Poster Presentation

SELF-ATTENUATION FACTORS IN GAMMA-RAY SPECTROMETRY OF SAMPLES CONTAINING RADIONUCLIDES OF NATURAL ORIGIN

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Abstract

High resolution gamma-ray spectrometry is currently the most widely used analytical technique for qualitative and quantitative determination of radionuclides. Quantification of elements relies on the correct analysis of the spectra, depending strongly on the efficiency calibration of the measurement apparatus, most often performed with aqueous standard multi-radionuclide solutions. For efficiency calibration curves obtained by this method and for samples containing radionuclides of natural origin such as sand, soil, rocks and wall paint with apparent typical densities higher than that of water, self-attenuation correction factors were experimentally determined for hundreds of different samples using the Cutshall transmission technique. The results show that, to obtain more reliable analyses, correction factors for the self-attenuation behaviour, especially in the lower part of the energy spectrum, should be used. Since attenuation depends not only on the density of the sample but also on its chemical composition, correction factors have to be determined for each sample.

1. INTRODUCTION

It is well known that natural radioactivity is ubiquitous in the environment, mainly in minerals such as sand, soil and rocks. High resolution gamma-ray spectrometry is currently the most widely used analytical technique for qualitative and quantitative determination of natural radioactivity in such materials [1, 2]. Quantification of elements relies on the correct analysis of the gamma spectra and depends strongly on the efficiency calibration of the measurement apparatus, which is usually performed with aqueous standard multi-radionuclide solutions.

Owing to self-absorption within the sample, lower energy gamma rays have less penetrating ability and tend to interact more readily with matter. So, when an efficiency calibration curve is obtained with an aqueous standard multi-radionuclide solution, a self-attenuation correction is required if samples present densities higher than those of water. Environmental samples such as sand, soil and rocks [3–5] or samples of manufactured products such as wall paint [6] containing radionuclides of natural origin usually have apparent densities higher than water, so correction of the efficiency curve is required for accurate characterization of the material [7, 8]. The full-energy peak efficiency of low energy emitters in semiconductor gamma spectrometers depends strongly on a number of factors including sample composition, density, sample size and gamma-ray energy. Several methods can be used for accurate determination of self-attenuation in the sample, such as computer simulation, the use of spiked or natural matrix reference materials that match each sample type to be analysed, the use of sets of gamma absorption curves, or direct gamma-ray transmission measurements for each sample [9–11].

The environmental laboratory at Instituto de Pesquisas Energéticas e Nucleares (IPEN) is currently using the transmission technique for its low cost and practical application [3–6, 12, 13]. Self-attenuation correction factors for samples of sand, soil, rocks and wall paint have been determined experimentally using high resolution gamma-ray spectrometry. For all samples with apparent densities higher than 1 g/cm^3, correction factors have to be determined for each sample since attenuation strongly depends not only on the density of the sample but also on its chemical composition.

2. GAMMA-RAY TRANSMISSION METHOD

The Cutshall technique [11] basically consists of measuring the transmission of gamma-rays through both the sample of interest and an ultra-pure water sample of the same geometry [12, 13]. IAEA gamma-ray sources of ^{152}Eu, ^{60}Co and ^{137}Cs, with energy peaks ranging from 122 keV to 1408 keV, are generally used in order to cover the range of energies of the radionuclides of interest. However, if assessment of only ^{210}Pb is required, only a ^{210}Pb source is needed. For each sample and specific density, a self-attenuation factor was obtained for each gamma transition energy of the sources, using Eq. (1).

$$f_i = \frac{\ln\left(S_i/W_i\right)}{\left(S_i/W_i - 1\right)} \quad (1)$$

where f_i is the self-attenuation factor for the i^{th} gamma transition, S_i is the beam intensity transmitted through the sample for the i^{th} gamma transition and W_i is the beam intensity transmitted through the ultra-pure water sample for the i^{th} gamma transition. A self-attenuation function was fitted for each sample, considering the attenuation factors acquired for all gamma transitions.

3. RESULTS AND DISCUSSION

The samples analysed over the last seven years at the Environmental Radiometric Laboratory of IPEN are summarized in Table 1.

TABLE 1. TYPES OF SAMPLES ANALYSED AND THEIR DENSITIES

	Density (g/cm3)	Total number of samples
Granitic rock	1.57–2.02	50
Sand	1.26–2.35	132
Urban soil	1.07–1.32	10
Wall paint	0.97–1.46	50
Soil and sedimemt	1.3–1.8	165

Figure 1 shows typical fitted self-attenuation curves in the range 122–1408 keV for wall paint, urban soil, sand and granitic rock samples with similar densities. As expected, the attenuation factors are higher for lower energies but depend also on the sample type. For energies in this range, the strong dependence on the sample chemical composition (in addition to energy) is shown in Fig. 2 for samples of wall paint and sand of the same density. Self-attenuation factors for the 46 keV gamma transition of ^{210}Pb for soil and sediment samples of various densities are shown in Fig. 3.

