Rutherford Backscattering Spectrometry (RBS) method for the Determination of Elemental Constituent of Tropical Wood Matrices from Western Nigeria

To cite this article: C. A. Onumejor *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **173** 012005

IOP Conf. Series: Earth and Environmental Science **173** (2018) 012005 doi:10.1088/1755-1315/173/1/012005

Rutherford Backscattering Spectrometry (RBS) method for the Determination of Elemental Constituent of Tropical Wood Matrices from Western Nigeria

Onumejor C. A.[1], Balogun F. A.[2], Akinpelu A. [1], Arijaje T. E.[1], Usikalu M. R.[1]

Department of Physics, Covenant University, Ota, Nigeria
Centre for Energy Research and Development, Obafemi Awolowo, University, Ile-Ife, Nigeria

charity.onumejor@covenantuniversity.edu.ng

Abstract. The elemental composition analysis and its concentration levels in percentage were done on several wood samples using Rutherford Backscattering Spectrometry (RBS) of Ion Beam Analytical (IBA) methods. A total of twenty seven (15) tropical hardwoods from south western Nigerian environment were analyzed and six (6) major elements (C, O, N, Na, S, Cl) were identified. Carbon has the highest percentage constituents, ranging from 58.30% to 73.46%, in all the samples with sample 4 (*Albizia gummifera*) having the highest concentration of carbon as 73.46% and sample 7 (*Anadelphia afzeliana*) having the least carbon quantity as 58.30%.Nitrogen N ranged from 1.21% - 7.76%, Oxygen O 17.96% - 34.83%, Sodium Na 0.36% - 1.08%, Chlorine Cl 0.11% - 0.46%, and Sulfur S 0.13% to 0.59%. C was above the overall wood estimated constituent 50%, O below estimated value of 40%. Cl and S were within estimated range as trace element percentage range. The variation in elemental composition of wood used in the experiment shows that wood species have thesame elemental compositional trend as some human tissues and could be harness for use as tissues equivalent material for application in medical radiation dosimetry.

Keywords: RBS method, Elemental composition of wood, Wood composition, Tissue equivalent material

1. Introduction

Ion Beam Analysis (IBA) consists of several methods of studying materials based on the interaction between accelerated charged particles (ions) and the bombarded materials (sample). IBA techniques include: PIXE (particle induced X-ray Emission) based on atomic fluorescence, PIGE (Particle Induced Gamma ray Emission) based on nuclear reaction, NRA (Nuclear Reaction Analysis) based on nuclear reaction, RBS (Rutherford Backscattering Spectrometry) based on nuclear scattering. RBS is an ion beam scattering techniques that is used primarily for thin film composition analysis. It is typically the choice method for other quantitative composition analysis as well, for example for optical coatings, elemental characteristics, depth profiling and other applications where control of film composition is critical. RBS can detect low Z elemental constituent in materials and can measure hydrogen H and all other elements except helium Hi, litium Li and beryllium Be. In this study, we are concentrating on use of RBS which is arguably the first nuclear reaction ever recorded, for the

determination of elemental composition of biomass material (that is; several wood samples). Natural biomass materials have been known to contain elements like carbon, oxygen, nitrogen, sulfur and silicon etc. wood as a biomass are composed of Low Z (atomic number) element of which RBS method has been found to be highly suitable. Overall, wood has an elemental composition of about 50% carbon, 6% hydrogen, 44% oxygen, and trace amounts of several metal ions (Pettersen, 1984). The detailed chemical composition break down of wood varies from species to species, but when accounting for trace element it is approximately 50% carbon, 6% hydrogen, 42% oxygen, 1% Nitrogen and 1% other elements (mainly calcium, potassium, sodium, magnesium, iron, and manganese) by weight [1]. Most studies on elemental composition of biomass use digestions and other destructive analytical methods. There are rare records of studies using non-destructive analytical such as RBS. Hence, this study is aimed at using RBS method for the elemental analysis of select tropical woods from western Nigeria. Knowing the elemental composition of wood can tell a lot about the possible usefulness of such wood for various purposes. The common use of wood is for furniture and as fuel. Recently, wood is becoming relevant in the medical radiation field of study. Scientist [2,3] and few others has done some study on wood for dosimetric purposes and medical phantom material suitability in radiation oncology. Bradley [4] studied the photon attenuation studies on tropical hardwoods, Tajuddin [5] reported radiographic and scattering investigation on the suitability of Rhophoraspp hardwood as tissue-equivalent medium for dosimetric study. Sudin [6] study included Rhizophoraspp tropical hardwood as water-equivalent materials. Investigation continued on Rhizophoraspp hardwood. The usefulness of this named hardwood began from its elemental constituent study. Thus, the elemental study of wide range of woods will form a basis for further discovery of some other useful tropical wood in radiobiology. The present study will report elemental compositions of 15 tropical woods from Western Nigeria as basis for further radiological wood property study.

