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Main

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FROM THE EDITOR

Paul Bergstrom

I wish to thank the International Radiation Physics Society for the opportunity to edit the Bulletin. It is quite clear that I will need the help of the members of the Society in order to be successful in this role.

Help has already been forthcoming in large amounts from Dudley Creagh and from Shirley McKeown in getting this issue out the door. I have the luxury of a gradual transfer of the editorial reins from Dudley to me. Indeed, this issue is more a product of the work of Dudley and Shirley than of my efforts.

As I look through the back issues of the Bulletin (nee Newsletter), one consistent plea that appears in the editor's column is for contributions from the membership. Let me stand on tradition and ask the members to submit items of interest to the Bulletin through Dudley, Shirley or me.

In the spirit of asking members for contributions, I knocked on John Hubbell's door and asked him to write up an account of the Monte Carlo 2000 conference that he attended in Lisbon last October. John has provided us with a fine account of that meeting devoted to the simulation of the transport of ionising radiation in matter.

As many of you already know, Ugo Fano, a pioneer in the theory of radiation physics died recently. John Hubbell kindly performed double duty by providing a retrospective of Fano's work for this issue.

We are also fortunate to have the technical article by Vaca, Manjon and Garcia-Leon on the presence of radionuclides in Eucalyptus trees and the surrounding soil. This study was an award winning poster presentation at the last meeting of the Society.

So, as you enjoy these articles, please consider submitting some of your own. You are also invited to send your suggestions for the continued improvement of the Bulletin.

Let me close this note by thanking Dudley for his tenure as editor of the Bulletin. I hope that, under his continued guidance, my efforts can be as successful.

Main	Next

PRESIDENT'S COLUMN

Malcolm Cooper

In the past few months my most pleasant duty in connection with IRPS has been to welcome two Nobel prize winners as members. Professors Georges Charpak and Carlo Rubbia have endorsed the aims of our Society by accepting membership. As most of you will already know Georges Charpak won his Nobel prize in 1992 for "the invention and development of particle detectors, in particular multiwire proportional counter" and Carlo Rubbia shared the 1984 Physics prize with Simon van der Meer for "their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of the weak interaction." I am sure that they, like many other IRPS members, are associated with other more prestigious organisations, but nonetheless value the role that IRPS plays in bringing together radiation physicists worldwide.

The topic of membership reminds me that Mic Farquharson has been working hard with Shirley McKeown, Dudley Creagh and Suprakash Roy to produce a definitive list of members, coupled with their electronic, as well as postal, addresses and contacts. It is vital to our fragile finances that as many members as possible are able to receive the Bulletin by email. This is almost as vital as ensuring that your membership subscription is paid up – have you checked? The state of our society and how to enhance it, will feature largely on the agenda of our next Council meeting, which is to be held in Exeter, UK at the end of May 2001. I really would like to receive all your suggestions to aid our discussions; please email me

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Looking back over the last few months it is not difficult to see where "radiation issues" have captured press headlines internationally. I mean of course "DU" (depleted uranium) and the possible harm that it can do to military and civilian personnel after it has been used in the heat of battle, as an armour-piercing warhead. I wonder how many of you have been called on to provide expert opinions either for the media or for your inquisitive friends?

I found an excellent balanced account in the Newsletter of the Swedish Radiation Protection Institute (***web address:*** www.ssi.sc), which quantified the radiation hazards compared with natural uranium. It is obvious that, if warheads were tipped with natural uranium, they would pose a much greater radiation hazard than DU, but that is hardly the point: pulverising, oxidising and dispersing any amount of actinide material is never going to be beneficial to health. On the other hand, if the military could afford to use tungsten alloy tips, deaths would probably be limited to those immediately at the receiving end of the projectile. In fact depleted uranium is cheap and plentiful and, at 1.7 times the density of lead, frighteningly effective at puncturing armour plating. Whether or not the illnesses now reported are consequential seems much more difficult to establish and therefore provides endless material for the media .

It would be nice to compile some radiation "Good News Items" but, apart from the fairly obvious area of diagnostic and therapeutic medical radiation, physics examples seem to be distressingly thin on the ground. Perhaps you might write to remind me of some of them to highlight in future columns.

Previous	Main	Next

OBITUARY : Ugo Fano

Ugo Fano's Contributions to Radiation Physics

by John H. Hubbell

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The Radiation Physics community was recently saddened by the passage on February 13, 2001, from complications of Alzheimer's disease, of one of our radiation physics giants Ugo Fano in Chicago, survived by his wife Camilla ("Lilla") and their two daughters Mary and Virginia. However, we are happy with the rich legacy he has left us, not only in radiation physics but also in broadly diverse areas including atomic physics, molecular biology and particle physics. This note will highlight his contributions to radiation physics during his 20-year tenure 1946-1966 at the National Bureau of Standards (NBS, now National Institute of Standards and Technology, NIST, since 1988).

