ESTIMATION OF BORON IN SOME LOCAL MATERIALS BY PROMPT GAMMA RAY NEUTRON ACTIVATION ANALYSIS TECHNIQUE.

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The neutron capture gamma-ray facility installed at the Radiative Environmental Pollution Dapartment using ^{252}Cf isotopic neutron source, is used for estimation of the concentration percentage values of Boron in an Egyptian Tomato and Spinach samples as biological materials, also in one of the byproducts of an Egyptian motor oil and glass samples, as industrial materials. A hyper pure germanium detection system is used for collecting the gamma-rays emitted due to neutron capture in the nuclei of each sample. Artificial standard were prepared in our laboratory using Boron-Carbide material for construction of the sensitivity curve up to 0.5% used in this work. The matrix elements interference in each case is considered. The concentration percentage values obtained in this work were between 0.0016 and 0.00887%.
Keywords: *PGNAA technique, Boron Estimation, Using ^{252}Cf neutron sources Sensitivity curve method, Biological and Industrial materials*

INTRODUCTION

Boron is considered as one of the most important commercial elements. It is added to sheet at low levels just to strengthen the grain boundaries, increase hardness and improve mechanical properties. It is also added to fertilizers and commonly used in the home for laundry and cleaning purpose. It has as well as effective role in the glass industry and used for safety purposes in the nuclear industry.

Boron Element has an energy band of 1.5 to 1.56 eV which is higher than of either Silicon or Germanium, so it can be dopted into semiconductor materials to alter electric properties and is the most important P-type dobant in silicon.

^{10}B occuring in natural Boron with an abundance of 19.6 % and it has a very large cross section for thermal neutron capture (3837 b). only two α-particles energy group are emitted when Boron is irradiated with thermal neutrons. One α-particle group decays directly to the ground state of ^{7}Li, while the other group decays to the 478 keV excited state of ^{7}Li. Most of the Li (93%) produced by the ^{10}B(n, α)^{7}Li reaction is in an excited state which decay within (5x10^{-14}s), emitting a 478 keV gamma-ray line. Since the gamma-ray is emitted while the recoiling ^{7}Li nucleus is in flight, it is Doppler-broadened in a distinctive rectangular energy distribution, as shown in fig. 1.

Accordingly, Boron concentration values in compounds can be determined with the aid of thermal neutron capture gamma-rays as ^{10}B undergoes as an (n,α) reaction producing ^{7}Li.

In this work, Boron concentration in some local biological and industrial samples will be estimated using the (PGNAA) technique. The constructed sensitivity curve for Boron will be used. The ^{252}Cf neutron source, and the neutron capture gamma-ray system installed at the hot laboratory are used as well.

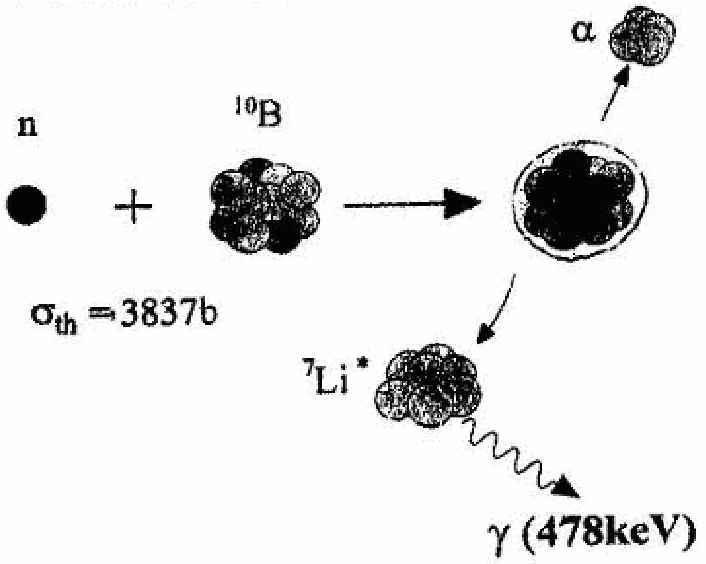


Figure 1. Neutron interaction with ^{10}B nucleus.