2. Materials and Method

2.1. Wood sample preparation

15 different wood samples were selected within the south-west region of Nigeria. Selection was based on abundance of the wood type, easy availability and cultivation possibility. Experts from Forest Research institute of Nigeria (FRIN) Ibadan were involved in the selection process. Selected samples were harvested in its timbers forms from different areas within the stated region. Identification of such tree to be harvested was done by trained personnel from the Forest Research institute of Nigeria (FRIN) Ibadan. The harvested samples were all transported from harvest zones to the Center for Energy Research and Development (CERD), at Obafemi Awolowo University Ile-Ife and stacked at the designated area within CERD space.

The harvested timbers thick back were peeled off immediately harvesting was completed. The peeled timber samples were sawed (cut) to smaller wood pieces and left to dry. Drying was done by construction of wood drying platform under open and direct sun rays. Sun drying of samples was from morning to dusk, at dusk; wood samples will be packed of the rancho (constructed hut or house for wood sample storage). Samples drying time was minimum of 100days. A Portion of each dried wood sample was pulverized and sieved with 2mm mesh size sieve. The sieved wood dust was scooped (about 20g per portion) into sample dispensary bags. The sample bags were properly labeled and bagged samples were then taken for pelletizing (pellet size of about 250 – 350mg). Each prepared (pelletized) sample was kept sealed in another labeled sample bag for elemental composition analysis. RBS (Rutherford Backscattering Spectrometry) ion beam analytical method was employed for sample elemental analysis. SIMNRA programing Software was used for RBS spectrum analysis of each wood sample.

2.2. Wood common names, scientific names and sample codes

The wood common names, scientific names and sample codes are as shown in table 1.

Table 1: Common, Botanical Name and Codes for Wood Samples

Sample Codes	Local or Common Names	Botanical Names
1	Afon	Treculiaafricana
2	Arere (Obeche)	Triplochitonscleroxylon
3	Aynure (white) or ayunre	Albizia zygia
4	Aynure or Ayunre (yellow)	Albizia gummifera
5	Cidrela	Cedrellaodorata
6	Efo-onibo	Basella alba
7	Bere	Anadelphia afzeliana
8	Gmelina	Gmelinaarborea
9	Ire	Funtumiasppelastic
10	Iroko	Milicia excels
11	Isin	Blahiasapida
12	Ita	Celtisspp
13	Kara koro	Irvingiagrandifolia
14	Kasia	Sennasiamea
15	Masonia	MansoniaAltissima

2.3. Description of accelerator facility for RBS

The NEC 5SDH 1.7 MV Accelerator machine at the Center for Energy Research and Development (CERD), ObafemiAwolowoUversity Ile-Ife was used for the Ion Beam Analysis (IBA). The IBA facility centred on this accelerator is equipped with a RF charge exchange ion source. The ion source is equipped to provide proton and helium ions. The accelerator has provision for five beam lines but is presently maintaining one that is equipped with a general purpose End Station for Particle Induced X-ray Emission (PIXE), Rutherford Backscattering Spectrometry (RBS), Elastic Recoil Detection Analysis (ERDA) and Particle Induced Gamma ray Emission (PIGE). Which are stationed at 135^{o}, 165^{o}, 30^{o} and 225^{o}angled position respectively, while the window for observing the beam position and size is at 0^{o}.Calibrations were done using commercially available standards for biological analysis. These standards were selected such that they provide a representation of the entire spectrum needed for the analysis. In calibrating the system, the 0.6 - 3.5MeV energy ranges of the 4He+ particles was used to bombard the standard samples.