Ugo was born in Turin, Italy, July 28, 1912, and after receiving a doctorate in mathematics from the University of Turin in 1934 he worked with various luminaries including Nobelists Enrico Fermi, Emilio Segre, Werner Heisenberg and Salvatore Luria (Medicine). By 1939, the Fascist regime under Mussolini made life untenable for persons with Jewish ancestry, resulting in his flight to the USA via Paris and Argentina. The final leg from Buenos Aires to New York was a 39-day voyage on a Norwegian freighter, which doubled as a honeymoon for him and his bride Lilla, with time for extensive discussions about the "hit theory" of genetic mutations and the influence of long protein molecules.

After his arrival in the USA, prior to coming to the NBS, Ugo worked at a succession of places such as the Carnegie Institution Department of Terrestrial Magnetism in Washington, the Ballistic Research Laboratory at the U.S. Army's Aberdeen Proving Grounds, and a year in the Physics Department at Columbia University, New York, on such diverse topics as the reproductive genetics of bacteriophages, tailoring bombs for specific types of targets, and finally, at Columbia, the action and degradation of ionizing radiation in a macroscopic material. The fascination and challenges of this last topic determined the direction of the balance of Ugo's career, in radiation and atomic physics.

Arriving at NBS, then at Connecticut and Van Ness in Washington DC in 1946, Ugo soon formed the Radiation Theory Group as part of the NBS Atomic and Radiation Physics Division under Lauriston Taylor. Ugo was a bold pioneer, not only in science, but also in diversity and independence in his hiring practices during those dark days of segregation (in restaurants and theaters) by skin-color in Washington, and male dominance in the scientific professions. Also, as another novelty, Ugo's "Theory Group" included several practicing experimentalists. When this reporter joined Ugo's Group in 1951, it was as an experimentalist, supervised by a female experimentalist, Evans Hayward, and there were three African-American mathematicians and physicists, two of them women, in his Group.

Fortunately, for our lunches together for special occasions, we found a Chinese restaurant, the Peking in Chevy Chase, which ignored the then-pervasive (in Washington) racial segregation, and Ugo's Radiation Theory Group became adept with chopsticks under the tutelage of a guest worker from Scotland, Jack Boag. Jack's final examination for us was to pluck an ice cube out of one's glass using the chopsticks, lick it, and return it to the glass without dropping it.

Ugo Fano's NBS Radiation Theory Group (NBS Section 4.8) in 1955 in front of the Peking Restaurant, Chevy Chase, Washington DC
Left to right: Ugo Fano, Hazel Baumer (Secretary), Evans Hayward, Ann Nelms,
Gladys (White) Grodstein, Martin Berger, John Doggett, Irwin Oppenheim
Ida Reingold, Lewis Spencer, Frank Titus, Richard Bach.
Not shown: John Hubbell ***(photographer)***

While Ugo's Group was doing all this, including some pioneering Monte Carlo radiation transport computations, first by hand (Evans Hayward and John Hubbell) and then using electronic computers (Martin Berger), also developing and exploiting the "moments method" (Lew Spencer), Ugo himself was quietly exercising his genius and creativity, producing ground-breaking atomic and radiation physics papers which still provide the foundations for hundreds of papers in the current literature, in particular his 1961 classic "configuration interaction" paper (see below). Ugo's final years at NBS were as a Senior Research Fellow, continuing his theoretical researches and book collaborations, before his move to the University of Chicago in 1966.

In 1995 Ugo returned to Washington to receive one of his many awards, the prestigious and well-earned Fermi Award from the U.S. Department of Energy, which occasion brought many members of his 1950's-1960's NBS Radiation Theory Group together for an enjoyable reunion with each other and with this great man.

His books, and a brief sampling of his wide-ranging and seminal papers, are listed below:

Fano, U. (1944) Experiments on Mutations Induced by Neutrons in Drosophila Melanogaster Sperm, Genetics 29, 361-369.

Fano, U. (1946) On the Theory of Ionization Yield of Radiation in Different Substances, Physical Review 70, 44-52.

Fano, U. (1947) Ionization Yield of Radiations. II. The Fluctuations of the Number of Ions, Physical Review 72, 26-29.

Fano, U. (1949) Remarks on the Classical and Quantum-Mechanical Treatment of Partial Polarization, J. Opt. Soc. Am. 39, 859-863.

Fano, U. (1953) Gamma-Ray Attenuation. Part I. Basic Processes, Nucleonics 11(8), 8-12, Part II. Analysis of Penetration, 11(9), 55-61.

