizing cosmic contribution to the total external background γ radiation.

	Ionizing part of cosmic radiation		
	outdoor	indoor	$80\% t_{\text{indoor}}$ $20\% t_{\text{outdoor}}$
This work	$E_c(z)$=(0.289 mSv/h)$e^{\frac{z}{2.5km}}$	$E_c(z)$=(0.237 mSv/h)$e^{\frac{z}{2.5km}}$	$E_c(z)$=(0.245 mSv/h)$e^{\frac{z}{2.5km}}$
CPR [12]	$E_c(z)$=(0.280 mSv/h)$e^{\frac{z}{2.5km}}$	$E_c(z)$=(0.228 mSv/h)$e^{\frac{z}{2.5km}}$	$E_c(z)$=(0.237 mSv/h)$e^{\frac{z}{2.5km}}$

results obtained in this work for cosmic to the external background dose to the results from the CPR [12].

The results given in the last table are the weighted average for the terrestrial and cosmic contribution to the total external absorbed dose. These results are given without uncertainties for simplicity. We can justify $\pm 20\%$ uncertainties on these average, arising from calibration and measurements methodology.

7.2 Future Projects

In this work, the indoor and outdoor external background γ radiation in the Fribourg urban area has been measured and evaluated. The different components, terrestrial and cosmic contribution, their average values and their variations were found. From Fig. 1.1, the external background γ radiation, including terrestrial and cosmic radiation, represents about 25% of the total radiation exposure. The terrestrial component includes γ radiation from natural and artificial sources. The artificial radiation comes primarily from the Chernobyl catastrophy and from nuclear weapon testing in the 1950's and 1960's. Its contribution is very small ($\leq 1\%$) compared to the natural terrestrial component. The reactors nearby, like Mühleberg, have not visible effect on the total radiation we are exposed to daily.

External background γ radiation in Switzerland

A future project could be imagined to measure and evaluate the indoor and outdoor external background γ radiation in other towns and regions of Switzerland. Constructions in various cities and regions of the country have different building materials, influencing both terrestrial and cosmic contribution to the indoor background γ radiation, as well as different soil composition and other parameters.

To expand this project to other regions of Switzerland, the following precautions have to be acknowledged.

1. Like for this work, measurements should be carried out in most possible sites, over the chosen territory, necessary for the best knowledge of the global situation. The sites should be chosen following these parameters:

   - geographical situation

     To have the best overview of the background radiation in an environment, measurements should be carried out systematically over the territory.

   - geological situation:

     outdoor measurements

     - should be carried over all the different ground and soils types found in the chosen environment. This would allow a better understand of the different background radiation emitted.
     - should be performed at different altitude.

     indoor measurements

     - should be performed in all the different building structures found in the territory.
     - should be made on many different stories, which would increase our knowledge of cosmic radiation absorption by the building structures.
     - should be carried in different rooms, and at different distances from the building structure. Therefore, the background radiation variation within a room could be determine.

2. Instruments and devices used for indoor measurements should be compact and set tightly. The lack of space in buildings and dwellings allows very little space for cumbersome devices. The setup should also allow ease of movement indoor. Like used for this work, the instruments should be set on a portable wheeled carriage.

3. Calibration measurements should be carried out properly in order to reduces the conversion uncertainties, from air KERMA (K_a) to ambient dose equivalent ($H^*(10)$).

4. To know the variation domain of the external background γ radiation, a statistically large number of measurements would be necessary.

5. Parallel measurements should be made using both *In Situ* γ spectrometry and dose rate measurements using an ionisation chamber. The results obtained from these measurements should be compared to Monte Carlo simulations [21] and previous measurements, like the ones made by H. U. Johner and H. Völkle [17].

Appendix A

Measurements

The purpose of this work is to measure and evaluate the total background γ radiation, from external sources, in an urban area, Chap. 1. From the results obtained and presented in Chap 6, the terrestrial and cosmic components average doses and deviations are found.

When measuring outdoors, the coordinates and the altitude were determined with a GPS. When measuring indoors, the coordinate and the altitude of the ground floor were determined with a GPS. 3 m were added to the altitude of the site for each story.

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:			coordonnées	Altitude:	identification	début de la mesure:	durée :
Fribourg Manor	**cnt/sec**	**beau**	**46°48' 15" N 7°9' 13" E**	**620**	**FRMANO05.dat**	**8/6/2005 6:45**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	431	50.4	0.11	22.33	1.30E-04	37.1			
Ra-226	186.20	592	35.1	0.15	17.67	1.20E-04	69.8			
Pb-214	351.93	2150	6.6	0.54	11.03	1.71E-03	28.5			
Bi-214 (Total U-238)	609.32	2253	5.1	0.56	6.85	2.76E-03	29.8	5.47E-01	16.3	
Ac-228 (Total Th-232)	911.07	987	9.3	0.25	4.89	2.07E-03	24.4	7.39E-01	18.0	
Pb-212	238.63	2975	6.7	0.74	15.01	1.73E-03	28.6			
Bi-212	727.33	328	20.9	0.08	5.89	4.30E-04	32.4			
Tl-208	583.19	1469	7.2	0.37	7.12	1.76E-03	29.3			
K-40	1,460.83	6005	2.6	1.50	3.35	9.70E-04	461.6	4.80E-02	22.2	
										R & S
										91.2
										3.40%
Cs-137	661.66				6.38	5.20E-03		1.92E-01		**Incertitude**
						Total :	**741.5**		**56.5**	**5.46**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	**56.5**	**0.0**	**40.5**	**97.0**		**91.2**	en %		**-5.9**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

FR Place :		coordonnées		Altitude:	identification	début de la mesure:	durée :
Georges_Python	140 cnt/sec beau	46°48'18"N	7°9'20"E	618	FRPLGP05.dat	8/6/2005 8:08	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	601	41.7	0.12	22.33	1.30E-04	41.4			
Ra-226	186.20	664	31	0.13	17.67	1.20E-04	62.6			
Pb-214	351.93	2720	5.9	0.54	11.03	1.71E-03	28.8			
Bi-214 (Total U-238)	609.32	2573	5	0.51	6.85	2.76E-03	27.2	5.47E-01	14.9	
Ac-228 (Total Th-232)	911.07	1339	7.3	0.27	4.89	2.07E-03	26.5	7.39E-01	19.6	
Pb-212	238.63	4240	4.2	0.85	15.01	1.73E-03	32.7			
Bi-212	727.33	361	19.9	0.07	5.89	4.30E-04	28.5			
Tl-208	583.19	1860	6.5	0.37	7.12	1.76E-03	29.7			
K-40	1,460.83	7556	2.4	1.51	3.35	9.70E-04	464.7	4.80E-02	22.3	
										R & S
										97.8
										2.40%
Cs-137	661.66				6.38	5.20E-03		1.92E-01		Incertitude
						Total :	742.1		56.7	5.25

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nGy/h	56.7	0.0	40.5	97.2	97.8	en %	0.6

REMARQUE : évaluation effectuée avec le software InterWinner5

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:			coordonnées		Altitude:	identification	début de la mesure:	durée :
FR DOMINO	**95 cnt/sec**	**beau**	**46°47'53"N**	**7°9'11"E**	**625**	**FRDOMI05.dat**	**8/6/2005 9:59**	**3209**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**egnc 30 ε=N/Ø %**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	262	38.7	0.08	17.67	1.20E-04	38.5			
Pb-214	351.93	1050	9.5	0.33	11.03	1.71E-03	17.3			
Bi-214 (Total U-238)	609.32	968	7.9	0.30	6.85	2.76E-03	16.0	5.47E-01	8.7	
Ac-228 (Total Th-232)	911.07	346	15.6	0.11	4.89	2.07E-03	10.7	7.39E-01	7.9	
Pb-212	238.63	867	12.9	0.27	15.01	1.73E-03	10.4			
Bi-212	727.33	82	46.2	0.03	5.89	4.30E-04	10.1			
Tl-208	583.19	483	12.8	0.15	7.12	1.76E-03	12.0			
K-40	1,460.83	2332	4.3	0.73	3.35	9.70E-04	223.5	4.80E-02	10.7	
										R & S
										71.9
										2.60%
Cs-137	661.66				6.38	5.20E-03		1.92E-01		**Incertitude**
						Total :	**338.4**		**27.3**	**10.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**Insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**27.3**	**0.0**	**40.6**	**67.9**		**71.9**	**en %**		**5.9**

Etabli avec courbe d'efficacité INSITU30_IW_BA_AB_corr.eff; degré 5; les aires nettes, et donc les efficacités, pour l'am-241 sont corrigées par rapport à BA_ABS_ESS
Pour établir cette courbe,les spectres ont été avec IW 5.0, mais l'absorption dans le détecteur a été recalculée par ESS
REMARQUE : la courbe d'efficacité a été renomée : INSITU30_IW_2004_final

INSITU 2005 - Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Fr Planche Supérieure		coordonnées		Altitude:	identification	début de la mesure:	durée :
Haut	130 cnt/sec beau	46°48'9"N	7°9'44"E	544	:RSUHA05.DAT	9/9/2005 11:42	4000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	566	50	0.14	22.33	1.30E-04	48.7			
Ra-226	186.20	441	40	0.11	17.67	1.20E-04	52.0			
Pb-214	351.93	2284	6.2	0.57	11.03	1.71E-03	30.3			
Bi-214 (Total U-238)	609.32	2205	5.2	0.55	6.85	2.76E-03	29.2	5.47E-01	15.9	
Ac-228 (Total Th-232)	911.07	852	8.9	0.21	4.89	2.07E-03	21.0	7.39E-01	15.6	
Pb-212	238.63	2470	6.4	0.62	15.01	1.73E-03	23.8			
Bi-212	727.33	352	20	0.09	5.89	4.30E-04	34.7			
Tl-208	583.19	1222	8.2	0.31	7.12	1.76E-03	24.4			
K-40	1,460.83	5332	2.8	1.33	3.35	9.70E-04	409.9	4.80E-02	19.7	
										R & S
										92.1
										2.50%
Cs-137	661.66	519	15	0.13	6.38	5.20E-03	3.9	1.92E-01	0.8	**Incertitude**
						Total :	**674.0**		**51.9**	**5.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	51.2	0.8	39.3	91.3	92.1	en %	0.9

INSITU 2005 - Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Fr Planche Supérieure		coordonnées	Altitude:	identification	début de la mesure:	durée :
Bas	120 cnt/sec beau	46°48'10"N 7°9'46"E	547	:RSUBA05.DAT	9/9/2005 10:26	4000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	355	49	0.09	17.67	1.20E-04	41.9			
Pb-214	351.93	2284	6.2	0.57	11.03	1.71E-03	30.3			
Bi-214 (Total U-238)	609.32	2268	5.2	0.57	6.85	2.76E-03	30.0	5.47E-01	16.4	
Ac-228 (Total Th-232)	911.07	794	9.2	0.20	4.89	2.07E-03	19.6	7.39E-01	14.5	
Pb-212	238.63	2339	7.7	0.58	15.01	1.73E-03	22.5			
Bi-212	727.33	192	23.6	0.05	5.89	4.30E-04	18.9			
Tl-208	583.19	1157	8.5	0.29	7.12	1.76E-03	23.1			
K-40	1,460.83	4438	3.1	1.11	3.35	9.70E-04	341.2	4.80E-02	16.4	
										R & S
										87.6
										2.20%
Cs-137	661.66	462	15.3	0.12	6.38	5.20E-03	3.5	1.92E-01	0.7	Incertitude
						Total :	527.5		47.9	5.8

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	47.3	0.7	39.4	87.3	87.6	en %	0.3

INSITU 2005 - Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:			coordonnées		Altitude:	identification	début de la mesure:	durée :
FR La Cigogne	**160 cnt/sec**	**beau**	**46°48'14"N**	**7°10'7"E**	**562**	**FRCIGO05.DAT**	**7/9/2005 9:18**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**egnc 30 ε=N/Ø %**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**débit de dose ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	917	28	0.18	17.67	1.20E-04	86.5			
Pb-214	351.93	3601	5.2	0.72	11.03	1.71E-03	38.2			
Bi-214 (Total U-238)	609.32	3496	4.3	0.70	6.85	2.76E-03	37.0	5.47E-01	20.2	
Ac-228 (Total Th-232)	911.07	1537	6.6	0.31	4.89	2.07E-03	30.4	7.39E-01	22.4	
Pb-212	238.63	4420	5.4	0.88	15.01	1.73E-03	34.0			
Bi-212	727.33	393	20.9	0.08	5.89	4.30E-04	31.0			
Tl-208	583.19	2037	6.4	0.41	7.12	1.76E-03	32.5			
K-40	1,460.83	7873	2.3	1.57	3.35	9.70E-04	484.2	4.80E-02	23.2	
										R & S
										109.6
										3.20%
Cs-137	661.66	415	20.4	0.08	6.38	5.20E-03	2.5	1.92E-01	0.5	**Incertitude**
						Total :	**773.8**		**66.4**	**4.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**65.9**	**0.5**	**39.6**	**106.0**	**109.6**	**en %**	**3.4**

INSITU 2005 - Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
FR Grandes Rames Ec 130 cnt/sec beau	46°48'14"N	7°9'42"E	550	RRAME05.DAT	9/9/2005 9:06	4000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	535	54	0.13	22.33	1.30E-04	46.1			
Ra-226	186.20	354	48	0.09	17.67	1.20E-04	41.7			
Pb-214	351.93	2425	6.1	0.61	11.03	1.71E-03	32.1			
Bi-214 (Total U-238)	609.32	2339	5	0.58	6.85	2.76E-03	30.9	5.47E-01	16.9	
Ac-228 (Total Th-232)	911.07	803	9.4	0.20	4.89	2.07E-03	19.8	7.39E-01	14.7	
Pb-212	238.63	2483	8.2	0.62	15.01	1.73E-03	23.9			
Bi-212	727.33	256	22	0.06	5.89	4.30E-04	25.3			
Tl-208	583.19	1102	8.3	0.28	7.12	1.76E-03	22.0			
K-40	1,460.83	4336	3.1	1.08	3.35	9.70E-04	333.3	4.80E-02	16.0	
										R & S
										91.7
										3.40%
Cs-137	661.66	391	18	0.10	6.38	5.20E-03	2.9	1.92E-01	0.6	Incertitude
						Total :	575.2		48.1	5.9

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu	R+S	déviation	R+S
en nSv/h	47.6	0.6	39.4	87.6	91.7	en %	4.7

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:				coordonnées		Altitude:	identification	début de la mesure:	durée :
Fribourg									
UniPérolles Mensa	90 cnt/sec	brumeux 11°C		46°47'36"N	7°9'29"E	630	FRCHMU05.dat	11/10/2005 12:20	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	eg nc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	230	69	0.05	17.67	1.20E-04	21.7			
Pb-214	351.93	2004	6.6	0.40	11.03	1.71E-03	21.3			
Bi-214 (Total U-238)	609.32	1935	5.4	0.39	6.85	2.76E-03	20.5	5.47E-01	11.2	
Ac-228 (Total Th-232)	911.07	495	12.1	0.10	4.89	2.07E-03	9.8	7.39E-01	7.2	
Pb-212	238.63	1290	11.2	0.26	15.01	1.73E-03	9.9			
Bi-212	727.33	201	23.9	0.04	5.89	4.30E-04	15.9			
Tl-208	583.19	715	11.2	0.14	7.12	1.76E-03	11.4			
K-40	1,460.83	2234	4.4	0.45	3.35	9.70E-04	137.4	4.80E-02	6.6	
										R & S
										71.8
										2.80%
Cs-137	661.66				6.38	5.20E-03		1.92E-01		Incertitude
						Total :	247.8		25.0	7.1

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	25.0	0.0	40.7	65.7		71.8	en %		9.3

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:						
Fribourg		coordonnées	Altitude:	identification	début de la mesure:	durée :
Aiglon Guintzet	**110 cnt/sec** brumeux	46°48'21"N 7°8'21"E	685	**FRAIGL05.dat**	**11/10/2005 8:52**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	equivalent de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20				17.67	1.20E-04				
Pb-214	351.93	1815	7	0.45	11.03	1.71E-03	24.1			
Bi-214 (Total U-238)	609.32	1767	5.7	0.44	6.85	2.76E-03	23.4	5.47E-01	12.8	
Ac-228 (Total Th-232)	911.07	431	13.6	0.11	4.89	2.07E-03	10.6	7.39E-01	7.9	
Pb-212	238.63	1268	11.4	0.32	15.01	1.73E-03	12.2			
Bi-212	727.33	155	30.1	0.04	5.89	4.30E-04	15.3			
Tl-208	583.19	868	11.4	0.22	7.12	1.76E-03	17.3			
K-40	1,460.83	2279	4.3	0.57	3.35	9.70E-04	175.2	4.80E-02	8.4	
										R & S
										76.1
										2.50%
Cs-137	661.66				6.38	5.20E-03		1.92E-01		Incertitude
						Total :	**278.1**		**29.1**	**7.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	**29.1**	**0.0**	**41.5**	**70.6**		**76.1**	en %		**7.8**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:			coordonnées		Altitude:	identification	début de la mesure:	durée :
Fribourg								
Grand_Rue 35	90 cnt/sec	brumeux 11°C	46°48'18"N	7°9'54"E	556	FRCHMU05.dat	11/10/2005 12:20	4000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	eg nc 30 ε=N/Ø %	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	790	29	0.20	17.67	1.20E-04	93.1			
Pb-214	351.93	2269	7.1	0.57	11.03	1.71E-03	30.1			
Bi-214 (Total U-238)	609.32	2204	5.5	0.55	6.85	2.76E-03	29.1	5.47E-01	15.9	
Ac-228 (Total Th-232)	911.07	1237	7.6	0.31	4.89	2.07E-03	30.6	7.39E-01	22.6	
Pb-212	238.63	3198	7	0.80	15.01	1.73E-03	30.8			
Bi-212	727.33	442	18.3	0.11	5.89	4.30E-04	43.6			
Tl-208	583.19	1530	7.3	0.38	7.12	1.76E-03	30.5			
K-40	1,460.83	7853	2.3	1.96	3.35	9.70E-04	603.7	4.80E-02	29.0	
										R & S
										103.7
										2.80%
Cs-137	661.66	126	51	0.03	6.38	5.20E-03	0.9	1.92E-01	0.2	Incertitude
						Total :	891.6		67.7	4.8

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	67.5	0.2	39.5	107.2		103.7	en %		-3.3

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
SUeR - salle de conférence	**46°47'35"N 7°9'28"E**	**642**	**suer_conference.spe**	**17/11/2005 11.45**	**5001**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**débit de dose ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	220	57.0	0.04	6.68	1.20E-04	54.9			
Pb-214	295.20	338	24.6	0.07	4.17	8.14E-04	19.9			
Pb-214	351.93	622	13.1	0.12	3.45	1.71E-03	21.1			
Bi-214 (Total U-238)	609.32	587	10.8	0.12	1.94	2.76E-03	21.9	5.47E-01	12.0	
Bi-214	1120.20	143	23.5	0.03	1.06	1.20E-03	22.7			
Bi-214	1764.50	136	18.5	0.03	0.69	1.56E-03	25.3			
Bi-214	2204.10	34	44.0	0.01	0.56	5.63E-04	21.6			
Ac-228 (Total Th-232)	911.07	201	19.8	0.04	1.29	2.07E-03	15.0	7.39E-01	11.1	
Ac-228	968.90	112.5	30.36	0.02	1.22	1.29E-03	14.4			
Pb-212	238.63	760	15.3	0.15	5.24	1.73E-03	16.7			
Bi-212	727.33	54	57.6	0.01	1.62	7.49E-04	8.9			
Tl-208	583.19	276	18.5	0.06	2.03	1.76E-03	15.5			
Tl-208	2614.40	178	15.6	0.04	0.48	1.21E-02	6.1			
K-40	1460.83	1204	6.0	0.24	0.82	9.70E-04	303.1	4.80E-02	14.5	**R & S**
										79.0
										4.05%
Cs-137	661.66	44	63.4	0.01	1.78	5.20E-03	0.9	1.92E-01	0.2	**Incertitude**
						Total :	**567.1**		**37.8**	**11.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**37.7**	**0.2**	**40.8**	**78.7**	**79.0**	**en %**	**0.4**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
SUeR - radiochimie	**46°47'35"N 7°9'28"E**	**622**	**suer_chimie.spe**	**17/11/2005 13.20**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	61	88.5	0.01	6.68	1.20E-04	15.1			
Pb-214	295.20	148	36.1	0.03	4.17	8.14E-04	8.7			
Pb-214	351.93	346	16.9	0.07	3.45	1.71E-03	11.7			
Bi-214 (Total U-238)	609.32	287	16.2	0.06	1.94	2.76E-03	10.7	5.47E-01	5.9	
Bi-214	1120.20	77	34.6	0.02	1.06	1.20E-03	12.2			
Bi-214	1764.50	55	33.5	0.01	0.69	1.56E-03	10.2			
Bi-214	2204.10	22	53.1	0.00	0.56	5.63E-04	13.7			
Ac-228 (Total Th-232)	911.07	119	26.0	0.02	1.29	2.07E-03	8.9	7.39E-01	6.6	
Ac-228	968.90	47.4	48.89	0.01	1.22	1.29E-03	6.0			
Pb-212	238.63	380	18.6	0.08	5.24	1.73E-03	8.4			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	215	16.9	0.04	2.03	1.76E-03	12.0			
Tl-208	2614.40	101	20.0	0.02	0.48	1.21E-02	3.5			
K-40	1460.83	713	7.8	0.14	0.82	9.70E-04	179.5	4.80E-02	8.6	**R & S**
										50.6
										4.55%
Cs-137	661.66	253	16.3	0.05	1.78	5.20E-03	5.5	1.92E-01	1.0	**Incertitude**
						Total :	**300.7**		**22.1**	**15.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	21.1	1.0	40.5	62.7		50.6	en %		-19.2

