Radiation Physics and Chemistry ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at SciVerse ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Self-attenuation factors in gamma-ray spectrometry of select sand samples from Camburi Beach, Vitória, Espírito Santo, Brazil

L.F. Barros *, B.R.S. Pecequilo

Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP), Av. Professor Lineu Prestes 2242, 05508-000 São Paulo, SP, Brazil

HIGHLIGHTS

- ▸ Self -attenuation factors correct the ^{226}Ra, ^{232}Th and ^{40}K sand concentrations.
- ▸ Self -attenuation factors are necessary for very dense sand samples.
- ▸ Density influences a lot the self-attenuation factor value.

ARTICLE INFO

Article history:
Received 29 September 2012
Accepted 22 December 2012

Keywords:
Sands
Self-attenuation factor
Gamma-ray spectrometry

ABSTRACT

Gamma-ray self-attenuation factors were calculated for sand samples collected in January 2011 at 11 selected locations covering the 6 km extension of Camburi Beach, ES, Brazil. Samples apparent densities ranged from 1.36 g/cm^3 to 1.81 g/cm^3. The self-attenuation factors varied from 1.04 for the ^{152}Eu 1408 keV gamma transition of the lower density sample to 1.62 for the ^{152}Eu 122 keV gamma transition of the higher density sample.

1. Introduction

High resolution gamma-ray spectrometry is a simple and effective method to analyze natural radionuclides activities in sands. Previous results for Camburi Beach, Espirito Santo State, Brazil (Barros et al., 2011; Aquino and Pecequilo, 2009) showed that the sand samples have different mineralogical composition and high densities. As the efficiency calibration curve used was obtained with an aqueous standard multi-radionuclides solution, a self-attenuation correction is required.

The self-attenuation phenomenon depends on the sample composition, its density and the emission energy.

Low energy gamma rays have less penetrating ability and tend to interact more readily with matter, so the gamma-ray interaction is different for the sand samples and the aqueous standard solution (Cutshall et al., 1983).

As concentration activities are critical for the assessment of effective doses and radiological indexes, in order to prevent eventual radiological impacts to humans (UNSCEAR, 2000), self-attenuation factors are of major concern for precise gamma-ray spectrometry. (Khater and Ebaid, 2008)

The self-attenuation correction factor, *f*, was experimentally determined by high resolution gamma-ray spectrometry, with a 20% relative efficiency HPGe detector. The apparent densities of sand samples from Camburi Beach are in a range from 1.36 g/cm^3 to 1.81 g/cm^3.

2. Materials and methodology

2.1. Samples collection and preparation

With an extension of 6 km, Camburi Beach, is located in Vitória, capital of Espírito Santo State, Brazil. Eleven collecting points (whose geographic coordinates are shown in Table 1) were selected along Camburi Beach as showed in Fig. 1. Camburi Beach is known to have silica group sands (SiO_2) and also monazite ((Ce, La, Nd, Th)PO_4) and ilmenite ($FeTiO_3$) (Machado et al., 2011).

Superficial beach sand samples with a depth of about 2 cm were collected at a distance of 3 m of the sea line. Each sample was sealed in a 100 ml polyethylene flask. The apparent density was determined dividing the mass of each sample by the flask volume of 100 mL.

2.2. Gamma-ray transmission method

The method is based on measuring the transmission of gamma-ray through the sand sample and an ultrapure water

* Corresponding author.
E-mail addresses: liviabarros4@gmail.com, lfbarros@ipen.br (L.F. Barros), brigitte@ipen.br (B.R.S. Pecequilo).

0969-806X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.radphyschem.2012.12.031

Please cite this article as: Barros, L.F., Pecequilo, B.R.S., Self-attenuation factors in gamma-ray spectrometry of select sand samples from Camburi Beach, Vitória, Espírito Santo, Brazil. Radiat. Phys. Chem. (2013), http://dx.doi.org/10.1016/j.radphyschem.2012.12.031

sample in the same geometry, with gamma transitions in the range of interest (Ferreira and Pecequilo, 2011), using punctual IAEA gamma-ray sources of ^{152}Eu, ^{60}Co and ^{137}Cs, ranging from 122 keV to 1408 keV, in order to cover the energies of the radionuclides used for the concentrations activities calculations. By the method described by Cutshall et al. (1983), shown in following equation , for each specific sand sample (a single density), a self-attenuation factor was obtained for each of the energy gamma transitions of the sources used:

$$f_i = \frac{\ln(A_i/P_i)}{((A_i/P)-1)} \qquad (1)$$

Table 1
Geographical coordinates of the collection sites (latitude and longitude).