EXPERIMENTAL

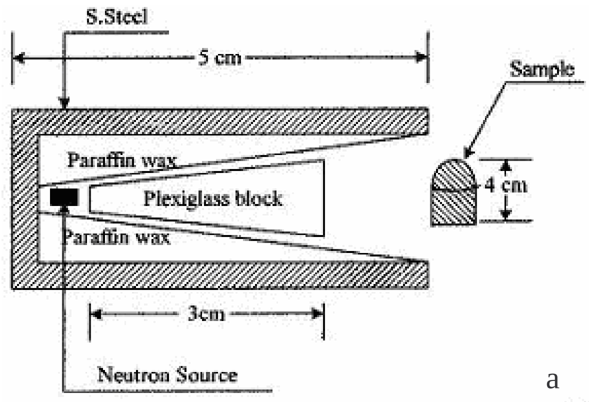
Sampling and Standard Samples Preparation:-

Tomato, Spinach seeds, motor oil and glass Egyptian samples have been selected to estimate the Boron content in each one, using the prompt gamma-ray technique of this work. Tomato juice and motor oil samples were in a liquid form while the glass and spinach seeds were grinded in small pieces (about 200 mesh for each one). A fifty gram polyethylene container is filled with each sample under investigation.

A set of standards was prepared using the B_4C compound. The standard sample was prepared as a mixture of B_4C and SiO_2 materials. A polyethylene bottle of 50 ml volume is used for each one. The concentration percentage standard values of Boron were at 0.0, 0.1, 0.2, 0.35, 0.4 and 0.5%.

Apparatus and Neutron Irradiation Facility

The prompt gamma-ray spectrometer has been described in details elswhere. It consists of a cubic container of polyethylene moderators of volume I m^3 with two steel-lead collimators, one for the neutron source and the other for the emitted gamma-ray spectra. At the axial center of the container a ^{252}Cf neutron source of 50 μgm, and the irradiated sample (polyethylene container of 50ml) were placed as shown in figures 2-a and 2-b. Two rectangular polyethylene holders for the neutron source and the sample with dimensions of 200 mm, H. 200 mm, W and 500 mm-L., for each, are prepared to slide easily at the axial center of the container assembly. The neutron source in its container is fixed at the inner end of the source holders. The neutron beam collimator made from steel in a conical shape of 50 mm long, lined with 5 mm lead sheet to attenuate the fission gamma-ray emitted within the ^{252}Cf neutron source and containing a 40 mm thick polyethylene plug. At the narrow end of the collimator, there is a hole of 12 mm diameter for holding the ^{252}Cf neutron source. The sample holder contains a hole with diameter 30 mm at its inner end for placing the sample bottle. The source sample holder assembly and their positions inside the polyethylene container are chosen in order to increase the neutron flux density at the target position as well as to prevent the gamma-ray detector from the direct neutron beam. Changing the sample under investigation or removing the neutron source is easily accomplished by sliding smoothly the two holders on both sides.



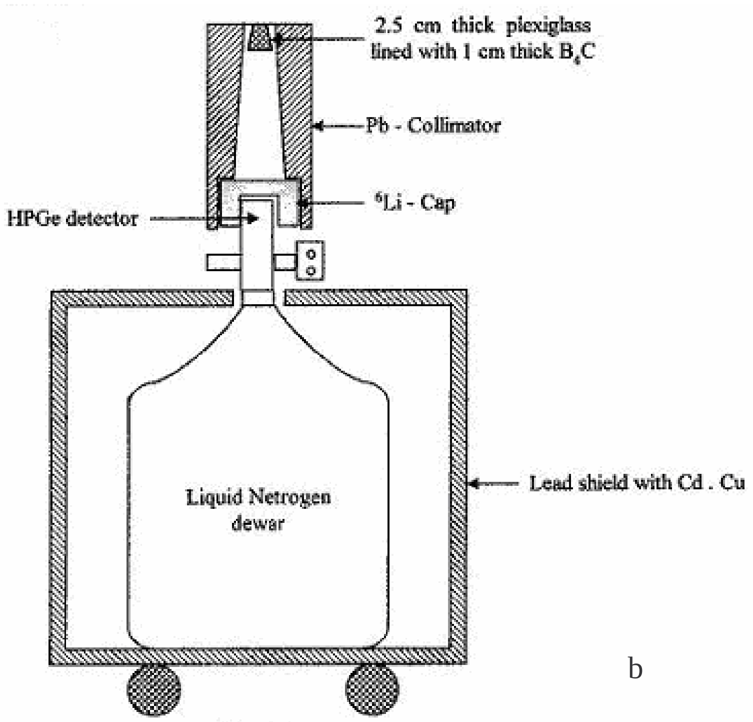


Figure 2. A sketch showing the neutron source – target – detector facility installed at the hot laboratory center.