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
2e étage du bâtiment de physique	**46°47'35"N 7°9'28"E**	**637**	**phys_2e.spe**	**22/11/2005 9:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	111	72.1	0.02	6.68	1.20E-04	27.6			
Pb-214	295.20	301	27.2	0.06	4.17	8.14E-04	17.7			
Pb-214	351.93	565	13.8	0.11	3.45	1.71E-03	19.1			
Bi-214 (Total U-238)	609.32	541	11.7	0.11	1.94	2.76E-03	20.2	5.47E-01	11.1	
Bi-214	1120.20	162	20.9	0.03	1.06	1.20E-03	25.6			
Bi-214	1764.50	158	16.4	0.03	0.69	1.56E-03	29.5			
Bi-214	2204.10	29	51.7	0.01	0.56	5.63E-04	18.5			
Ac-228 (Total Th-232)	911.07	156	23.9	0.03	1.29	2.07E-03	11.6	7.39E-01	8.6	
Ac-228	968.90	123.2	28.81	0.02	1.22	1.29E-03	15.7			
Pb-212	238.63	651	17.0	0.13	5.24	1.73E-03	14.4			
Bi-212	727.33	62	55.5	0.01	1.62	7.49E-04	10.3			
Tl-208	583.19	230	21.7	0.05	2.03	1.76E-03	12.9			
Tl-208	2614.40	177	15.2	0.04	0.48	1.21E-02	6.1			
K-40	1460.83	974	6.6	0.19	0.82	9.70E-04	245.3	4.80E-02	11.8	**R & S**
										75.3
										2.92%
Cs-137	661.66	40	72.7	0.01	1.78	5.20E-03	0.9	1.92E-01	0.2	**Incertitude**
						Total :	**474.6**		**31.6**	**13.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**31.4**	**0.2**	**40.8**	**72.4**		**75.3**	en %		**4.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
1er étage du bâtiment de physique	**46°47'35"N 7°9'28"E**	**632**	**phys_1er.spe**	**22/11/2005 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	196	54.8	0.04	6.68	1.20E-04	49.0			
Pb-214	295.20	301	27.8	0.06	4.17	8.14E-04	17.7			
Pb-214	351.93	613	13.6	0.12	3.45	1.71E-03	20.8			
Bi-214 (Total U-238)	609.32	610	10.4	0.12	1.94	2.76E-03	22.8	5.47E-01	12.5	
Bi-214	1120.20	141	25.7	0.03	1.06	1.20E-03	22.3			
Bi-214	1764.50	154	17.2	0.03	0.69	1.56E-03	28.6			
Bi-214	2204.10	55	30.6	0.01	0.56	5.63E-04	35.0			
Ac-228 (Total Th-232)	911.07	202	20.3	0.04	1.29	2.07E-03	15.1	7.39E-01	11.2	
Ac-228	968.90	103	32.2	0.02	1.22	1.29E-03	13.1			
Pb-212	238.63	698	15.1	0.14	5.24	1.73E-03	15.4			
Bi-212	727.33	69	45.3	0.01	1.62	7.49E-04	11.4			
Tl-208	583.19	317	18.2	0.06	2.03	1.76E-03	17.7			
Tl-208	2614.40	189	15.0	0.04	0.48	1.21E-02	6.5			
K-40	1460.83	1077	6.4	0.22	0.82	9.70E-04	271.2	4.80E-02	13.0	**R & S**
										73.2
										3.55%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**546.6**		**36.6**	**12.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**36.6**	**0.0**	**40.7**	**77.3**		**73.2**	en %		**-5.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rez-de-chaussée bâtiment de physique	**46°47'35"N 7°9'28"E**	**627**	**phys_rez.spe**	**22/11/2005 11:50**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	219	37.6	0.04	4.17	8.14E-04	12.9			
Pb-214	351.93	636	13.5	0.13	3.45	1.71E-03	21.5			
Bi-214 (Total U-238)	609.32	595	11.1	0.12	1.94	2.76E-03	22.3	5.47E-01	12.2	
Bi-214	1120.20	111	31.9	0.02	1.06	1.20E-03	17.6			
Bi-214	1764.50	124	19.5	0.02	0.69	1.56E-03	23.1			
Bi-214	2204.10	38	38.6	0.01	0.56	5.63E-04	24.1			
Ac-228 (Total Th-232)	911.07	155	25.2	0.03	1.29	2.07E-03	11.6	7.39E-01	8.6	
Ac-228	968.90	131	28.1	0.03	1.22	1.29E-03	16.7			
Pb-212	238.63	554	20.3	0.11	5.24	1.73E-03	12.2			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	260	20.5	0.05	2.03	1.76E-03	14.5			
Tl-208	2614.40	146	16.8	0.03	0.48	1.21E-02	5.0			
K-40	1460.83	1070	6.3	0.21	0.82	9.70E-04	269.4	4.80E-02	12.9	**R & S**
										70.8
										3.40%
Cs-137	661.66	66	56.5	0.01	1.78	5.20E-03	1.4	1.92E-01	0.3	**Incertitude**
						Total :	**451.0**		**34.0**	**12.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**33.7**	**0.3**	**40.6**	**74.6**		**70.8**	**en %**		**-5.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
SUeR conférence vers extérieur	**46°47'35"N**	**7°9'28"E**	**642**	**suer_conference_ext.spe**	**23/11/2005 14:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	323	24.8	0.06	4.17	8.14E-04	19.0			
Pb-214	351.93	478	16.2	0.10	3.45	1.71E-03	16.2			
Bi-214 (Total U-238)	609.32	522	11.6	0.10	1.94	2.76E-03	19.5	5.47E-01	10.7	
Bi-214	1120.20	145	23.6	0.03	1.06	1.20E-03	23.0			
Bi-214	1764.50	96	23.1	0.02	0.69	1.56E-03	17.9			
Bi-214	2204.10	40	35.5	0.01	0.56	5.63E-04	25.7			
Ac-228 (Total Th-232)	911.07	190	20.5	0.04	1.29	2.07E-03	14.2	7.39E-01	10.5	
Ac-228	968.90	87	35.2	0.02	1.22	1.29E-03	11.2			
Pb-212	238.63	431	23.3	0.09	5.24	1.73E-03	9.5			
Bi-212	727.33	56	51.7	0.01	1.62	7.49E-04	9.2			
Tl-208	583.19	279	20.2	0.06	2.03	1.76E-03	15.6			
Tl-208	2614.40	155	16.2	0.03	0.48	1.21E-02	5.3			
K-40	1460.83	944	6.9	0.19	0.82	9.70E-04	237.6	4.80E-02	11.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**79.3**
										4.04%
Cs-137	661.66	106	36.1	0.02	1.78	5.20E-03	2.3	1.92E-01	0.4	**Incertitude**
						Total :	**423.9**		**33.0**	**13.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**32.6**	**0.4**	**40.8**	**73.9**	**79.3**	en %	**7.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
1^er^ étage bâtiment de physique	**46°47'35"N 7°9'26"E**	**632**	**phys_1er_ext.spe**	**23/11/2005 15:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	307	26.5	0.06	4.17	8.14E-04	18.1			
Pb-214	351.93	497	15.6	0.10	3.45	1.71E-03	16.8			
Bi-214 (Total U-238)	609.32	522	11.1	0.10	1.94	2.76E-03	19.5	5.47E-01	10.7	
Bi-214	1120.20	133	25.0	0.03	1.06	1.20E-03	21.0			
Bi-214	1764.50	119	20.0	0.02	0.69	1.56E-03	22.2			
Bi-214	2204.10	40	36.4	0.01	0.56	5.63E-04	25.2			
Ac-228 (Total Th-232)	911.07	199	20.3	0.04	1.29	2.07E-03	14.9	7.39E-01	11.0	
Ac-228	968.90	70	44.5	0.01	1.22	1.29E-03	9.0			
Pb-212	238.63	446	24.2	0.09	5.24	1.73E-03	9.8			
Bi-212	727.33	81	42.5	0.02	1.62	7.49E-04	13.3			
Tl-208	583.19	46	83.3	0.01	2.03	1.76E-03	2.6			
Tl-208	2614.40	184	15.3	0.04	0.48	1.21E-02	6.3			
K-40	1460.83	1070	6.3	0.21	0.82	9.70E-04	269.4	4.80E-02	12.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**72.7**
										3.16%
Cs-137	661.66	66	56.5	0.01	1.78	5.20E-03	1.4	1.92E-01	0.3	**Incertitude**
						Total :	**448.2**		**34.9**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**34.6**	**0.3**	**40.7**	**75.6**	**72.7**	en %	**-3.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire du Botzet - rez-de-chaussée	**N 46°47.500 E 7°09.253**	630	**botzet12_rez.spe**	**29/11/2005 8:30**	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	621	18.4	0.12	4.17	8.14E-04	36.5			
Pb-214	351.93	1087	10.2	0.22	3.45	1.71E-03	36.8			
Bi-214 (Total U-238)	609.32	1116	8.2	0.22	1.94	2.76E-03	41.7	5.47E-01	22.8	
Bi-214	1120.20	227	18.3	0.05	1.06	1.20E-03	35.9			
Bi-214	1764.50	231	14.5	0.05	0.69	1.56E-03	43.1			
Bi-214	2204.10	43	40.8	0.01	0.56	5.63E-04	27.3			
Ac-228 (Total Th-232)	911.07	494	12.2	0.10	1.29	2.07E-03	37.0	7.39E-01	27.3	
Ac-228	968.90	285.8	19.38	0.06	1.22	1.29E-03	36.5			
Pb-212	238.63	1490	10.8	0.30	5.24	1.73E-03	32.8			
Bi-212	727.33	164	33.2	0.03	1.62	7.49E-04	27.0			
Tl-208	583.19	659	11.5	0.13	2.03	1.76E-03	36.9			
Tl-208	2614.40	402	10.2	0.08	0.48	1.21E-02	13.9			
K-40	1460.83	2346	4.3	0.47	0.82	9.70E-04	590.6	4.80E-02	28.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**119.3**
										2.26%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**996.1**		**78.5**	**8.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**78.5**	**0.0**	**40.7**	**119.1**	**119.3**	en %	**0.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude	identification	début de la mesure:	durée :
Ecole primaire du Botzet - 1er étage	**N 46°47.503 E 7°09.252**	**625**	**botzet12_1er.spc**	**29/11/2005 13:00**	**5100**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette inc %	Netto-fläche N (cps)	Detective ε=N/Φ	facteur (*1 fa= Φ/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th 234	92.60				5.43	1.30E-04				
Ra 226	186.20				5.68	1.20E-04				
Pb 214	295.20	537	22.0	0.11	4.17	8.14E-04	31.0			
Pb-214	351.90	1157	10.1	0.23	3.45	1.71E-03	30.4			
Bi 214 (Total U 238)	609.32	1040	6.7	0.20	1.04	2.76E-03	30.1	5.47E-01	20.0	
Bi-214	1120.20	243	21.0	0.05	1.06	1.20E-03	37.7			
Bi-214	1764.50	237	14.4	0.05	0.09	1.56E-03	43.3			
Bi-214	2204.10	50	40.8	0.01	0.56	5.63E-04	31.4			
Ac-228 (Total Th-232)	911.07	474	12.6	0.08	1.29	2.07E-03	34.7	7.39E-01	25.7	
Ac-228	968.90	313	13.78	0.07	1.22	1.29E-03	39.3			
Pb-212	238.63	1731	5.9	0.34	7.24	1.79E-03	37.4			
Bi-212	727.33	129	35.5	0.03	1.62	7.49E-04	20.7			
Tl-208	583.19	683	11.7	0.13	2.08	1.76E-03	37.7			
Tl-208	2614.40	413	10.0	0.09	0.48	1.21E-02	14.0			
K-40	1460.83	2393	4.2	0.47	0.82	9.70E-04	590.8	4.90E-02	28.9	**R & S**
Be-7	477.60				2.50	5.71E-01				114.9
										3.22%
Cs-137	661.66				1.78	5.20E-03		1.32E-01		**Incertitude**
						Total :	**995.0**		**74.9**	**8.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol)