Locations	Latitude and longitude
1	20°17′32.89″S 40°17′20.85″W
2	20°17′27.46″S 40°17′23.16″W
3	20°17′15.25″S 40°17′25.40″W
4	20°17′8.47″S 40°17′24.24″W
5	20°16′57.35″S 40°17′19.38″W
6	20°16′39.35″S 40°17′4.82″W
7	20°16′31.48″S 40°16′54.35″W
8	20°16′26.05″S 40°16′46.12″W
9	20°16′11.34″S 40°16′24.26″W
10	20°16′4.45″S 40°16′13.33″W
11	20°15′58.29″S 40°15′54.98″W

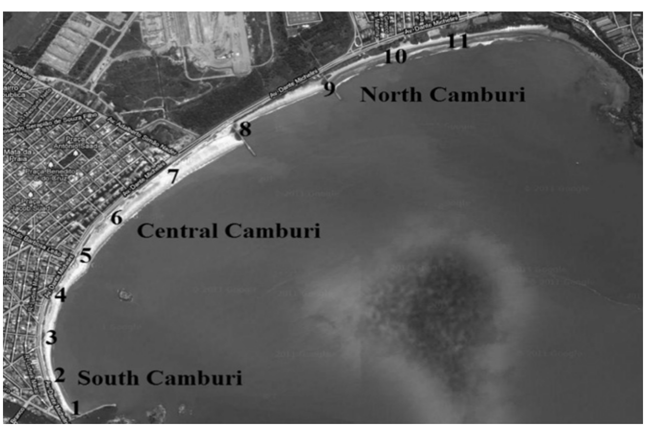

Fig. 1. Camburi beach with the 11 locations of the collected samples.

where

f_i is the self-attenuation factor for a particular *i*th gamma transition,
A_i is the beam intensity transmitted through the sand sample for a particular *i*th gamma transition and ,
P_i is the beam intensity transmitted through the ultrapure water sample for a particular *i*th gamma transition.

2.3. Gamma-ray detection system

Both the sand samples and the ultrapure water sample were measured with a 20% HPGe ORTEC EG&G detector with ACE-2K system, in the same geometry. The spectra were analyzed with the InterWinner software (INTERWINNER, 2004).

3. Results and discussion

3.1. Self-attenuation factors in Camburi sands

A self-attenuation factor was found for each energy gamma transition, using Eq. (1), totaling 7 self-attenuation factors for each examined sand sample. The self-attenuation factors and the apparent densities are shown in Table 2, in order of increasing density.

A self-attenuation function was fitted for each sand sample, considering the attenuation factors acquired for all gamma transitions. In Fig. 2 the typical variation of the self-attenuation factors with the samples densities is presented for two densities: 1.62 g/cm^3 and 1.81 g/cm^3.

The data from Table 1 and Fig. 1 indicate that self-attenuation factors show a behavior directly proportional to the sample apparent density and inversely proportional to the gamma transition energy.

The mean increase, for all samples, in the activities due to self-attenuation correction is around 10% for ^{40}K, 17% for ^{226}Ra and 23% for ^{232}Th.

4. Conclusions

As expected, the results showed that the apparent density has a large influence on the self-attenuation factor and a self-attenuation correction should be considered in the concentration activity of the sample.

Once different mineralogical compositions present different sample densities, it is necessary to determine self-attenuation factors for every single sample studied.

Table 2
Self-attenuation factors of sand samples of collection locations 1–11 for the energy gamma transitions of ^{152}Eu, ^{137}Cs and ^{60}Co (IAEA-TECDOC-619, 1991); in brackets are the uncertainties.

Locations	Density (g/cm^3)	^{152}Eu 121.78 keV	^{152}Eu 244.95 keV	^{152}Eu 344.28 keV	^{137}Cs 661.66 keV	^{60}Co 1173.24 keV	^{60}Co 1332.5 keV	^{152}Eu 1408 keV
1	1.36(4)	1.24(1)	1.17(2)	1.13(1)	1.12(1)	1.02(2)	1.02(2)	1.04(1)
3	1.59(5)	1.82(3)	1.64(5)	1.50(1)	1.14(1)	1.08(2)	1.05(2)	1.12(1)
10	1.62(5)	1.42(1)	1.34(3)	1.28(1)	1.18(1)	1.09(2)	1.07(2)	1.09(1)
6	1.66(5)	1.24(1)	1.15(2)	1.14(1)	1.15(1)	1.09(2)	1.06(2)	1.06(1)
8	1.70(5)	1.59(2)	1.39(4)	1.35(1)	1.18(1)	1.12(2)	1.10(2)	1.12(1)
4	1.73(5)	1.40(1)	1.29(2)	1.27(1)	1.16(1)	1.09(2)	1.07(2)	1.12(1)
9	1.73(5)	1.39(1)	1.29(3)	1.26(1)	1.19(1)	1.10(2)	1.07(2)	1.09(1)
11	1.75(5)	1.77(2)	1.58(4)	1.46(1)	1.21(1)	1.07(2)	1.06(2)	1.13(1)
7	1.77(5)	1.24(1)	1.16(2)	1.15(1)	1.17(1)	1.13(2)	1.10(2)	1.07(1)
2	1.78(5)	1.93(3)	1.63(4)	1.50(2)	1.21(1)	1.08(2)	1.07(2)	1.13(1)
5	1.81(5)	1.62(2)	1.44(3)	1.37(1)	1.19(1)	1.10(2)	1.09(2)	1.12(1)