Fano, U. (1953) Penetration of X- and Gamma Rays to Extremely Great Depths, J. Res. NBS 51, 95-122.

Fano, U. (1954) Note on the Bragg-Gray Cavity Principle for Measuring Energy Dissipation, Radiation Research 1, 237-240.

Fano, U. (1954) Principles of Radiological Physics, Chapter 1 in Radiation Biology, Vol. 1: High Energy Radiation, A. Hollaender, Ed. (McGraw-Hill, NY), 1-144.

Fano. U. (1954) Inelastic Collisions and the Molière Theory of Multiple Scattering, Phys. Rev. 93, 117-120.

Fano, U., Spencer, L.V. and Berger, M.J. (1959) Penetration and Diffusion of X Rays, in Encyclopedia of Physics, Vol. 38/2, S. Flügge, Ed. (Springer, Berlin), 659-817.

Fano, U. and Racah, G. (1959) Irreducible Tensorial Sets (Academic Press, NY).

Fano, U. and Fano, L. (1959) Basic Physics of Atoms and Molecules (Wiley, NY).

Fano, U. (1960) On the Scattering of g Rays by Nuclei, NBS Technical Note 83.

Fano, U. (1961) Effects of Configuration Interaction on Intensities and Phase Shifts, Phys. Rev. 124, 1866-1878 [Ugo's most-cited work, still cited 147 times in the year 2000, 39 years after its publication, according to the Science Citation Index].

Fano, U., Zerby, C.D. and Berger, M.J. (1962) Gamma-Ray Attenuation, Chapter 10 in Reactor Handbook, Vol. 3, Part B: Shielding, E.P. Blizard and L.S. Abbott, Eds. (Interscience, Wiley), 102-127.

Fano, U. and Cooper, J.W. (1968) Spectral Distribution of Atomic Oscillator Strengths, Rev. Mod. Phys. 40, 441-507 [Ugo's second-most-cited work].

Fano, U. (1969) Spin Orientation of Photoelectrons Ejected by Circularly Polarized Light, Phys. Rev. 178, 131-136.

Fano, U. and Fano, L. (1973) Physics of Atoms and Molecules: An Introduction to the Structure of Matter (Univ. Chicago Press).

Fano, U. and Rau, A.R.P. (1986) Atomic Collisions and Spectra (Academic Press, Orlando).

Fano, U. and Rau, A.R.P. (1996) Symmetries in Quantum Physics (Academic Press, Orlando).

REPORTS FROM MEMBERS

Monte Carlo 2000: Advanced Monte Carlo on Radiation Physics, Particle Transport Simulation and Applications (MC-2000)

Lisbon, Portugal, October 23-26, 2000

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An international conference on Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications (MC-2000) was held in Lisbon, Portugal in the IST (Instituto Superior Técnico) Congress Centre, October 23-26, 2000. The Conference Chairman was Masayuki Nakagawa (JAERI, Japan) and the Technical Program Coordinator was Pedro Vaz (IST, Portugal, and OECD/NEA, Paris).

The conference was divided into three main categories: (1) electron-photon (EG) Monte Carlo, (2) neutron-gamma (NG) Monte Carlo and (3) Hadronic (HAD) Monte Carlo, with papers in these three areas presented orally and by poster in parallel sessions except for the opening and closing plenary sessions in which the lectures in each area were presented, in series, to the entire assemblage.

In each of these three categories (EG, NG, HAD), the aim was to address the following issues: Theory and methods, physics and modeling issues, algorithm developments, computational science, basic data, analysis of experiments and measurements, benchmarks, status of general-purpose codes, tools (graphics and analysis), and applications. Within the limitations of available speakers, this aim was successfully accomplished.

Prior to the main conference, on Saturday and Sunday, October 21-22, tutorial sessions were offered. The Saturday tutorial lectures, on Electron/Gamma Monte Carlo: Building Blocks and Applications, were given by F. Salvat, H. Hirayama, A. Bielajew, A. Nahum, D. Rogers, and M.C. Lopes. The Sunday morning tutorial lectures, on Hadronic Physics Monte Carlo, were given by A. Ferrari, R. Prael, W. Newhauser and J. Siebers. Sunday afternoon the tutorial lectures, on Neutron-Gamma Physics and MC Codes, were presented by N. Smith, J. Wellisch and G. McKinney.

Monday morning, in the opening plenary session, following welcoming remarks by conference, university, and local governmental officials, A. Bielajew (U. Michigan) spoke retrospectively "On electron-photon Monte Carlo" including well-deserved tributes to M.J. Berger and W.R. Nelson. This was followed by I. Lux (HAEA, Hungary), "Neutron and photon MC - fragments from its history," and by R. Prael (LANL), "On hadronic physics Monte Carlo" to close the opening session.