débit d'exposition:	naturel	artificiel	cosmique	Insitu	R/S	déviation		R/S
en nSv/h	**74.9**	**0.0**	**40.7**	**115.6**	**114.9**	en %		**-0.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bureau d'état civil - rez-de-chaussée	**N46°48.229 E 7°09.479**	**560**	**etatcivil_rez.spe**	**5/12/2005 8:30**	**4600**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	123	88.6	0.03	6.68	1.20E-04	33.3			
Pb-214	295.20	339	26.4	0.07	4.17	8.14E-04	21.7			
Pb-214	351.93	525	17.2	0.11	3.45	1.71E-03	19.3			
Bi-214 (Total U-238)	609.32	535	12.8	0.12	1.94	2.76E-03	21.7	5.47E-01	11.9	
Bi-214	1120.20	140	28.5	0.03	1.06	1.20E-03	24.0			
Bi-214	1764.50	117	20.3	0.03	0.69	1.56E-03	23.8			
Bi-214	2204.10	36	43.4	0.01	0.56	5.63E-04	24.7			
Ac-228 (Total Th-232)	911.07	270	18.6	0.06	1.29	2.07E-03	21.9	7.39E-01	16.2	
Ac-228	968.90	172.9	25.23	0.04	1.22	1.29E-03	24.0			
Pb-212	238.63	691	18.8	0.15	5.24	1.73E-03	16.6			
Bi-212	727.33	64	61.6	0.01	1.62	7.49E-04	11.4			
Tl-208	583.19	485	14.7	0.11	2.03	1.76E-03	29.5			
Tl-208	2614.40	295	11.9	0.06	0.48	1.21E-02	11.1			
K-40	1460.83	2025	4.6	0.44	0.82	9.70E-04	554.3	4.80E-02	26.6	**R & S**
Be-7	477.60				2.50	5.41E-04				**98.1**
										2.55%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**837.3**		**54.7**	**10.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**54.7**	**0.0**	**39.6**	**94.3**	**98.1**	en %	**4.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bureau d'état civil - 1^er étage	**N46°48.229 E 7°09.479**	**565**	**etatcivil_1er.spe**	**5/12/2005 10:20**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	137	88.4	0.03	6.43	1.30E-04	32.8			
Ra-226	186.20	200	57.6	0.04	6.68	1.20E-04	49.9			
Pb-214	295.20	215	41.0	0.04	4.17	8.14E-04	12.6			
Pb-214	351.93	524	16.5	0.10	3.45	1.71E-03	17.8			
Bi-214 (Total U-238)	609.32	443	14.5	0.09	1.94	2.76E-03	16.6	5.47E-01	9.1	
Bi-214	1120.20	109	33.8	0.02	1.06	1.20E-03	17.2			
Bi-214	1764.50	152	17.4	0.03	0.69	1.56E-03	28.4			
Bi-214	2204.10	39	39.0	0.01	0.56	5.63E-04	25.0			
Ac-228 (Total Th-232)	911.07	244	19.8	0.05	1.29	2.07E-03	18.2	7.39E-01	13.5	
Ac-228	968.90	121.3	31.66	0.02	1.22	1.29E-03	15.5			
Pb-212	238.63	862	17.3	0.17	5.24	1.73E-03	19.0			
Bi-212	727.33	73	50.5	0.01	1.62	7.49E-04	12.0			
Tl-208	583.19	264	22.2	0.05	2.03	1.76E-03	14.8			
Tl-208	2614.40	274	12.1	0.05	0.48	1.21E-02	9.5			
K-40	1460.83	1892	4.7	0.38	0.82	9.70E-04	476.2	4.80E-02	22.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**92.3**
										2.82%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**765.4**		**45.4**	**11.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**45.4**	**0.0**	**39.7**	**85.1**		**92.3**	en %		**8.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bureau d'état civil - 2e étage	**N46°48.229 E 7°09.479**	**570**	**etatcivil_2e.spe**	**5/12/2005 11:50**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	164	59.2	0.03	6.68	1.20E-04	41.0			
Pb-214	295.20	318	30.0	0.06	4.17	8.14E-04	18.7			
Pb-214	351.93	735	13.6	0.15	3.45	1.71E-03	24.9			
Bi-214 (Total U-238)	609.32	712	10.3	0.14	1.94	2.76E-03	26.6	5.47E-01	14.6	
Bi-214	1120.20	186	22.6	0.04	1.06	1.20E-03	29.3			
Bi-214	1764.50	155	18.3	0.03	0.69	1.56E-03	29.0			
Bi-214	2204.10	35	45.7	0.01	0.56	5.63E-04	22.4			
Ac-228 (Total Th-232)	911.07	317	16.1	0.06	1.29	2.07E-03	23.7	7.39E-01	17.5	
Ac-228	968.90	186.1	23.74	0.04	1.22	1.29E-03	23.7			
Pb-212	238.63	850	14.7	0.17	5.24	1.73E-03	18.8			
Bi-212	727.33	76	50.5	0.02	1.62	7.49E-04	12.5			
Tl-208	583.19	365	17.8	0.07	2.03	1.76E-03	20.4			
Tl-208	2614.40	317	11.4	0.06	0.48	1.21E-02	10.9			
K-40	1460.83	1873	4.8	0.37	0.82	9.70E-04	471.7	4.80E-02	22.6	**R & S**
Be-7	477.60				2.50	5.41E-04				**98.2**
										3.16%
Cs-137	661.66	36	85.7	0.01	1.78	5.20E-03	0.8	1.92E-01	0.1	**Incertitude**
						Total :	**773.5**		**54.9**	**9.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**54.7**	**0.1**	**39.7**	**94.6**		**98.2**	en %		**3.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire du Bourg - rez-de-chaussée	**N 46°48.296 E 7°09.277**	**610**	**bourg_rez.spe**	**13/12/2005 8:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	287	51.8	0.06	6.68	1.20E-04	71.5			
Pb-214	295.20	846	15.0	0.17	4.17	8.14E-04	49.8			
Pb-214	351.93	1500	8.3	0.30	3.45	1.71E-03	50.8			
Bi-214 (Total U-238)	609.32	1319	7.1	0.26	1.94	2.76E-03	49.3	5.47E-01	27.0	
Bi-214	1120.20	314	17.3	0.06	1.06	1.20E-03	49.7			
Bi-214	1764.50	253	14.5	0.05	0.69	1.56E-03	47.1			
Bi-214	2204.10	75	30.1	0.02	0.56	5.63E-04	47.8			
Ac-228 (Total Th-232)	911.07	724	9.8	0.14	1.29	2.07E-03	54.1	7.39E-01	40.0	
Ac-228	968.90	447.5	13.0	0.09	1.22	1.29E-03	57.1			
Pb-212	238.63	2778	6.5	0.56	5.24	1.73E-03	61.3			
Bi-212	727.33	261	22.4	0.05	1.62	7.49E-04	43.1			
Tl-208	583.19	1095	8.3	0.22	2.03	1.76E-03	61.4			
Tl-208	2614.40	620	8.1	0.12	0.48	1.21E-02	21.4			
K-40	1460.83	2275	4.4	0.45	0.82	9.70E-04	572.7	4.80E-02	27.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**119.1**
										3.19%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,237.2**		**94.5**	**7.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**94.5**	**0.0**	**40.3**	**134.8**	**119.1**	**en %**	**-11.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire du Bourg - 2ᵉ étage	**N 46°48.296 E 7°09.277**	**620**	**bourg_2e.spe**	**13/12/2005 9:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	226	60.4	0.05	6.68	1.20E-04	56.4			
Pb-214	295.20	874	14.8	0.17	4.17	8.14E-04	51.4			
Pb-214	351.93	1405	9.1	0.28	3.45	1.71E-03	47.6			
Bi-214 (Total U-238)	609.32	1269	7.6	0.25	1.94	2.76E-03	47.5	5.47E-01	26.0	
Bi-214	1120.20	293	18.4	0.06	1.06	1.20E-03	46.4			
Bi-214	1764.50	282	13.4	0.06	0.69	1.56E-03	52.7			
Bi-214	2204.10	72	34.7	0.01	0.56	5.63E-04	45.9			
Ac-228 (Total Th-232)	911.07	742	9.5	0.15	1.29	2.07E-03	55.5	7.39E-01	41.0	
Ac-228	968.90	400	14.8	0.08	1.22	1.29E-03	51.0			
Pb-212	238.63	3035	6.2	0.61	5.24	1.73E-03	66.9			
Bi-212	727.33	209	26.2	0.04	1.62	7.49E-04	34.4			
Tl-208	583.19	1146	8.4	0.23	2.03	1.76E-03	64.3			
Tl-208	2614.40	594	8.3	0.12	0.48	1.21E-02	20.5			
K-40	1460.83	2324	4.4	0.46	0.82	9.70E-04	585.2	4.80E-02	28.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**122.9**
										2.69%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,225.5**		**95.0**	**7.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**95.0**	**0.0**	**40.5**	**135.5**	**122.9**	en %	**-9.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
CO du Belluard - 1er sous-soul	**N 46°48.363 E 7°09.252**	**597**	**belluard_1ss.spe**	**13/12/2005 13:27**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	371	26.5	0.07	4.17	8.14E-04	21.8			
Pb-214	351.93	822	12.4	0.16	3.45	1.71E-03	27.8			
Bi-214 (Total U-238)	609.32	645	10.8	0.13	1.94	2.76E-03	24.1	5.47E-01	13.2	
Bi-214	1120.20	179	23.9	0.04	1.06	1.20E-03	28.3			
Bi-214	1764.50	159	17.9	0.03	0.69	1.56E-03	29.7			
Bi-214	2204.10	58	31.0	0.01	0.56	5.63E-04	37.0			
Ac-228 (Total Th-232)	911.07	253	19.8	0.05	1.29	2.07E-03	18.9	7.39E-01	14.0	
Ac-228	968.90	184.2	22.19	0.04	1.22	1.29E-03	23.5			
Pb-212	238.63	838	15.1	0.17	5.24	1.73E-03	18.5			
Bi-212	727.33	62	61.0	0.01	1.62	7.49E-04	10.2			
Tl-208	583.19	444	15.2	0.09	2.03	1.76E-03	24.9			
Tl-208	2614.40	293	11.9	0.06	0.48	1.21E-02	10.1			
K-40	1460.83	1862	4.8	0.37	0.82	9.70E-04	468.7	4.80E-02	22.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**91.1**
										2.00%
Cs-137	661.66	79	51.9	0.02	1.78	5.20E-03	1.7	1.92E-01	0.3	**Incertitude**
						Total :	**743.7**		**50.0**	**10.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**49.7**	**0.3**	**40.1**	**90.1**		**91.1**	en %		**1.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
CO du Belluard - 2e étage	**N 46°48.363 E 7°09.252**	**612**	**belluard_2e.spe**	**13/12/2005 15:00**	**4500**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	115	87.2	0.03	6.68	1.20E-04	32.0			
Pb-214	295.20	367	25.0	0.08	4.17	8.14E-04	24.0			
Pb-214	351.93	716	13.6	0.16	3.45	1.71E-03	26.9			
Bi-214 (Total U-238)	609.32	673	10.2	0.15	1.94	2.76E-03	28.0	5.47E-01	15.3	
Bi-214	1120.20	181	22.3	0.04	1.06	1.20E-03	31.8			
Bi-214	1764.50	164	17.1	0.04	0.69	1.56E-03	33.9			
Bi-214	2204.10	36	43.1	0.01	0.56	5.63E-04	25.7			
Ac-228 (Total Th-232)	911.07	264	17.9	0.06	1.29	2.07E-03	21.9	7.39E-01	16.2	
Ac-228	968.90	146.7	26.63	0.03	1.22	1.29E-03	20.8			
Pb-212	238.63	876	14.4	0.19	5.24	1.73E-03	21.5			
Bi-212	727.33	97	41.8	0.02	1.62	7.49E-04	17.9			
Tl-208	583.19	340	17.3	0.08	2.03	1.76E-03	21.2			
Tl-208	2614.40	213	14.1	0.05	0.48	1.21E-02	8.2			
K-40	1460.83	1406	5.5	0.31	0.82	9.70E-04	393.4	4.80E-02	18.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**100.5**
										2.49%
Cs-137	661.66	46	70.3	0.01	1.78	5.20E-03	1.1	1.92E-01	0.2	**Incertitude**
						Total :	**707.0**		**50.6**	**10.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**50.4**	**0.2**	**40.4**	**91.0**	**100.5**	en %	**10.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire des Neigles - rez-de-chaussée	**N 46°48.298 E 7°09.563**	**577**	**neigles_rez.spe**	**15/12/2005 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	578	18.8	0.12	4.17	8.14E-04	34.0			
Pb-214	351.93	1133	9.7	0.23	3.45	1.71E-03	38.4			
Bi-214 (Total U-238)	609.32	974	8.7	0.19	1.94	2.76E-03	36.4	5.47E-01	19.9	
Bi-214	1120.20	214	22.8	0.04	1.06	1.20E-03	33.9			
Bi-214	1764.50	206	15.4	0.04	0.69	1.56E-03	38.4			
Bi-214	2204.10	57	36.0	0.01	0.56	5.63E-04	35.9			
Ac-228 (Total Th-232)	911.07	493	12.3	0.10	1.29	2.07E-03	36.9	7.39E-01	27.2	
Ac-228	968.90	275.7	19.26	0.06	1.22	1.29E-03	35.2			
Pb-212	238.63	1657	9.1	0.33	5.24	1.73E-03	36.5			
Bi-212	727.33	86	47.6	0.02	1.62	7.49E-04	14.2			
Tl-208	583.19	719	10.5	0.14	2.03	1.76E-03	40.3			
Tl-208	2614.40	380	10.4	0.08	0.48	1.21E-02	13.1			
K-40	1460.83	2153	4.5	0.43	0.82	9.70E-04	542.1	4.80E-02	26.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**103.9**
										2.28%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**935.2**		**73.2**	**8.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**73.2**	**0.0**	**39.8**	**113.0**	**103.9**	**en %**	**-8.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire des Neiges - 1er étage	**N 46°48.298 E 7°09.563**	**583**	**neiges_1er.spe**	**15/12/2005 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	299	53.8	0.06	6.43	1.30E-04	71.5			
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	328	32.3	0.07	4.17	8.14E-04	19.3			
Pb-214	351.93	913	12.3	0.18	3.45	1.71E-03	30.9			
Bi-214 (Total U-238)	609.32	876	9.5	0.18	1.94	2.76E-03	32.8	5.47E-01	17.9	
Bi-214	1120.20	247	18.2	0.05	1.06	1.20E-03	39.0			
Bi-214	1764.50	174	17.6	0.03	0.69	1.56E-03	32.4			
Bi-214	2204.10	58	34.4	0.01	0.56	5.63E-04	36.9			
Ac-228 (Total Th-232)	911.07	376	14.3	0.08	1.29	2.07E-03	28.1	7.39E-01	20.8	
Ac-228	968.90	248	19.49	0.05	1.22	1.29E-03	31.6			
Pb-212	238.63	1530	9.7	0.31	5.24	1.73E-03	33.7			
Bi-212	727.33	159	29.4	0.03	1.62	7.49E-04	26.2			
Tl-208	583.19	585	12.8	0.12	2.03	1.76E-03	32.8			
Tl-208	2614.40	367	10.5	0.07	0.48	1.21E-02	12.7			
K-40	1460.83	1928	4.8	0.39	0.82	9.70E-04	485.5	4.80E-02	23.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**103.7**
										2.45%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**913.4**		**62.0**	**9.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**62.0**	**0.0**	**39.9**	**101.9**		**103.7**	en %		**1.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Service de l'édilité - rez-de-chaussée	**N 46°48.253 E 7°09.182**	**627**	**joseph-piller_rez.spe**	**20/12/2005 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	583	18.0	0.12	4.17	8.14E-04	34.3			
Pb-214	351.93	919	11.2	0.18	3.45	1.71E-03	31.1			
Bi-214 (Total U-238)	609.32	886	8.9	0.18	1.94	2.76E-03	33.1	5.47E-01	18.1	
Bi-214	1120.20	224	20.2	0.04	1.06	1.20E-03	35.4			
Bi-214	1764.50	173	17.3	0.03	0.69	1.56E-03	32.3			
Bi-214	2204.10	42	42.3	0.01	0.56	5.63E-04	26.9			
Ac-228 (Total Th-232)	911.07	405	13.2	0.08	1.29	2.07E-03	30.3	7.39E-01	22.4	
Ac-228	968.90	217	21.87	0.04	1.22	1.29E-03	27.7			
Pb-212	238.63	1444	10.0	0.29	5.24	1.73E-03	31.9			
Bi-212	727.33	105	43.6	0.02	1.62	7.49E-04	17.3			
Tl-208	583.19	494	14.3	0.10	2.03	1.76E-03	27.7			
Tl-208	2614.40	314	11.4	0.06	0.48	1.21E-02	10.8			
K-40	1460.83	1919	4.7	0.38	0.82	9.70E-04	483.2	4.80E-02	23.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**95.4**
										3.05%
Cs-137	661.66	80	48.3	0.02	1.78	5.20E-03	1.7	1.92E-01	0.3	**Incertitude**
						Total :	**821.9**		**64.0**	**9.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**63.7**	**0.3**	**40.6**	**104.6**		**95.4**	**en %**		**-8.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Service de l'édilité - 1[er] étage	**N 46°48.253 E 7°09.182**	**632**	**joseph-piller_1er.spe**	**20/12/2005 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose amblante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	578	17.8	0.12	4.17	8.14E-04	34.0			
Pb-214	351.93	1052	10.3	0.21	3.45	1.71E-03	35.6			
Bi-214 (Total U-238)	609.32	907	8.8	0.18	1.94	2.76E-03	33.9	5.47E-01	18.5	
Bi-214	1120.20	242	20.1	0.05	1.06	1.20E-03	38.2			
Bi-214	1764.50	193	15.9	0.04	0.69	1.56E-03	36.0			
Bi-214	2204.10	57	32.5	0.01	0.56	5.63E-04	36.4			
Ac-228 (Total Th-232)	911.07	386	14.3	0.08	1.29	2.07E-03	28.9	7.39E-01	21.3	
Ac-228	968.90	243.7	20.39	0.05	1.22	1.29E-03	31.1			
Pb-212	238.63	1398	10.3	0.28	5.24	1.73E-03	30.8			
Bi-212	727.33	89	46.1	0.02	1.62	7.49E-04	14.7			
Tl-208	583.19	552	13.1	0.11	2.03	1.76E-03	31.0			
Tl-208	2614.40	318	11.3	0.06	0.48	1.21E-02	11.0			
K-40	1460.83	1861	4.8	0.37	0.82	9.70E-04	468.5	4.80E-02	22.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**102.3**
										2.59%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**830.1**		**62.4**	**9.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**62.4**	**0.0**	**40.7**	**103.1**	**102.3**	en %	**-0.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire - Général Guisan 53 - rez-de-chaussée	**N 46°48.437 E 7°08.580**	**645**	**guisan53_rez.spe**	**20/12/2005 13:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	158	74.6	0.03	6.68	1.20E-04	39.4			
Pb-214	295.20	579	18.8	0.12	4.17	8.14E-04	34.1			
Pb-214	351.93	917	11.3	0.18	3.45	1.71E-03	31.1			
Bi-214 (Total U-238)	609.32	944	8.8	0.19	1.94	2.76E-03	35.3	5.47E-01	19.3	
Bi-214	1120.20	221	21.1	0.04	1.06	1.20E-03	34.9			
Bi-214	1764.50	164	18.1	0.03	0.69	1.56E-03	30.5			
Bi-214	2204.10	44	38.8	0.01	0.56	5.63E-04	28.1			
Ac-228 (Total Th-232)	911.07	431	13.8	0.09	1.29	2.07E-03	32.2	7.39E-01	23.8	
Ac-228	968.90	203.8	23.93	0.04	1.22	1.29E-03	26.0			
Pb-212	238.63	1450	10.1	0.29	5.24	1.73E-03	32.0			
Bi-212	727.33	84	54.2	0.02	1.62	7.49E-04	13.9			
Tl-208	583.19	571	12.9	0.11	2.03	1.76E-03	32.0			
Tl-208	2614.40	380	10.4	0.08	0.48	1.21E-02	13.1			
K-40	1460.83	2334	4.2	0.47	0.82	9.70E-04	587.7	4.80E-02	28.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**94.3**
										2.19%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**970.2**		**71.3**	**8.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**71.3**	**0.0**	**40.9**	**112.2**	**94.3**	en %	**-15.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire - Général Gulsan 53 - 1er étage	**N 46°48.437 E 7°08.580**	**650**	**gulsan53_1er.spe**	**20/12/2005 15:15**	**4092**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	190	65.8	0.05	6.68	1.20E-04	57.8			
Pb-214	295.20	423	22.9	0.10	4.17	8.14E-04	30.4			
Pb-214	351.93	709	13.4	0.17	3.45	1.71E-03	29.3			
Bi-214 (Total U-238)	609.32	707	9.8	0.17	1.94	2.76E-03	32.3	5.47E-01	17.7	
Bi-214	1120.20	194	23.5	0.05	1.06	1.20E-03	37.4			
Bi-214	1764.50	173	16.7	0.04	0.69	1.56E-03	39.4			
Bi-214	2204.10	41	38.4	0.01	0.56	5.63E-04	32.0			
Ac-228 (Total Th-232)	911.07	260	19.1	0.06	1.29	2.07E-03	23.8	7.39E-01	17.6	
Ac-228	968.90	129.6	34.05	0.03	1.22	1.29E-03	20.2			
Pb-212	238.63	1008	12.7	0.25	5.24	1.73E-03	27.2			
Bi-212	727.33	105	38.2	0.03	1.62	7.49E-04	21.2			
Tl-208	583.19	442	15.3	0.11	2.03	1.76E-03	30.3			
Tl-208	2614.40	269	12.4	0.07	0.48	1.21E-02	11.3			
K-40	1460.83	1880	4.8	0.46	0.82	9.70E-04	578.5	4.80E-02	27.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**96.7**
										3.20%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**971.0**		**63.0**	**10.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**63.0**	**0.0**	**41.0**	**104.0**		**96.7**	en %		**-7.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bâtiment de Pérolles 2 - rez-de-chaussée	**N 46°47.380 E 7°09.334**	**630**	**perolles2_rez.spe**	**22/12/2005 8:40**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	136	84.2	0.03	6.68	1.20E-04	34.0			
Pb-214	295.20	515	19.6	0.10	4.17	8.14E-04	30.3			
Pb-214	351.93	885	10.7	0.18	3.45	1.71E-03	30.0			
Bi-214 (Total U-238)	609.32	822	8.7	0.16	1.94	2.76E-03	30.7	5.47E-01	16.8	
Bi-214	1120.20	239	17.9	0.05	1.06	1.20E-03	37.7			
Bi-214	1764.50	141	18.4	0.03	0.69	1.56E-03	26.3			
Bi-214	2204.10	53	30.4	0.01	0.56	5.63E-04	33.3			
Ac-228 (Total Th-232)	911.07	367	13.7	0.07	1.29	2.07E-03	27.4	7.39E-01	20.3	
Ac-228	968.90	203	21.1	0.04	1.22	1.29E-03	25.9			
Pb-212	238.63	1289	10.1	0.26	5.24	1.73E-03	28.4			
Bi-212	727.33	142	28.2	0.03	1.62	7.49E-04	23.5			
Tl-208	583.19	446	13.6	0.09	2.03	1.76E-03	25.0			
Tl-208	2614.40	267	12.4	0.05	0.48	1.21E-02	9.2			
K-40	1460.83	1423	5.5	0.28	0.82	9.70E-04	358.4	4.80E-02	17.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**71.0**
										2.98%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**720.2**		**54.3**	**9.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**54.3**	**0.0**	**40.7**	**94.9**		**71.0**	en %		**-25.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bâtiment de Pérolles 2 - 1er étage	**N 46°47.380 E 7°09.334**	**635**	**perolles2_1er.spe**	**22/12/2005 10:10**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	164	64.9	0.03	6.68	1.20E-04	40.9			
Pb-214	295.20	301	26.6	0.06	4.17	8.14E-04	17.7			
Pb-214	351.93	620	13.5	0.12	3.45	1.71E-03	21.0			
Bi-214 (Total U-238)	609.32	610	10.5	0.12	1.94	2.76E-03	22.8	5.47E-01	12.5	
Bi-214	1120.20	148	25.2	0.03	1.06	1.20E-03	23.4			
Bi-214	1764.50	131	19.6	0.03	0.69	1.56E-03	24.3			
Bi-214	2204.10	29	47.4	0.01	0.56	5.63E-04	18.7			
Ac-228 (Total Th-232)	911.07	170	23.6	0.03	1.29	2.07E-03	12.7	7.39E-01	9.4	
Ac-228	968.90	108	30.6	0.02	1.22	1.29E-03	13.7			
Pb-212	238.63	721	15.5	0.14	5.24	1.73E-03	15.9			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	323	17.4	0.06	2.03	1.76E-03	18.1			
Tl-208	2614.40	200	14.3	0.04	0.48	1.21E-02	6.9			
K-40	1460.83	1182	6.0	0.24	0.82	9.70E-04	297.7	4.80E-02	14.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**66.7**
										2.82%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**533.8**		**36.1**	**12.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**36.1**	**0.0**	**40.7**	**76.9**		**66.7**	en %		**-13.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bâtiment de Pérolles 2 - 2ᵉ étage	**N 46°47.380 E 7°09.334**	**640**	**perolles2_2e.spe**	**22/12/2005 11:40**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	148	63.1	0.03	6.68	1.20E-04	36.8			
Pb-214	295.20	398	21.4	0.08	4.17	8.14E-04	23.4			
Pb-214	351.93	595	14.1	0.12	3.45	1.71E-03	20.2			
Bi-214 (Total U-238)	609.32	532	11.7	0.11	1.94	2.76E-03	19.9	5.47E-01	10.9	
Bi-214	1120.20	178	21.7	0.04	1.06	1.20E-03	28.1			
Bi-214	1764.50	127	19.7	0.03	0.69	1.56E-03	23.6			
Bi-214	2204.10	33	42.0	0.01	0.56	5.63E-04	20.8			
Ac-228 (Total Th-232)	911.07	238	18.1	0.05	1.29	2.07E-03	17.8	7.39E-01	13.2	
Ac-228	968.90	139	25.6	0.03	1.22	1.29E-03	17.7			
Pb-212	238.63	752	14.6	0.15	5.24	1.73E-03	16.6			
Bi-212	727.33	35	77.5	0.01	1.62	7.49E-04	5.7			
Tl-208	583.19	330	18.2	0.07	2.03	1.76E-03	18.5			
Tl-208	2614.40	212	14.0	0.04	0.48	1.21E-02	7.3			
K-40	1460.83	1297	5.9	0.26	0.82	9.70E-04	326.6	4.80E-02	15.7	**R & S**
Be-7	477.60				2.50	5.41E-04				**70.6**
										3.23%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**583.0**		**39.7**	**11.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**39.7**	**0.0**	**40.8**	**80.5**	**70.6**	en %	**-12.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Bâtiment de Pérolles 2 - 3e étage	**N 46°47.380 E 7°09.334**	**645**	**perolles2_3e.spe**	**22/12/2005 13:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	140	65.9	0.03	6.68	1.20E-04	34.9			
Pb-214	295.20	259	29.3	0.05	4.17	8.14E-04	15.2			
Pb-214	351.93	463	17.2	0.09	3.45	1.71E-03	15.7			
Bi-214 (Total U-238)	609.32	487	12.1	0.10	1.94	2.76E-03	18.2	5.47E-01	10.0	
Bi-214	1120.20	152	23.3	0.03	1.06	1.20E-03	24.1			
Bi-214	1764.50	106	20.8	0.02	0.69	1.56E-03	19.8			
Bi-214	2204.10	28	47.3	0.01	0.56	5.63E-04	17.8			
Ac-228 (Total Th-232)	911.07	136	26.8	0.03	1.29	2.07E-03	10.2	7.39E-01	7.5	
Ac-228	968.90	83	33.3	0.02	1.22	1.29E-03	10.6			
Pb-212	238.63	403	25.3	0.08	5.24	1.73E-03	8.9			
Bi-212	727.33	33	81.0	0.01	1.62	7.49E-04	5.4			
Tl-208	583.19	229	21.2	0.05	2.03	1.76E-03	12.8			
Tl-208	2614.40	165	15.7	0.03	0.48	1.21E-02	5.7			
K-40	1460.83	937	6.7	0.19	0.82	9.70E-04	235.9	4.80E-02	11.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**63.9**
										3.83%
Cs-137	661.66	29	89.4	0.01	1.78	5.20E-03	0.6	1.92E-01	0.1	**Incertitude**
						Total :	**435.2**		**28.9**	**13.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**28.8**	**0.1**	**40.9**	**69.8**	**63.9**	en %	**-8.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire de la Vignettaz - rez-de-chaussée	**N 46°47.529 E 7°08.388**	**645**	**vingettaz_rez.spe**	**10/1/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	327	46.5	0.07	6.68	1.20E-04	81.7			
Pb-214	295.20	560	19.5	0.11	4.17	8.14E-04	33.0			
Pb-214	351.93	1147	9.7	0.23	3.45	1.71E-03	38.9			
Bi-214 (Total U-238)	609.32	1147	7.8	0.23	1.94	2.76E-03	42.9	5.47E-01	23.5	
Bi-214	1120.20	235	21.1	0.05	1.06	1.20E-03	37.2			
Bi-214	1764.50	217	15.0	0.04	0.69	1.56E-03	40.4			
Bi-214	2204.10	61	32.4	0.01	0.56	5.63E-04	38.9			
Ac-228 (Total Th-232)	911.07	407	14.4	0.08	1.29	2.07E-03	30.4	7.39E-01	22.5	
Ac-228	968.90	269	19.3	0.05	1.22	1.29E-03	34.3			
Pb-212	238.63	1734	9.3	0.35	5.24	1.73E-03	38.2			
Bi-212	727.33	136	32.9	0.03	1.62	7.49E-04	22.5			
Tl-208	583.19	683	11.2	0.14	2.03	1.76E-03	38.3			
Tl-208	2614.40	357	10.8	0.07	0.48	1.21E-02	12.3			
K-40	1460.83	2713	4.0	0.54	0.82	9.70E-04	683.2	4.80E-02	32.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**107.6**
										2.91%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,172.1**		**78.7**	**8.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**78.7**	**0.0**	**40.9**	**119.6**	**107.6**	en %	**-10.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire - rte de Berne 10 - rez-de-chaussée	**N 46°48.372 E 7°10.290**	600	**rteberne10_rez.spe**	**16/1/2006 8:45**	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	169	74.8	0.03	6.68	1.20E-04	42.2			
Pb-214	295.20	511	22.6	0.10	4.17	8.14E-04	30.1			
Pb-214	351.93	976	11.9	0.20	3.45	1.71E-03	33.1			
Bi-214 (Total U-238)	609.32	993	9.0	0.20	1.94	2.76E-03	37.1	5.47E-01	20.3	
Bi-214	1120.20	269	18.4	0.05	1.06	1.20E-03	42.6			
Bi-214	1764.50	244	14.6	0.05	0.69	1.56E-03	45.5			
Bi-214	2204.10	69	30.9	0.01	0.56	5.63E-04	43.8			
Ac-228 (Total Th-232)	911.07	421	14.7	0.08	1.29	2.07E-03	31.5	7.39E-01	23.3	
Ac-228	968.90	292	19.2	0.06	1.22	1.29E-03	37.3			
Pb-212	238.63	1400	11.0	0.28	5.24	1.73E-03	30.9			
Bi-212	727.33	106	44.9	0.02	1.62	7.49E-04	17.5			
Tl-208	583.19	570	13.8	0.11	2.03	1.76E-03	32.0			
Tl-208	2614.40	382	10.4	0.08	0.48	1.21E-02	13.2			
K-40	1460.83	2251	4.4	0.45	0.82	9.70E-04	566.9	4.80E-02	27.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**110.1**
										3.05%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,003.4**		**70.8**	**9.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**70.8**	**0.0**	**40.2**	**111.0**	**110.1**	en %	**-0.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole primaire - rte de Berne 10 - 1er étage	**N 46°46.372 E 7°10.290**	**605**	**rteberne10_1er.spe**	**16/1/2006 10:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	255	57.6	0.05	6.68	1.20E-04	63.7			
Pb-214	295.20	622	20.7	0.12	4.17	8.14E-04	36.6			
Pb-214	351.93	1275	10.0	0.26	3.45	1.71E-03	43.2			
Bi-214 (Total U-238)	609.32	1187	8.3	0.24	1.94	2.76E-03	44.4	5.47E-01	24.3	
Bi-214	1120.20	279	18.2	0.06	1.06	1.20E-03	44.2			
Bi-214	1764.50	283	13.5	0.06	0.69	1.56E-03	52.8			
Bi-214	2204.10	97	25.3	0.02	0.56	5.63E-04	61.4			
Ac-228 (Total Th-232)	911.07	485	13.0	0.10	1.29	2.07E-03	36.3	7.39E-01	26.8	
Ac-228	968.90	302	17.1	0.06	1.22	1.29E-03	38.5			
Pb-212	238.63	1538	10.6	0.31	5.24	1.73E-03	33.9			
Bi-212	727.33	109	46.8	0.02	1.62	7.49E-04	17.9			
Tl-208	583.19	654	13.3	0.13	2.03	1.76E-03	36.7			
Tl-208	2614.40	447	9.6	0.09	0.48	1.21E-02	15.4			
K-40	1460.83	2474	4.2	0.49	0.82	9.70E-04	623.0	4.80E-02	29.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**120.9**
										3.51%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,147.9**		**81.0**	**8.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	**81.0**	**0.0**	**40.3**	**121.3**		**120.9**	en %		**-0.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole enfantine - Mon Repos 9 - rez-de-chaussée	**N 46°48.304 E 7°10.249**	**636**	**monrepos9_rez.spe**	**16/1/2006 13:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	481	21.1	0.10	4.17	8.14E-04	28.3			
Pb-214	351.93	812	11.6	0.16	3.45	1.71E-03	27.5			
Bi-214 (Total U-238)	609.32	696	10.3	0.14	1.94	2.76E-03	26.0	5.47E-01	14.2	
Bi-214	1120.20	223	18.7	0.04	1.06	1.20E-03	35.2			
Bi-214	1764.50	185	16.2	0.04	0.69	1.56E-03	34.5			
Bi-214	2204.10	49	35.4	0.01	0.56	5.63E-04	31.1			
Ac-228 (Total Th-232)	911.07	313	15.6	0.06	1.29	2.07E-03	23.4	7.39E-01	17.3	
Ac-228	968.90	142	27.0	0.03	1.22	1.29E-03	18.1			
Pb-212	238.63	990	13.1	0.20	5.24	1.73E-03	21.8			
Bi-212	727.33	93	42.9	0.02	1.62	7.49E-04	15.3			
Tl-208	583.19	472	13.8	0.09	2.03	1.76E-03	26.5			
Tl-208	2614.40	258	12.7	0.05	0.48	1.21E-02	8.9			
K-40	1460.83	1589	5.2	0.32	0.82	9.70E-04	400.0	4.80E-02	19.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**83.2**
										2.96%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**696.6**		**50.7**	**10.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**50.7**	**0.0**	**40.7**	**91.5**		**83.2**	en %		**-9.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Co de Jolimont - rez-de-chaussée	**N 46°48.145 E 7°08.552**	**645**	**cojolimont_rez.spe**	**24/1/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	311	24.5	0.06	4.17	8.14E-04	18.3			
Pb-214	351.93	531	14.1	0.11	3.45	1.71E-03	18.0			
Bi-214 (Total U-238)	609.32	534	11.1	0.11	1.94	2.76E-03	20.0	5.47E-01	10.9	
Bi-214	1120.20	119	27.1	0.02	1.06	1.20E-03	18.9			
Bi-214	1764.50	117	19.8	0.02	0.69	1.56E-03	21.8			
Bi-214	2204.10	31	44.8	0.01	0.56	5.63E-04	19.5			
Ac-228 (Total Th-232)	911.07	171	20.6	0.03	1.29	2.07E-03	12.8	7.39E-01	9.4	
Ac-228	968.90	82	34.4	0.02	1.22	1.29E-03	10.4			
Pb-212	238.63	469	21.5	0.09	5.24	1.73E-03	10.3			
Bi-212	727.33	48	60.5	0.01	1.62	7.49E-04	7.9			
Tl-208	583.19	222	21.6	0.04	2.03	1.76E-03	12.4			
Tl-208	2614.40	166	15.7	0.03	0.48	1.21E-02	5.7			
K-40	1460.83	755	7.8	0.15	0.82	9.70E-04	190.1	4.80E-02	9.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**65.8**
										2.96%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**366.2**		**29.5**	**13.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**29.5**	**0.0**	**40.9**	**70.4**	**65.8**	en %	**-6.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Co de Jolimont - 1er étage	**N 46°48.145 E 7°08.552**	**650**	**cojolimont_1er.spe**	**24/1/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	184	54.8	0.04	6.68	1.20E-04	45.8			
Pb-214	295.20	301	27.9	0.06	4.17	8.14E-04	17.7			
Pb-214	351.93	628	13.2	0.13	3.45	1.71E-03	21.3			
Bi-214 (Total U-238)	609.32	557	11.6	0.11	1.94	2.76E-03	20.8	5.47E-01	11.4	
Bi-214	1120.20	160	23.1	0.03	1.06	1.20E-03	25.2			
Bi-214	1764.50	175	16.3	0.03	0.69	1.56E-03	32.6			
Bi-214	2204.10	48	34.0	0.01	0.56	5.63E-04	30.4			
Ac-228 (Total Th-232)	911.07	148	25.3	0.03	1.29	2.07E-03	11.1	7.39E-01	8.2	
Ac-228	968.90	83	36.8	0.02	1.22	1.29E-03	10.6			
Pb-212	238.63	571	18.6	0.11	5.24	1.73E-03	12.6			
Bi-212	727.33	66	53.8	0.01	1.62	7.49E-04	11.0			
Tl-208	583.19	289	19.1	0.06	2.03	1.76E-03	16.2			
Tl-208	2614.40	185	14.9	0.04	0.48	1.21E-02	6.4			
K-40	1460.83	1116	6.3	0.22	0.82	9.70E-04	281.0	4.80E-02	13.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**81.1**
										3.47%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**542.8**		**33.1**	**12.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**33.1**	**0.0**	**41.0**	**74.0**		**81.1**	en %		**9.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
ECDD - rue du Moléson 17 - rez-de-chaussée	**N 46°48.215 E 7°08.512**	**668**	**ecdd_rez.spe**	**30/1/2006 8:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	416	22.8	0.08	4.17	8.14E-04	24.5			
Pb-214	351.93	813	11.8	0.16	3.45	1.71E-03	27.5			
Bi-214 (Total U-238)	609.32	760	9.7	0.15	1.94	2.76E-03	28.4	5.47E-01	15.5	
Bi-214	1120.20	195	20.9	0.04	1.06	1.20E-03	30.9			
Bi-214	1764.50	170	16.7	0.03	0.69	1.56E-03	31.6			
Bi-214	2204.10	40	40.2	0.01	0.56	5.63E-04	25.3			
Ac-228 (Total Th-232)	911.07	250	18.8	0.05	1.29	2.07E-03	18.7	7.39E-01	13.8	
Ac-228	968.90	127	29.6	0.03	1.22	1.29E-03	16.2			
Pb-212	238.63	906	15.3	0.18	5.24	1.73E-03	20.0			
Bi-212	727.33	92	41.0	0.02	1.62	7.49E-04	15.2			
Tl-208	583.19	360	17.6	0.07	2.03	1.76E-03	20.2			
Tl-208	2614.40	198	14.4	0.04	0.48	1.21E-02	6.8			
K-40	1460.83	1520	5.3	0.30	0.82	9.70E-04	382.7	4.80E-02	18.4	**R & S**
Be-7	477.60				2.50	5.41E-04				78.0
										3.28%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**648.0**		**47.7**	**10.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**47.7**	**0.0**	**41.2**	**89.0**	**78.0**	en %	**-12.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
ECDD - rue du Moléson 17 - 1er étage	**N 46°48.215 E 7°08.512**	**673**	**ecdd_1er.spe**	**30/1/2006 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	473	20.8	0.09	4.17	8.14E-04	27.8			
Pb-214	351.93	853	11.4	0.17	3.45	1.71E-03	28.9			
Bi-214 (Total U-238)	609.32	797	9.5	0.16	1.94	2.76E-03	29.8	5.47E-01	16.3	
Bi-214	1120.20	249	18.0	0.05	1.06	1.20E-03	39.4			
Bi-214	1764.50	169	17.5	0.03	0.69	1.56E-03	31.5			
Bi-214	2204.10	54	34.5	0.01	0.56	5.63E-04	34.2			
Ac-228 (Total Th-232)	911.07	304	16.0	0.06	1.29	2.07E-03	22.8	7.39E-01	16.8	
Ac-228	968.90	134	30.4	0.03	1.22	1.29E-03	17.1			
Pb-212	238.63	892	14.5	0.18	5.24	1.73E-03	19.7			
Bi-212	727.33	93	38.6	0.02	1.62	7.49E-04	15.4			
Tl-208	583.19	371	17.3	0.07	2.03	1.76E-03	20.8			
Tl-208	2614.40	227	13.4	0.05	0.48	1.21E-02	7.8			
K-40	1460.83	1689	5.0	0.34	0.82	9.70E-04	425.2	4.80E-02	20.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**87.9**
										3.27%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**720.4**		**53.5**	**9.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**53.5**	**0.0**	**41.3**	**94.9**	**87.9**	en %	**-7.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
ECDD - rue du Moléson 17 - 2^e^ étage	**N 46°48.215 E 7°08.512**	**678**	**ecdd_2e.spe**	**30/1/2006 11:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	202	52.5	0.04	6.68	1.20E-04	50.4			
Pb-214	295.20	385	25.6	0.08	4.17	8.14E-04	22.7			
Pb-214	351.93	842	11.9	0.17	3.45	1.71E-03	28.5			
Bi-214 (Total U-238)	609.32	846	9.2	0.17	1.94	2.76E-03	31.6	5.47E-01	17.3	
Bi-214	1120.20	194	23.2	0.04	1.06	1.20E-03	30.7			
Bi-214	1764.50	178	17.1	0.04	0.69	1.56E-03	33.3			
Bi-214	2204.10	53	32.8	0.01	0.56	5.63E-04	33.6			
Ac-228 (Total Th-232)	911.07	243	19.1	0.05	1.29	2.07E-03	18.1	7.39E-01	13.4	
Ac-228	968.90	112	33.8	0.02	1.22	1.29E-03	14.2			
Pb-212	238.63	803	17.4	0.16	5.24	1.73E-03	17.7			
Bi-212	727.33	44	78.2	0.01	1.62	7.49E-04	7.2			
Tl-208	583.19	359	18.3	0.07	2.03	1.76E-03	20.1			
Tl-208	2614.40	248	12.9	0.05	0.48	1.21E-02	8.5			
K-40	1460.83	1570	5.3	0.31	0.82	9.70E-04	395.3	4.80E-02	19.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**91.2**
										3.14%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**712.1**		**49.7**	**10.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**49.7**	**0.0**	**41.4**	**91.1**		**91.2**	en %		**0.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
ECDD - rue du Moléson 17 - 3^e étage	**N 46°48.215 E 7°08.512**	683	**ecdd_3e.spe**	**30/1/2006 13:15**	**4007**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	604	16.3	0.15	4.17	8.14E-04	44.3			
Pb-214	351.93	759	13.0	0.19	3.45	1.71E-03	32.1			
Bi-214 (Total U-238)	609.32	639	10.8	0.16	1.94	2.76E-03	29.8	5.47E-01	16.3	
Bi-214	1120.20	181	21.9	0.05	1.06	1.20E-03	35.7			
Bi-214	1764.50	158	17.8	0.04	0.69	1.56E-03	36.8			
Bi-214	2204.10	36	39.6	0.01	0.56	5.63E-04	28.4			
Ac-228 (Total Th-232)	911.07	278	16.9	0.07	1.29	2.07E-03	26.0	7.39E-01	19.2	
Ac-228	968.90	138	29.4	0.03	1.22	1.29E-03	22.0			
Pb-212	238.63	716	17.1	0.18	5.24	1.73E-03	19.7			
Bi-212	727.33	91	45.4	0.02	1.62	7.49E-04	18.6			
Tl-208	583.19	342	17.5	0.09	2.03	1.76E-03	23.9			
Tl-208	2614.40	239	13.2	0.06	0.48	1.21E-02	10.3			
K-40	1460.83	1503	5.3	0.38	0.82	9.70E-04	472.2	4.80E-02	22.7	**R & S**
Be-7	477.60				2.50	5.41E-04				**113.9**
										3.13%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**799.8**		**58.2**	**10.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**58.2**	**0.0**	**41.5**	**99.7**		**113.9**	en %		**14.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Centre Fribourg - 1er étage	**N 46°48.117 E 7°09.980**	**617**	**centrefribourg_1er.spe**	**31/1/2006 8:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	109	77.6	0.02	6.68	1.20E-04	27.1			
Pb-214	295.20	408	22.2	0.08	4.17	8.14E-04	24.0			
Pb-214	351.93	723	11.8	0.14	3.45	1.71E-03	24.5			
Bi-214 (Total U-238)	609.32	714	9.7	0.14	1.94	2.76E-03	26.7	5.47E-01	14.6	
Bi-214	1120.20	183	20.5	0.04	1.06	1.20E-03	28.9			
Bi-214	1764.50	160	17.6	0.03	0.69	1.56E-03	29.9			
Bi-214	2204.10	41	36.9	0.01	0.56	5.63E-04	26.3			
Ac-228 (Total Th-232)	911.07	185	23.1	0.04	1.29	2.07E-03	13.8	7.39E-01	10.2	
Ac-228	968.90	116	30.0	0.02	1.22	1.29E-03	14.8			
Pb-212	238.63	697	16.0	0.14	5.24	1.73E-03	15.4			
Bi-212	727.33	52	63.1	0.01	1.62	7.49E-04	8.5			
Tl-208	583.19	305	19.1	0.06	2.03	1.76E-03	17.1			
Tl-208	2614.40	195	14.7	0.04	0.48	1.21E-02	6.7			
K-40	1460.83	1156	6.1	0.23	0.82	9.70E-04	291.0	4.80E-02	14.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**64.8**
										3.53%
Cs-137	661.66	59	62.2	0.01	1.78	5.20E-03	1.3	1.92E-01	0.2	**Incertitude**
						Total :	**554.6**		**39.0**	**11.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**38.8**	**0.2**	**40.5**	**79.5**	**64.8**	**en %**	**-18.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Centre Fribourg - 2e étage	**N 46°48.117 E 7°09.980**	**623**	**centrefribourg_2e.spe**	**31/1/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	470	20.3	0.09	4.17	8.14E-04	27.7			
Pb-214	351.93	871	10.8	0.17	3.45	1.71E-03	29.5			
Bi-214 (Total U-238)	609.32	731	9.3	0.15	1.94	2.76E-03	27.3	5.47E-01	14.9	
Bi-214	1120.20	189	21.2	0.04	1.06	1.20E-03	29.9			
Bi-214	1764.50	150	17.8	0.03	0.69	1.56E-03	28.0			
Bi-214	2204.10	34	44.9	0.01	0.56	5.63E-04	21.3			
Ac-228 (Total Th-232)	911.07	191	21.6	0.04	1.29	2.07E-03	14.3	7.39E-01	10.6	
Ac-228	968.90	83	40.2	0.02	1.22	1.29E-03	10.6			
Pb-212	238.63	357	29.7	0.07	5.24	1.73E-03	7.9			
Bi-212	727.33	43	72.0	0.01	1.62	7.49E-04	7.2			
Tl-208	583.19	265	20.6	0.05	2.03	1.76E-03	14.9			
Tl-208	2614.40	189	14.9	0.04	0.48	1.21E-02	6.5			
K-40	1460.83	1144	6.2	0.23	0.82	9.70E-04	288.0	4.80E-02	13.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**63.3**
										2.67%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**512.9**		**39.3**	**11.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**39.3**	**0.0**	**40.5**	**79.9**		**63.3**	en %		**-20.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Centre Fribourg - 4[e] étage	**N 46°48.117 E 7°09.980**	**633**	**centrefribourg_4e.spe**	**31/1/2006 11:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	417	30.9	0.08	4.17	8.14E-04	24.5			
Pb-214	351.93	728	17.6	0.15	3.45	1.71E-03	24.6			
Bi-214 (Total U-238)	609.32	679	14.8	0.14	1.94	2.76E-03	25.4	5.47E-01	13.9	
Bi-214	1120.20	175	32.5	0.04	1.06	1.20E-03	27.7			
Bi-214	1764.50	148	26.8	0.03	0.69	1.56E-03	27.6			
Bi-214	2204.10	34	65.5	0.01	0.56	5.63E-04	21.6			
Ac-228 (Total Th-232)	911.07	153	36.8	0.03	1.29	2.07E-03	11.4	7.39E-01	8.5	
Ac-228	968.90	144	37.0	0.03	1.22	1.29E-03	18.4			
Pb-212	238.63	438	35.2	0.09	5.24	1.73E-03	9.7			
Bi-212	727.33	43	73.6	0.01	1.62	7.49E-04	7.1			
Tl-208	583.19	230	23.1	0.05	2.03	1.76E-03	12.9			
Tl-208	2614.40	176	15.3	0.04	0.48	1.21E-02	6.1			
K-40	1460.83	980	6.7	0.20	0.82	9.70E-04	246.6	4.80E-02	11.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**66.8**
										4.21%
Cs-137	661.66	40	77.3	0.01	1.78	5.20E-03	0.9	1.92E-01	0.2	**Incertitude**
						Total :	**463.6**		**34.3**	**17.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**34.2**	**0.2**	**40.7**	**75.0**	**66.8**	en %	**-11.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Miséricorde - rez-de-chaussée	**N 46°48.221 E 7°09.610**	636	**misericorde_rez.spe**	**14/2/2006 8:20**	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	168	70.5	0.03	6.68	1.20E-04	41.8			
Pb-214	295.20	380	25.7	0.08	4.17	8.14E-04	22.3			
Pb-214	351.93	847	11.6	0.17	3.45	1.71E-03	28.7			
Bi-214 (Total U-238)	609.32	756	10.1	0.15	1.94	2.76E-03	28.3	5.47E-01	15.5	
Bi-214	1120.20	168	24.5	0.03	1.06	1.20E-03	26.6			
Bi-214	1764.50	178	16.7	0.04	0.69	1.56E-03	33.2			
Bi-214	2204.10	41	39.3	0.01	0.56	5.63E-04	26.0			
Ac-228 (Total Th-232)	911.07	342	16.0	0.07	1.29	2.07E-03	25.6	7.39E-01	18.9	
Ac-228	968.90	222	20.7	0.04	1.22	1.29E-03	28.3			
Pb-212	238.63	926	13.1	0.19	5.24	1.73E-03	20.4			
Bi-212	727.33	124	34.0	0.02	1.62	7.49E-04	20.4			
Tl-208	583.19	462	14.9	0.09	2.03	1.76E-03	25.9			
Tl-208	2614.40	292	11.7	0.06	0.48	1.21E-02	10.1			
K-40	1460.83	1754	5.0	0.35	0.82	9.70E-04	441.7	4.80E-02	21.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**91.3**
										3.02%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**779.3**		**55.6**	**10.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition: en nSv/h	naturel	artificiel	cosmique	insitu		R+S	déviation en %		R+S
	55.6	**0.0**	**40.7**	**96.3**		**91.3**			**-5.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Miséricorde - 1^er étage	**N 46°48.221 E 7°09.610**	**641**	**misericorde_1er.spe**	**14/2/2006 9:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	142	72.6	0.03	6.68	1.20E-04	35.5			
Pb-214	295.20	452	20.5	0.09	4.17	8.14E-04	26.6			
Pb-214	351.93	810	12.3	0.16	3.45	1.71E-03	27.4			
Bi-214 (Total U-238)	609.32	745	10.4	0.15	1.94	2.76E-03	27.9	5.47E-01	15.2	
Bi-214	1120.20	198	21.2	0.04	1.06	1.20E-03	31.3			
Bi-214	1764.50	180	16.5	0.04	0.69	1.56E-03	33.6			
Bi-214	2204.10	50	34.6	0.01	0.56	5.63E-04	31.9			
Ac-228 (Total Th-232)	911.07	307	16.3	0.06	1.29	2.07E-03	23.0	7.39E-01	17.0	
Ac-228	968.90	136	28.8	0.03	1.22	1.29E-03	17.4			
Pb-212	238.63	966	13.6	0.19	5.24	1.73E-03	21.3			
Bi-212	727.33	53	62.2	0.01	1.62	7.49E-04	8.7			
Tl-208	583.19	399	15.7	0.08	2.03	1.76E-03	22.4			
Tl-208	2614.40	245	12.9	0.05	0.48	1.21E-02	8.5			
K-40	1460.83	1574	5.2	0.31	0.82	9.70E-04	396.2	4.80E-02	19.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**90.5**
										2.49%
Cs-137	661.66	51	63.4	0.01	1.78	5.20E-03	1.1	1.92E-01	0.2	**Incertitude**
						Total :	**711.7**		**51.4**	**10.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**51.2**	**0.2**	**40.8**	**92.3**		**90.5**	**en %**		**-1.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Miséricorde - 2e étage	**N 46°48.221 E 7°09.610**	**646**	**misericorde_2e.spe**	**14/2/2006 11:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	345	28.1	0.07	4.17	8.14E-04	20.3			
Pb-214	351.93	782	12.4	0.16	3.45	1.71E-03	26.5			
Bi-214 (Total U-238)	609.32	688	10.6	0.14	1.94	2.76E-03	25.7	5.47E-01	14.1	
Bi-214	1120.20	165	24.0	0.03	1.06	1.20E-03	26.1			
Bi-214	1764.50	151	18.2	0.03	0.69	1.56E-03	28.2			
Bi-214	2204.10	54	30.9	0.01	0.56	5.63E-04	34.0			
Ac-228 (Total Th-232)	911.07	308	15.7	0.06	1.29	2.07E-03	23.1	7.39E-01	17.0	
Ac-228	968.90	189	21.8	0.04	1.22	1.29E-03	24.1			
Pb-212	238.63	989	13.2	0.20	5.24	1.73E-03	21.8			
Bi-212	727.33	103	36.6	0.02	1.62	7.49E-04	17.0			
Tl-208	583.19	408	15.4	0.08	2.03	1.76E-03	22.9			
Tl-208	2614.40	270	12.3	0.05	0.48	1.21E-02	9.3			
K-40	1460.83	1485	5.4	0.30	0.82	9.70E-04	373.9	4.80E-02	17.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**87.5**
										2.65%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**652.9**		**49.1**	**10.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**49.1**	**0.0**	**40.9**	**90.0**	**87.5**	en %	**-2.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège St.-Michel - rez-de-chaussée	**N 46°48.246 E 7°09.326**	**608**	**stmichel_rez.spe**	**16/2/2006 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	172	82.9	0.03	6.68	1.20E-04	42.9			
Pb-214	295.20	459	23.8	0.09	4.17	8.14E-04	27.0			
Pb-214	351.93	723	14.6	0.14	3.45	1.71E-03	24.5			
Bi-214 (Total U-238)	609.32	650	12.1	0.13	1.94	2.76E-03	24.3	5.47E-01	13.3	
Bi-214	1120.20	157	28.5	0.03	1.06	1.20E-03	24.8			
Bi-214	1764.50	157	18.2	0.03	0.69	1.56E-03	29.2			
Bi-214	2204.10	56	34.6	0.01	0.56	5.63E-04	35.3			
Ac-228 (Total Th-232)	911.07	354	15.7	0.07	1.29	2.07E-03	26.5	7.39E-01	19.6	
Ac-228	968.90	200	23.9	0.04	1.22	1.29E-03	25.5			
Pb-212	238.63	1149	12.8	0.23	5.24	1.73E-03	25.3			
Bi-212	727.33	109	44.5	0.02	1.62	7.49E-04	18.0			
Tl-208	583.19	536	14.0	0.11	2.03	1.76E-03	30.1			
Tl-208	2614.40	417	9.9	0.08	0.48	1.21E-02	14.4			
K-40	1460.83	2554	4.1	0.51	0.82	9.70E-04	643.2	4.80E-02	30.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**107.8**
										1.76%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**990.9**		**63.7**	**9.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**63.7**	**0.0**	**40.3**	**104.0**	**107.8**	en %	**3.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège St.-Michel - 1er étage	**N 46°48.246 E 7°09.326**	**613**	**stmichel_1er.spe**	**16/2/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	360	30.4	0.07	4.17	8.14E-04	21.2			
Pb-214	351.93	575	16.8	0.12	3.45	1.71E-03	19.5			
Bi-214 (Total U-238)	609.32	552	13.3	0.11	1.94	2.76E-03	20.6	5.47E-01	11.3	
Bi-214	1120.20	201	24.1	0.04	1.06	1.20E-03	31.8			
Bi-214	1764.50	134	20.2	0.03	0.69	1.56E-03	24.9			
Bi-214	2204.10	38	44.5	0.01	0.56	5.63E-04	24.2			
Ac-228 (Total Th-232)	911.07	310	17.0	0.06	1.29	2.07E-03	23.2	7.39E-01	17.1	
Ac-228	968.90	221	22.1	0.04	1.22	1.29E-03	28.2			
Pb-212	238.63	953	14.8	0.19	5.24	1.73E-03	21.0			
Bi-212	727.33	76	51.5	0.02	1.62	7.49E-04	12.5			
Tl-208	583.19	420	16.5	0.08	2.03	1.76E-03	23.5			
Tl-208	2614.40	344	10.9	0.07	0.48	1.21E-02	11.9			
K-40	1460.83	2383	4.2	0.48	0.82	9.70E-04	600.0	4.80E-02	28.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**109.4**
										3.14%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**862.6**		**57.2**	**9.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**57.2**	**0.0**	**40.4**	**97.6**		**109.4**	en %		**12.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège St.-Michel - 2^e étage	N 46°48.246 E 7°09.326	618	stmichel_2e.spe	16/2/2006 11:30	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	349	27.9	0.07	4.17	8.14E-04	20.5			
Pb-214	351.93	650	14.8	0.13	3.45	1.71E-03	22.0			
Bi-214 (Total U-238)	609.32	517	13.5	0.10	1.94	2.76E-03	19.3	5.47E-01	10.6	
Bi-214	1120.20	158	26.2	0.03	1.06	1.20E-03	25.0			
Bi-214	1764.50	134	20.1	0.03	0.69	1.56E-03	25.0			
Bi-214	2204.10	38	40.3	0.01	0.56	5.63E-04	24.1			
Ac-228 (Total Th-232)	911.07	239	20.7	0.05	1.29	2.07E-03	17.9	7.39E-01	13.2	
Ac-228	968.90	174	26.7	0.03	1.22	1.29E-03	22.2			
Pb-212	238.63	764	16.7	0.15	5.24	1.73E-03	16.8			
Bi-212	727.33	106	40.0	0.02	1.62	7.49E-04	17.4			
Tl-208	583.19	435	16.6	0.09	2.03	1.76E-03	24.4			
Tl-208	2614.40	277	12.1	0.06	0.48	1.21E-02	9.6			
K-40	1460.83	1931	4.7	0.39	0.82	9.70E-04	486.2	4.80E-02	23.3	R & S
Be-7	477.60				2.50	5.41E-04				107.0
										2.63%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	730.4		47.1	11.1

