

# Soil Analysis using the semi-parametric NAA technique

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## Abstract.

The semi-parametric Neutron Activation Analysis technique, using Au as a flux monitor, was applied to measure element concentrations of Br, Ca, Cl, K, Mn and Na for soil characterization. The results were compared with those using the Instrumental Neutron Activation Analysis technique and they found to be compatible. The viability, advantages, and limitations of using these two analytic methodologies are discussed.

**Keywords:** neutron activation, soil characterization, gamma-ray spectroscopy

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## INTRODUCTION

In this work we performed soil characterization using Instrumental Neutron Activation Analysis (INAA) as well as Neutron Activation Analysis (NAA) with Au as a flux monitor, i.e., a variant of  $k_o$  – NAA [1]. These data are very important for environmental studies. For the development of this investigation, NIST 1573a Tomato Leaves [2] were first analyzed to verify the accuracy and precision of the results. After that, the soil sample analysis was performed.

## EXPERIMENTAL PROCEDURES

The soil samples were collected in São Bernardo do Campo, a city placed on the border of an industrialized region and near the protected area of the Serra do Mar. A total of three samples of soil ( $\approx 500$ mg) were analyzed in replicate. We used different aliquots of the same sample to verify its homogeneity. To perform measurements using reference material, five samples ( $\approx 150$  mg) of NIST 1573a Tomato Leaves were prepared and analyzed in replicate. In order to determine the concentration of the elements in the certified biological reference material, the Cadmium Ratio Technique was used for the measurement of 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, 2-4 MW, pool type), allowing the simultaneous activation of these materials under the same irradiation conditions. Using this procedure, the  $\gamma$ -ray activities induced in the Au foils by both the thermal and epithermal neutrons were obtained, as well as the activation of the soil sample. A  $\gamma$  spectrometer system with

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an HPGe detector connected to an ADCAM multichannel analyzer and to a PC computer were used to measure the induced  $\gamma$ -ray activity. The concentration of each element, using the semi-parametric procedure, was obtained using the ACTIVATION software [3]. For the analysis using the comparative method (INAA), the standard Tomato Leaves (NIST 1573a) and the soil samples were irradiated together. The concentration was then obtained by using an in-house software [4].

## RESULTS AND DISCUSSION

The element concentrations of certified reference materials, by using NAA, with Au as a flux monitor, are shown in Table 1. Also, the concentration of the elements in the soil sample by the semi-parametric method as well as the comparative (INAA), using NIST 1573a Tomato Leaves as standard, are shown in this Table.

**TABLE 1.** Analysis of certified reference material, NIST 1573a Tomato Leaves, and the soil sample using the semi-parametric Neutron Activation Analysis technique NAA (with flux monitor). The results from INAA measurements are presented for comparison.

Elements g/kg	Reference Material NAA 5 samples	Reference Material Certified Values [2]	Soil sample INAA 3 samples	Soil sample NAA 3 samples
Br	1.31(10)	1.30 *	0.087(7)	0.092(19)
Ca	53.6(44)	50.5(9)	0.52(11)	0.48(14)
Cl	6.56(45)	6.60 *	0.051(13)	0.052(10)
K	26.9(21)	27.0(5)	10.8(3)	10.8(4)
Mn	0.245(18)	0.246(8)	0.216(7)	0.217(16)
Na	0.135(13)	0.136(4)	0.621(20)	0.624(38)

\* not certified

The results obtained using Au as a flux monitor are compatible with INAA suggesting that the semi-parametric procedure could be an alternative for soil characterization. This procedure can also be useful when the neutron flux is very stable, which is the case for the Neutron Irradiator and Neutron Generator, available for our measurements [5]. This methodology could be used when standards are not available, as well as an alternative to perform studies that involve a large number of samples for quantitative analyses of several elements, i.e., in routine work. The results obtained using the INAA method could be used with the advantage of obtaining a smaller relative uncertainty.

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