3. Results and discussion

A total of 6 elements of interest were entered into the SIMNRA software setup for RBS spectra processes. The percentage weighted fractions for each of these elements are as shown in table 2.

Table 2: Element concentration of wood samples in %

Elements/sample ID	C	N	O	Na	Cl	S
1	64.73	2.0	32.31	0.49	0.14	0.33
2	65.10	2.27	31.48	0.54	0.18	0.42
3	64.48	3.33	30.96	0.65	0.18	0.38
4	73.46	7.50	17.96	0.37	0.11	0.59
5	70.00	7.76	21.11	0.68	0.26	0.43
6	69.01	6.48	22.90	0.84	0.32	0.45
7	58.30	5.05	34.83	0.89	0.42	0.51
8	70.51	7.54	20.91	0.36	0.11	0.56
9	66.13	1.97	30.51	0.73	0.41	0.34
10	67.91	5.87	24.76	0.79	0.34	0.33
11	63.96	4.02	30.21	1.08	0.39	0.34
12	67.17	2.36	26.41	1.02	0.46	0.57
13	64.18	4.16	30.19	0.72	0.35	0.40
14	67.02	4.66	26.76	0.76	0.38	0.48
15	64.03	1.21	33.79	0.63	0.21	0.13

3.1. Elemental analysis

A total of 6 elements of dosimetric interest were inputted into RBS spectra processing software for identification in samples. This was done for each of the 15 different wood pellets. The elements identified are C, N, O, Na, Cl and S. The results of the elemental compositions for the studied samples are presented in table 2. The concentrations of all the detected elements in the samples were found to vary slightly, but had the same concentration trend as shown in the graphical plots of element concentration against samples in table 2. Figure 1-6 shows the comparison of each element concentration in all the studied samples. Major points of variation were noted as are clearly seen on the graphs. The concentrations of Carbon C was found to be within the range of 58.30% -73.46%, Nitrogen N ranged from 1.21% - 7.76%, Oxygen O 17.96% - 34.83%, Sodium Na 0.36% - 1.08%, Chlorine Cl 0.11% - 0.46%, and Sulfur S 0.13% to 0.59%. C was above the overall wood estimated constituent 50%, O below estimated value of 40%.Cl and S were within estimated range as trace element percentage range. The results tallies with wood elemental constituents trend as reported by WPGS [1,7] and Pettersen, [8,9]. These detected elements were so called elements of dosimetric interest because they covered about 99% of the elemental constituents of the various human tissues and organs. Other detectable elements are in trace levels. According to Nelson [8,10], almost 99% of the mass of the human body is made up of six elements: oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus. Only about 0.85% is composed of another five elements: potassium, sulfur, sodium, chlorine, and magnesium. All 11 are necessary for life. The remaining elements are trace elements.