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	47.1	0.0	40.5	87.6	107.0	en %	22.2

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Gambach - rez-de-chaussée	**N 46°48.258 E 7°09.070**	**647**	**gambach_rez.spe**	**14/3/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	697	16.7	0.14	4.17	8.14E-04	41.0			
Pb-214	351.93	1087	10.4	0.22	3.45	1.71E-03	36.8			
Bi-214 (Total U-238)	609.32	1015	8.5	0.20	1.94	2.76E-03	38.0	5.47E-01	20.8	
Bi-214	1120.20	293	16.9	0.06	1.06	1.20E-03	46.3			
Bi-214	1764.50	230	15.3	0.05	0.69	1.56E-03	42.9			
Bi-214	2204.10	76	27.0	0.02	0.56	5.63E-04	48.3			
Ac-228 (Total Th-232)	911.07	500	12.6	0.10	1.29	2.07E-03	37.4	7.39E-01	27.6	
Ac-228	968.90	332	15.5	0.07	1.22	1.29E-03	42.4			
Pb-212	238.63	1891	8.6	0.38	5.24	1.73E-03	41.7			
Bi-212	727.33	183	29.3	0.04	1.62	7.49E-04	30.2			
Tl-208	583.19	784	10.5	0.16	2.03	1.76E-03	44.0			
Tl-208	2614.40	416	9.9	0.08	0.48	1.21E-02	14.3			
K-40	1460.83	2558	4.1	0.51	0.82	9.70E-04	644.1	4.80E-02	30.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**108.2**
										2.24%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,107.4**		**79.3**	**8.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**79.3**	**0.0**	**40.9**	**120.2**	**108.2**	en %	**-10.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Gambach - 1[er] étage	N 46°48.258 E 7°09.070	652	gambach_1er.spe	14/3/2006 10:00	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	510	22.8	0.10	4.17	8.14E-04	30.0			
Pb-214	351.93	1067	10.3	0.21	3.45	1.71E-03	36.1			
Bi-214 (Total U-238)	609.32	986	8.7	0.20	1.94	2.76E-03	36.9	5.47E-01	20.2	
Bi-214	1120.20	201	25.4	0.04	1.06	1.20E-03	31.8			
Bi-214	1764.50	209	15.6	0.04	0.69	1.56E-03	38.9			
Bi-214	2204.10	21	63.9	0.00	0.56	5.63E-04	13.3			
Ac-228 (Total Th-232)	911.07	424	14.1	0.08	1.29	2.07E-03	31.7	7.39E-01	23.4	
Ac-228	968.90	276	19.2	0.06	1.22	1.29E-03	35.1			
Pb-212	238.63	1561	9.8	0.31	5.24	1.73E-03	34.4			
Bi-212	727.33	172	30.3	0.03	1.62	7.49E-04	28.4			
Tl-208	583.19	661	11.8	0.13	2.03	1.76E-03	37.1			
Tl-208	2614.40	429	9.7	0.09	0.48	1.21E-02	14.8			
K-40	1460.83	2377	4.2	0.48	0.82	9.70E-04	598.5	4.80E-02	28.7	R & S
Be-7	477.60				2.50	5.41E-04				106.9
										2.15%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	967.0		72.3	8.6

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	72.3	0.0	41.0	113.3		106.9	en %		-5.7

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Gambach - 2e étage	**N 46°48.258 E 7°09.070**	**657**	**gambach_2e.spe**	**14/3/2006 11:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	166	76.4	0.03	6.68	1.20E-04	41.5			
Pb-214	295.20	460	22.4	0.09	4.17	8.14E-04	27.1			
Pb-214	351.93	904	11.5	0.18	3.45	1.71E-03	30.6			
Bi-214 (Total U-238)	609.32	868	9.5	0.17	1.94	2.76E-03	32.5	5.47E-01	17.8	
Bi-214	1120.20	242	20.1	0.05	1.06	1.20E-03	38.3			
Bi-214	1764.50	179	16.7	0.04	0.69	1.56E-03	33.4			
Bi-214	2204.10	44	42.0	0.01	0.56	5.63E-04	28.0			
Ac-228 (Total Th-232)	911.07	441	13.6	0.09	1.29	2.07E-03	32.9	7.39E-01	24.3	
Ac-228	968.90	206	22.2	0.04	1.22	1.29E-03	26.2			
Pb-212	238.63	1202	12.2	0.24	5.24	1.73E-03	26.5			
Bi-212	727.33	113	41.0	0.02	1.62	7.49E-04	18.6			
Tl-208	583.19	509	14.4	0.10	2.03	1.76E-03	28.5			
Tl-208	2614.40	367	10.5	0.07	0.48	1.21E-02	12.7			
K-40	1460.83	2025	4.6	0.41	0.82	9.70E-04	509.9	4.80E-02	24.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**105.5**
										2.76%
Cs-137	661.66	69	57.4	0.01	1.78	5.20E-03	1.5	1.92E-01	0.3	**Incertitude**
						Total :	**886.7**		**66.9**	**9.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**66.6**	**0.3**	**41.1**	**107.9**		**105.5**	en %		**-2.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de la Heltera 21 - rez-de-chaussée	**N 46°46.365 E 7°10.319**	**643**	**heltera21_rez.spe**	**28/3/2006 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	372	37.6	0.07	6.68	1.20E-04	92.9			
Pb-214	295.20	585	19.5	0.12	4.17	8.14E-04	34.4			
Pb-214	351.93	1246	9.1	0.25	3.45	1.71E-03	42.2			
Bi-214 (Total U-238)	609.32	986	8.5	0.20	1.94	2.76E-03	36.9	5.47E-01	20.2	
Bi-214	1120.20	217	21.4	0.04	1.06	1.20E-03	34.3			
Bi-214	1764.50	231	14.5	0.05	0.69	1.56E-03	43.1			
Bi-214	2204.10	51	36.1	0.01	0.56	5.63E-04	32.1			
Ac-228 (Total Th-232)	911.07	480	12.2	0.10	1.29	2.07E-03	35.9	7.39E-01	26.5	
Ac-228	968.90	248	19.8	0.05	1.22	1.29E-03	31.6			
Pb-212	238.63	1789	8.7	0.36	5.24	1.73E-03	39.5			
Bi-212	727.33	135	36.3	0.03	1.62	7.49E-04	22.2			
Tl-208	583.19	741	10.5	0.15	2.03	1.76E-03	41.5			
Tl-208	2614.40	399	10.2	0.08	0.48	1.21E-02	13.8			
K-40	1460.83	2086	4.5	0.42	0.82	9.70E-04	525.1	4.80E-02	25.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**95.0**
										3.17%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,025.6**		**71.9**	**8.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**71.9**	**0.0**	**40.9**	**112.8**	**95.0**	en %	**-15.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de la Heltera 21 - 1er étage	**N 46°48.365 E 7°10.319**	**647**	**heltera21_1er.spe**	**28/3/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	582	19.1	0.12	4.17	8.14E-04	34.3			
Pb-214	351.93	1215	9.5	0.24	3.45	1.71E-03	41.2			
Bi-214 (Total U-238)	609.32	1099	7.9	0.22	1.94	2.76E-03	41.1	5.47E-01	22.5	
Bi-214	1120.20	314	16.4	0.06	1.06	1.20E-03	49.6			
Bi-214	1764.50	222	14.5	0.04	0.69	1.56E-03	41.4			
Bi-214	2204.10	64	31.3	0.01	0.56	5.63E-04	40.8			
Ac-228 (Total Th-232)	911.07	503	12.3	0.10	1.29	2.07E-03	37.6	7.39E-01	27.8	
Ac-228	968.90	282	17.9	0.06	1.22	1.29E-03	35.9			
Pb-212	238.63	1976	8.4	0.40	5.24	1.73E-03	43.6			
Bi-212	727.33	178	28.4	0.04	1.62	7.49E-04	29.4			
Tl-208	583.19	761	10.7	0.15	2.03	1.76E-03	42.7			
Tl-208	2614.40	380	10.3	0.08	0.48	1.21E-02	13.1			
K-40	1460.83	2195	4.5	0.44	0.82	9.70E-04	552.6	4.80E-02	26.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**103.1**
										2.53%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,003.2**		**76.8**	**8.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**76.8**	**0.0**	**40.9**	**117.7**	**103.1**	en %	**-12.4**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Hotel de Ville 3 - rez-de-chaussée	**N 46°48.206 E 7°09.397**	**573**	**maison-ville_rez.spe**	**4/4/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	311	55.2	0.06	6.68	1.20E-04	77.6			
Pb-214	295.20	538	21.4	0.11	4.17	8.14E-04	31.7			
Pb-214	351.93	924	12.4	0.18	3.45	1.71E-03	31.3			
Bi-214 (Total U-238)	609.32	940	9.5	0.19	1.94	2.76E-03	35.1	5.47E-01	19.2	
Bi-214	1120.20	251	22.1	0.05	1.06	1.20E-03	39.7			
Bi-214	1764.50	210	15.6	0.04	0.69	1.56E-03	39.2			
Bi-214	2204.10	57	35.3	0.01	0.56	5.63E-04	36.5			
Ac-228 (Total Th-232)	911.07	519	11.4	0.10	1.29	2.07E-03	38.8	7.39E-01	28.6	
Ac-228	968.90	269	19.0	0.05	1.22	1.29E-03	34.3			
Pb-212	238.63	1397	11.2	0.28	5.24	1.73E-03	30.8			
Bi-212	727.33	118	39.0	0.02	1.62	7.49E-04	19.5			
Tl-208	583.19	654	11.9	0.13	2.03	1.76E-03	36.7			
Tl-208	2614.40	401	10.1	0.08	0.48	1.21E-02	13.8			
K-40	1460.83	2787	3.9	0.56	0.82	9.70E-04	701.7	4.80E-02	33.7	**R & S**
Be-7	477.60				2.50	5.41E-04				**109.6**
										2.72%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,166.6**		**81.6**	**7.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**81.6**	**0.0**	**39.8**	**121.3**	**109.6**	en %	**-9.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Hotel de Ville 3 - 3ᵉ étage	**N 46°48.206 E 7°09.397**	**588**	**maison-ville_3e.spe**	**4/4/2006 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	436	38.3	0.09	6.68	1.20E-04	108.8			
Pb-214	295.20	496	22.8	0.10	4.17	8.14E-04	29.2			
Pb-214	351.93	993	10.9	0.20	3.45	1.71E-03	33.6			
Bi-214 (Total U-238)	609.32	928	9.0	0.19	1.94	2.76E-03	34.7	5.47E-01	19.0	
Bi-214	1120.20	212	22.5	0.04	1.06	1.20E-03	33.5			
Bi-214	1764.50	198	15.8	0.04	0.69	1.56E-03	37.0			
Bi-214	2204.10	57	36.3	0.01	0.56	5.63E-04	35.9			
Ac-228 (Total Th-232)	911.07	410	14.1	0.08	1.29	2.07E-03	30.6	7.39E-01	22.6	
Ac-228	968.90	216	26.6	0.04	1.22	1.29E-03	27.5			
Pb-212	238.63	1767	9.5	0.35	5.24	1.73E-03	39.0			
Bi-212	727.33	123	37.1	0.02	1.62	7.49E-04	20.4			
Tl-208	583.19	674	11.6	0.13	2.03	1.76E-03	37.8			
Tl-208	2614.40	377	10.5	0.08	0.48	1.21E-02	13.0			
K-40	1460.83	2326	4.3	0.47	0.82	9.70E-04	585.6	4.80E-02	28.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**116.4**
										3.03%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,066.6**		**69.7**	**8.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**69.7**	**0.0**	**40.0**	**109.7**		**116.4**	en %		**6.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Grand'Rue 37 - Police locale - rez-de-chaussée	**N 46°48.185 E 7°09.543**	**556**	**grandrue37_rez.spe**	**6/4/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	207	62.7	0.04	6.68	1.20E-04	51.6			
Pb-214	295.20	491	22.6	0.10	4.17	8.14E-04	28.9			
Pb-214	351.93	810	12.5	0.16	3.45	1.71E-03	27.4			
Bi-214 (Total U-238)	609.32	845	9.3	0.17	1.94	2.76E-03	31.6	5.47E-01	17.3	
Bi-214	1120.20	208	21.8	0.04	1.06	1.20E-03	32.9			
Bi-214	1764.50	176	17.7	0.04	0.69	1.56E-03	32.9			
Bi-214	2204.10	44	40.5	0.01	0.56	5.63E-04	28.1			
Ac-228 (Total Th-232)	911.07	434	13.4	0.09	1.29	2.07E-03	32.5	7.39E-01	24.0	
Ac-228	968.90	234	20.1	0.05	1.22	1.29E-03	29.8			
Pb-212	238.63	1194	12.4	0.24	5.24	1.73E-03	26.3			
Bi-212	727.33	87	52.2	0.02	1.62	7.49E-04	14.3			
Tl-208	583.19	532	13.6	0.11	2.03	1.76E-03	29.8			
Tl-208	2614.40	388	10.3	0.08	0.48	1.21E-02	13.4			
K-40	1460.83	2257	4.3	0.45	0.82	9.70E-04	568.2	4.80E-02	27.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**101.7**
										2.73%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**947.7**		**68.6**	**8.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**68.6**	**0.0**	**39.5**	**108.1**		**101.7**	en %		**-5.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Grand'Rue 37 - Police locale - 1er étage	N 46°48.185 E 7°09.543	561	grandrue37_1er.spe	6/4/2006 9:45	4770

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	399	26.4	0.08	4.17	8.14E-04	24.6			
Pb-214	351.93	880	12.1	0.18	3.45	1.71E-03	31.2			
Bi-214 (Total U-238)	609.32	789	9.8	0.17	1.94	2.76E-03	30.9	5.47E-01	16.9	
Bi-214	1120.20	183	24.2	0.04	1.06	1.20E-03	30.3			
Bi-214	1764.50	166	17.3	0.03	0.69	1.56E-03	32.4			
Bi-214	2204.10	56	32.6	0.01	0.56	5.63E-04	37.1			
Ac-228 (Total Th-232)	911.07	416	14.0	0.09	1.29	2.07E-03	32.6	7.39E-01	24.1	
Ac-228	968.90	268	17.4	0.06	1.22	1.29E-03	35.9			
Pb-212	238.63	1187	11.3	0.25	5.24	1.73E-03	27.4			
Bi-212	727.33	126	37.8	0.03	1.62	7.49E-04	21.8			
Tl-208	583.19	588	12.9	0.12	2.03	1.76E-03	34.5			
Tl-208	2614.40	309	11.7	0.06	0.48	1.21E-02	11.2			
K-40	1460.83	2188	4.4	0.46	0.82	9.70E-04	577.5	4.80E-02	27.7	R & S
Be-7	477.60				2.50	5.41E-04				105.2
										2.14%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	927.5		68.7	9.1

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	68.7	0.0	39.6	108.3		105.2	en %		-2.9

