SOIL CHARACTERIZATION WITH NEUTRON ACTIVATION

M. A. G. Silveira[1], N. H. Medina[2], and C. B. Zamboni[3]

[1] Centro Universitário da FEI
Av. Humberto Alencar de Castelo Branco 3972
09850-901 São Bernardo do Campo, SP
shila@if.usp.br

[2] Instituto de Física da Universidade de São Paulo
Travessa R da Rua do Matão 187
05508-090 São Paulo, SP
medina@if.usp.br

[3] Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN – SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
czamboni@ipen.br

ABSTRACT

Neutron Activation Analysis technique using Au as flux monitor, was applied to determine element concentrations in the soil of an industrialized city, São Bernado do Campo, in the São Paulo metropolitan area. The results were compared with those using the neutron Irradiator, which has a stable neutron flux, and they were compatible. The viability, advantages, and limitations of using this analytic procedure are discussed.

Introduction

In recent years the Nuclear Structure Laboratory (LEN) at Instituto de Pesquisas Energéticas e Nucleares (IPEN) has investigated several certified reference materials, using neutron activation, aiming to optimize its uses in different areas. Based on it, several works have been performed using the comparative method Instrumental Neutron Activation Analysis (INAA), as well as the semi - parametric methodology (a variant of k_0 – NAA) or combination of both techniques using different experimental facilities at IPEN: the IEA-R1 and MB-01 Nuclear Reactors, and the Neutron Irradiator [1-10]. The basic principle of the activation analysis consists in the irradiation of material with neutrons followed by the measurement of the γ-ray activities induced in the sample, where the elements can be identified by the nuclear properties of emitted γ-rays.

In this study the aim was to check the viability of using the semi - parametric methodology for activating samples with neutrons using the nuclear reactor as well as

the neutron irradiator, both at the IPEN facilities, to perform soil characterization. This material was selected considering the facilities in its collection, preparation and storage. In addition, these data are very important for the environmental studies.

For the development of these measurements the samples were collected in São Bernardo do Campo, São Paulo, which is an industrialized region and . This city is located in the boundery of the Serra do Mar, a protected area.

Experimental Procedure

The soil sample was collected at the Ginásio Poliesportivo in São Bernardo do Campo, São Paulo, Brazil, which is located near Serra do Mar protected area. The sample was dried in a oven at about 100 ^{o}C for 24 hours and divided in different aliquots (0.5 g and 2.0g) . The analyses were performed in two steps: first, two samples (~ 0.5 g) were analyzed in the IEA-R1 nuclear reactor , in a flux of about 10^{11} n.cm^{-2}s^{-1}; after, one sample (~ 2 g) was analyzed in the neutron irradiator, in a flux of about 10^{5} n.cm^{-2}s^{-1}.

In order to determine the concentration of the elements using the nuclear reactor, the Cadmium Ratio Technique was used for the measurement of both thermal and epithermal flux distribution [1]. In this technique, Au foils, both bare and Cd covered, are irradiated together with the soil sample in the IEA-R1 nuclear reactor at IPEN/SP (IEA-R1, 2-4MW, pool type), for a few minutes, allowing the simultaneous activation of these materials under the exact same irradiation conditions. Using this procedure the γ-ray activities, induced in the Au foils, by both thermal and epithermal neutrons were obtained as well as the activation of soil sample.

To perform the analysis using the neutron irradiator it is not necessary to determine the neutron flux distribution once it has a very stable flux [11,12]. In this way, the activation process become practical and economic, but quantities at gram levels of samples are necessary to achieve good sensitivity, mainly when the material has a low thermal neutron cross section, as well as a long irradiation time (hours to days) .

A γ-spectrometer system with a semiconductor detector connected to an ADCAM multichannel analyzer and to a PC computer was then used to measure the induced gamma-ray activity. The detector was a HPGe (FWHM=1.87 keV) calibrated for energy and efficiency through the measurements of standard sources of ^{56}Co and ^{152}Eu [13]. The energy of the radiation emitted from the product nuclei during

radioactive decay indicates from which element the product nuclide was formed and the intensity of the radiation at a given energy is directly proportional to the amount of that element. The irradiation time and subsequent gamma-ray counting depends on the lifetime of the isotope of interest. The γ-ray spectrum analysis was performed using the IDF computer code [14]. The concentration of each element was then obtained by using an in-house software [15].

Results and Discussion

The element concentrations in soil sample by using NAA using Au as a flux monitor, as well as the results obtained using the neutron irradiator, are shown in Table 1. Due the dimensions of the samples used (15mm diameter by 25mm long), in the neutron irradiator facility, the results have been calculated performing the geometry and self-absorption corrections [16].