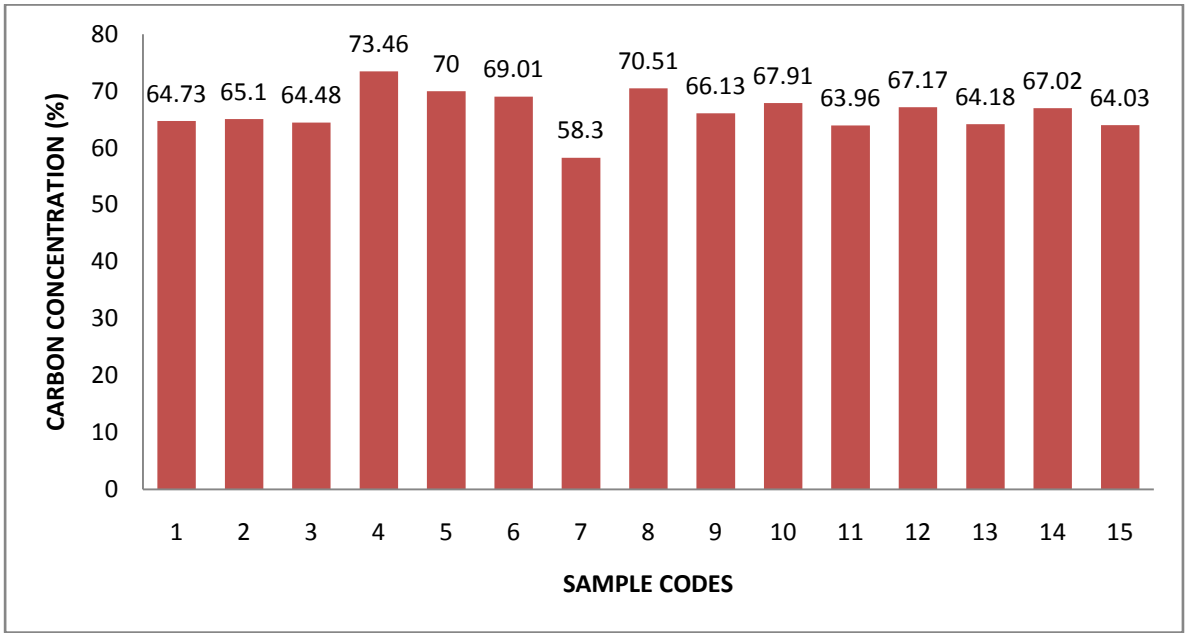

Figure 1: Comparison of Carbon Concentration in Samples

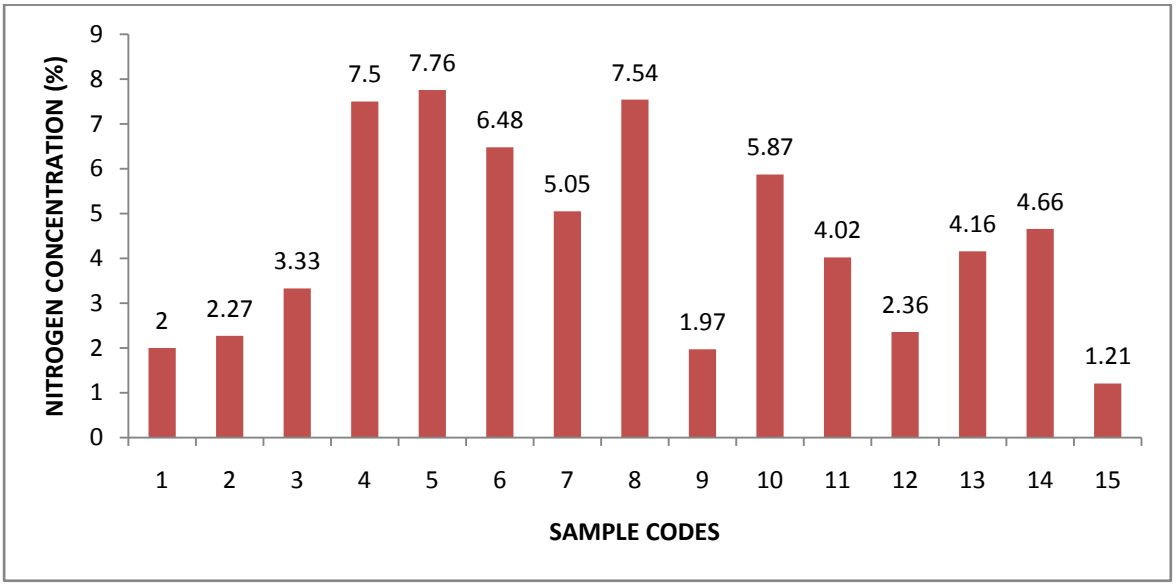

Figure 2: Comparison of Nitrogen Concentration in Samples

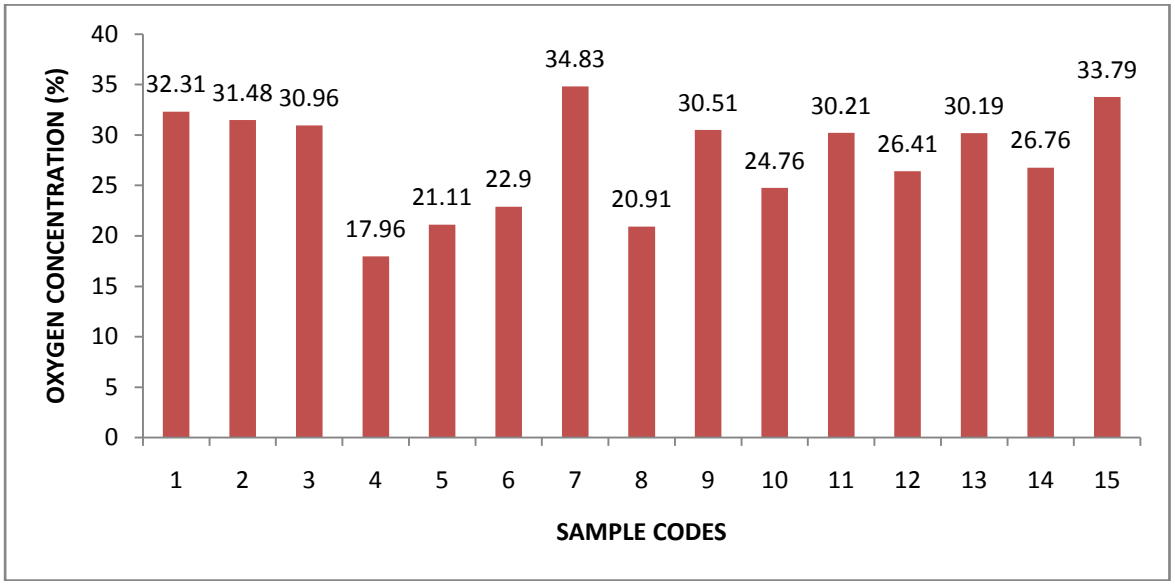

Figure 3: Comparison of Oxygen Concentration in Samples

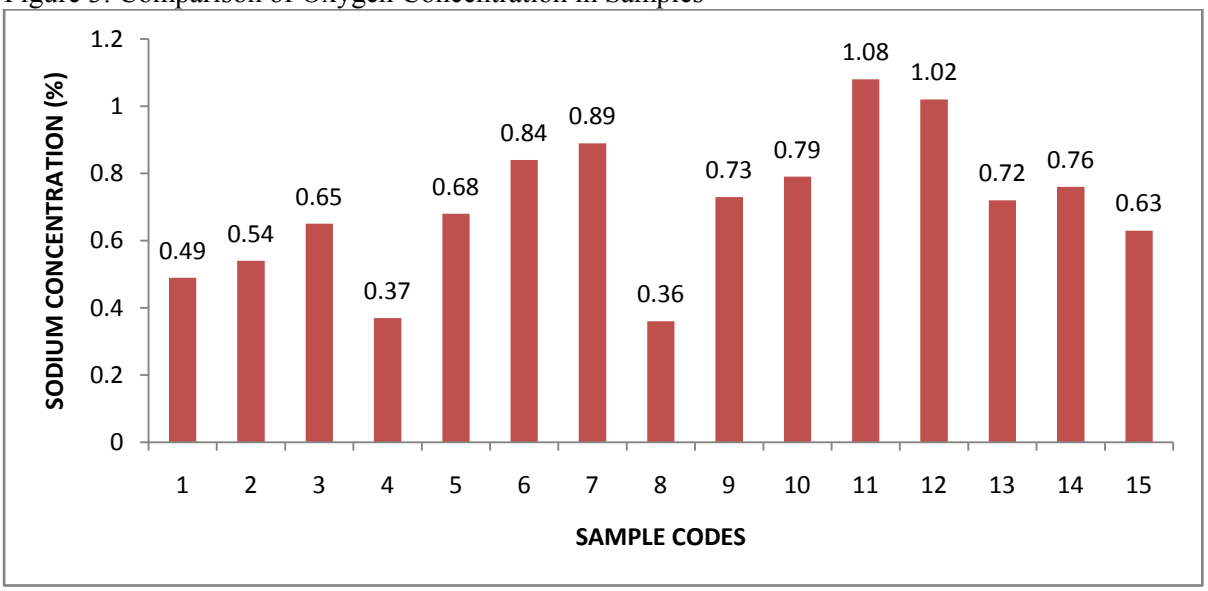

Figure 4: Comparison of Sodium Concentration in Samples

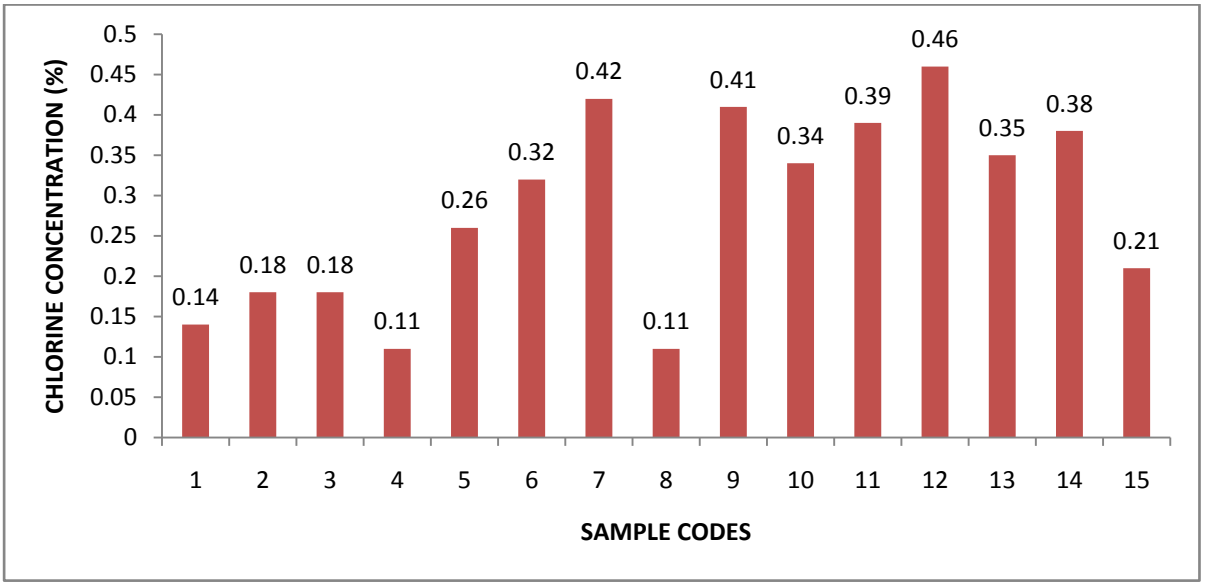

Figure 5: Comparison of Chlorine Concentration in Samples

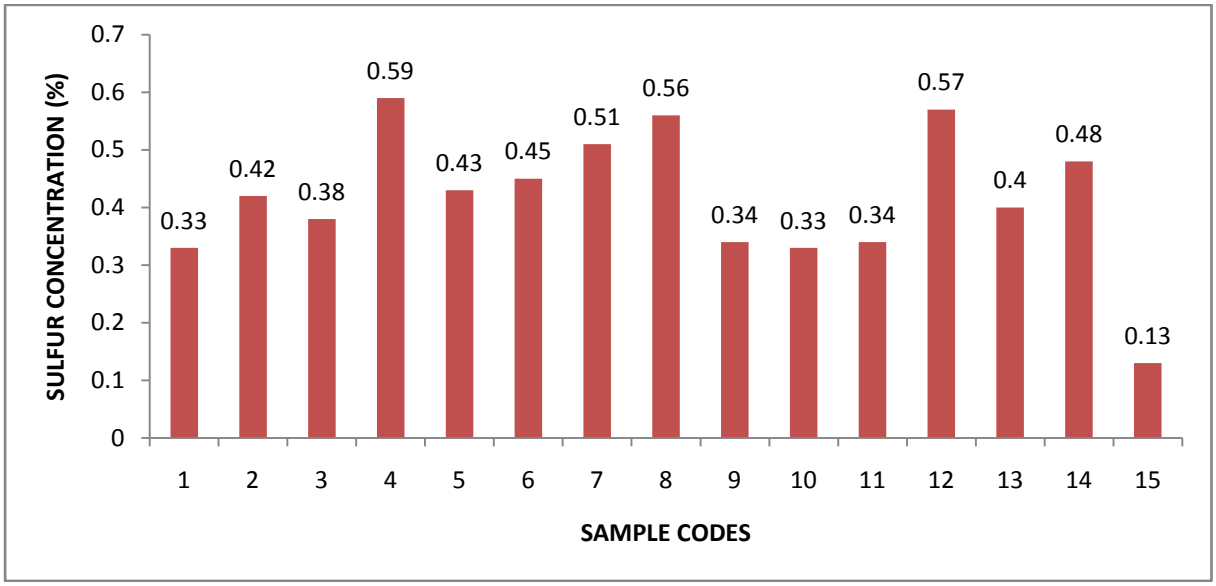

Figure 6: Comparison of Sulfur Concentration in Samples

4. Conclusion

RBS method has been used to determine the elemental constituent of several wood samples. The methods capability to detect element with low atomic number, has been harnessed as the idea non-invasive method for determination of low Z elemental matrix in materials