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Ste-Croix - rez-de-chaussée	**N 46°47.499 E 7°09.309**	**616**	**stecroix_rez.spe**	**10/4/2006 8:15**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	341	40.3	0.07	6.68	1.20E-04	85.1			
Pb-214	295.20	368	23.1	0.07	4.17	8.14E-04	21.7			
Pb-214	351.93	728	11.8	0.15	3.45	1.71E-03	24.7			
Bi-214 (Total U-238)	609.32	693	10.0	0.14	1.94	2.76E-03	25.9	5.47E-01	14.2	
Bi-214	1120.20	188	20.5	0.04	1.06	1.20E-03	29.7			
Bi-214	1764.50	154	17.2	0.03	0.69	1.56E-03	28.6			
Bi-214	2204.10	47	36.2	0.01	0.56	5.63E-04	29.9			
Ac-228 (Total Th-232)	911.07	156	23.7	0.03	1.29	2.07E-03	11.7	7.39E-01	8.6	
Ac-228	968.90	68	47.9	0.01	1.22	1.29E-03	8.7			
Pb-212	238.63	632	17.0	0.13	5.24	1.73E-03	13.9			
Bi-212	727.33	66	47.9	0.01	1.62	7.49E-04	10.9			
Tl-208	583.19	258	21.1	0.05	2.03	1.76E-03	14.4			
Tl-208	2614.40	187	14.7	0.04	0.48	1.21E-02	6.4			
K-40	1460.83	1117	6.3	0.22	0.82	9.70E-04	281.2	4.80E-02	13.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**68.9**
										2.61%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**593.0**		**36.3**	**11.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**36.3**	**0.0**	**40.4**	**76.7**	**68.9**	**en %**	**-10.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Ste-Croix - 4e étage	**N 46°47.499 E 7°09.309**	**635**	**stecroix_4e.spe**	**10/4/2006 9:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	323	25.0	0.06	4.17	8.14E-04	19.0			
Pb-214	351.93	646	13.4	0.13	3.45	1.71E-03	21.9			
Bi-214 (Total U-238)	609.32	601	11.1	0.12	1.94	2.76E-03	22.5	5.47E-01	12.3	
Bi-214	1120.20	159	22.1	0.03	1.06	1.20E-03	25.1			
Bi-214	1764.50	139	19.8	0.03	0.69	1.56E-03	25.9			
Bi-214	2204.10	41	40.6	0.01	0.56	5.63E-04	25.7			
Ac-228 (Total Th-232)	911.07	212	19.3	0.04	1.29	2.07E-03	15.8	7.39E-01	11.7	
Ac-228	968.90	70	43.5	0.01	1.22	1.29E-03	8.9			
Pb-212	238.63	465	21.3	0.09	5.24	1.73E-03	10.3			
Bi-212	727.33	30	78.0	0.01	1.62	7.49E-04	4.9			
Tl-208	583.19	271	18.9	0.05	2.03	1.76E-03	15.2			
Tl-208	2614.40	153	16.8	0.03	0.48	1.21E-02	5.3			
K-40	1460.83	940	6.9	0.19	0.82	9.70E-04	236.7	4.80E-02	11.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**85.7**
										2.62%
Cs-137	661.66	116	35.2	0.02	1.78	5.20E-03	2.5	1.92E-01	0.5	**Incertitude**
						Total :	**437.1**		**35.8**	**12.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**35.3**	**0.5**	**40.7**	**76.6**	**85.7**	en %	**11.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Collège Ste-Croix - 2e étage	**N 46°47.499 E 7°09.309**	**626**	**stecroix_2e.spe**	**10/4/2006 11:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	261	44.9	0.05	6.68	1.20E-04	65.2			
Pb-214	295.20	507	18.6	0.10	4.17	8.14E-04	29.9			
Pb-214	351.93	847	11.4	0.17	3.45	1.71E-03	28.7			
Bi-214 (Total U-238)	609.32	773	10.0	0.15	1.94	2.76E-03	28.9	5.47E-01	15.8	
Bi-214	1120.20	194	20.5	0.04	1.06	1.20E-03	30.6			
Bi-214	1764.50	184	15.8	0.04	0.69	1.56E-03	34.3			
Bi-214	2204.10	53	31.3	0.01	0.56	5.63E-04	33.3			
Ac-228 (Total Th-232)	911.07	220	19.3	0.04	1.29	2.07E-03	16.4	7.39E-01	12.2	
Ac-228	968.90	142	26.5	0.03	1.22	1.29E-03	18.1			
Pb-212	238.63	737	16.3	0.15	5.24	1.73E-03	16.3			
Bi-212	727.33	54	62.0	0.01	1.62	7.49E-04	8.9			
Tl-208	583.19	301	19.1	0.06	2.03	1.76E-03	16.9			
Tl-208	2614.40	227	13.5	0.05	0.48	1.21E-02	7.8			
K-40	1460.83	1230	6.0	0.25	0.82	9.70E-04	309.7	4.80E-02	14.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**76.1**
										2.94%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**645.0**		**42.8**	**11.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**42.8**	**0.0**	**40.6**	**83.4**		**76.1**	**en %**		**-8.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole des Infirmières - rez-de-chaussée	**N 46°47.347 E 7°09.155**	**621**	**Infirmieres_rez.spe**	**11/4/2006 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose amblante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	579	17.9	0.12	4.17	8.14E-04	34.0			
Pb-214	351.93	863	11.8	0.17	3.45	1.71E-03	29.2			
Bi-214 (Total U-238)	609.32	761	9.7	0.15	1.94	2.76E-03	28.4	5.47E-01	15.6	
Bi-214	1120.20	197	21.0	0.04	1.06	1.20E-03	31.1			
Bi-214	1764.50	177	16.8	0.04	0.69	1.56E-03	33.0			
Bi-214	2204.10	49	34.9	0.01	0.56	5.63E-04	30.8			
Ac-228 (Total Th-232)	911.07	299	16.5	0.06	1.29	2.07E-03	22.3	7.39E-01	16.5	
Ac-228	968.90	136	27.5	0.03	1.22	1.29E-03	17.3			
Pb-212	238.63	901	14.1	0.18	5.24	1.73E-03	19.9			
Bi-212	727.33	62	60.1	0.01	1.62	7.49E-04	10.2			
Tl-208	583.19	375	17.0	0.07	2.03	1.76E-03	21.0			
Tl-208	2614.40	257	12.6	0.05	0.48	1.21E-02	8.9			
K-40	1460.83	1565	5.2	0.31	0.82	9.70E-04	394.0	4.80E-02	18.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**79.3**
										2.85%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**680.2**		**51.0**	**10.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition: en nSv/h	naturel	artificiel	cosmique	insitu	R+S	déviation en %	R+S
	51.0	**0.0**	**40.5**	**91.5**	**79.3**		**-13.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
Ecole des Infirmières - 5e étage	**N 46°47.347 E 7°09.155**	**637**	**Infirmieres_5e.spe**	**11/4/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	293	48.6	0.06	6.68	1.20E-04	73.0			
Pb-214	295.20	570	22.3	0.11	4.17	8.14E-04	33.5			
Pb-214	351.93	1122	11.0	0.22	3.45	1.71E-03	38.0			
Bi-214 (Total U-238)	609.32	1099	8.3	0.22	1.94	2.76E-03	41.1	5.47E-01	22.5	
Bi-214	1120.20	266	19.6	0.05	1.06	1.20E-03	42.0			
Bi-214	1764.50	229	15.1	0.05	0.69	1.56E-03	42.8			
Bi-214	2204.10	81	28.1	0.02	0.56	5.63E-04	51.4			
Ac-228 (Total Th-232)	911.07	494	12.5	0.10	1.29	2.07E-03	37.0	7.39E-01	27.3	
Ac-228	968.90	208	25.5	0.04	1.22	1.29E-03	26.5			
Pb-212	238.63	1215	12.8	0.24	5.24	1.73E-03	26.8			
Bi-212	727.33	135	39.3	0.03	1.62	7.49E-04	22.3			
Tl-208	583.19	628	12.7	0.13	2.03	1.76E-03	35.2			
Tl-208	2614.40	409	10.0	0.08	0.48	1.21E-02	14.1			
K-40	1460.83	2589	4.1	0.52	0.82	9.70E-04	652.0	4.80E-02	31.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**125.2**
										2.52%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,135.6**		**81.1**	**8.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**81.1**	**0.0**	**40.8**	**121.9**		**125.2**	en %		**2.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
NH Hotel - 4e étage	**N 46°48.790 E 7°09.134**	**627**	**nhhotel_4e.spe**	**2/5/2006 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	374	35.2	0.07	6.68	1.20E-04	93.4			
Pb-214	295.20	544	20.0	0.11	4.17	8.14E-04	32.0			
Pb-214	351.93	904	10.7	0.18	3.45	1.71E-03	30.6			
Bi-214 (Total U-238)	609.32	931	8.1	0.19	1.94	2.76E-03	34.8	5.47E-01	19.0	
Bi-214	1120.20	207	20.1	0.04	1.06	1.20E-03	32.8			
Bi-214	1764.50	183	16.0	0.04	0.69	1.56E-03	34.1			
Bi-214	2204.10	57	31.8	0.01	0.56	5.63E-04	36.4			
Ac-228 (Total Th-232)	911.07	274	17.1	0.05	1.29	2.07E-03	20.5	7.39E-01	15.1	
Ac-228	968.90	152	25.8	0.03	1.22	1.29E-03	19.3			
Pb-212	238.63	754	16.0	0.15	5.24	1.73E-03	16.6			
Bi-212	727.33	56	59.2	0.01	1.62	7.49E-04	9.2			
Tl-208	583.19	374	16.1	0.07	2.03	1.76E-03	21.0			
Tl-208	2614.40	240	13.1	0.05	0.48	1.21E-02	8.3			
K-40	1460.83	1350	5.6	0.27	0.82	9.70E-04	339.9	4.80E-02	16.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**74.2**
										3.48%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**728.9**		**50.5**	**10.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**50.5**	**0.0**	**40.6**	**91.1**	**74.2**	en %	**-18.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
NH Hotel - 7^e étage	**N 46°48.790 E 7°09.134**	**636**	**nhhotel_7e.spe**	**2/5/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	453	20.5	0.09	4.17	8.14E-04	26.6			
Pb-214	351.93	903	11.4	0.18	3.45	1.71E-03	30.6			
Bi-214 (Total U-238)	609.32	895	8.5	0.18	1.94	2.76E-03	33.5	5.47E-01	18.3	
Bi-214	1120.20	243	18.9	0.05	1.06	1.20E-03	38.5			
Bi-214	1764.50	174	17.1	0.03	0.69	1.56E-03	32.5			
Bi-214	2204.10	59	33.1	0.01	0.56	5.63E-04	37.7			
Ac-228 (Total Th-232)	911.07	276	17.4	0.06	1.29	2.07E-03	20.6	7.39E-01	15.2	
Ac-228	968.90	162	25.1	0.03	1.22	1.29E-03	20.7			
Pb-212	238.63	744	16.8	0.15	5.24	1.73E-03	16.4			
Bi-212	727.33	67	53.1	0.01	1.62	7.49E-04	11.0			
Tl-208	583.19	333	17.8	0.07	2.03	1.76E-03	18.7			
Tl-208	2614.40	239	13.2	0.05	0.48	1.21E-02	8.2			
K-40	1460.83	1452	5.5	0.29	0.82	9.70E-04	365.7	4.80E-02	17.6	**R & S**
Be-7	477.60				2.50	5.41E-04				**75.8**
										2.84%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**660.7**		**51.1**	**10.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**51.1**	**0.0**	**40.7**	**91.8**	**75.8**	**en %**	**-17.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
NH Hotel - 12e étage	**N 46°48.790 E 7°09.134**	**651**	**nhhotel_12e.spe**	**2/5/2006 11:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	302	46.8	0.06	6.68	1.20E-04	75.2			
Pb-214	295.20	551	19.1	0.11	4.17	8.14E-04	32.4			
Pb-214	351.93	930	10.9	0.19	3.45	1.71E-03	31.5			
Bi-214 (Total U-238)	609.32	888	8.7	0.18	1.94	2.76E-03	33.2	5.47E-01	18.2	
Bi-214	1120.20	233	18.7	0.05	1.06	1.20E-03	36.8			
Bi-214	1764.50	192	16.3	0.04	0.69	1.56E-03	35.8			
Bi-214	2204.10	51	34.9	0.01	0.56	5.63E-04	32.4			
Ac-228 (Total Th-232)	911.07	264	18.4	0.05	1.29	2.07E-03	19.8	7.39E-01	14.6	
Ac-228	968.90	137	30.5	0.03	1.22	1.29E-03	17.5			
Pb-212	238.63	895	14.1	0.18	5.24	1.73E-03	19.7			
Bi-212	727.33	89	45.4	0.02	1.62	7.49E-04	14.7			
Tl-208	583.19	393	16.8	0.08	2.03	1.76E-03	22.0			
Tl-208	2614.40	229	13.7	0.05	0.48	1.21E-02	7.9			
K-40	1460.83	1413	5.5	0.28	0.82	9.70E-04	355.8	4.80E-02	17.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**79.2**
										3.20%
Cs-137	661.66	72	52.6	0.01	1.78	5.20E-03	1.5	1.92E-01	0.3	**Incertitude**
						Total :	**734.8**		**50.1**	**10.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**49.8**	**0.3**	**41.0**	**91.1**	**79.2**	en %	**-13.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
NH Hotel - 17ᵉ étage	**N 46°46.790 E 7°09.134**	**666**	**nhhotel_17e.spe**	**2/5/2006 13:00**	**3379**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	331	25.1	0.10	4.17	8.14E-04	28.8			
Pb-214	351.93	719	12.7	0.21	3.45	1.71E-03	36.0			
Bi-214 (Total U-238)	609.32	574	10.7	0.17	1.94	2.76E-03	31.8	5.47E-01	17.4	
Bi-214	1120.20	127	26.4	0.04	1.06	1.20E-03	29.8			
Bi-214	1764.50	125	20.3	0.04	0.69	1.56E-03	34.5			
Bi-214	2204.10	21	61.1	0.01	0.56	5.63E-04	19.7			
Ac-228 (Total Th-232)	911.07	151	25.2	0.04	1.29	2.07E-03	16.7	7.39E-01	12.3	
Ac-228	968.90	86	34.4	0.03	1.22	1.29E-03	16.2			
Pb-212	238.63	434	25.3	0.13	5.24	1.73E-03	14.2			
Bi-212	727.33	51	56.2	0.02	1.62	7.49E-04	12.4			
Tl-208	583.19	220	22.1	0.07	2.03	1.76E-03	18.2			
Tl-208	2614.40	168	15.8	0.05	0.48	1.21E-02	8.6			
K-40	1460.83	956	6.7	0.28	0.82	9.70E-04	356.2	4.80E-02	17.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**90.4**
										3.17%
Cs-137	661.66	38	72.9	0.01	1.78	5.20E-03	1.2	1.92E-01	0.2	**Incertitude**
						Total :	**623.1**		**47.0**	**13.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**46.8**	**0.2**	**41.2**	**88.2**	**90.4**	en %	**2.4**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
bd. de Pérolles 41 - rze-de-chaussée	**N46°47'50.0 E007°09'15.0**	**626**	**perolles41_rez.spe**	**17/7/2006 9:45**	**4438**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	136	78.5	0.03	6.68	1.20E-04	38.3			
Pb-214	295.20	561	18.1	0.13	4.17	8.14E-04	37.2			
Pb-214	351.93	1132	9.7	0.26	3.45	1.71E-03	43.2			
Bi-214 (Total U-238)	609.32	959	8.7	0.22	1.94	2.76E-03	40.4	5.47E-01	22.1	
Bi-214	1120.20	274	17.2	0.06	1.06	1.20E-03	48.8			
Bi-214	1764.50	227	14.3	0.05	0.69	1.56E-03	47.6			
Bi-214	2204.10	52	35.1	0.01	0.56	5.63E-04	37.0			
Ac-228 (Total Th-232)	911.07	397	13.7	0.09	1.29	2.07E-03	33.5	7.39E-01	24.7	
Ac-228	968.90	257	18.0	0.06	1.22	1.29E-03	36.9			
Pb-212	238.63	1354	11.0	0.30	5.24	1.73E-03	33.6			
Bi-212	727.33	126	38.3	0.03	1.62	7.49E-04	23.5			
Tl-208	583.19	619	12.5	0.14	2.03	1.76E-03	39.1			
Tl-208	2614.40	355	10.7	0.08	0.48	1.21E-02	13.8			
K-40	1460.83	1803	4.9	0.41	0.82	9.70E-04	511.3	4.80E-02	24.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**99.5**
										2.31%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**984.0**		**71.3**	**9.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**71.3**	**0.0**	**40.6**	**111.9**		**99.5**	en %		**-11.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
bd. de Pérolles 5 - rez-de-chaussée	**N46°48'51.0 E007°09'52.0**	**627**	**perolles5_rez.spe**	**18/7/2006 8:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	456	22.3	0.09	4.17	8.14E-04	26.8			
Pb-214	351.93	879	11.4	0.18	3.45	1.71E-03	29.8			
Bi-214 (Total U-238)	609.32	748	9.8	0.15	1.94	2.76E-03	28.0	5.47E-01	15.3	
Bi-214	1120.20	146	27.3	0.03	1.06	1.20E-03	23.1			
Bi-214	1764.50	157	17.5	0.03	0.69	1.56E-03	29.3			
Bi-214	2204.10	38	38.6	0.01	0.56	5.63E-04	24.2			
Ac-228 (Total Th-232)	911.07	367	14.2	0.07	1.29	2.07E-03	27.4	7.39E-01	20.3	
Ac-228	968.90	161	26.1	0.03	1.22	1.29E-03	20.5			
Pb-212	238.63	1148	12.2	0.23	5.24	1.73E-03	25.3			
Bi-212	727.33	84	43.1	0.02	1.62	7.49E-04	13.8			
Tl-208	583.19	457	15.0	0.09	2.03	1.76E-03	25.6			
Tl-208	2614.40	309	11.6	0.06	0.48	1.21E-02	10.7			
K-40	1460.83	1578	5.2	0.32	0.82	9.70E-04	397.2	4.80E-02	19.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**77.2**
										3.17%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**681.7**		**54.6**	**9.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**54.6**	**0.0**	**40.6**	**95.2**	**77.2**	en %	**-18.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. des Arsenaux 21 - rez-de-chaussée	**N46°47'53.4 E007°08'59.9**	**630**	**arsenaux21_rez.spe**	**20/7/2006 8:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	213	85.1	0.04	6.68	1.20E-04	53.1			
Pb-214	295.20	430	33.5	0.09	4.17	8.14E-04	25.3			
Pb-214	351.93	900	17.0	0.18	3.45	1.71E-03	30.5			
Bi-214 (Total U-238)	609.32	769	14.3	0.15	1.94	2.76E-03	28.8	5.47E-01	15.7	
Bi-214	1120.20	198	31.0	0.04	1.06	1.20E-03	31.2			
Bi-214	1764.50	183	24.9	0.04	0.69	1.56E-03	34.2			
Bi-214	2204.10	38	62.6	0.01	0.56	5.63E-04	24.3			
Ac-228 (Total Th-232)	911.07	273	26.1	0.05	1.29	2.07E-03	20.4	7.39E-01	15.1	
Ac-228	968.90	165	35.7	0.03	1.22	1.29E-03	21.1			
Pb-212	238.63	1247	15.2	0.25	5.24	1.73E-03	27.5			
Bi-212	727.33	71	72.3	0.01	1.62	7.49E-04	11.6			
Tl-208	583.19	421	22.6	0.08	2.03	1.76E-03	23.6			
Tl-208	2614.40	236	19.8	0.05	0.48	1.21E-02	8.1			
K-40	1460.83	1367	8.5	0.27	0.82	9.70E-04	344.2	4.80E-02	16.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**70.7**
										2.92%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**683.9**		**47.3**	**16.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu	R+S	déviation	R+S
en nSv/h	**47.3**	**0.0**	**40.7**	**88.0**	**70.7**	en %	**-19.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. des Arsenaux 21 - 3e étage	**N46°47'53.4 E007°08'59.9**	**639**	**arsenaux21_3e.spe**	**20/7/2006 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	424	34.5	0.08	4.17	8.14E-04	24.9			
Pb-214	351.93	833	16.9	0.17	3.45	1.71E-03	28.2			
Bi-214 (Total U-238)	609.32	751	14.0	0.15	1.94	2.76E-03	28.1	5.47E-01	15.4	
Bi-214	1120.20	207	29.1	0.04	1.06	1.20E-03	32.7			
Bi-214	1764.50	157	26.5	0.03	0.69	1.56E-03	29.2			
Bi-214	2204.10	47	52.0	0.01	0.56	5.63E-04	29.6			
Ac-228 (Total Th-232)	911.07	307	22.7	0.06	1.29	2.07E-03	23.0	7.39E-01	17.0	
Ac-228	968.90	113	45.8	0.02	1.22	1.29E-03	14.5			
Pb-212	238.63	873	20.2	0.17	5.24	1.73E-03	19.2			
Bi-212	727.33	104	54.9	0.02	1.62	7.49E-04	17.1			
Tl-208	583.19	440	20.9	0.09	2.03	1.76E-03	24.7			
Tl-208	2614.40	222	20.6	0.04	0.48	1.21E-02	7.6			
K-40	1460.83	1282	8.7	0.26	0.82	9.70E-04	322.7	4.80E-02	15.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**72.3**
										3.15%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**601.5**		**47.8**	**15.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**47.8**	**0.0**	**40.8**	**88.6**		**72.3**	en %		**-18.4**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. des Arsenaux 21 - 4e étage	**N46°47'53.4 E007°08'59.9**	**642**	**arsenaux21_4e.spe**	**20/7/2006 11:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	187	87.9	0.04	6.68	1.20E-04	46.6			
Pb-214	295.20	401	36.3	0.08	4.17	8.14E-04	23.6			
Pb-214	351.93	836	17.2	0.17	3.45	1.71E-03	28.3			
Bi-214 (Total U-238)	609.32	782	13.9	0.16	1.94	2.76E-03	29.2	5.47E-01	16.0	
Bi-214	1120.20	99	67.5	0.02	1.06	1.20E-03	15.6			
Bi-214	1764.50	167	25.1	0.03	0.69	1.56E-03	31.1			
Bi-214	2204.10	42	54.1	0.01	0.56	5.63E-04	26.8			
Ac-228 (Total Th-232)	911.07	246	27.9	0.05	1.29	2.07E-03	18.4	7.39E-01	13.6	
Ac-228	968.90	108	52.2	0.02	1.22	1.29E-03	13.7			
Pb-212	238.63	822	21.4	0.16	5.24	1.73E-03	18.1			
Bi-212	727.33	97	55.6	0.02	1.62	7.49E-04	16.0			
Tl-208	583.19	397	23.5	0.08	2.03	1.76E-03	22.3			
Tl-208	2614.40	210	21.0	0.04	0.48	1.21E-02	7.2			
K-40	1460.83	1300	8.6	0.26	0.82	9.70E-04	327.2	4.80E-02	15.7	**R & S**
Be-7	477.60				2.50	5.41E-04				**75.1**
										3.28%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**624.1**		**45.3**	**16.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**45.3**	**0.0**	**40.8**	**86.1**		**75.1**	en %		**-12.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. de la Gare 7 - rez-de-chaussée	**N46°48'11.8 E007°09'75.0**	**625**	**gare7_rez.spe**	**24/7/2006 9:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	262	43.8	0.05	4.17	8.14E-04	15.4			
Pb-214	351.93	509	23.1	0.10	3.45	1.71E-03	17.3			
Bi-214 (Total U-238)	609.32	438	19.3	0.09	1.94	2.76E-03	16.4	5.47E-01	9.0	
Bi-214	1120.20	111	42.7	0.02	1.06	1.20E-03	17.6			
Bi-214	1764.50	102	33.3	0.02	0.69	1.56E-03	19.0			
Bi-214	2204.10	20	91.4	0.00	0.56	5.63E-04	12.8			
Ac-228 (Total Th-232)	911.07	174	30.5	0.03	1.29	2.07E-03	13.0	7.39E-01	9.6	
Ac-228	968.90	108	44.6	0.02	1.22	1.29E-03	13.8			
Pb-212	238.63	524	28.7	0.10	5.24	1.73E-03	11.6			
Bi-212	727.33	62	70.4	0.01	1.62	7.49E-04	10.3			
Tl-208	583.19	197	36.5	0.04	2.03	1.76E-03	11.0			
Tl-208	2614.40	165	24.3	0.03	0.48	1.21E-02	5.7			
K-40	1460.83	946	10.2	0.19	0.82	9.70E-04	238.2	4.80E-02	11.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**59.5**
										3.90%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**402.1**		**30.0**	**19.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation	R+S
en nSv/h	**30.0**	**0.0**	**40.6**	**70.6**		**59.5**	en %	**-15.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. de la Gare 7 - 4e étage	N46°48'11.8 E007°09'75.0	635	gare7_4e.spe	24/7/2006 11:20	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	266	45.6	0.05	4.17	8.14E-04	15.6			
Pb-214	351.93	392	29.2	0.08	3.45	1.71E-03	13.3			
Bi-214 (Total U-238)	609.32	423	20.8	0.08	1.94	2.76E-03	15.8	5.47E-01	8.7	
Bi-214	1120.20	135	37.6	0.03	1.06	1.20E-03	21.4			
Bi-214	1764.50	121	30.1	0.02	0.69	1.56E-03	22.6			
Bi-214	2204.10	22	82.8	0.00	0.56	5.63E-04	13.8			
Ac-228 (Total Th-232)	911.07	142	38.9	0.03	1.29	2.07E-03	10.6	7.39E-01	7.9	
Ac-228	968.90	77	59.3	0.02	1.22	1.29E-03	9.8			
Pb-212	238.63	301	50.9	0.06	5.24	1.73E-03	6.6			
Bi-212	727.33	47	81.3	0.01	1.62	7.49E-04	7.7			
Tl-208	583.19	226	33.2	0.05	2.03	1.76E-03	12.7			
Tl-208	2614.40	192	22.3	0.04	0.48	1.21E-02	6.6			
K-40	1460.83	976	10.0	0.20	0.82	9.70E-04	245.6	4.80E-02	11.8	R & S
Be-7	477.60				2.50	5.41E-04				67.8
										4.42%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	402.3		28.3	21.3

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	28.3	0.0	40.7	69.0		67.8	en %		-1.8