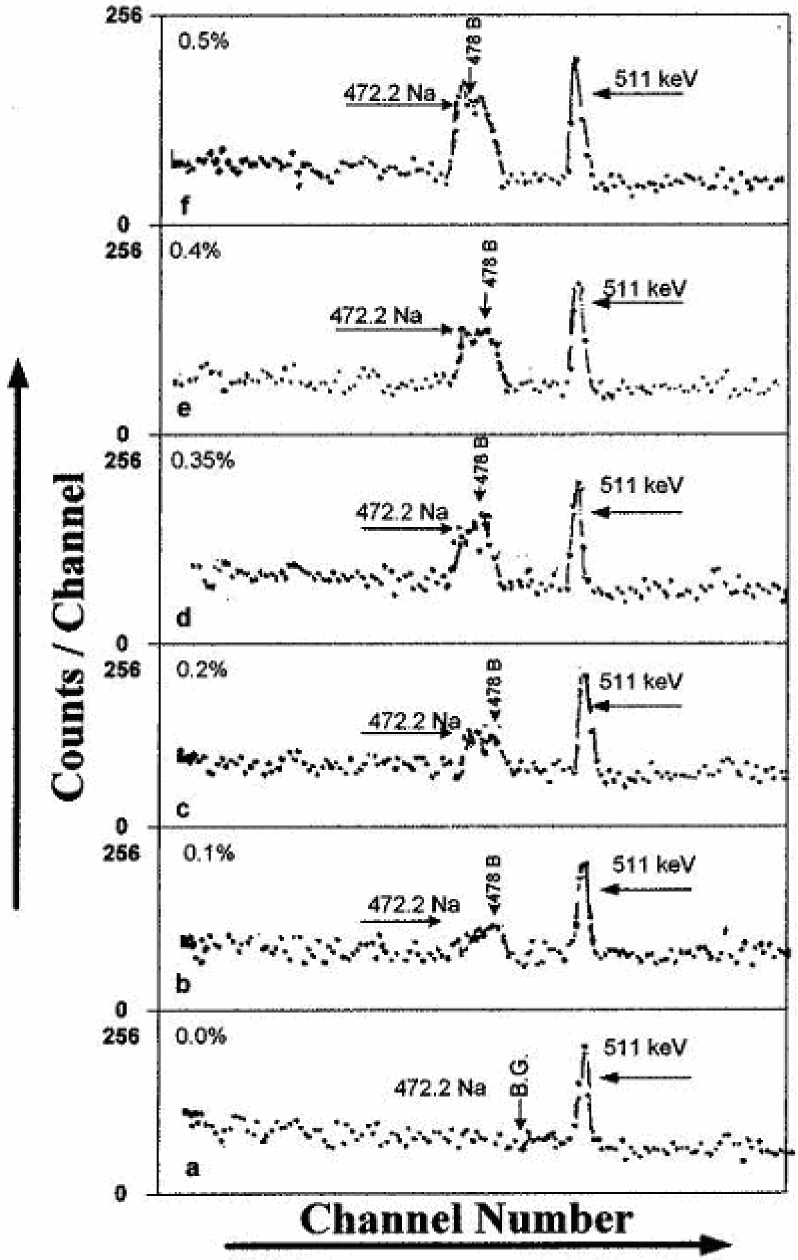


Figure 3. The prompt gamma-ray spectra of the artificial standard values at 0.0, 0.1, 0.2, 0.35, 0.4, and 0.5 % of Boron.

Prompt gamma-rays emitted from investigated sample due to thermal neutrons captured are collimated at right angle to the gamma-ray detector array to minimize the neutron source background effect. The gamma-ray lead collimator is designed in a cylindrical form with dimensions 50 mm Φ x 400 mm L., ended by an aperture of 16 mm at the HPGe detector to protect the NaI(TI) shielded-crystal from facing directly the measured gamma-rays. At the upper end of the collimator, near to the irradiated sample, a polyethylene box with 50 mm Φ x 25 mm L., filled with Li_2CO_3 an absorber enriched in Li-6 is placed to absorb the scattered thermal neutrons from reaching to the HPGe-detector. As well as to absorb radiation emitted from concerned radionuclides in the irradiated samples. The neutron flux density was measured around the target and the detector position using gold foil technique. It was about 5. 10^5 n/cm2 .s. at target position. At the detector position the neutron flux was too low to be detected.

Gamma-Ray Detection System

A closed-end coaxial HPGe detector with dimensions of 4.35 cm length, 4.8 cm diameter and a relative photopeak efficiency of 16.3% and resolution of 1.87 keV FWHM at 1332.46 keV is used for gamma-ray detection. Signals from the detector were passed through a FET preamplifier to be amplified by a spectroscopy linear amplifier, which fed the 4096 MCA card. A Tennelec model series II, personal computer analyzer (PCA-II) is also used in the present work as a radiation energy spectrum recorder. PCA-II software designed to be physically installed in most IBM personal computers. The PCA-II card contains a 100 MHz Wlkinson Analog-to-Digital Converter (ADC).