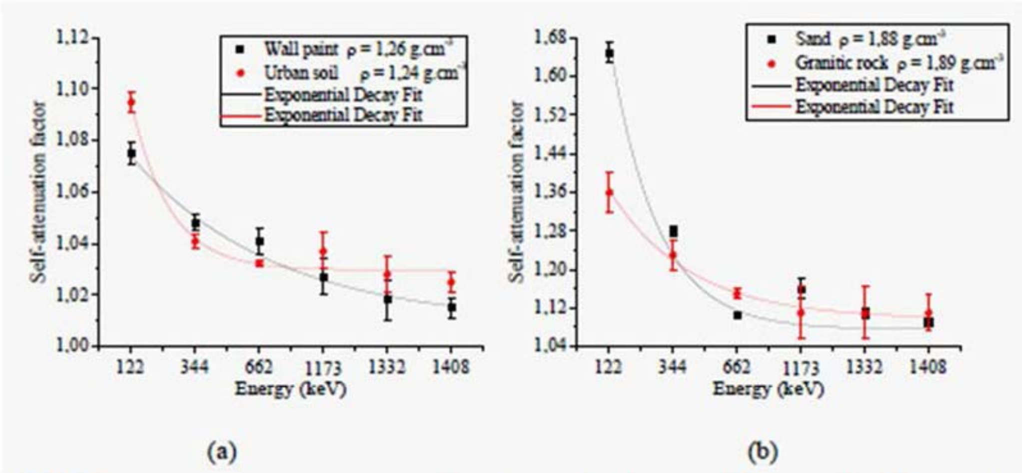

FIG. 1. Self-attenuation curves: (a) wall paint and urban soil, (b) sand and granitic rock.

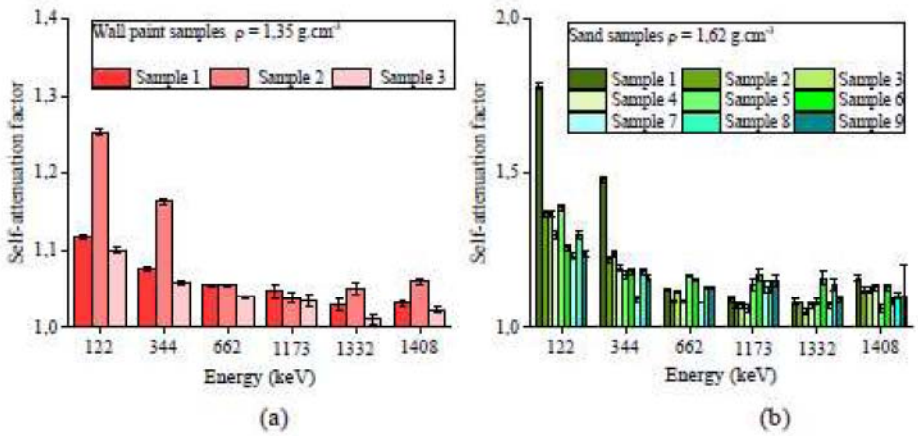

FIG. 2. Self-attenuation factors for samples of similar density: (a) wall paint, (b) sand.

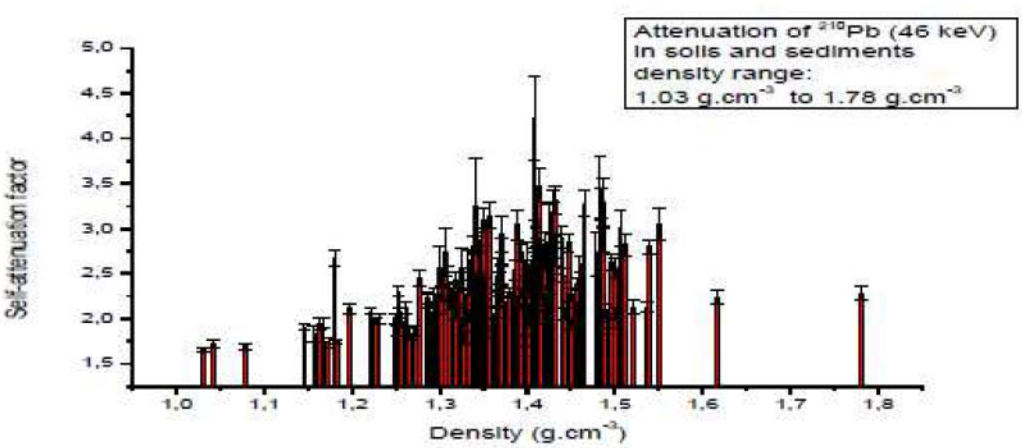

FIG. 3. Self-attenuation factors of ^{210}Pb for sediment and soil samples of different densities.

4. CONCLUSIONS

The self-attenuation correction factors determined by high resolution gamma-ray spectrometry for samples with high apparent densities such as sand, soil, rock and wall paint confirm that attenuation strongly depends on not only the density but also the sample chemical composition, so correction factors have to be determined for each sample. Such correction factors are needed not only for samples containing radionuclides of natural origin but for all samples with high densities when the efficiency curve is obtained with aqueous standard multi-radionuclide solutions.

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