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue Joseph-Reichlen 2 - rez-de-chaussée	**N46°47'52.7 E007°09'10.0**	**626**	**Joseph-reichlen2_rez.spe**	**25/7/2006 8:20**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	440	32.5	0.09	4.17	8.14E-04	25.9			
Pb-214	351.93	716	20.1	0.14	3.45	1.71E-03	24.2			
Bi-214 (Total U-238)	609.32	686	15.7	0.14	1.94	2.76E-03	25.6	5.47E-01	14.0	
Bi-214	1120.20	168	36.0	0.03	1.06	1.20E-03	26.6			
Bi-214	1764.50	139	28.8	0.03	0.69	1.56E-03	26.0			
Bi-214	2204.10	27	77.0	0.01	0.56	5.63E-04	17.1			
Ac-228 (Total Th-232)	911.07	255	28.0	0.05	1.29	2.07E-03	19.1	7.39E-01	14.1	
Ac-228	968.90	204	31.0	0.04	1.22	1.29E-03	26.0			
Pb-212	238.63	900	20.4	0.18	5.24	1.73E-03	19.9			
Bi-212	727.33	98	61.3	0.02	1.62	7.49E-04	16.1			
Tl-208	583.19	431	22.7	0.09	2.03	1.76E-03	24.2			
Tl-208	2614.40	241	19.6	0.05	0.48	1.21E-02	8.3			
K-40	1460.83	1527	8.0	0.31	0.82	9.70E-04	384.6	4.80E-02	18.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**74.5**
										3.84%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**643.5**		**46.6**	**16.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**46.6**	**0.0**	**40.6**	**87.2**		**74.5**	en %		**-14.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue Joseph-Reichlen 2 - 3ᵉ étage	**N46°47'52.7 E007°09'10.0**	**635**	**Joseph-reichlen2_3e.spe**	**25/7/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	472	36.8	0.09	4.17	8.14E-04	27.8			
Pb-214	351.93	1277	14.5	0.26	3.45	1.71E-03	43.2			
Bi-214 (Total U-238)	609.32	1035	12.6	0.21	1.94	2.76E-03	38.7	5.47E-01	21.2	
Bi-214	1120.20	255	30.2	0.05	1.06	1.20E-03	40.3			
Bi-214	1764.50	240	20.4	0.05	0.69	1.56E-03	44.8			
Bi-214	2204.10	53	53.3	0.01	0.56	5.63E-04	33.4			
Ac-228 (Total Th-232)	911.07	464	19.5	0.09	1.29	2.07E-03	34.7	7.39E-01	25.6	
Ac-228	968.90	306	26.0	0.06	1.22	1.29E-03	39.0			
Pb-212	238.63	1765	14.8	0.35	5.24	1.73E-03	38.9			
Bi-212	727.33	160	47.7	0.03	1.62	7.49E-04	26.4			
Tl-208	583.19	691	18.4	0.14	2.03	1.76E-03	38.7			
Tl-208	2614.40	426	14.8	0.09	0.48	1.21E-02	14.7			
K-40	1460.83	2399	6.4	0.48	0.82	9.70E-04	604.1	4.80E-02	29.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**108.9**
										2.26%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,024.8**		**75.8**	**12.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**75.8**	**0.0**	**40.7**	**116.5**		**108.9**	en %		**-6.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue Joseph-Reichlen 2 - 6ᵉ étage	**N46°47'52.7 E007°09'10.0**	**644**	**Joseph-reichlen2_6e.spe**	**25/7/2006 11:30**	**4801**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	225	64.7	0.05	6.68	1.20E-04	58.5			
Pb-214	295.20	601	20.2	0.13	4.17	8.14E-04	36.8			
Pb-214	351.93	997	11.2	0.21	3.45	1.71E-03	35.2			
Bi-214 (Total U-238)	609.32	1062	8.4	0.22	1.94	2.76E-03	41.4	5.47E-01	22.6	
Bi-214	1120.20	264	18.7	0.06	1.06	1.20E-03	43.5			
Bi-214	1764.50	211	15.0	0.04	0.69	1.56E-03	41.0			
Bi-214	2204.10	73	29.6	0.02	0.56	5.63E-04	47.9			
Ac-228 (Total Th-232)	911.07	484	12.7	0.10	1.29	2.07E-03	37.6	7.39E-01	27.8	
Ac-228	968.90	274	18.3	0.06	1.22	1.29E-03	36.5			
Pb-212	238.63	1523	9.5	0.32	5.24	1.73E-03	35.0			
Bi-212	727.33	78	60.3	0.02	1.62	7.49E-04	13.4			
Tl-208	583.19	676	11.2	0.14	2.03	1.76E-03	39.4			
Tl-208	2614.40	400	10.1	0.08	0.48	1.21E-02	14.4			
K-40	1460.83	2379	4.2	0.50	0.82	9.70E-04	623.8	4.80E-02	29.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**112.8**
										2.95%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,104.4**		**80.4**	**8.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**80.4**	**0.0**	**40.9**	**121.3**	**112.8**	en %	**-7.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 9 - 2^e sous-sol	**N46°47'45.5 E007°08'25.0**	**658**	**beaumont9_2ss.spe**	**9/8/2006 8:10**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	506	18.9	0.10	4.17	8.14E-04	29.8			
Pb-214	351.93	980	10.0	0.20	3.45	1.71E-03	33.2			
Bi-214 (Total U-238)	609.32	796	9.5	0.16	1.94	2.76E-03	29.8	5.47E-01	16.3	
Bi-214	1120.20	204	20.3	0.04	1.06	1.20E-03	32.2			
Bi-214	1764.50	198	15.4	0.04	0.69	1.56E-03	36.9			
Bi-214	2204.10	62	29.6	0.01	0.56	5.63E-04	39.4			
Ac-228 (Total Th-232)	911.07	310	16.2	0.06	1.29	2.07E-03	23.2	7.39E-01	17.1	
Ac-228	968.90	175	23.5	0.04	1.22	1.29E-03	22.4			
Pb-212	238.63	1107	11.3	0.22	5.24	1.73E-03	24.4			
Bi-212	727.33	62	56.1	0.01	1.62	7.49E-04	10.2			
Tl-208	583.19	474	14.0	0.09	2.03	1.76E-03	26.6			
Tl-208	2614.40	255	12.7	0.05	0.48	1.21E-02	8.8			
K-40	1460.83	1729	5.0	0.35	0.82	9.70E-04	435.2	4.80E-02	20.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**74.4**
										3.31%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**752.0**		**54.3**	**9.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**54.3**	**0.0**	**41.1**	**95.4**		**74.4**	**en %**		**-22.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 9 - 5^e étage	**N46°47'45.5 E007°08'25.0**	**686**	**beaumont9_5e.spe**	**9/8/2006 9:45**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	151	65.3	0.03	6.68	1.20E-04	37.6			
Pb-214	295.20	514	18.8	0.10	4.17	8.14E-04	30.3			
Pb-214	351.93	709	12.1	0.14	3.45	1.71E-03	24.0			
Bi-214 (Total U-238)	609.32	692	9.7	0.14	1.94	2.76E-03	25.9	5.47E-01	14.2	
Bi-214	1120.20	209	17.3	0.04	1.06	1.20E-03	33.1			
Bi-214	1764.50	139	18.1	0.03	0.69	1.56E-03	25.8			
Bi-214	2204.10	53	31.3	0.01	0.56	5.63E-04	33.4			
Ac-228 (Total Th-232)	911.07	180	20.8	0.04	1.29	2.07E-03	13.4	7.39E-01	9.9	
Ac-228	968.90	87	34.7	0.02	1.22	1.29E-03	11.2			
Pb-212	238.63	551	18.7	0.11	5.24	1.73E-03	12.1			
Bi-212	727.33	56	61.0	0.01	1.62	7.49E-04	9.2			
Tl-208	583.19	287	19.1	0.06	2.03	1.76E-03	16.1			
Tl-208	2614.40	194	14.6	0.04	0.48	1.21E-02	6.7			
K-40	1460.83	914	6.9	0.18	0.82	9.70E-04	230.2	4.80E-02	11.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**60.8**
										4.29%
Cs-137	661.66	31	83.9	0.01	1.78	5.20E-03	0.7	1.92E-01	0.1	**Incertitude**
						Total :	**508.9**		**35.2**	**11.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**35.1**	**0.1**	**41.5**	**76.8**		**60.8**	**en %**		**-20.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 9 - 12^{e} étage	**N46°47'45.5 E007°08'25.0**	**704**	**beaumont9_12e.spe**	**9/8/2006 11:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	193	54.7	0.04	6.68	1.20E-04	48.2			
Pb-214	295.20	421	20.9	0.08	4.17	8.14E-04	24.8			
Pb-214	351.93	638	13.5	0.13	3.45	1.71E-03	21.6			
Bi-214 (Total U-238)	609.32	703	9.6	0.14	1.94	2.76E-03	26.3	5.47E-01	14.4	
Bi-214	1120.20	168	22.1	0.03	1.06	1.20E-03	26.6			
Bi-214	1764.50	162	17.3	0.03	0.69	1.56E-03	30.3			
Bi-214	2204.10	37	38.7	0.01	0.56	5.63E-04	23.4			
Ac-228 (Total Th-232)	911.07	184	21.2	0.04	1.29	2.07E-03	13.7	7.39E-01	10.2	
Ac-228	968.90	67	43.2	0.01	1.22	1.29E-03	8.6			
Pb-212	238.63	511	20.6	0.10	5.24	1.73E-03	11.3			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	280	17.5	0.06	2.03	1.76E-03	15.7			
Tl-208	2614.40	177	15.4	0.04	0.48	1.21E-02	6.1			
K-40	1460.83	870	7.2	0.17	0.82	9.70E-04	219.1	4.80E-02	10.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**73.7**
										3.28%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**475.7**		**35.1**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition: en nSv/h	naturel	artificiel	cosmique	insitu		R+S	déviation en %		R+S
	35.1	**0.0**	**41.8**	**76.9**		**73.7**			**-4.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. du Châtelet 8 - rez-de-chaussée	**N46°47'49.9 E007°08'37.3**	**647**	**chatelet8_rez.spe**	**10/8/2006 9:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	362	25.7	0.07	4.17	8.14E-04	21.3			
Pb-214	351.93	580	14.8	0.12	3.45	1.71E-03	19.7			
Bi-214 (Total U-238)	609.32	626	11.0	0.13	1.94	2.76E-03	23.4	5.47E-01	12.8	
Bi-214	1120.20	226	19.0	0.05	1.06	1.20E-03	35.7			
Bi-214	1764.50	138	19.0	0.03	0.69	1.56E-03	25.8			
Bi-214	2204.10	49	34.9	0.01	0.56	5.63E-04	31.1			
Ac-228 (Total Th-232)	911.07	274	17.1	0.05	1.29	2.07E-03	20.5	7.39E-01	15.1	
Ac-228	968.90	180	23.4	0.04	1.22	1.29E-03	23.0			
Pb-212	238.63	839	13.8	0.17	5.24	1.73E-03	18.5			
Bi-212	727.33	64	63.5	0.01	1.62	7.49E-04	10.5			
Tl-208	583.19	334	17.3	0.07	2.03	1.76E-03	18.7			
Tl-208	2614.40	285	12.0	0.06	0.48	1.21E-02	9.8			
K-40	1460.83	1605	5.2	0.32	0.82	9.70E-04	404.0	4.80E-02	19.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**76.1**
										2.76%
Cs-137	661.66	75	54.4	0.02	1.78	5.20E-03	1.6	1.92E-01	0.3	**Incertitude**
						Total :	**662.0**		**47.7**	**10.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**47.3**	**0.3**	**40.9**	**88.6**		**76.1**	en %		**-14.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. du Châtelet 8 - 6e étage	**N46°47'49.9 E007°08'37.3**	**677**	**chatelet8_6e.spe**	**10/8/2006 11:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	243	55.9	0.05	6.68	1.20E-04	60.6			
Pb-214	295.20	512	22.8	0.10	4.17	8.14E-04	30.1			
Pb-214	351.93	1014	11.7	0.20	3.45	1.71E-03	34.4			
Bi-214 (Total U-238)	609.32	927	9.4	0.19	1.94	2.76E-03	34.7	5.47E-01	19.0	
Bi-214	1120.20	237	21.3	0.05	1.06	1.20E-03	37.5			
Bi-214	1764.50	217	15.4	0.04	0.69	1.56E-03	40.5			
Bi-214	2204.10	64	33.9	0.01	0.56	5.63E-04	40.5			
Ac-228 (Total Th-232)	911.07	428	13.8	0.09	1.29	2.07E-03	32.0	7.39E-01	23.6	
Ac-228	968.90	254	19.1	0.05	1.22	1.29E-03	32.4			
Pb-212	238.63	1647	10.1	0.33	5.24	1.73E-03	36.3			
Bi-212	727.33	154	35.4	0.03	1.62	7.49E-04	25.4			
Tl-208	583.19	696	11.6	0.14	2.03	1.76E-03	39.0			
Tl-208	2614.40	400	10.1	0.08	0.48	1.21E-02	13.8			
K-40	1460.83	2591	4.1	0.52	0.82	9.70E-04	652.3	4.80E-02	31.3	**R & S**
Be-7	477.60				2.50	5.41E-04				**105.7**
										2.47%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,109.5**		**73.9**	**8.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	**73.9**	**0.0**	**41.4**	**115.3**		**105.7**	en %		**-8.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. du Châtelet 8 - 12^e étage	N46°47'49.9 E007°08'37.3	707	chatelet8_12e.spe	10/8/2006 12:30	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	513	23.8	0.10	4.17	8.14E-04	30.2			
Pb-214	351.93	1051	11.1	0.21	3.45	1.71E-03	35.6			
Bi-214 (Total U-238)	609.32	1028	8.6	0.21	1.94	2.76E-03	38.4	5.47E-01	21.0	
Bi-214	1120.20	280	18.6	0.06	1.06	1.20E-03	44.2			
Bi-214	1764.50	220	14.9	0.04	0.69	1.56E-03	41.0			
Bi-214	2204.10	60	36.0	0.01	0.56	5.63E-04	38.0			
Ac-228 (Total Th-232)	911.07	476	13.1	0.10	1.29	2.07E-03	35.6	7.39E-01	26.3	
Ac-228	968.90	281	17.5	0.06	1.22	1.29E-03	35.9			
Pb-212	238.63	1477	10.9	0.30	5.24	1.73E-03	32.6			
Bi-212	727.33	108	44.6	0.02	1.62	7.49E-04	17.8			
Tl-208	583.19	682	11.9	0.14	2.03	1.76E-03	38.3			
Tl-208	2614.40	422	9.8	0.08	0.48	1.21E-02	14.6			
K-40	1460.83	2350	4.3	0.47	0.82	9.70E-04	591.7	4.80E-02	28.4	R & S
Be-7	477.60				2.50	5.41E-04				115.1
										3.36%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	993.9		75.7	8.6

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	75.7	0.0	41.9	117.6	115.1	en %	-2.1

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 14 - rez-de-chaussée	N46°47'47.8 E007°08'31.2	651	beaumont14_rez.spe	11/8/2006 8:15	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	155	65.9	0.03	6.68	1.20E-04	38.6			
Pb-214	295.20	336	28.7	0.07	4.17	8.14E-04	19.8			
Pb-214	351.93	842	11.0	0.17	3.45	1.71E-03	28.5			
Bi-214 (Total U-238)	609.32	754	9.6	0.15	1.94	2.76E-03	28.2	5.47E-01	15.4	
Bi-214	1120.20	184	22.3	0.04	1.06	1.20E-03	29.1			
Bi-214	1764.50	163	17.6	0.03	0.69	1.56E-03	30.5			
Bi-214	2204.10	71	26.3	0.01	0.56	5.63E-04	45.1			
Ac-228 (Total Th-232)	911.07	263	17.8	0.05	1.29	2.07E-03	19.7	7.39E-01	14.5	
Ac-228	968.90	107	33.4	0.02	1.22	1.29E-03	13.6			
Pb-212	238.63	820	14.5	0.16	5.24	1.73E-03	18.1			
Bi-212	727.33	61	54.0	0.01	1.62	7.49E-04	10.1			
Tl-208	583.19	324	17.2	0.06	2.03	1.76E-03	18.2			
Tl-208	2614.40	212	13.9	0.04	0.48	1.21E-02	7.3			
K-40	1460.83	1353	5.6	0.27	0.82	9.70E-04	340.8	4.80E-02	16.4	R & S
Be-7	477.60				2.50	5.41E-04				68.5
										3.36%
Cs-137	661.66	48	67.6	0.01	1.78	5.20E-03	1.0	1.92E-01	0.2	Incertitude
						Total :	647.5		46.5	10.7

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition: en nSv/h	naturel	artificiel	cosmique	insitu	R+S	déviation en %	R+S
	46.3	0.2	41.0	87.5	68.5		-21.7

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 14 - 7ᵉ étage	**N46°47'47.8 E007°08'31.2**	**686**	**beaumont14_7e.spe**	**11/8/2006 9:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	219	48.3	0.04	6.68	1.20E-04	54.7			
Pb-214	295.20	397	22.2	0.08	4.17	8.14E-04	23.4			
Pb-214	351.93	732	12.3	0.15	3.45	1.71E-03	24.8			
Bi-214 (Total U-238)	609.32	637	11.1	0.13	1.94	2.76E-03	23.8	5.47E-01	13.0	
Bi-214	1120.20	213	19.2	0.04	1.06	1.20E-03	33.7			
Bi-214	1764.50	159	17.8	0.03	0.69	1.56E-03	29.6			
Bi-214	2204.10	40	40.2	0.01	0.56	5.63E-04	25.6			
Ac-228 (Total Th-232)	911.07	223	20.3	0.04	1.29	2.07E-03	16.7	7.39E-01	12.3	
Ac-228	968.90	110	31.3	0.02	1.22	1.29E-03	14.0			
Pb-212	238.63	414	27.6	0.08	5.24	1.73E-03	9.1			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	307	19.3	0.06	2.03	1.76E-03	17.2			
Tl-208	2614.40	204	14.3	0.04	0.48	1.21E-02	7.0			
K-40	1460.83	1162	6.2	0.23	0.82	9.70E-04	292.6	4.80E-02	14.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**69.5**
										2.99%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**572.3**		**39.4**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**39.4**	**0.0**	**41.5**	**80.9**		**69.5**	en %		**-14.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Beaumont 14 - 15ᵉ étage	**N46°47'47.8 E007°08'31.2**	**716**	**beaumont14_15e.spe**	**11/8/2006 11:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	150	74.2	0.03	6.43	1.30E-04	35.9			
Ra-226	186.20	144	68.5	0.03	6.68	1.20E-04	36.0			
Pb-214	295.20	357	25.1	0.07	4.17	8.14E-04	21.0			
Pb-214	351.93	687	13.0	0.14	3.45	1.71E-03	23.3			
Bi-214 (Total U-238)	609.32	658	10.5	0.13	1.94	2.76E-03	24.6	5.47E-01	13.5	
Bi-214	1120.20	67	51.8	0.01	1.06	1.20E-03	10.6			
Bi-214	1764.50	162	17.5	0.03	0.69	1.56E-03	30.1			
Bi-214	2204.10	52	31.4	0.01	0.56	5.63E-04	33.3			
Ac-228 (Total Th-232)	911.07	226	20.3	0.05	1.29	2.07E-03	16.9	7.39E-01	12.5	
Ac-228	968.90	144	25.2	0.03	1.22	1.29E-03	18.3			
Pb-212	238.63	662	17.7	0.13	5.24	1.73E-03	14.6			
Bi-212	727.33	60	56.5	0.01	1.62	7.49E-04	9.8			
Tl-208	583.19	359	17.0	0.07	2.03	1.76E-03	20.1			
Tl-208	2614.40	226	13.8	0.05	0.48	1.21E-02	7.8			
K-40	1460.83	1257	5.9	0.25	0.82	9.70E-04	316.5	4.80E-02	15.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**81.6**
										4.07%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**618.8**		**41.1**	**11.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**41.1**	**0.0**	**42.0**	**83.2**		**81.6**	en %		**-1.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue de la Carrière 28 - 2e sous-sol	**N46°48'11.6 E007°08'40.9**	**642**	**carriere28_2ss.spe**	**15/8/2006 8:10**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	155	71.0	0.03	6.43	1.30E-04	37.2			
Ra-226	186.20	163	65.1	0.03	6.68	1.20E-04	40.6			
Pb-214	295.20	467	20.0	0.09	4.17	8.14E-04	27.5			
Pb-214	351.93	834	10.7	0.17	3.45	1.71E-03	28.3			
Bi-214 (Total U-238)	609.32	785	9.1	0.16	1.94	2.76E-03	29.3	5.47E-01	16.0	
Bi-214	1120.20	189	21.8	0.04	1.06	1.20E-03	30.0			
Bi-214	1764.50	174	16.2	0.03	0.69	1.56E-03	32.4			
Bi-214	2204.10	41	37.9	0.01	0.56	5.63E-04	25.8			
Ac-228 (Total Th-232)	911.07	249	18.7	0.05	1.29	2.07E-03	18.6	7.39E-01	13.8	
Ac-228	968.90	181	22.5	0.04	1.22	1.29E-03	23.0			
Pb-212	238.63	1004	12.5	0.20	5.24	1.73E-03	22.1			
Bi-212	727.33	77	44.1	0.02	1.62	7.49E-04	12.7			
Tl-208	583.19	371	16.6	0.07	2.03	1.76E-03	20.8			
Tl-208	2614.40	233	13.2	0.05	0.48	1.21E-02	8.0			
K-40	1460.83	1388	5.5	0.28	0.82	9.70E-04	349.5	4.80E-02	16.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**64.6**
										3.62%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**705.7**		**46.6**	**10.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**46.6**	**0.0**	**40.8**	**87.4**		**64.6**	en %		**-26.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue de la Carrière 28 - rez-de-chaussée	**N46°48'11.6 E007°08'40.9**	**652**	**carriere28_rez.spe**	**15/8/2006 9:35**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	468	19.4	0.09	4.17	8.14E-04	27.5			
Pb-214	351.93	715	12.4	0.14	3.45	1.71E-03	24.2			
Bi-214 (Total U-238)	609.32	680	10.1	0.14	1.94	2.76E-03	25.4	5.47E-01	13.9	
Bi-214	1120.20	164	23.0	0.03	1.06	1.20E-03	26.0			
Bi-214	1764.50	148	18.6	0.03	0.69	1.56E-03	27.5			
Bi-214	2204.10	41	38.2	0.01	0.56	5.63E-04	26.3			
Ac-228 (Total Th-232)	911.07	237	18.9	0.05	1.29	2.07E-03	17.7	7.39E-01	13.1	
Ac-228	968.90	129	29.3	0.03	1.22	1.29E-03	16.5			
Pb-212	238.63	929	12.7	0.19	5.24	1.73E-03	20.5			
Bi-212	727.33	52	65.9	0.01	1.62	7.49E-04	8.5			
Tl-208	583.19	293	17.5	0.06	2.03	1.76E-03	16.4			
Tl-208	2614.40	187	15.0	0.04	0.48	1.21E-02	6.5			
K-40	1460.83	1167	6.2	0.23	0.82	9.70E-04	293.9	4.80E-02	14.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**68.2**
										2.31%
Cs-137	661.66	42	66.2	0.01	1.78	5.20E-03	0.9	1.92E-01	0.2	**Incertitude**
						Total :	**537.0**		**41.3**	**11.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**41.1**	**0.2**	**41.0**	**82.3**	**68.2**	en %	**-17.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue de la Carrière 28 - 7ᵉ étage	**N46°48'11.6 E007°08'40.9**	**687**	**carriere28_7e.spe**	**15/8/2006 11:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	454	21.4	0.09	4.17	8.14E-04	26.7			
Pb-214	351.93	713	13.2	0.14	3.45	1.71E-03	24.1			
Bi-214 (Total U-238)	609.32	697	9.8	0.14	1.94	2.76E-03	26.1	5.47E-01	14.3	
Bi-214	1120.20	155	25.6	0.03	1.06	1.20E-03	24.6			
Bi-214	1764.50	140	18.9	0.03	0.69	1.56E-03	26.2			
Bi-214	2204.10	41	40.5	0.01	0.56	5.63E-04	25.7			
Ac-228 (Total Th-232)	911.07	224	20.4	0.04	1.29	2.07E-03	16.8	7.39E-01	12.4	
Ac-228	968.90	153	25.4	0.03	1.22	1.29E-03	19.5			
Pb-212	238.63	784	15.4	0.16	5.24	1.73E-03	17.3			
Bi-212	727.33	92	40.4	0.02	1.62	7.49E-04	15.2			
Tl-208	583.19	344	18.0	0.07	2.03	1.76E-03	19.3			
Tl-208	2614.40	222	13.7	0.04	0.48	1.21E-02	7.7			
K-40	1460.83	1426	5.5	0.29	0.82	9.70E-04	359.1	4.80E-02	17.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**87.6**
										2.81%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**608.3**		**43.9**	**11.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nGy/h	**43.9**	**0.0**	**41.5**	**85.4**		**87.6**	en %		**2.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. de Beauregadrd 13 - rez-de-chaussée	**N46°48'81.0 E007°08'45.4**	**633**	**beauregard13_rez.spe**	**16/8/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	120	78.7	0.02	6.68	1.20E-04	30.0			
Pb-214	295.20	245	35.1	0.05	4.17	8.14E-04	14.4			
Pb-214	351.93	657	12.9	0.13	3.45	1.71E-03	22.3			
Bi-214 (Total U-238)	609.32	627	10.7	0.13	1.94	2.76E-03	23.4	5.47E-01	12.8	
Bi-214	1120.20	179	20.4	0.04	1.06	1.20E-03	28.4			
Bi-214	1764.50	135	19.3	0.03	0.69	1.56E-03	25.2			
Bi-214	2204.10	33	43.9	0.01	0.56	5.63E-04	21.0			
Ac-228 (Total Th-232)	911.07	224	19.9	0.04	1.29	2.07E-03	16.8	7.39E-01	12.4	
Ac-228	968.90	114	31.5	0.02	1.22	1.29E-03	14.6			
Pb-212	238.63	821	14.5	0.16	5.24	1.73E-03	18.1			
Bi-212	727.33	59	56.8	0.01	1.62	7.49E-04	9.8			
Tl-208	583.19	344	16.3	0.07	2.03	1.76E-03	19.3			
Tl-208	2614.40	218	13.7	0.04	0.48	1.21E-02	7.5			
K-40	1460.83	1443	5.4	0.29	0.82	9.70E-04	363.2	4.80E-02	17.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**70.1**
										2.94%
Cs-137	661.66	34	80.4	0.01	1.78	5.20E-03	0.7	1.92E-01	0.1	**Incertitude**
						Total :	**614.0**		**42.8**	**11.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**42.6**	**0.1**	**40.7**	**83.5**	**70.1**	en %	**-16.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. de Beauregard 13 - 3ᵉ étage	**N46°48'81.0 E007°08'45.4**	**652**	**beauregard13_3e.spe**	**16/8/2006 10:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	316	25.9	0.06	4.17	8.14E-04	18.6			
Pb-214	351.93	641	13.4	0.13	3.45	1.71E-03	21.7			
Bi-214 (Total U-238)	609.32	612	11.3	0.12	1.94	2.76E-03	22.9	5.47E-01	12.5	
Bi-214	1120.20	150	24.0	0.03	1.06	1.20E-03	23.7			
Bi-214	1764.50				0.69	1.56E-03				
Bi-214	2204.10				0.56	5.63E-04				
Ac-228 (Total Th-232)	911.07	202	19.0	0.04	1.29	2.07E-03	15.1	7.39E-01	11.2	
Ac-228	968.90	90	36.2	0.02	1.22	1.29E-03	11.4			
Pb-212	238.63	480	23.3	0.10	5.24	1.73E-03	10.6			
Bi-212	727.33	75	43.4	0.01	1.62	7.49E-04	12.3			
Tl-208	583.19	327	17.3	0.07	2.03	1.76E-03	18.3			
Tl-208	2614.40				0.48	1.21E-02				
K-40	1460.83	1150	6.1	0.23	0.82	9.70E-04	289.6	4.80E-02	13.9	**R & S**
Be-7	477.60				2.50	5.41E-04				78.5
										3.61%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**444.4**		**37.6**	**11.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**37.6**	**0.0**	**41.0**	**78.6**		**78.5**	en %		**-0.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. de Beauregard 13 - 6ᵉ étage	**N46°48'81.0 E007°08'45.4**	**655**	**beauregard13_6e.spe**	**16/8/2006 11:00**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	336	25.2	0.07	4.17	8.14E-04	19.8			
Pb-214	351.93	678	12.9	0.14	3.45	1.71E-03	23.0			
Bi-214 (Total U-238)	609.32	576	11.4	0.12	1.94	2.76E-03	21.5	5.47E-01	11.8	
Bi-214	1120.20	159	22.6	0.03	1.06	1.20E-03	25.2			
Bi-214	1764.50	77	36.2	0.02	0.69	1.56E-03	14.4			
Bi-214	2204.10	43	33.4	0.01	0.56	5.63E-04	27.6			
Ac-228 (Total Th-232)	911.07	208	19.5	0.04	1.29	2.07E-03	15.5	7.39E-01	11.5	
Ac-228	968.90	85	42.5	0.02	1.22	1.29E-03	10.9			
Pb-212	238.63	463	22.0	0.09	5.24	1.73E-03	10.2			
Bi-212	727.33	56	58.4	0.01	1.62	7.49E-04	9.2			
Tl-208	583.19	213	24.4	0.04	2.03	1.76E-03	11.9			
Tl-208	2614.40	190	14.7	0.04	0.48	1.21E-02	6.5			
K-40	1460.83	1060	6.4	0.21	0.82	9.70E-04	266.8	4.80E-02	12.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**78.5**
										3.61%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**462.5**		**36.1**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**Insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**36.1**	**0.0**	**41.0**	**77.1**		**78.5**	**en %**		**1.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Gruyère 17 - rez-de-chaussée	**N46°47'44.6 E007°08'33.1**	**657**	**gruyere17_rez.spe**	**23/8/2006 8:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	250	51.4	0.05	6.68	1.20E-04	62.4			
Pb-214	295.20	592	17.0	0.12	4.17	8.14E-04	34.9			
Pb-214	351.93	1006	10.1	0.20	3.45	1.71E-03	34.1			
Bi-214 (Total U-238)	609.32	968	8.5	0.19	1.94	2.76E-03	36.2	5.47E-01	19.8	
Bi-214	1120.20	212	20.4	0.04	1.06	1.20E-03	33.6			
Bi-214	1764.50	203	15.8	0.04	0.69	1.56E-03	37.9			
Bi-214	2204.10	53	34.1	0.01	0.56	5.63E-04	33.6			
Ac-228 (Total Th-232)	911.07	321	16.4	0.06	1.29	2.07E-03	24.0	7.39E-01	17.7	
Ac-228	968.90	205	20.7	0.04	1.22	1.29E-03	26.1			
Pb-212	238.63	1172	11.8	0.23	5.24	1.73E-03	25.8			
Bi-212	727.33	116	39.1	0.02	1.62	7.49E-04	19.1			
Tl-208	583.19	503	13.1	0.10	2.03	1.76E-03	28.2			
Tl-208	2614.40	297	11.7	0.06	0.48	1.21E-02	10.2			
K-40	1460.83	1789	4.9	0.36	0.82	9.70E-04	450.4	4.80E-02	21.6	**R & S**
Be-7	477.60				2.50	5.41E-04				83
										2.46%
Cs-137	661.66	43	82.3	0.01	1.78	5.20E-03	0.9	1.92E-01	0.2	**Incertitude**
						Total :	**856.5**		**59.3**	**9.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nGy/h	59.1	0.2	41.1	100.4		83.0	en %		-17.3

