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VIABILITY OF SOIL ANALYSIS USING DIFFERENT NEUTRON ASSEMBLIES

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ABSTRACT

Neutron Activation Analysis technique, the semi - parametric analytic procedure, was applied to determine some element concentrations (Br, Ca, Cl, K, Mg, Mn and Na) in a soil sample, collected in an industrialized city, São Bernardo do Campo, in the São Paulo metropolitan area. The measurements were performed at the IEA-R1 nuclear reactor and also using the neutron irradiator, both at the IPEN facilities. The viability, advantages, and limitations of these facilities to analyze soil samples are discussed.

1. INTRODUCTION

In recent years, in the Nuclear Structure Laboratory at IPEN, several works have been performed using the Instrumental Neutron Activation Analysis (INAA), as well the semi-parametric methodology (a variant of k_o –NAA) or a combination of both techniques using different experimental facilities: the IEA-R1 and MB-01 Nuclear Reactors, and the Neutron Irradiator, aiming to optimize analyses in biological materials. Based on these investigations, in this study we want to check the viability of using the semi - parametric methodology for activating soil samples with neutrons using the nuclear reactor, as well as the neutron irradiator, both at the IPEN facilities.

This work is part of a cooperation between IFUSP, FEI and IPEN to implant analysis techniques based on nuclear physics for soil analysis. The presence of potassium, for example, can be quantified by neutron activation and gamma-ray measurements of natural radioactivity.

For the development of these measurements the soil sample was collected in São Bernardo do Campo, São Paulo, Brazil, which is an industrialized region, located near the Serra do Mar, a protected area.

2. EXPERIMENTAL PROCEDURE

The soil sample was collected at 10 cm depth, preventing surface residues, from the Ginásio Poliesportivo in São Bernardo do Campo, São Paulo. The sample was dried in an oven at about 100 ^{o}C for 24 hours and divided in different aliquots (0.5 g and 2.0 g). 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}; later, another sample (~ 2 g) was analyzed in the neutron irradiator, in a flux of about 10^{5} n.cm^{-2}s^{-1}. We used different aliquots to verify the sample homogeneity.

In order to determine the concentration of the elements using the nuclear reactor, the Cadmium Ratio Technique was used for the measurement of both the thermal and the epithermal flux distribution [1]. In this technique, Au foils, both bare and Cd covered, are irradiated together with the soil sample (0.5g) 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 the soil sample. To perform the analysis using the neutron irradiator it is not necessary to determine the neutron flux distribution since it has a very stable flux [2,3], but quantities at gram levels of samples (~ 2.0 g) as well as a long irradiation time (16 hours) are necessary to achieve good sensitivity.

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 [4]. 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 γ-ray spectrum analysis was performed using the IDF computer code [5]. The concentration of each element was then obtained by using in-house software [6].

3. RESULTS AND DISCUSSION

The element concentrations in the soil sample performed at IEA-R1 nuclear reactor and also using the neutron irradiator are shown in Table 1. Due to the dimensions of the samples used in the neutron irradiator facility (15 mm diameter by 25 mm long), the results have been calculated performing geometric and self-absorption corrections [7]. For comparison, the results from the Instrumental Neutron Activation Analysis (INAA) are also shown in Table 1 [8].

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)	IEA-R1 nuclear reactor using INAA (g/kg)
Br	0.099 ± 0.021	0.092 ± 0.019	0.087 ± 0.007
Ca	0.51 ± 0.08	0.48 ± 0.14	0.52 ± 0.11
Cl	0.06 ± 0.01	0.052 ± 0.010	0.051 ± 0.013
K	11.1± 0.8	10.8 ± 0.4	10.8 ± 0.3
Mg	nd	5.47 ± 0.59	nd
Mn	nd	0.217 ± 0.016	0.216 ± 0.007
Na	0.629 ± 0.077	0.624± 0.038	0.621± 0.020

nd : not determined

According to Table 1, 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 (semi- parametric procedure) using the γ-rays of 844 keV and 847 keV, respectively. The activation performed with the neutron irradiator and using the standard had poor statistics for the γ-peak of 847 keV, which made it difficult to calculate the area of this doublet.

The results obtained suggest that both of these facilities, associated with the semi-parametric methodology for NAA, could be an alternative when standards are not available, as well as in studies involving a large number of samples for quantitative analysis simultaneously (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 as an alternative procedure. Of course, the comparative method [8] 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.

4. CONCLUSIONS

The soil analysis has been carried out using the semi-parametric neutron activation analysis technique. Conditions for performing measurements at IEA-R1 nuclear reactor and also at the neutron irradiator were optimized, in order to make simultaneous analysis of several elements and eliminate the necessity for standards.

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