Table 1. Analysis of soil performed at the nuclear reactor and at the neutron irradiator.

Elements	Neutron Irradiator (g/kg)	IEA-R1 nuclear reactor using Au as flux monitor (g/kg)
Br	0.099 ± 0.021	0.092 ± 0.019
Ca	0.51 ± 0.08	0.48 ± 0.14
Cl	0.06 ± 0.01	0.052 ± 0.010
K	11.1± 0.8	10.8 ± 0.4
Mg	Nd	5.47 ± 0.59
Mn	nd	0.217 ± 0.016
Na	0.629 ± 0.077	0.624± 0.038

nd : not determined

According to this table the elements Br, Ca, Cl, K and Na could be identified and quantified by both nuclear facilities (the IEA-R1 nuclear reactor and the neutron

irradiator) and the results are in agreement. The elements Mg and Mn were also quantified but only through the measurements performed in the nuclear reactor, using the γ-rays of 844 keV and 847 keV, respectively. The activation performed with the neutron irradiator had poor statistics, mainly for the γ-peak of 847 keV, which made it difficult to calculate the area of this doublet.

The results obtained suggest that the NAA technique, performed in the nuclear reactor, associated with the semi-parametric methodology could be an alternative when standards are not available as well as in studies involving a large number of samples for quantitative analysis simultaneously (i. e., in routine work for example). However, when large samples must be analyzed or large quantities of samples are available, the neutron irradiator can be used.

Based on these advantages, soil characterization using the semi-parametric methodology could be considered an efficient tool. Of course, the comparative method (NAA using standards) gives a very small uncertainly but this instrumental procedure can demand much more time, mainly when elements of short half-life are involved due to the necessity to analyze the standards and the sample separately and as some of them can decay before being gamma counted, then several irradiations usually must be performed.

Conclusions

The soil characterization has been done using the neutron activation analysis technique. Optimized conditions were established to perform measurements at IEA-R1 nuclear reactor and also at the neutron irradiator became the semi - parametric procedure agile and economic.

References

[1] L. C. Oliveira, C. B. Zamboni, F. A. Genezini, A. M. G. Figueiredo, G. S. Zahn. Journal of Radioanalitical and Nuclear Chemistry. 263, 3(2005)783.

[2] L. C. Oliveira, C. B. Zamboni, A. C. Cestari, L. Dalaqua JR., M. V. Manso, A. M. G. Figueiredo, J. T. Aruda-Neto. Rev. Bras. Pesq. Des., 4(2002)1035.

[3] L. C. Oliveira, C. B. Zamboni, G. S. Zahn, M. A. Maschio, M. P. Raele. Braz. J. Phys 34 (2004) 811.

[4] C. B. Zamboni, L. C. Oliveira, L. Dalaqua Jr., Diagnostic Application of Absolute Neutron Activation Analysis in Hematology, in: Proc. ANES, USA, 2004.

[5] L. C. Oliveira, C. B. Zamboni, P. S. Lins, M. R. Azevedo. Braz. J. Phys, 35(2005)793.

[6] I. M. M. A. Medeiros, C. B. Zamboni, J. A. G. Medeiros, M. A. Rizzutto, N. Added, M. H. Tabacnicks, Braz. J. Phys., 35(2005)814.

[7] C. B. Zamboni , G. S. Zahn, O. A. Sant'Anna . AIP., 884(2007)507.

[9] C. B. Zamboni, L. C. Oliveira , L. Dalaqua Jr, J. Mesa **.** Journal of Radioanalitical and Nuclear Chemistry. 269, 2(2006)331.

[10] L. C. Oliveira, C. B. Zamboni, J. Mesa**.** Journal of Radioanalitical and Nuclear Chemistry. 269, 3(2006)541.

[11] K. Shteejer, C. B. Zamboni, G. S. Zahn, J. Y. Zevallos-Chávez. Appl. Rad. Isot., 59 (2003) 263.

[12] J. Y. Zevallos-Chávez and C. B. Zamboni**.** Braz. J. Phys, 35(2005)797.

[13] IAEA_TECDOC-619.

[14] P. Gouffon, Manual do Programa IDF, Instituto de Física da Universidade de São Paulo, Laboratório do Acelerador Linear, Brazil, 1982.

[15] J. A. G. Medeiros, *private communication* (IPEN, 2003).

[16] M .T. F da Cruz , *private communication* (IFUSP, 2001).