ENVIRONMENTAL STUDIES WITH THE MELBOURNE UNIVERSITY CYCLOTRON.

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Abstract

Multi-element analysis of environmental samples have been carried out by charged-particle activation using the Melbourne University Cyclotron. The air particulate matter collected in polystyerine filters around Brisbane have been found to contain S, Ca, Ti, Cr, Fe, Ni, Cu, Zn, Se, Sr, Y, Zr, Nb, Ru, Pt and Hg ranging in concentration from 0.01 μg to 1.02 μg/m^3. A comparison of the elemental concentration between the ashed roots of diseased and healthy eucalyptus trees from the Brisbane Ranges in Victoria using proton activation has indicated that the diseased tree contents of iron and titanium are only 30% and 59% respectively of that contained in healthy trees.

1. Introduction

There is a great deal of interest in analysing the elemental concentration, especially of the heavier metals in environmental samples in and around various cities and locations of the world. It is not only the pollution studies where this type of analysis is important but also in atmospheric physics and other branches of science where elemental concentration comparison in different samples of soil, vegetation, sea water, marine life etc., from different locations can be of great value.

Elemental concentration analysis of environmental samples can be carried out chemically or by using physical techniques like atomic absorption spectroscopy, activation analysis etc., However, chemical analysis may be quite tedious and may require a pre-knowledge of the type of elements to look for. Moreover, it is destructive, suffers from possible contamination during chemical processing and may not be very sensitive except in some special cases. Atomic absorption spectroscopy looks much better but it also suffers from lack of extreme sensitivity. Activation analysis on the other hand, seems to be the ideal technique for analysing environmental samples as it can be non-destructive and provide sensitivities as low as 1 p.p.b. quite conveniently.

It has been proven by Chaudhri and Batra[1]) that sensitivities from 1 p.p.m. to 1 p.p.b. are obtainable through thick target activation analysis by charged-particles from cyclotrons. With this technique one can detect and quantitate a number of elements in one run quite easily. We have used the proton beams from the Melbourne University Cyclotron for activation of air samples and of ashed eucalyptus trees. The results reported in this paper are a part of a major study dealing with elemental analysis of:-

(i) Solid particulate matter collected around Australian cities in collaboration with the C.S.I.R.O.
(ii) In healthy and diseased plants and the soil around them in order to find the causes of diseases and their possible cure in collaboration with the School of Botany, University of Melbourne.

2. Principle of the Method.

Elemental analysis by thick target charged particle activation is based on the principle that when thick targets of the unknown sample and the known standard are bombarded with indentical beams the concentrations of various elements in the two targets are related by the following equations[2]).

$$\frac{N}{N_s} = \frac{C}{C_s} \cdot \frac{I}{I_s} \cdot \frac{R}{R_s} \qquad (1)$$

Where N is the measured count rate of gammas coming from the activation of a certain element with a concentration C (micrograms of element per gram of matrix, parts per million, parts per billion etc.,) In the unknown sample,I is the beam intensity with which the sample has been irradiated and R the range of incident charged particles within. The same notations with the subscript s refer to the known standard for identical irradiation and detection conditions. For the equation to be valid the matrices of both the sample and standard should be similar, that is, having similar densities and average atomic numbers. Moreover, the element which is being determined should be homogenously distributed. The range of protons in a mixture or compound of elements 1, 2, 3,.....is given by Bragg Additivity Rule which has only a small error at the energies of interest here[3]).

3. Experimental Set-up and Procedure

The air particulate matter used for activation was collected in Brisbane during seven days in the month of June, 1974, by pumping 6.8 x 10^3 m^3 air through 2 micron polystyrene filters. The filter was cut into small pieces, placed in a 1mm deep and 15mm diameter groove of an alluminum target holder and covered with a thin aluminium foil. The thickness of this filter target was greater than the range of 8.5 MeV protons.

The roots of healthy and diseased eucalyptus trees from the Brisbane Ranges were ashed, compressed into pellets in the grooves of the aluminium target holders and covered with thin aluminium foil.

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The targets were placed in an insulated chamber and cooled with liquid nitrogen. They were bombarded with 8.5 MeV protons from the Cyclotron for one hour each at intensity of up to 1 μA. Blank filters were also used to estimate their contribution to various elements found in the atmospheric solid particulates.

The irradiated samples were allowed to decay for one hour before being counted with a high resolution Ge(Li) and PDP-9 Computer-Analyser System. This delay was necessary in order to eliminate the high count rates due to the induced positron activities. As a consequence, neither the elements giving rise to the positron activities or to other short lived activities could be measured.

4. Results and Discussion

4.1 Filters

The gamma ray spectrum in the region 0 - 2 MeV from the irradiated filter is shown in figure 1.