samples such as wood. Looking at the composition for the wood samples, it was seen that the elemental composition of the wood followed the same trend as stated in literature. The knowledge of the elemental composition of wood can be harnessed as substitute material for animal and human biomas in application in health physics for radiological studies, medical application, radiation physics, radiology, nuclear engineering, radiation dosimetry, phantoms, radiation protection and space research.

Acknowledgement

We appreciate the management of Covenant University, Nigeria for the publication support received from them.

References

[1] WPGS (2015) - Wood Properties Growth and Structure 2015. treetesting.com.
[2] WHITE, D. R. An analysis of the Z-dependence of photon and electron interactions. *Physics in Medicine and Biology, 22,* 1977b219-228.
[3] C. Constantinou., "Phantom materials for radiation dosimetry," I. liquids and gels*British Journal of Radiology,* 1982, *52*217-224.
[4] D. A. Bradley, A. A. Tajuddin, C. W. A. C. W. Sudin, and S. Bauk, " Photon attenuation studies on tropical hardwoods," International Journal of Radiation Applications and Instrumentation. Part A. Applied Radiation and Isotopes, 1991, 42771-773.
[5] Tajuddin, A.A., Sudin, C.W.A.C.W., and Bradley, D.A., Radiographic and scattering investigation on the suitability of Rhizophora spp. as tissue-equivalent medium for dosimetric study, Radiation Physics and Chemistry, 1996, 47 739-740 .
[6] Sudin, C.W.A.C.W., Tajuddin, A.A., and Bradley, D.A., Evaluation of tissue-equivalent media for dosimetric studies, Proceeding of local seminar activities on radiation physics, biophysics and medical physics, Universiti Malaya, Kuala Lumpur, Malaysia, 1988. pp. 71-80.
[7] R.C. Pettersen, "The Chemical Composition of Wood" U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI 53705.1984, 57-58.
[8] Nielsen and H. Forrest "Ultratrace minerals". Authors: USDA, ARS Source: Modern nutrition in health and disease / editors, Maurice E. Shils ... et al..Baltimore : Williams & Wilkins, c. 1999, 1283-303, Issue Date: 1999
[9] C. W. A. C. W. Sudin, A. A. Tajuddin, and D. A. Bradley, "Evaluation of tissue-equivalent media for dosimetric studies, Proceeding of local seminar activities on radiation physics, biophysics and medical physics," Universiti Malaya, Kuala Lumpur, Malaysia, 1988, 71-80.
[10] A. A. Tajuddin, C. W. A. C. W. Sudin,and D. A. Bradley, "Radiographic and scattering investigation on the suitability of Rhizophora spp. as tissue-equivalent medium for dosimetric study," Radiation Physics and Chemistry,1991, 47 739-740.