Please cite this article as: Barros, L.F., Pecequilo, B.R.S., Self-attenuation factors in gamma-ray spectrometry of select sand samples from Camburi Beach, Vitória, Espírito Santo, Brazil. Radiat. Phys. Chem. (2013), http://dx.doi.org/10.1016/j.radphyschem.2012.12.031

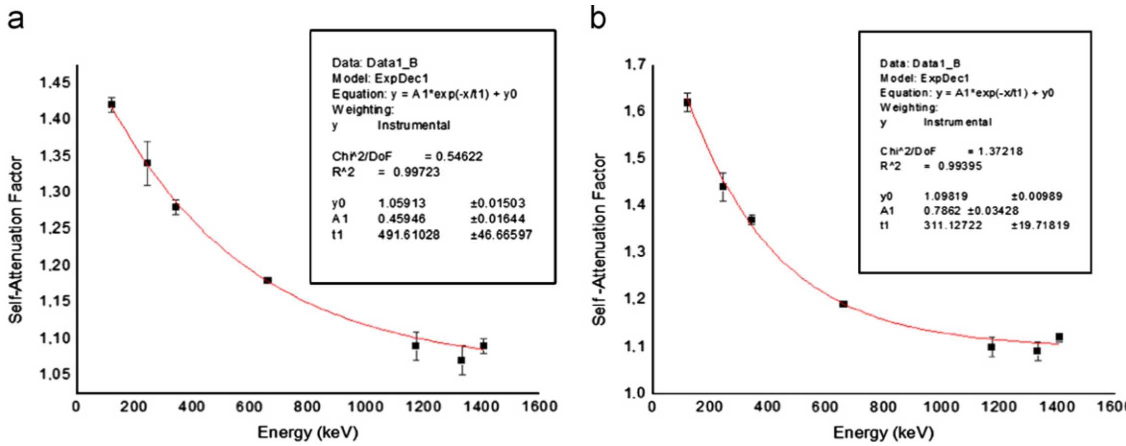

Fig. 2. Self-attenuation factor as a function of gamma-ray energy: (a) sand sample with density 1.62 g/cm^3 and (b) sand sample with density 1.81 g/cm^3.

Acknowledgments

The authors will like to thank the Nuclear and Energy Research Institute (IPEN/SP) for the Master Degree and the Environmental Radiometric Laboratory of IPEN for the use of the facilities.

References

Aquino, R.R., Pecequilo, B.R.S., 2009. ^{226}Ra, ^{232}Th and ^{40}K analysis in sand samples from some beaches of Great Vitória, Espírito Santo, Brazil: preliminary results. In: Proceedings of the International Nuclear Atlantic Conference, 2009.

Barros, L.F., et al., 2011. Gamma radiation measurements in select sand samples from Camburi Beach-Vitória, Espírito Santo, Brazil preliminary results. In: Proceedings of the International Nuclear Atlantic Conference, 2011.

Cutshall, N.H., et al., 1983. Direct analysis of ^{210}Pb in sediment samples: self-absorption corrections. Nucl. Instrum. Methods Phys. Res. 206, 309–312.

Ferreira, A.O., Pecequilo, B.R.S., 2011. A study of self-attenuation correction for geological measures of Paraná State granites with high resolution gamma-ray spectrometry. In: Proceedings of the International Nuclear Atlantic Conference, 2011.

IAEA-TECDOC-619, 1991. X-ray and Gamma-ray Standards for Detector Calibration.

INTERWINNER, 2004. TM 6.0 MCA Emulation, Data Acquisition and Analysis software for Gamma and Alpha Spectroscopy. IW-B32 2004, ORTEC, Oak Ridge, TN, USA.

Khater, A.E.M., Ebaid, Y.Y., 2008. A simplified gamma-ray self-attenuation correction in bulk samples. Appl. Radiat. Isot. 66, 407–413.

Machado, F.B., et al.,2011. Enciclopédia Multimídia de Minerais. ISBN: 85-89082-11-3 available at: 〈http://www.rc.unesp.br/museudpm〉 (accessed in 20.08.2011).

UNSCEAR, 2000. Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations, New York.

Please cite this article as: Barros, L.F., Pecequilo, B.R.S., Self-attenuation factors in gamma-ray spectrometry of select sand samples from Camburi Beach, Vitória, Espírito Santo, Brazil. Radiat. Phys. Chem. (2013), http://dx.doi.org/10.1016/j.radphyschem.2012.12.031