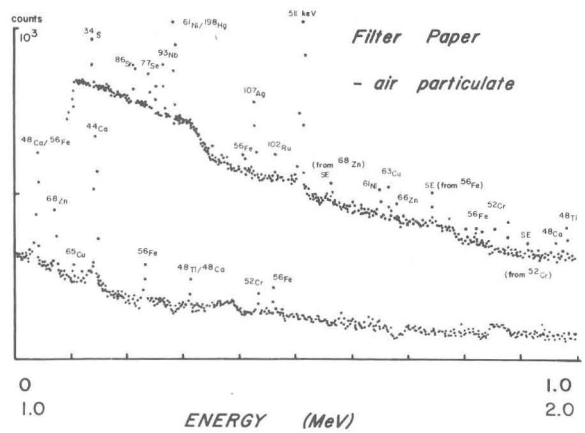

Fig.1. Gamma spectrum of activities induced by 8.5 MeV protons into the filter containing air particulates.

The analysis of the spectrum was carried out using automatic and user-interactive programmes[4]) on a PDP-15. Nuclide assignment to various peaks was made after a study of the gamma energies[5]), correlation with associated gammas, relative gamma intensities and additivity checks when a peak has more than one contributing species.

Various peaks in the figure have been labelled according to the elements present in the filter rather than to the induced activities. A total of 16 elements have been detected. These are:- S,Ca,Ti,Cr,Fe,Ni,Cu,Zn,Se,Sr,Y,Zr,Nb,Ru, Pt and Hg out of which Ca,Cr,Fe,Ni,Cu,and Zn are also found to exist in the "blank" filter. There may also be other elements present in the atmosphere which we could not detect either because they could not be activated with 8.5 MeV protons or the induced activities in them were too short lived.

Using suitable standards the quantitative figures for some of the elements have been calculated and shown in Table 1. The quantitation for the remaining elements is in progress at present. The Matrix of the filter paper with the solid particulate has been measured to consist of:-

7.5% H, 88% C, 2.5% O and 0.3% N[4])

TABLE 1: Elemental concentration in solid particulate matter in Brisbane air.

Element	Concentration μg/m^2
Ca	0.69
Cr	0.01
Fe	1.02
Ni	0.07
Cu	0.02
Zr	0.12
Sr	0.16

4.2 Eucalyptus

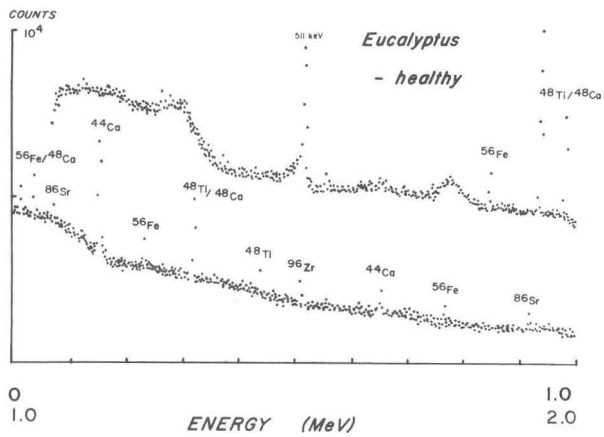

Fig.2. Gamma spectrum of activities induced into healthy eucalyptus by 8.5 MeV protons.

The induced activity in the 0 - 2 MeV range from healthy and diseased eucalyptus trees are shown in figures 2 and 3. No measurable peaks were found beyond 2 MeV.

The irradiation and counting for both the healthy and diseased samples were carried out under identical conditions. Therefore, the spectra in the two figures are comparable. From the areas under various peaks it was calculated that the iron content of the diseased eucalyptus was only (30±1)% of the healthy one whilst its titanium was only 59% of the healthy tree. There might well be other elements which are lacking in concentration or completely missing in the diseased trees which we could not see due to the limitations of our experimental set-up.

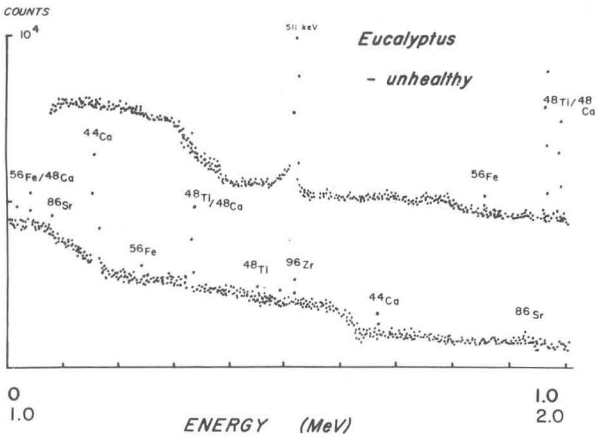

Fig.3. Gamma spectrum of activites induced into unhealthy eucalyptus by 8.5 MeV protons.

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