The balance of the conference, through Thursday morning, consisted of parallel quarter-day sessions in each of the three above-mentioned categories, EG, NG and HAD. Most of these sessions were keynoted and opened with an invited lecture. In the EG (electron-photon Monte Carlo) sessions attended by this reporter, such keynotes included, for example, lectures by F. Salvat: "Analog electron physics: Interaction cross sections", by J. Hubbell: "A half-century of Monte Carlo, from slide rule and mechanical desk calculator to the laptop supercomputer", by H. Hirayama: "Application of EGS4 Monte Carlo code to a study of gamma-ray buildup factors", and by B. Grosswendt: "The track structures of photons, electrons and a-particles from the point of view of ionization cluster formation."

Among the social events provided by the conference was the Wednesday evening visit to the Jerónimos Monastery containing the tombs of such Portuguese notables as Bartholomeu Dias, discoverer of the Cape of Good Hope (which the IRPS will also discover, at ISRP-9 in 2003!). From the Monastery our buses took us to our conference banquet in a nearby electric power plant building on the Tagus River, now converted to a technical museum. John Hubbell was requested to open the after-dinner remarks. After thanking and congratulating the conference organizers, he made reference to the Portuguese explorers such as Henry the Navigator (and his School), Dias, and Vasco da Gama (sea route to India) who carried Portugal to the far corners of the globe, and how now, at MC-2000 in Lisbon, scientific representatives from these "far corners" have here converged back to Portugal. In acknowledgement of the brave and intrepid Portuguese seafarers, John concluded his remarks with a lively rendition of the "Sailor's Hornpipe" on his well-travelled harmonica.

The Conference Chairman Masayuki Nakagawa in his subsequent remarks mentioned that MC-2000 could be the start of a conference series, with the next one to take place in Japan. MC-2000 was concluded with a Thursday afternoon retrospective session in which F. Salvat summarized and mentioned highlights of the electron-gamma (EG) sessions, G. McKinney reviewed the neutron-gamma (NG) sessions, and D. Filges and W. Gudowski shared in reviewing the hadronic (HAD) sessions, all of them providing some speculation and prospects for the future of the Monte Carlo method and its role in radiation physics, particle transport simulation and applications.

PAPER

Radionuclides of the ^{238}U- and ^{232}T-series in soil samples collected in a Mediterranean Eucalyptus forest: transference from soil to Eucalyptus trees

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Abstract

Eucalyptus forests are the main source of raw material (wood and bark) for the Spanish pulp industry. The presence of radioactivity in such forests can cause the introduction of radionuclides in factories and, consequently, the possibility of producing radiation dose to the workers and the public in general through waste releases. An exhaustive study has been carried out in one Eucalyptus forest located in the south of Spain of which some results are presented. Thus, results on natural radionuclide concentration (^{238}U, ^{234}U, ^{228}Th, ^{230}Th, ^{232}Th) in soil samples, determined by α - and γ -spectrometry, are presented. A comparison between ^{228}Th activity, determined by γ -spectrometry, and ^{232}Th activity, determined by α -spectrometry, was used as a quality control parameter for analyses. Using activity concentration of radionuclides in other forest components (wood, bark, leaves, litter), transference factors were finally evaluated.

1. Introduction

The forest ecosystems act very efficiently as sinks of radionuclides coming from radioactive fallout or released into the environment as a consequence of nuclear accidents, e.g. Chernobyl. The study of the concentrations, flows and dynamics of radionuclides in these scenarios has received a growing amount of attention during the last several years.

In 1993, we started an intense campaign of studies related to the pulp mill industry and their associated plantations of Eucalyptus, where the raw material used in the production of cellulose is collected (Manjón et al., 1996). The transference of artificial and natural radionuclides associated with the raw materials (wood and bark) from the forest to the factory, the concentration and distribution processes in the factory and the release into the environment, associated with wastes discharges, were the main objectives of this work. In previous papers (Vaca et al., 1999; Vaca et al., 2000), we have published the activity concentration of radionuclides (^{90}Sr, ^{137}Cs and natural occurring radionuclides) in samples collected within the pulp factory of Huelva (in southwestern Spain). In these papers, the behaviour of the mentioned radionuclides in the factory was reported. Indeed, it was observed that the re-circulation and recovery processes, used in this type of industry, causes the concentration of radionuclides in some stages and in some waste discharges generated during the industrial process (Vaca et al., 1999). These facts were compared to similar studies carried out by other researchers in similar factories located in Sweden and Norway (Ravila and Holm, 1994; Krosshavn et al., 1996). Additionally, the activity concentration of the same radionuclides (^{90}Sr, ^{137}Cs and natural radionuclides) in samples collected in a Eucalyptus plantation, located not far from the pulp mill of Huelva, was also studied. Results, corresponding to artificial radionuclides, were presented and discussed elsewhere (Vaca et al., 2001a).