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Gruyère 17 - 7ᵉ étage	**N46°47'44.6 E007°08'33.1**	**675**	**gruyere17_7e.spe**	**23/8/2006 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	210	55.6	0.04	6.68	1.20E-04	52.4			
Pb-214	295.20	463	21.9	0.09	4.17	8.14E-04	27.3			
Pb-214	351.93	773	13.0	0.15	3.45	1.71E-03	26.2			
Bi-214 (Total U-238)	609.32	802	9.6	0.16	1.94	2.76E-03	30.0	5.47E-01	16.4	
Bi-214	1120.20	201	21.7	0.04	1.06	1.20E-03	31.7			
Bi-214	1764.50	184	16.5	0.04	0.69	1.56E-03	34.3			
Bi-214	2204.10	30	52.0	0.01	0.56	5.63E-04	19.0			
Ac-228 (Total Th-232)	911.07	305	16.8	0.06	1.29	2.07E-03	22.8	7.39E-01	16.9	
Ac-228	968.90	147	28.4	0.03	1.22	1.29E-03	18.7			
Pb-212	238.63	1024	13.6	0.20	5.24	1.73E-03	22.6			
Bi-212	727.33	97	43.7	0.02	1.62	7.49E-04	16.0			
Tl-208	583.19	436	14.8	0.09	2.03	1.76E-03	24.4			
Tl-208	2614.40	280	12.0	0.06	0.48	1.21E-02	9.7			
K-40	1460.83	1671	5.1	0.33	0.82	9.70E-04	420.6	4.80E-02	20.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**92.1**
										3.05%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**755.7**		**53.5**	**10.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**53.5**	**0.0**	**41.4**	**94.8**		**92.1**	en %		**-2.9**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue François-Guillimann 9 - rze-de-chaussée	**N46°47'55.2 E007°09'33.0**	**629**	**guillimann9_rez.spe**	**29/8/2006 8:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	210	73.3	0.04	6.68	1.20E-04	52.3			
Pb-214	295.20	639	19.4	0.13	4.17	8.14E-04	37.6			
Pb-214	351.93	1174	10.1	0.23	3.45	1.71E-03	39.8			
Bi-214 (Total U-238)	609.32	1112	8.3	0.22	1.94	2.76E-03	41.6	5.47E-01	22.8	
Bi-214	1120.20	242	22.1	0.05	1.06	1.20E-03	38.2			
Bi-214	1764.50	237	15.2	0.05	0.69	1.56E-03	44.1			
Bi-214	2204.10	77	28.7	0.02	0.56	5.63E-04	48.7			
Ac-228 (Total Th-232)	911.07	488	13.1	0.10	1.29	2.07E-03	36.5	7.39E-01	26.9	
Ac-228	968.90	322	16.2	0.06	1.22	1.29E-03	41.0			
Pb-212	238.63	1851	9.3	0.37	5.24	1.73E-03	40.8			
Bi-212	727.33	124	42.4	0.02	1.62	7.49E-04	20.4			
Tl-208	583.19	704	12.0	0.14	2.03	1.76E-03	39.5			
Tl-208	2614.40	420	9.9	0.08	0.48	1.21E-02	14.5			
K-40	1460.83	2571	4.1	0.51	0.82	9.70E-04	647.3	4.80E-02	31.1	**R & S**
Be-7	477.60				2.50	5.41E-04				**108.3**
										2.21%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,142.2**		**80.8**	**8.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**80.8**	**0.0**	**40.6**	**121.4**		**108.3**	en %		**-10.8**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue François-Guillimann 9 - 3^e étage	N46°47'55.2 E007°09'33.0	641	guillimann9_3e.spe	29/8/2006 10:00	5000

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	débit de dose ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	260	55.2	0.05	6.68	1.20E-04	64.9			
Pb-214	295.20	637	18.5	0.13	4.17	8.14E-04	37.5			
Pb-214	351.93	1064	10.9	0.21	3.45	1.71E-03	36.1			
Bi-214 (Total U-238)	609.32	996	8.9	0.20	1.94	2.76E-03	37.2	5.47E-01	20.4	
Bi-214	1120.20	260	18.3	0.05	1.06	1.20E-03	41.2			
Bi-214	1764.50	211	15.7	0.04	0.69	1.56E-03	39.4			
Bi-214	2204.10	64	33.4	0.01	0.56	5.63E-04	40.9			
Ac-228 (Total Th-232)	911.07	522	12.6	0.10	1.29	2.07E-03	39.0	7.39E-01	28.8	
Ac-228	968.90	326	15.7	0.07	1.22	1.29E-03	41.6			
Pb-212	238.63	1666	9.9	0.33	5.24	1.73E-03	36.7			
Bi-212	727.33	192	28.7	0.04	1.62	7.49E-04	31.6			
Tl-208	583.19	744	11.3	0.15	2.03	1.76E-03	41.7			
Tl-208	2614.40	487	9.2	0.10	0.48	1.21E-02	16.8			
K-40	1460.83	2448	4.2	0.49	0.82	9.70E-04	616.3	4.80E-02	29.6	R & S
Be-7	477.60				2.50	5.41E-04				116.8
										1.72%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	1,120.9		78.8	8.5

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	78.8	0.0	40.8	119.6	116.8	en %	-2.3

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue François-Guillimann 9 - 6ᵉ étage	**N46°47'55.2 E007°09'33.0**	**650**	**guillimann9_6e.spe**	**29/8/2006 11:25**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	520	23.4	0.10	4.17	8.14E-04	30.6			
Pb-214	351.93	992	11.6	0.20	3.45	1.71E-03	33.6			
Bi-214 (Total U-238)	609.32	920	9.5	0.18	1.94	2.76E-03	34.4	5.47E-01	18.8	
Bi-214	1120.20	286	18.7	0.06	1.06	1.20E-03	45.3			
Bi-214	1764.50	176	17.5	0.04	0.69	1.56E-03	32.7			
Bi-214	2204.10	59	32.6	0.01	0.56	5.63E-04	37.3			
Ac-228 (Total Th-232)	911.07	392	15.3	0.08	1.29	2.07E-03	29.3	7.39E-01	21.6	
Ac-228	968.90	280	19.4	0.06	1.22	1.29E-03	35.7			
Pb-212	238.63	1254	12.0	0.25	5.24	1.73E-03	27.7			
Bi-212	727.33	124	38.3	0.02	1.62	7.49E-04	20.4			
Tl-208	583.19	671	12.5	0.13	2.03	1.76E-03	37.6			
Tl-208	2614.40	382	10.6	0.08	0.48	1.21E-02	13.2			
K-40	1460.83	2226	4.4	0.45	0.82	9.70E-04	560.5	4.80E-02	26.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**123.9**
										2.05%
Cs-137	661.66	52	76.5	0.01	1.78	5.20E-03	1.1	1.92E-01	0.2	**Incertitude**
						Total :	**938.3**		**67.6**	**9.3**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel		cosmique	insitu		R+S	déviation		R+S
en nSv/h	**67.3**	**0.2**		**41.0**	**108.5**		**123.9**	en %		**14.2**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue du Simplon 6 - rez-de-chaussée	**N46°47'56.5 E007°09'19.0**	**629**	**sim6_0.spe**	**30/8/2006 11:00**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nGy/h)	mesure en (nSv/h)
Th-234	92.60	373.8	58.38	0.09	22.33	1.30E-04	32.2			
Ra-226	186.20	615.8	32.62	0.15	17.67	1.20E-04	72.6			
Pb-214	351.93	2860.8	5.89	0.72	11.03	1.71E-03	37.9			
Bi-214 (Total U-238)	609.32	2841.9	4.7	0.71	6.85	2.76E-03	37.6	5.47E-01	20.6	
Ac-228 (Total Th-232)	911.07	1350.9	7.14	0.34	4.89	2.07E-03	33.4	7.39E-01	24.7	
Pb-212	238.63	3597	5.99	0.90	15.01	1.73E-03	34.6			
Bi-212	727.33	454	17.64	0.11	5.89	4.30E-04	44.8			
Tl-208	583.19	1017.1	12.39	0.25	7.12	1.76E-03	20.3			
K-40	1,460.83	7468.3	2.38	1.87	3.35	9.70E-04	574.1	4.80E-02	27.6	
										R & S
										96.5
										2.54%
Cs-137	661.66	401.6	18.5	0.10	6.38	5.20E-03	3.0	1.92E-01	0.6	**Incertitude**
						Total :	**887.5**		**73.3**	**4.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition: en nSv/h	naturel	artificiel	cosmique	insitu	R+S	déviation en %	R+S
	72.8	**0.6**	**40.6**	**114.0**	**96.5**		**-15.3**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rue du Simplon 6 - 1er étage	**N46°47'56.5 E007°09'19.0**	**632**	**sim6_1.spe**	**30/8/2006 12:30**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	370	65.87	0.09	22.33	1.30E-04	31.9			
Ra-226	186.20	526	36.62	0.13	17.67	1.20E-04	62.0			
Pb-214	351.93	2420	6.4	0.61	11.03	1.71E-03	32.1			
Bi-214 (Total U-238)	609.32	2525	5.06	0.63	6.85	2.76E-03	33.4	5.47E-01	18.3	
Ac-228 (Total Th-232)	911.07	1116	7.79	0.28	4.89	2.07E-03	27.6	7.39E-01	20.4	
Pb-212	238.63	3270.3	6.22	0.82	15.01	1.73E-03	31.5			
Bi-212	727.33	342.5	5.06	0.09	5.89	4.30E-04	33.8			
Tl-208	583.19	1576	6.89	0.39	7.12	1.76E-03	31.5			
K-40	1,460.83	6193	2.61	1.55	3.35	9.70E-04	476.1	4.80E-02	22.9	
										R & S
										94.1
										2.63%
Cs-137	661.66	323	21.98	0.08	6.38	5.20E-03	2.4	1.92E-01	0.5	**Incertitude**
						Total :	**759.7**		**61.9**	**5.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**61.5**	**0.5**	**40.7**	**102.6**	**94.1**	en %	**-8.3**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
av. du Midi 11 - rez-de-chaussée	**N46°48'420**	**E007°08'54.2**	**633**	**midi11_0.spe**	**31/8/2006 8:00**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				22.33	1.30E-04				
Ra-226	186.20	445	58.9	0.11	17.67	1.20E-04	52.5			
Pb-214	351.93	1875	11.03	0.47	11.03	1.71E-03	24.9			
Bi-214 (Total U-238)	609.32	2100	8.08	0.53	6.85	2.76E-03	27.8	5.47E-01	15.2	
Ac-228 (Total Th-232)	911.07	702	16.09	0.18	4.89	2.07E-03	17.3	7.39E-01	12.8	
Pb-212	238.63	1766	14.32	0.44	15.01	1.73E-03	17.0			
Bi-212	727.33	216	39.73	0.05	5.89	4.30E-04	21.3			
Tl-208	583.19	944	14.36	0.24	7.12	1.76E-03	18.8			
K-40	1,460.83	4652	4.5	1.16	3.35	9.70E-04	357.6	4.80E-02	17.2	
										R & S
										70.3
										2.59%
Cs-137	661.66	346	30.62	0.09	6.38	5.20E-03	2.6	1.92E-01	0.5	**Incertitude**
						Total :	**537.2**		**45.7**	**9.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**45.2**	**0.5**	**40.7**	**86.4**	**70.3**	en %	**-18.6**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
av. du Midi 11 - 4e étage	**N46°48'420**	**E007°08'54.2**	**645**	**midi11_4.spe**	**31/8/2006 9:30**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	egnc 30 ε=N/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60	354	94.47	0.09	22.33	1.30E-04	30.5			
Ra-226	186.20	751	42.47	0.19	17.67	1.20E-04	88.5			
Pb-214	351.93	2697	9.54	0.67	11.03	1.71E-03	35.7			
Bi-214 (Total U-238)	609.32	3014	6.95	0.75	6.85	2.76E-03	39.8	5.47E-01	21.8	
Ac-228 (Total Th-232)	911.07	1398	10.57	0.35	4.89	2.07E-03	34.5	7.39E-01	25.5	
Pb-212	238.63	304	82.57	0.08	15.01	1.73E-03	2.9			
Bi-212	727.33	396	28.16	0.10	5.89	4.30E-04	39.1			
Tl-208	583.19	1746	10.47	0.44	7.12	1.76E-03	34.9			
K-40	1,460.83	7654	3.51	1.91	3.35	9.70E-04	588.4	4.80E-02	28.2	
										R & S
										112.3
										2.15%
Cs-137	661.66	359	32.49	0.09	6.38	5.20E-03	2.7	1.92E-01	0.5	**Incertitude**
						Total :	**894.4**		**76.1**	**7.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu	R+S	déviation	R+S
en nSv/h	**75.6**	**0.5**	**40.9**	**117.0**	**112.3**	en %	**-4.0**

Courbe efficacité de 2004 - Evaluation IW5 - Détecteur 30 %

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
av. du Midi 11 - 7e étage	**N46°48'420**	**E007°08'54.2**	**654**	**midi11_7.spe**	**31/8/2006 10:45**	**4000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**egnc 30 ε=N/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60	767	35.6	0.19	22.33	1.30E-04	66.0			
Ra-226	186.20	751	29.68	0.19	17.67	1.20E-04	88.5			
Pb-214	351.93	2940	6.08	0.74	11.03	1.71E-03	39.0			
Bi-214 (Total U-238)	609.32	3085	4.6	0.77	6.85	2.76E-03	40.8	5.47E-01	22.3	
Ac-228 (Total Th-232)	911.07	1536	6.86	0.38	4.89	2.07E-03	37.9	7.39E-01	28.0	
Pb-212	238.63	3681	6.07	0.92	15.01	1.73E-03	35.4			
Bi-212	727.33	387	21.6	0.10	5.89	4.30E-04	38.2			
Tl-208	583.19	1933	6.42	0.48	7.12	1.76E-03	38.6			
K-40	1,460.83	8596	2.21	2.15	3.35	9.70E-04	660.8	4.80E-02	31.7	
										R & S
										124.5
										2.62%
Cs-137	661.66	358	22.49	0.09	6.38	5.20E-03	2.7	1.92E-01	0.5	**Incertitude**
						Total :	**1,045.3**		**82.6**	**4.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**	**R+S**	**déviation**	**R+S**
en nSv/h	**82.1**	**0.5**	**41.0**	**123.6**	**124.5**	**en %**	**0.7**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. Jean-BourgKnecht 18 - rez-de-chaussée	**N46°48'50.1 E007°08'59.7**	**660**	**bourgknecth18_rez.spe**	**28/9/2006 8:30**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	518	20.9	0.10	4.17	8.14E-04	30.5			
Pb-214	351.93	953	11.7	0.19	3.45	1.71E-03	32.3			
Bi-214 (Total U-238)	609.32	931	9.1	0.19	1.94	2.76E-03	34.8	5.47E-01	19.1	
Bi-214	1120.20	249	19.8	0.05	1.06	1.20E-03	39.3			
Bi-214	1764.50	218	15.0	0.04	0.69	1.56E-03	40.6			
Bi-214	2204.10	72	30.2	0.01	0.56	5.63E-04	45.4			
Ac-228 (Total Th-232)	911.07	354	15.2	0.07	1.29	2.07E-03	26.5	7.39E-01	19.6	
Ac-228	968.90	203	22.7	0.04	1.22	1.29E-03	25.9			
Pb-212	238.63	1260	11.7	0.25	5.24	1.73E-03	27.8			
Bi-212	727.33	119	39.6	0.02	1.62	7.49E-04	19.6			
Tl-208	583.19	466	15.9	0.09	2.03	1.76E-03	26.1			
Tl-208	2614.40	325	11.1	0.07	0.48	1.21E-02	11.2			
K-40	1460.83	2230	4.4	0.45	0.82	9.70E-04	561.5	4.80E-02	27.0	**R & S**
Be-7	477.60				2.50	5.41E-04				**95.4**
										2.20%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**921.6**		**65.6**	**9.0**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**65.6**	**0.0**	**41.1**	**106.7**		**95.4**	**en %**		**-10.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. Jean-BourgKnecht 18 - 4e étage	**N46°48'50.1 E007°08'59.7**	**672**	**bourgknecth18_4e.spe**	**28/9/2006 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	150	87.1	0.03	6.68	1.20E-04	37.4			
Pb-214	295.20	621	20.6	0.12	4.17	8.14E-04	36.5			
Pb-214	351.93	1214	9.9	0.24	3.45	1.71E-03	41.1			
Bi-214 (Total U-238)	609.32	1163	8.1	0.23	1.94	2.76E-03	43.5	5.47E-01	23.8	
Bi-214	1120.20	308	17.8	0.06	1.06	1.20E-03	48.8			
Bi-214	1764.50	255	13.7	0.05	0.69	1.56E-03	47.6			
Bi-214	2204.10	64	32.7	0.01	0.56	5.63E-04	40.8			
Ac-228 (Total Th-232)	911.07	419	14.6	0.08	1.29	2.07E-03	31.3	7.39E-01	23.2	
Ac-228	968.90	238	21.8	0.05	1.22	1.29E-03	30.4			
Pb-212	238.63	1408	12.1	0.28	5.24	1.73E-03	31.1			
Bi-212	727.33	117	41.2	0.02	1.62	7.49E-04	19.3			
Tl-208	583.19	594	13.2	0.12	2.03	1.76E-03	33.3			
Tl-208	2614.40	416	10.0	0.08	0.48	1.21E-02	14.3			
K-40	1460.83	2547	4.1	0.51	0.82	9.70E-04	641.4	4.80E-02	30.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**116.6**
										2.27%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**1,096.7**		**77.7**	**8.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**77.7**	**0.0**	**41.3**	**119.0**		**116.6**	en %		**-2.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. Jean-BourgKnecht 18 - 7^e étage	N46°48'50.1 E007°08'59.7	681	bourgknecth18_7e.spe	28/9/2006 11:30	2188

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	186	38.2	0.08	4.17	8.14E-04	25.0			
Pb-214	351.93	411	19.2	0.19	3.45	1.71E-03	31.8			
Bi-214 (Total U-238)	609.32	479	12.4	0.22	1.94	2.76E-03	40.9	5.47E-01	22.4	
Bi-214	1120.20	124	27.1	0.06	1.06	1.20E-03	44.7			
Bi-214	1764.50	99	23.0	0.05	0.69	1.56E-03	42.1			
Bi-214	2204.10	42	35.4	0.02	0.56	5.63E-04	61.2			
Ac-228 (Total Th-232)	911.07	198	19.9	0.09	1.29	2.07E-03	33.9	7.39E-01	25.0	
Ac-228	968.90	109	32.1	0.05	1.22	1.29E-03	31.8			
Pb-212	238.63	518	21.5	0.24	5.24	1.73E-03	26.1			
Bi-212	727.33	82	40.1	0.04	1.62	7.49E-04	31.0			
Tl-208	583.19	295	18.7	0.13	2.03	1.76E-03	37.7			
Tl-208	2614.40	77	34.3	0.04	0.48	1.21E-02	6.1			
K-40	1460.83	1150	6.2	0.53	0.82	9.70E-04	662.0	4.80E-02	31.8	R & S
Be-7	477.60				2.50	5.41E-04				125.2
										2.31%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		Incertitude
						Total :	1,074.3		79.2	12.2

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nGy/h	79.2	0.0	41.5	120.6		125.2	en %		3.8