Energy Calibration and Sensitivity Curves of The System.

In order to calibrate the gamma-ray detection system, the gamma-ray lines of the standard radioactive source of ^{133}Ba, ^{109}Cd, ^{54}Mn, ^{137}Cs and ^{60}Co are used to construct the energy calibration line. This is used for estimating the exact energy value of Boron at 478 keV due to $^{10}B(n,\alpha)^7Li$. In case of constructing the sensitivity curve, the data was collected for each sample for 7000 s. The spectrum of each was as shown in figs. (3-a, 3-b, 3-c, 3-d, 3-e and 3-f). The concentration percentage value against the net peak area of Boron is illustrated as the sensitivity curve of the system on fig. (4).

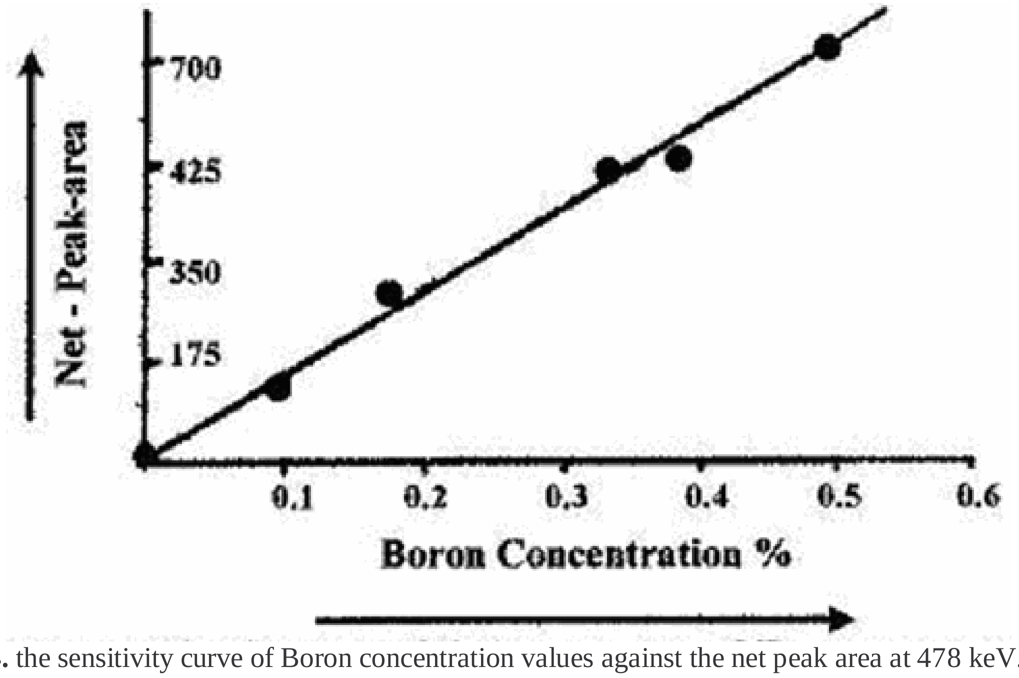


Figure 4. the sensitivity curve of Boron concentration values against the net peak area at 478 keV.

RESULTS AND DISCUSSION

Table 1. summarizes the experimental results obtained in this work for Boron concentration percentage values in Egyptian Tomato and Spinach samples, as well as the motor oil and glass samples. These values were in the range of 0.0016 to 0.00887 %. The experimental error was about 2.3 % which including the error in the net peak area calculations and the interfering of Na gamma-ray line at 472.2 keV background line.

Table 1. The concentration percentage values of Boron obtained in this work using the net peak area of the gamma-ray line at 487 keV

Material	Concentration %
Tomato.	0.00299
Spinach seeds.	0.00379
motor oil.	0.00160
Glass.	0.00887

In absence of the samples under investigation, a small Boron counting rate is detected. This may be due to neutron capture by Boron in an adjacent neutron guide. This Boron background count rate was measured by irradiating an empty polyethylene container for the same time of collecting the data for each sample. This background was negligible in most cases, it was very low comparing with the Boron content in the samples under investigation.

CONCLUSION

It is shown that the prompt gamma-ray technique using 252Cf isotopic neutron source among other analytical tools an appreciably useful for Boron estimation in different complex biological and industrial materials. The samples were in solid and liquid forms and a remarkable improvement of detection limit (0.0016 to 0.00887) is obtained. Also, the artificial standard samples done in our lab were suitable for construction of the sensitivity curve needed.

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