ARCHIVE EDITION OF

IRPS BULLETIN

Volume 19 No 3 December, 2005

Office Bearers : 2003 - 2006

Editorial

President's Report - "Origins of Radiation"

Member's Paper

Members' Reports

Return to Archive Home Page

OFFICE BEARERS : 2003 - 2006

President:

R.H. Pratt
Dept. of Physics
Univ Pittsburgh, PA
15260 USA

Secretariat:

D.A. Bradley
School of Physics,
University of Exeter
Stocker Road
Exeter EX4 4QL UK

Treasurer:

A. Ljubicic
Rudjer Boskovic Institute
Bijenicka 54
Zagreb 41000 Croatia

Chair, Advisory Board

M.J. Cooper
Department of Physics
University of Warwick
Coventry CV4 7AL U.K.

Regional Vice Presidents:

North America:
J. Hubbell (USA)

South and Central America:

A. Paschoa (Brazil)

Africa and Middle East:

D.T.L. Jones (South Africa)

East Europe
L. Musilek (Czech Republic)

F.S.U
A.V. Korol (Russia)

Western Europe:

M.J. Farquharson (U. K.)

S.E. Asia :

S.C. Roy (India)

Australasia :
D.C. Creagh (Australia)

North East Asia:

Luo Zhengming (PR China)

Executive Councillors:

P. Bergstrom (U.S.A.)

L. Gerward (Denmark)

J.E. Fernandez (Italy)

R.T. Mainardi (Argentina)

J. O'Meara (Canada)

K. Singh Thind (India)

D. McLean (Australia)

T. Nakamura (Japan)

EDITORIAL BOARD

Editors : P.M. Bergstrom (U.S.A.), L. Hudson (U.S.A.), R. Tosh (U.S.A.)

Editorial Committee : D.C. Creagh (Australia) S.A. McKeown (Australia)

Home Page

EDITORIAL

As 2005 draws to a close, we are happy to distribute IRPS bulletin, Volume 19 No. 3 (the 4th issue produced this year). As always we appreciate and subsist on submissions by the membership. As illustrated in recent bulletins, this includes reports from conferences, articles and tutorials on radiation physics, and announcements of upcoming conferences, symposia, and IRPS activities.

In this issue we begin to shine a spotlight on the 10th International Symposium on Radiation Physics (ISRP-10) to be held 17-22 September 2006 in Coimbra, Portugal. You are also encouraged to learn about the associated Workshop on Use of Monte Carlo Techniques for Design and Analysis of Radiation Detectors (15-17 September 2006, Coimbra).

In upcoming issues we plan to include further symposium details, lists of invited speakers, abstracts, and helpful logistical guidance in making one's way to Coimbra.

After ISRP-10, and with your assistance, we hope to provide reflections from this triennial meeting of the Society and a review of the technical content from Coimbra for the membership at large.

Wishing you a peaceful and happy new year,

Larry Hudson

Home Page | Next

PRESIDENT'S REPORT

Origins of "Radiation"

As members of the International Radiation Physics Society, it is interesting for us to note the origins of the word "radiation," which apparently entered the English language at the end of the 16th century. (It would be interesting to hear of the origins in other languages, if some member of IRPS could provide information.)

The concept of radiation is of course much older, and we find it, for example, in the ancient Greek atomists. Thus Epicurus, in his summary of such thought in his "Letter to Herodotus", writes:

> "We see a thing when something (idols) comes to us from its surface, their energies impressed on them by the vibrations in the depth of the solid object ...the particles composing them retain the form they had on its surface..."

Note that the discussion is of what we would now call electromagnetic radiation, but a radiation composed of particles. (If we wish, we could now understand "photons.") Newton (talking about polarization) expresses a similar view in his "Optiks":

> "Even the rays of light seem to be hard bodies, for otherwise they would not retain different properties on their different sides."