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. du Général-Guisan 42 -rze.de.chaussée	**N46°48'39.7 E007°08'47.9**	**650**	**guisan42_rez.spe**	**10/10/2006 8:30**	**4000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	196	57.0	0.05	6.68	1.20E-04	61.1			
Pb-214	295.20	384	24.2	0.10	4.17	8.14E-04	28.2			
Pb-214	351.93	662	13.9	0.17	3.45	1.71E-03	28.0			
Bi-214 (Total U-238)	609.32	713	10.0	0.18	1.94	2.76E-03	33.3	5.47E-01	18.2	
Bi-214	1120.20	185	21.7	0.05	1.06	1.20E-03	36.6			
Bi-214	1764.50	149	18.7	0.04	0.69	1.56E-03	34.7			
Bi-214	2204.10	43	36.8	0.01	0.56	5.63E-04	34.2			
Ac-228 (Total Th-232)	911.07	254	18.8	0.06	1.29	2.07E-03	23.8	7.39E-01	17.6	
Ac-228	968.90	155	25.7	0.04	1.22	1.29E-03	24.8			
Pb-212	238.63	731	16.3	0.18	5.24	1.73E-03	20.2			
Bi-212	727.33	39	72.9	0.01	1.62	7.49E-04	8.0			
Tl-208	583.19	357	17.2	0.09	2.03	1.76E-03	25.0			
Tl-208	2614.40	270	12.4	0.07	0.48	1.21E-02	11.7			
K-40	1460.83	1552	5.3	0.39	0.82	9.70E-04	488.5	4.80E-02	23.4	**R & S**
Be-7	477.60				2.50	5.41E-04				88
										2.35%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**858.1**		**59.2**	**10.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	Insitu		R+S	déviation		R+S
en nSv/h	**59.2**	**0.0**	**41.0**	**100.2**		**88.0**	en %		**-12.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. Henri-Dunant - Schönberg	**N46°48'25.5 E007°10'40.8**	**676**	**MB_FR_Henri-Dunant.spe**	**15/5/2007 10:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	250	32.6	0.05	4.17	8.14E-04	14.7			
Pb-214	351.93	529	15.2	0.11	3.45	1.71E-03	17.9			
Bi-214 (Total U-238)	609.32	549	11.2	0.11	1.94	2.76E-03	20.5	5.47E-01	11.2	
Bi-214	1120.20	161	22.0	0.03	1.06	1.20E-03	25.5			
Bi-214	1764.50	101	23.3	0.02	0.69	1.56E-03	18.9			
Bi-214	2204.10	14	88.6	0.00	0.56	5.63E-04	9.0			
Ac-228 (Total Th-232)	911.07	208	19.7	0.04	1.29	2.07E-03	15.5	7.39E-01	11.5	
Ac-228	968.90	142	25.0	0.03	1.22	1.29E-03	18.2			
Pb-212	238.63	793	14.6	0.16	5.24	1.73E-03	17.5			
Bi-212	727.33	100	37.3	0.02	1.62	7.49E-04	16.4			
Tl-208	583.19	304	18.1	0.06	2.03	1.76E-03	17.0			
Tl-208	2614.40	184	15.2	0.04	0.48	1.21E-02	6.3			
K-40	1460.83	1029	6.4	0.21	0.82	9.70E-04	259.1	4.80E-02	12.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**91.6**
										2.49%
Cs-137	661.66	60	59.5	0.01	1.78	5.20E-03	1.3	1.92E-01	0.2	**Incertitude**
						Total :	**456.7**		**35.4**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**35.2**	**0.2**	**41.4**	**76.8**		**91.6**	en %		**19.3**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Berne	**N46°48'55.3 E007°10'24.5**	**632**	**MB_FR_rte_Berne**	**15/5/2007 12:15**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose amblante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	172	57.8	0.03	6.68	1.20E-04	42.9			
Pb-214	295.20	241	32.2	0.05	4.17	8.14E-04	14.2			
Pb-214	351.93	398	18.4	0.08	3.45	1.71E-03	13.5			
Bi-214 (Total U-238)	609.32	469	12.7	0.09	1.94	2.76E-03	17.5	5.47E-01	9.6	
Bi-214	1120.20	113	29.5	0.02	1.06	1.20E-03	17.9			
Bi-214	1764.50	85	25.8	0.02	0.69	1.56E-03	15.9			
Bi-214	2204.10	31	44.3	0.01	0.56	5.63E-04	19.6			
Ac-228 (Total Th-232)	911.07	244	16.7	0.05	1.29	2.07E-03	18.2	7.39E-01	13.5	
Ac-228	968.90	118	29.6	0.02	1.22	1.29E-03	15.1			
Pb-212	238.63	605	18.0	0.12	5.24	1.73E-03	13.3			
Bi-212	727.33	61	53.5	0.01	1.62	7.49E-04	10.0			
Tl-208	583.19	291	18.5	0.06	2.03	1.76E-03	16.3			
Tl-208	2614.40	184	15.0	0.04	0.48	1.21E-02	6.4			
K-40	1460.83	1150	6.1	0.23	0.82	9.70E-04	289.5	4.80E-02	13.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**93.5**
										3.23%
Cs-137	661.66	217	22.0	0.04	1.78	5.20E-03	4.7	1.92E-01	0.9	**Incertitude**
						Total :	**510.4**		**37.9**	**11.9**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**37.0**	**0.9**	**40.7**	**78.5**		**93.5**	**en %**		**19.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de Bertigny - derrière Hôpital Daler	**N46°48'5.4 E007°08'26.0**	**674**	**MB_FR_Daler.spe**	**15/5/2007 14:30**	**4984**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	352	24.0	0.07	4.17	8.14E-04	20.8			
Pb-214	351.93	504	15.7	0.10	3.45	1.71E-03	17.1			
Bi-214 (Total U-238)	609.32	502	12.2	0.10	1.94	2.76E-03	18.8	5.47E-01	10.3	
Bi-214	1120.20	116	29.1	0.02	1.06	1.20E-03	18.4			
Bi-214	1764.50	94	23.6	0.02	0.69	1.56E-03	17.5			
Bi-214	2204.10				0.56	5.63E-04				
Ac-228 (Total Th-232)	911.07	243	17.6	0.05	1.29	2.07E-03	18.2	7.39E-01	13.5	
Ac-228	968.90	109	30.1	0.02	1.22	1.29E-03	14.0			
Pb-212	238.63	785	14.3	0.16	5.24	1.73E-03	17.4			
Bi-212	727.33	59	52.7	0.01	1.62	7.49E-04	9.7			
Tl-208	583.19	311	18.0	0.06	2.03	1.76E-03	17.5			
Tl-208	2614.40	200	14.6	0.04	0.48	1.21E-02	6.9			
K-40	1460.83	1178	6.0	0.24	0.82	9.70E-04	297.5	4.80E-02	14.3	**R & S**
Be-7	477.60				2.50	5.41E-04				93.5
										3.23%
Cs-137	661.66	94	41.6	0.02	1.78	5.20E-03	2.0	1.92E-01	0.4	**Incertitude**
						Total :	**474.0**		**38.5**	**12.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**38.1**	**0.4**	**41.3**	**79.8**	**93.5**	en %	**17.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de la vignettaz - après le rond point	**N46°47'56.1 E007°08'41.8**	**643**	**MB_FR_Vignettaz.spe**	**18/5/2007 8:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	135	71.4	0.03	6.68	1.20E-04	33.7			
Pb-214	295.20	305	27.8	0.06	4.17	8.14E-04	17.9			
Pb-214	351.93	581	13.4	0.12	3.45	1.71E-03	19.7			
Bi-214 (Total U-238)	609.32	470	12.3	0.09	1.94	2.76E-03	17.6	5.47E-01	9.6	
Bi-214	1120.20	152	22.4	0.03	1.06	1.20E-03	24.0			
Bi-214	1764.50	146	17.6	0.03	0.69	1.56E-03	27.2			
Bi-214	2204.10	19	64.3	0.00	0.56	5.63E-04	12.3			
Ac-228 (Total Th-232)	911.07	166	23.5	0.03	1.29	2.07E-03	12.4	7.39E-01	9.2	
Ac-228	968.90	82	38.3	0.02	1.22	1.29E-03	10.5			
Pb-212	238.63	714	14.3	0.14	5.24	1.73E-03	15.7			
Bi-212	727.33	36	72.0	0.01	1.62	7.49E-04	6.0			
Tl-208	583.19	315	17.1	0.06	2.03	1.76E-03	17.7			
Tl-208	2614.40	181	15.1	0.04	0.48	1.21E-02	6.2			
K-40	1460.83	965	6.7	0.19	0.82	9.70E-04	242.9	4.80E-02	11.7	**R & S**
Be-7	477.60				2.50	5.41E-04				**87.4**
										3.20%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**463.8**		**30.4**	**13.5**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**30.4**	**0.0**	**40.9**	**71.3**	**87.4**	en %	**22.6**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées		Altitude:	identification	début de la mesure:	durée :
coin - rte. de Villars et rte. de la Vignettaz	**N46°48'0.5**	**E007°08'25.9**	**663**	**MB_FR_Villars.spe**	**18/5/2007 10:15**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose amblante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	123	81.3	0.02	6.68	1.20E-04	30.6			
Pb-214	295.20	219	36.2	0.04	4.17	8.14E-04	12.9			
Pb-214	351.93	592	14.4	0.12	3.45	1.71E-03	20.1			
Bi-214 (Total U-238)	609.32	520	11.9	0.10	1.94	2.76E-03	19.4	5.47E-01	10.6	
Bi-214	1120.20	111	32.5	0.02	1.06	1.20E-03	17.5			
Bi-214	1764.50	111	21.3	0.02	0.69	1.56E-03	20.6			
Bi-214	2204.10	14	78.4	0.00	0.56	5.63E-04	8.9			
Ac-228 (Total Th-232)	911.07	255	17.9	0.05	1.29	2.07E-03	19.0	7.39E-01	14.1	
Ac-228	968.90	157	23.6	0.03	1.22	1.29E-03	20.1			
Pb-212	238.63	1022	12.7	0.20	5.24	1.73E-03	22.5			
Bi-212	727.33	57	59.9	0.01	1.62	7.49E-04	9.4			
Tl-208	583.19	399	16.0	0.08	2.03	1.76E-03	22.4			
Tl-208	2614.40	221	13.8	0.04	0.48	1.21E-02	7.6			
K-40	1460.83	1424	5.6	0.28	0.82	9.70E-04	358.4	4.80E-02	17.2	**R & S**
Be-7	477.60				2.50	5.41E-04				**98.1**
										3.21%
Cs-137	661.66	368	14.9	0.07	1.78	5.20E-03	7.9	1.92E-01	1.5	**Incertitude**
						Total :	**589.5**		**43.4**	**11.4**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**41.9**	**1.5**	**41.2**	**84.6**	**98.1**	en %	**16.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de la Glâne + rte. de la Fonderie	**N46°47'43.1 E007°08'44.5**	**648**	**MB_FR_Beaumont.spe**	**18/5/2007 12:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	128	76.0	0.03	6.68	1.20E-04	32.0			
Pb-214	295.20	216	38.4	0.04	4.17	8.14E-04	12.7			
Pb-214	351.93	501	16.5	0.10	3.45	1.71E-03	17.0			
Bi-214 (Total U-238)	609.32	458	13.8	0.09	1.94	2.76E-03	17.1	5.47E-01	9.4	
Bi-214	1120.20	82	41.8	0.02	1.06	1.20E-03	13.0			
Bi-214	1764.50	109	22.4	0.02	0.69	1.56E-03	20.4			
Bi-214	2204.10	26	55.4	0.01	0.56	5.63E-04	16.3			
Ac-228 (Total Th-232)	911.07	265	17.5	0.05	1.29	2.07E-03	19.8	7.39E-01	14.6	
Ac-228	968.90	174	23.4	0.03	1.22	1.29E-03	22.2			
Pb-212	238.63	962	13.0	0.19	5.24	1.73E-03	21.2			
Bi-212	727.33	74	51.5	0.01	1.62	7.49E-04	12.2			
Tl-208	583.19	365	16.4	0.07	2.03	1.76E-03	20.4			
Tl-208	2614.40	246	12.8	0.05	0.48	1.21E-02	8.5			
K-40	1460.83	1528	5.3	0.31	0.82	9.70E-04	384.8	4.80E-02	18.5	**R & S**
Be-7	477.60				2.50	5.41E-04				**95.4**
										3.13%
Cs-137	661.66	217	24.0	0.04	1.78	5.20E-03	4.7	1.92E-01	0.9	**Incertitude**
						Total :	**617.7**		**43.4**	**11.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**42.5**	**0.9**	**40.9**	**84.3**	**95.4**	en %	**13.2**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
devant maison Villa-Beau-Site - parking	**N46°47'32.8 E007°08'54.9**	**612**	**MB_FR_Villa-Beau-site.spe**	**18/5/2007 14:00**	**5000**

Isotope	**Energie (keV)**	**Aire nette (Counts)**	**Aire nette Inc %**	**Netto-fläche N (cps)**	**Detective ε=Nf/Ø**	**facteur (*1 fa= Ø/A (Bq/kg)**	**Activité Ak=N/ε*fa (Bq/kg)**	**facteur (*1 fd=ODL/Ak nSv/h*Bq/kg**	**dose ambiante ODL=Ak*fd (nSv/h)**	**mesure en (nSv/h)**
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	120	48.7	0.02	4.17	8.14E-04	7.1			
Pb-214	351.93	343	17.9	0.07	3.45	1.71E-03	11.6			
Bi-214 (Total U-238)	609.32	336	14.5	0.07	1.94	2.76E-03	12.5	5.47E-01	6.9	
Bi-214	1120.20	89	29.4	0.02	1.06	1.20E-03	14.0			
Bi-214	1764.50	71	26.3	0.01	0.69	1.56E-03	13.2			
Bi-214	2204.10				0.56	5.63E-04				
Ac-228 (Total Th-232)	911.07	101	28.7	0.02	1.29	2.07E-03	7.6	7.39E-01	5.6	
Ac-228	968.90	37	63.8	0.01	1.22	1.29E-03	4.7			
Pb-212	238.63	407	23.8	0.08	5.24	1.73E-03	9.0			
Bi-212	727.33	33	67.3	0.01	1.62	7.49E-04	5.4			
Tl-208	583.19	134	30.4	0.03	2.03	1.76E-03	7.5			
Tl-208	2614.40	116	18.9	0.02	0.48	1.21E-02	4.0			
K-40	1460.83	561	8.9	0.11	0.82	9.70E-04	141.2	4.80E-02	6.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**76**
										4.68%
Cs-137	661.66				1.78	5.20E-03		1.92E-01		**Incertitude**
						Total :	**238.0**		**19.2**	**16.6**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	**naturel**	**artificiel**	**cosmique**	**insitu**		**R+S**	**déviation**		**R+S**
en nSv/h	**19.2**	**0.0**	**40.4**	**59.6**		**76.0**	**en %**		**27.5**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
av. des Vanils - près des escaliers	**N46°48'22.9 E007°08'46.9**	**679**	**MB_FR_Guintzet.spe**	**21/5/2007 10:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	115	89.0	0.02	6.68	1.20E-04	28.6			
Pb-214	295.20	286	29.4	0.06	4.17	8.14E-04	16.8			
Pb-214	351.93	465	17.9	0.09	3.45	1.71E-03	15.8			
Bi-214 (Total U-238)	609.32	454	12.9	0.09	1.94	2.76E-03	17.0	5.47E-01	9.3	
Bi-214	1120.20	117	30.1	0.02	1.06	1.20E-03	18.5			
Bi-214	1764.50	102	23.0	0.02	0.69	1.56E-03	18.9			
Bi-214	2204.10				0.56	5.63E-04				
Ac-228 (Total Th-232)	911.07	234	18.7	0.05	1.29	2.07E-03	17.5	7.39E-01	12.9	
Ac-228	968.90	97	36.7	0.02	1.22	1.29E-03	12.3			
Pb-212	238.63	644	18.9	0.13	5.24	1.73E-03	14.2			
Bi-212	727.33	72	47.9	0.01	1.62	7.49E-04	11.8			
Tl-208	583.19	290	18.6	0.06	2.03	1.76E-03	16.2			
Tl-208	2614.40	209	14.2	0.04	0.48	1.21E-02	7.2			
K-40	1460.83	1288	5.8	0.26	0.82	9.70E-04	324.3	4.80E-02	15.6	**R & S**
Be-7	477.60				2.50	5.41E-04				**92.9**
										2.70%
Cs-137	661.66	378	14.6	0.08	1.78	5.20E-03	8.2	1.92E-01	1.6	**Incertitude**
						Total :	**519.2**		**39.3**	**12.1**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**37.8**	**1.6**	**41.4**	**80.7**		**92.9**	en %		**15.0**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. de la Broye + rte. du Jura	**N46°48'38.9 E007°08'21.4**	**648**	**MB_FR_rte_Jura.spe**	**21/5/2007 11:30**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20	157	96.4	0.03	6.68	1.20E-04	39.1			
Pb-214	295.20	251	33.0	0.05	4.17	8.14E-04	14.8			
Pb-214	351.93	647	13.0	0.13	3.45	1.71E-03	21.9			
Bi-214 (Total U-238)	609.32	490	12.3	0.10	1.94	2.76E-03	18.3	5.47E-01	10.0	
Bi-214	1120.20	110	31.5	0.02	1.06	1.20E-03	17.4			
Bi-214	1764.50	114	21.7	0.02	0.69	1.56E-03	21.2			
Bi-214	2204.10	47	34.8	0.01	0.56	5.63E-04	29.8			
Ac-228 (Total Th-232)	911.07	234	18.0	0.05	1.29	2.07E-03	17.5	7.39E-01	12.9	
Ac-228	968.90	110	36.7	0.02	1.22	1.29E-03	14.0			
Pb-212	238.63	913	12.7	0.18	5.24	1.73E-03	20.1			
Bi-212	727.33	61	68.7	0.01	1.62	7.49E-04	10.1			
Tl-208	583.19	381	14.7	0.08	2.03	1.76E-03	21.4			
Tl-208	2614.40	191	15.0	0.04	0.48	1.21E-02	6.6			
K-40	1460.83	1308	5.8	0.26	0.82	9.70E-04	329.4	4.80E-02	15.8	**R & S**
Be-7	477.60				2.50	5.41E-04				**92.3**
										3.28%
Cs-137	661.66	126	33.9	0.03	1.78	5.20E-03	2.7	1.92E-01	0.5	**Incertitude**
						Total :	**581.7**		**39.3**	**11.8**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**38.8**	**0.5**	**40.9**	**80.2**	**92.3**	en %	**15.1**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. du Palatinat - derrière mur Morat	**N46°48'43.9 E007°09'30.1**	**582**	**MB_FR_mur_Morat.spe**	**21/5/2007 13:00**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20	242	30.0	0.05	4.17	8.14E-04	14.2			
Pb-214	351.93	478	16.3	0.10	3.45	1.71E-03	16.2			
Bi-214 (Total U-238)	609.32	412	13.7	0.08	1.94	2.76E-03	15.4	5.47E-01	8.4	
Bi-214	1120.20	103	31.0	0.02	1.06	1.20E-03	16.2			
Bi-214	1764.50	89	24.4	0.02	0.69	1.56E-03	16.6			
Bi-214	2204.10	29	46.7	0.01	0.56	5.63E-04	18.6			
Ac-228 (Total Th-232)	911.07	219	19.3	0.04	1.29	2.07E-03	16.4	7.39E-01	12.1	
Ac-228	968.90	83	39.2	0.02	1.22	1.29E-03	10.6			
Pb-212	238.63	589	17.8	0.12	5.24	1.73E-03	13.0			
Bi-212	727.33				1.62	7.49E-04				
Tl-208	583.19	263	20.5	0.05	2.03	1.76E-03	14.8			
Tl-208	2614.40	179	15.2	0.04	0.48	1.21E-02	6.2			
K-40	1460.83	1191	6.0	0.24	0.82	9.70E-04	299.8	4.80E-02	14.4	**R & S**
Be-7	477.60				2.50	5.41E-04				**88.4**
										3.81%
Cs-137	661.66	260	19.1	0.05	1.78	5.20E-03	5.6	1.92E-01	1.1	**Incertitude**
						Total :	**457.9**		**36.0**	**12.7**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu		R+S	déviation		R+S
en nSv/h	**34.9**	**1.1**	**39.9**	**75.9**		**88.4**	en %		**16.4**

Courbe efficacité de 2005 - Evaluation IW5 - DETECTIVE

Site de mesure:	coordonnées	Altitude:	identification	début de la mesure:	durée :
rte. des Neiges	**N46°48'43.8 E007°09'47.4**	**543**	**MB_FR_rte_Neiges.spe**	**21/5/2007 14:45**	**5000**

Isotope	Energie (keV)	Aire nette (Counts)	Aire nette Inc %	Netto-fläche N (cps)	Detective ε=Nf/Ø	facteur (*1 fa= Ø/A (Bq/kg)	Activité Ak=N/ε*fa (Bq/kg)	facteur (*1 fd=ODL/Ak nSv/h*Bq/kg	dose ambiante ODL=Ak*fd (nSv/h)	mesure en (nSv/h)
Th-234	92.60				6.43	1.30E-04				
Ra-226	186.20				6.68	1.20E-04				
Pb-214	295.20				4.17	8.14E-04				
Pb-214	351.93	459	17.4	0.09	3.45	1.71E-03	15.5			
Bi-214 (Total U-238)	609.32	478	12.3	0.10	1.94	2.76E-03	17.9	5.47E-01	9.8	
Bi-214	1120.20	103	29.3	0.02	1.06	1.20E-03	16.3			
Bi-214	1764.50	88	25.1	0.02	0.69	1.56E-03	16.3			
Bi-214	2204.10	19	59.4	0.00	0.56	5.63E-04	12.3			
Ac-228 (Total Th-232)	911.07	252	17.0	0.05	1.29	2.07E-03	18.9	7.39E-01	13.9	
Ac-228	968.90	148	25.8	0.03	1.22	1.29E-03	18.9			
Pb-212	238.63	780	17.0	0.16	5.24	1.73E-03	17.2			
Bi-212	727.33	81	42.9	0.02	1.62	7.49E-04	13.3			
Tl-208	583.19	347	16.4	0.07	2.03	1.76E-03	19.5			
Tl-208	2614.40	191	14.6	0.04	0.48	1.21E-02	6.6			
K-40	1460.83	1066	6.3	0.21	0.82	9.70E-04	268.3	4.80E-02	12.9	**R & S**
Be-7	477.60				2.50	5.41E-04				**84.7**
										3.34%
Cs-137	661.66	213	21.6	0.04	1.78	5.20E-03	4.6	1.92E-01	0.9	**Incertitude**
						Total :	**440.9**		**37.5**	**12.2**

(*1 = facteurs de conversion pour l'activité et le débit d'exposition selon ICRU Report 53 pour une distribution homogène dans le sol

débit d'exposition:	naturel	artificiel	cosmique	insitu	R+S	déviation	R+S
en nSv/h	**36.6**	**0.9**	**39.3**	**76.8**	**84.7**	en %	**10.3**

Appendix B

Abbreviations

Table B.1: List of the abbreviations used in the text. The abbreviations are put in alphabetical order.

Abbreviations	Word or Phrase
CERN	Conseil Européen pour la Recherche Nucléaire
PSI	Paul Scherrer Institut
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
CFSR	Commission fédérale pour la surveillance de la radioactivité
KUeR	Eidgenössischen Kommission für Überwachung der Radioaktivität
CFR	Commission fédérale de protection contre les radiations
EKS	Eidgenössischen Kommission für Strahlenschutz
CPR	Commission fédérale de la protection contre les radiations et de surveillance de la radioactivité
KSR	Eidgensössische Kommission für Strahlenschutz und Überwachung des Radioaktivität
NADAM	Netz für Automatische DosisAlarmierung und -Messung
NEOC	National Emergency Operations Centre
IRA	Institut universitaire de Radiophysique Appliquée, Lausanne
ISR	International Society of Radiology
ICRP	International Commission on Radiological Protection
KERMA	kinetic energy released in mtter
ICRU	International Commission on Radiation Units and Measurements
eV	*electron-volt* $1e\,\text{V} = 1.602 \times 10^{-19}$ J
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
NIST	National Institute Standards and Technology
FWHM	Full Width Half Maximum
a.s.l.	above sea level

Bibliography

[1] Serway R. A. *Optique et Physique Moderne*. Éditions Études Vivantes, 3^e edition edition, 1992.

[2] W. M. Lowder A. Bouville. Human population exposure to cosmic radiation. *Radiation Protection Dosimetry*, 24(1/4):293–299, 1998.

[3] S. Xanthos A. Clouvas and M. Antonopoulos-Domis. Radiological maps of outdoor and indoor gamma dose rates in greek urban areas obtained by *In Situ* gamma spectrometry. *Radiation Protection Dosimetry*, 112(2):267–275, 2004.

[4] R. Bollin. *Natursteine in Freiburg*. Editions Meandre, 1996.

[5] O. Huber C. Murith, H. Völkle. Radioactivity measurements in the vicinity of swiss nuclear power plants. *Nuclear Instruments and Methods in Physics Research*, A(243):549–560, 1986.

[6] G. Grisanti S. Risica C. Nuccetelli, C. Bolzan. Building materials as a source of gamma radiation and radon concentration: tests and improvements of experimental methods. *International Congress of the International Radiation Protection Association "IRPA*, Hiroshima 2000:P–1b–19, May 14-19. 2000.

[7] S. Charalambous C. Papastefanou, M. Manolopoulou. Exposure from the radioactivity in building materials. *Health Physics*, 47(5):775–783, November 1984.

[8] Ordonnance du DFI du 26 juin 1995 sur les substances étrangères et les composants dans les denrées alimentaires. Ordonnance sur les substances étrangères et les composants (osec), 1995.

[9] G. Federmann. Viktor hess und die entdeckung der kosmischen strahlung, January 2003.

[10] Th. Flury. Natural and artificial radioactivity monitoring at the high altitude research station jungfraujoch: Installation and test of the new high volume aerosol sampler in combination with laboratory gamma-spectroscopy, October 2006.

[11] Swiss Federal Office for Public Health. Ordonnance du 22 juin 1994 sur la radioprotection (orap). Technical report, Bern, 1994.

[12] Commission fédérale de la protection contre les radiations et de surveillance de la radioactivité. Analyse des contributions à l'irradiation de la population suisse en 2004, 2005.

[13] Granier R Gambini D. J. *manuel pratique de Radioprotection.* TEC & DOC Lavoisier, 1992.

[14] GE-Reuter-Stokes. Calibration certificate. Technical report, November 11, 2003.

[15] IAEA. purchase certificat. Technical report, IAEA, May 1^{st} 2004.

[16] David R. Lide (Editor in Chief). *CRC - Habdbook of Chemistry and Physics.* CRC Press, 86^{th} edition, 2005-2006.

[17] H. U. Johner and H. Völkle. Die natürliche strahlung in der schweiz. August 1998.

[18] J. Kern. *Physique nucléaire III – Instrumentation.* (unpublished), 1971.

[19] C. Kittel. *Introduction to Solid State Physics.* Wiley, 1968.

[20] B. Bucher L. Rybach, D. Bächler and G. Schwarz. Radiation doses of swiss population from external source. *Journal of Envrionmental Radioactivity*, 62:277–286, 2002.

[21] Bochud F. Laedermann J. P. Rapport : Simulation monte carlo de détecteurs hpge de la suer, June 29th, 2006.

[22] J. F. Loude. Energy resolution in nuclear spectroscopy. January 2002.

[23] K. M. Miller. February 1997. Technical report, Ionization Chambers.

[24] M. F. Máduar and G. Hiromoto. Evaluation of indoor gamma radiation dose in dwellings. *Radiation Protection Dosimetry*, 111(2):221–228, 2004.

[25] Department of Physics and Geosciences. `http://physics.tamuk.edu/`.

[26] Environmental Radioactivity Section Swiss Federal Office of Public Health. Annual report 2005, 2005.

[27] International Commission on Radiation Units and Measurements. Gamma-ray spectrometry in the environment.

[28] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation, 2000.

[29] Britannica Online. `www.britannica.com`, ©2007 Encyclopedia Britannica, Inc.

[30] Wikipedia Online. `www.wikipedia.org`, Wikipedia©– 2008.

[31] ORTEC-DETECTIVE. Administrator's manual, Copyright ©2004.

[32] J. Halter P. Winiger, O. Huber. Analytische methoden in der gamma-spektroskipie mit anwendungsbeispielen. *IAEA reprint*, 1971.

[33] Swiss Inspection Service Paul Scherrer Institut. Verification certificate. Technical report, February 15, 2005.

[34] R. Resnick R. Eisberg. *Quantum Physics of atoms, molecules, solids, nuclei and particles.* Wiley, second edition edition, 1986.

[35] W. Herbst Von Ed. Halm and A. Mastrocola. Messung des natürlichen strahlenpegels in der schweiz. *Bulletin des Eidg. Gesundheitsamtes*, Sonderdruck aus Beilage B(6), December 22, 1962.

[36] website of the Egglescliffe School. `http://www.egglescliffe.org.uk/`.

[37] website of the GEANT4 Monte Carlo simulation software. `http://geant4.web.cern.ch/geant4/`.

[38] website of the German national institute of metrology. `www.ptb.de`.

[39] website of the International Commission of Radiological Protection. `www.icrp.org`.

[40] website of the National Emergency Operations Center. `https://www.naz.ch`.

[41] website of the National Institute of Standards and Technology. url-http://physics.nist.gov/PhysRefData/, Online: June 1994 – Last update: September 2007.

Thanks

I have been working on this project for the past years. From the moment I started to the point I handed my essay, many people have been involved in this project.

I would like to thank from the bottom of my heart all the people that helped me accomplish this project. I would like to specially thank:

- Swiss Federal Office for Public Health, who financed my project.

  I am very grateful that the Swiss Federal Office for Public Health thought that my project was worth the investment.

- Environmental Radioactivity Section, with which I had a great collaboration.

  I could use the instruments from the Environmental Radioactivity Section. Furthermore, I met some very interesting collaborators, who helped me whenever needed.

- Physics Department at Fribourg University, in which I had my experimental setup.

  The physics department kindly let me use their infrastructure.

- Prof. Dr. Hansruedi Völkle, who was my mentor in this project.

  He supported my efforts through this project, without whom I could not have made it to the end. He gave me alot more than just the opportunity to accomplish this project. He helped me develop a great interest for the field of envrionmental radiation protection. I truly enjoyed working with Prof. Dr. Völkle.

- Dr. Jost Eikenberg, who gave a great expertise of my work.

  I really appreciate the time and the effort that Dr. Eikenberg took to give a great feedback on my essay. It is through his comments that I could assure a decent, comprehensible text.

- Prof. Dr. Jean-Claude Dousse for his expertise of my work.

  I really appreciate the time and the effort that Prof. Dr. Dousse took, despite his very busy schedule, to support my work to the end.

- Dr. Paul Knowles, who read my essay through with alot of details and criticism.

  I really appreciate the time and the effort that Dr. Knowles took to verify my essay. He read my work with great attention, to improve the content and the presentation of this essay.

- The town of Fribourg

  All the autorities that allowed me to make measurements, both indoor and outdoor. A special thanks to Mr. Dominique Ding who allowed me to measure on all outdoor public grounds, and Mr. Jean-Pierre Aeby, who gave me the contacts and allowed me to measure in all the municipal buildings.