In this paper, we will present the activity concentration of natural radionuclides in the Eucalyptus forest, mainly in soil samples. Furthermore, the behavior of these radionuclides in the forest will be discussed. For activity determinations of natural radionuclides, two different techniques (alpha and gamma spectrometry) were used. Two different sample pretreatments, atmospheric and microwave digestion, in uranium analyses will be discussed. The activity concentration of Th-isotopes, obtained by both techniques (alpha and gamma spectrometry), was compared to evaluate the accuracy of radiometric procedures and the quality of the analyses.

2. Sampling

A Eucalyptus plantation, located in the South of Spain (37º49'30" N latitude), was intensively sampled in 1995 (see ***Figure 1***). The surface of the plantation was 2.3×10^5 m^2. The number of trees in this forest was estimated to be 14,400 at the moment of sampling. A Mediterranean weather can be assumed in the zone and the annual rainfall ranges from 750 up to 1000 mm per square meter, with a dry period as long as five months. The forest is located in a 2000 year old mining area (***Figure 1***) and its height varies between 360 and 400 m above sea level. The tree species cultivated in the plantation was ***Eucalyptus Globulus***, which is the variety most used as raw material for pulp production in Spain. Eucalyptus trees were 14 years old at the time of sampling. After planting the trees, different works (pruning, cleaning) were carried out in the forest. Therefore, the Eucalyptus forest cannot be considered a natural ecosystem.

However, sampling was done just before the first cutting of trees, which allows a study of the transference of radionuclides soil - trees. Usually, successive cuttings are carried out in a Eucalyptus forest after planting. Five trees were selected for the study (***Figure 2***). Trees were identified by the codes {1}, {2}, {3}, {4} and {5}.

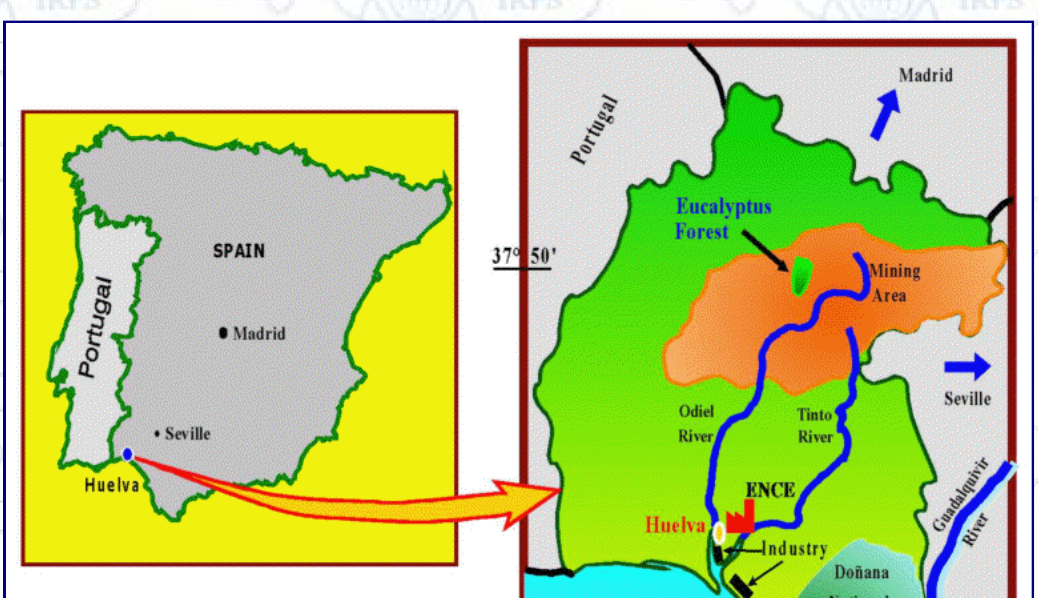

Figure 1. Localization of the Eucalyptus plantation in the north zone of Province of Huelva, South of Spain

The tree {1} was intensively studied : samples of wood and bark at different trunk heights, all of the branches and leaves, and some roots were taken. A representative sample of wood and bark was selected from the rest of the trees.

Two soil samples were collected close to tree {1}. These samples were identified by the codes 1SI and 1SD. Each soil sample was distributed in four layers according to depth. For the sample 1SI, each sample was identified by the codes $1SI_1$ (upper layer), $1SI_2$, $1SI_3$, $1SI_4$ (lower layer); and for 1SD soil sample, the samples were $1SD_1$ (upper layer), $1SD_2$, $1SD_3$, $1SD_4$ (lower layer). The top layer surface was 50 cm x 50 cm (Schimmack et al., 1989). Three other soil samples were collected in the vicinity of the rest of the trees. They were identified as 2S, 3S and 4S. Two layers (upper and lower) were distinguished in these last samples. Finally, samples of litter and herbs were also taken (***Figure 2***).

Physical parameters (pH, humidity, density) and chemical components (major and trace stable elements) were exhaustively determined in soil samples. The samples were dried and homogenised for γ -spectrometry measurements.

3. Experimental

The activity concentration of some natural radionuclides was determined by γ-spectrometry. ^{228}Ra and ^{228}Th are determined through the emissions of the ^{228}Ac (E_γ = 911.1 KeV) and the
^{208}Tl (E_γ = 583.2 KeV), respectively. ^{226}Ra activity concentration have been measured by the emissions of ^{214}Pb (E_γ = 352.0 KeV). For it, a conventional HPGe coaxial counter (1.88 keV of resolution and 14% of relative efficiency for the 1330 keV photopeak of ^{60}Co) was used. Adapting the method of Bolívar et al., 1996, to our conditions, we did the determination of photopeak efficiency. The samples were measured with a consistently defined geometry in a cylinder of polyethylene of fixed diameter and different sample height.

Alpha emitting radionuclides (^{210}Po, ^{234}U, ^{238}U, ^{230}Th and ^{232}Th) were measured by
α -spectrometry with ion-implanted silicon detectors, after a sequential extraction with TBP (Bolívar et al., 1995). The samples were dissolved applying two alternative digestion processes, an acid atmospheric digestion with aqua regia and a digestion with aqua regia + hydrofluoric acid in a microwave (González-Labajo et al., 2001).

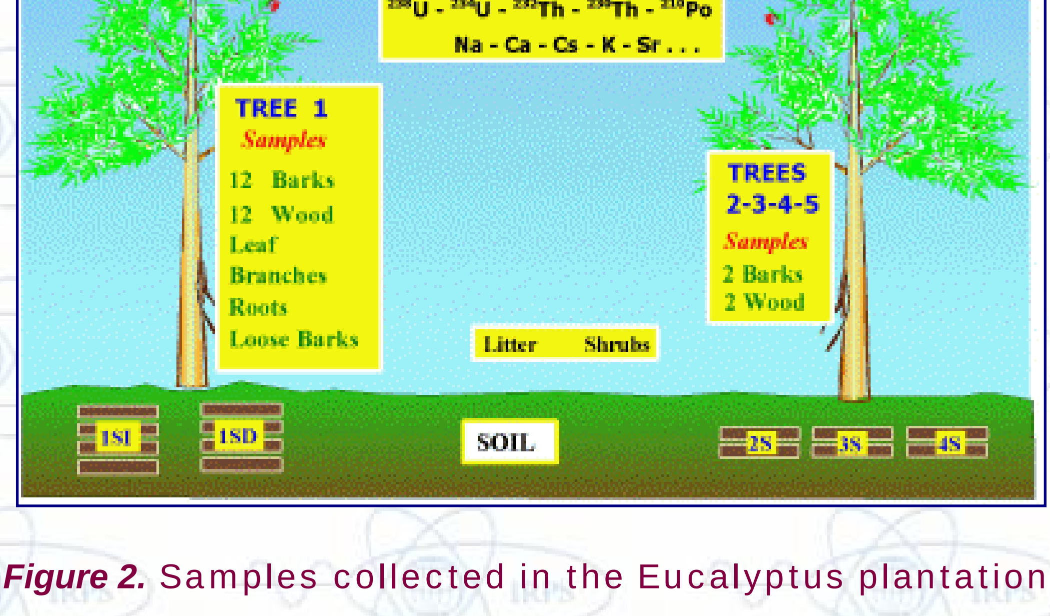

Figure 2. Samples collected in the Eucalyptus plantation.

4. Results and Discussion

NEW MEMBERS, ADDRESS CHANGES

Welcome to New Members :

Professor Georges Charpak, **SWITZERLAND**

Dr Vladimir Maisheev, **RUSSIA**

Dr Pirunthavany Muthuvely, **U.K.**

Professor Carlo Rubbia, **SWITZERLAND**

Dr Luis M Tavora, **PORTUGAL**

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Prof. Fouad Lahlou **MOROCCO**

Dr Ramkumar Saptharashi **INDIA**

Professor A.J. Simmons **U.K.**

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Previous	Main

4. Results and Discussion

Natural radionuclide activity concentrations (Bq/kg dry weight) in soil samples are listed in Table 1. Since a depth dependence was not found, we presented the mean activity value averaged along the profile. Density and pH were similar in all samples, but some differences can be observed in water content. Thus, the higher values (9.4 – 14.6 %) correspond to samples $1SI_1$, $1SI_2$, $1SI_3$, $1SI_4$ and $1SD_1$. In the rest of the soil samples, lower values (3 – 5.5%) were found. The organic matter content was higher in the samples 1SD and 1SI, collected near the tree {1}.

Activity concentrations of ^{90}Sr and ^{137}Cs in these soil samples (Vaca et al., 2001b) are presented in Table 2. The values found in our study are similar to those referred by Baeza et al., 1994, in the province of Cáceres (western Spain) and slightly higher than those obtained by González Labajo, 1998, in Doñana National Reservation (***Figure 1***).

Furthermore, the mean $^{137}Cs/^{90}Sr$-activity ratio in soil samples is 2.2, slightly higher than atmospheric fallout.

The $^{234}U/^{238}U$ activity ratio in soils approaches in general the condition of secular equilibrium (see ***Figure 3***). This finding is not so apparent when an atmospheric digestion is used. It shows the importance of the sample pre-treatment to analyse the equilibrium between nuclides. As expected, only uranium isotopes (^{238}U and ^{234}U) are in secular equilibrium. The rest of the isotopes of the uranium series present higher (the activity concentration of ^{226}Ra is, in general, twice as high as the ^{238}U activity concentration) or lower levels. Isotopes of thorium series were also determined and the respective activity concentrations in soil samples are also listed in Table 1. In this case, all the radioisotopes studied present secular equilibrium, meaning that the sampled soil can be considered unperturbed.

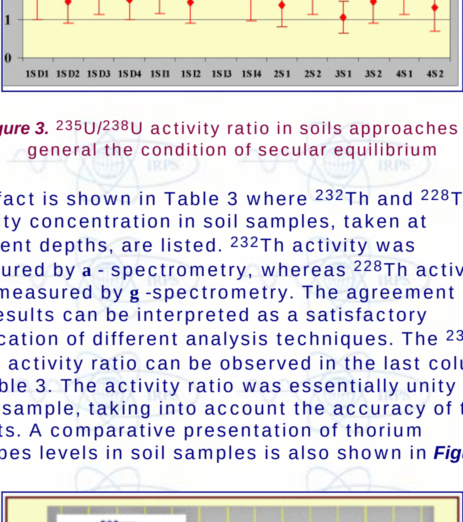

Figure 3. $^{235}U/^{238}U$ activity ratio in soils approaches in general the condition of secular equilibrium

This fact is shown in Table 3 where ^{232}Th and ^{228}Th activity concentration in soil samples, taken at different depths, are listed. ^{232}Th activity was measured by a - spectrometry, whereas ^{228}Th activity was measured by g -spectrometry. The agreement of the results can be interpreted as a satisfactory application of different analysis techniques. The ^{232}Th / ^{228}Th activity ratio can be observed in the last column of Table 3. The activity ratio was essentially unity in each sample, taking into account the accuracy of the results. A comparative presentation of thorium isotopes levels in soil samples is also shown in ***Figure 4***.

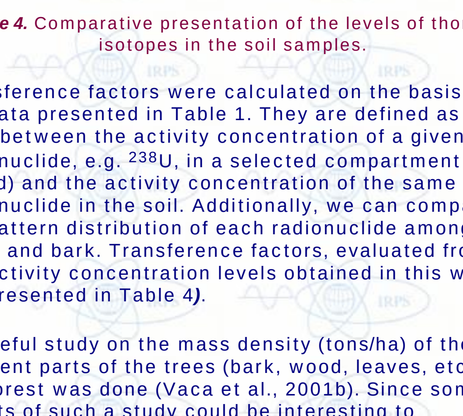

Figure 4. Comparative presentation of the levels of thorium isotopes in the soil samples.

Transference factors were calculated on the basis of the data presented in Table 1. They are defined as the ratio between the activity concentration of a given radionuclide, e.g. ^{238}U, in a selected compartment (wood) and the activity concentration of the same radionuclide in the soil. Additionally, we can compare the pattern distribution of each radionuclide among wood and bark. Transference factors, evaluated from the activity concentration levels obtained in this work, are presented in Table 4***)***.

A careful study on the mass density (tons/ha) of the different parts of the trees (bark, wood, leaves, etc.) in the forest was done (Vaca et al., 2001b). Since some results of such a study could be interesting to understand the soil composition, they will be reviewed in the following lines. Using the data obtained by measuring the perimeter of the trunks at different heights, the thickness of bark and the masses of the samples collected (branches, litter), it was possible to determine the volume and the mass of the different components of the Eucalyptus in the forest. Our empirical data present a good agreement with typical values found in the literature.

According to our calculations, the production of the forest, fourteen years after plantation, was 32.21 tons/ha of wood and 4.08 tons/ha of bark. Using these data, we can estimate the flux of radionuclides, associated with wood and bark, transferred into the forest industry.

The radioactivity density, expressed in kBq/ha, for the different radionuclides, in the Eucalyptus plantation, is presented in ***Figure 5***.

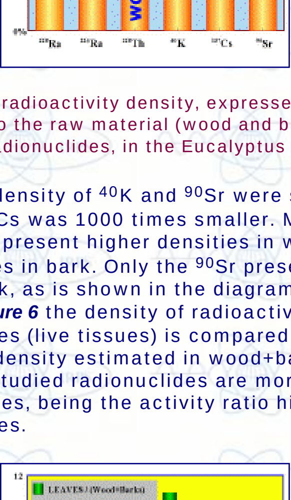

Figure 5. The radioactivity density, expressed in kBq/ha, associated to the raw material (wood and barks) for the different radionuclides, in the Eucalyptus plantation.

Whereas the density of ^{40}K and ^{90}Sr were similar, the density of ^{137}Cs was 1000 times smaller. Most of the radionuclides present higher densities in wood and lower densities in bark. Only the ^{90}Sr present a higher density in bark, as is shown in the diagram of ***Figure 5*** (down). In ***Figure 6*** the density of radioactivity in leaves and in branches (live tissues) is compared to the radioactivity density estimated in wood+bark, i.e. dead tissues. The studied radionuclides are more associated with live tissues, being the activity ratio higher than four in all cases.

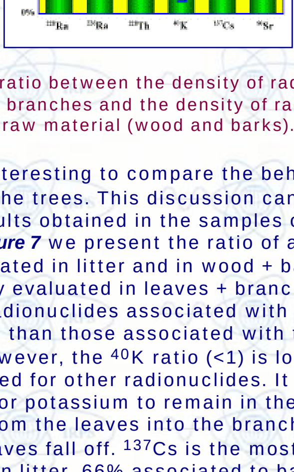

Figure 6. The ratio between the density of radioactivity in leaves and in branches and the density of radioactivity in raw material (wood and barks).

It would be interesting to compare the behaviour of ^{40}K and ^{137}Cs in the trees. This discussion can be made using the results obtained in the samples of litter. Indeed, in ***Figure 7*** we present the ratio of activity density estimated in litter and in wood + bark as well as the density evaluated in leaves + branches. The amounts of radionuclides associated with litter are clearly higher than those associated with the leaves + branches. However, the ^{40}K ratio (<1) is lower than the ratio calculated for other radionuclides. It seems a trend exists for potassium to remain in the trees, being transferred from the leaves into the branches just before the leaves fall off. ^{137}Cs is the most abundant radionuclide in litter, 66% associated to bark + wood. This percentage was 8% for ^{40}K and 25% for the ^{90}Sr. According to these results, litter will be an important component of the forest in the case of a contamination event.

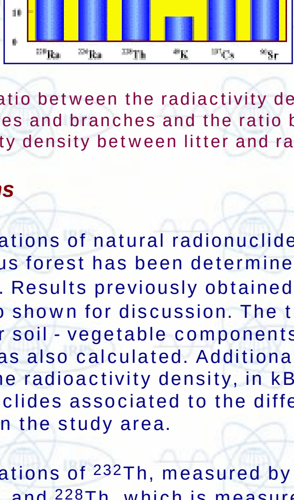

Figure 7. The ratio between the radiactivity density in litter and leaves and branches and the ratio between radioactivity density between litter and raw material.

5. Conclusions

The concentrations of natural radionuclides in samples of a Eucalyptus forest has been determined by a - or g - spectrometry. Results previously obtained of ^{90}Sr and ^{137}Cs are also shown for discussion. The transfer coefficient for soil - vegetable components of this ecosystem was also calculated. Additionally, we have determined the radioactivity density, in kBq/ha, of these radionuclides associated to the different components in the study area.

The concentrations of ^{232}Th, measured by a - spectrometry, and ^{228}Th, which is measured through the emissions of the ^{208}Tl (Eg = 583.2 KeV) by g - spectrometry, in all soil-samples are similar, as expected. This was an excellent test of the goodness of both techniques.

Two different soil digestions were used for U analyses. The results show that the digestion with a microwave oven, using HF, is the most appropriate method for the sample digestion.

Activity concentration of long-lived artificial radionuclides in the Eucalyptus forest was reviewed for discussion.

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Tables