According to my dictionary, the use of the word "ray" is ancient, coming from Middle English, from Middle French, from Latin. But "radiation" is first used in 1570, radiance in 1601, radiate in 1619, radiancy in 1646, radiant in 1727, radiant heat in 1794, radiator in 1836, radiant energy in 1890, and radiant flux in 1925.

By the 19th century such rays or radiations were considered as wave motions, not particles, and radiation was commonly understood as referring to light or heat.

But the terms "ray" and "radiation" were still also understood more generally. Thus J. J. Thomson in his 1897 paper "Cathode Rays", viewed as reporting the discovery of the electron, writes that the rays are

> "...wholly material, and mark the paths of particles of matter charged with negative electricity..."

Similarly Rutherford and Soddy, in their classic 1903 paper discussing "Radioactive Change", speak of the "synchronism between the change and the radiation", of "the material nature of the radiations," and that "alpha and beta rays (are) two types of radiation."

We see both views in the 1911 Encyclopedia Britannica (11th Edition), in which the article "Radiation, Theory of" treats electromagnetic radiation, light and heat, while the article "Radioactivity" (written by Rutherford) says that "these substances spontaneously emit radiations...able to penetrate through matter opaque to ordinary light."

Webster's Collegiate Dictionary in 1936 (Fifth Edition) talks of "radiant energy...(as in light rays, x-rays, gamma rays, etc.)," while by 1985 (Ninth Edition) it talks of "radiant energy in the form of waves or particles." Similarly, by 1974 (15th Edition) the Britannica says that

> "Radiation consists of a flow of atomic and subatomic particles and of waves, such as those that characterize heat rays, light rays, and X-rays. All matter is constantly bombarded with radiation of both types from cosmic and terrestrial sources."

When the International Radiation Physics Society was founded in 1985 its Constitution stated that

> "Radiation Physics is defined as the branch of science which deals with the physical aspects of interactions of ionizing radiations (both electromagnetic and particulate) with matter."

The emphasis is less on the nature of the radiations than on what they do. (Note that the restriction to ionizing radiation was subsequently removed, recognizing the importance of also including non-ionizing radiations in modern Radiation Physics.)

I hope this account provides some insight into the use of the word "radiation," as in the name of our Society. I would welcome further information, comments, and viewpoints.

Richard Pratt

Previous | Home Page | Next

MEMBER'S PAPER

A Study of the Linear Attenuation Property of some Materials and their Influence on Radiographic Contrast

[1]N. O. Egbe*, B. F. Olisemeke, [2]S. O. Inyang, [1]N. O. Chiaghanam and [1]V.C.Ikamaise

[1]Department of Radiography, University of Calabar, Calabar, Nigeria
[2]Department of Physics, Medunsa, South Africa

*Author for correspondence - ***e-mail:*** nneoyiegbe@yahoo.com

ABSTRACT:

The attenuation property of Ebony wood and Perspex, as well as the radiographic contrast produced by these materials, were studied along side those of aluminium, tin and copper metals (for comparison) at the x-ray energy of 67kV and 40mAs, to assess the possibility of the adoption of Ebony wood and Perspex as x-ray cassette window materials. Results obtained revealed that ebony wood and Perspex attenuated the beam moderately (42.3% and 47.4%, respectively) and recorded radiographic contrast values above 0.5 (50% of optimum contrast in radiology), higher than values obtained for tin and copper, but less than contrast values recorded with aluminium. The results suggest the possibility of the use of ebony wood and Perspex, probably with treatment for enhancement, as x-ray cassette window materials, in addition to their use as shielding materials at much lower energies.

Keywords: Attenuation, Ebony wood, Perspex, Cassette, Contrast

INTRODUCTION :

Radiographic image quality is a primary factor in the utility of a radiograph for diagnostic purposes. The image must contain certain diagnostic information in a form that is easy to extract visually. The ease with which this information is extracted is dependent on the magnitude of the densities and density difference (Jenkins,1981) recorded on the radiograph.

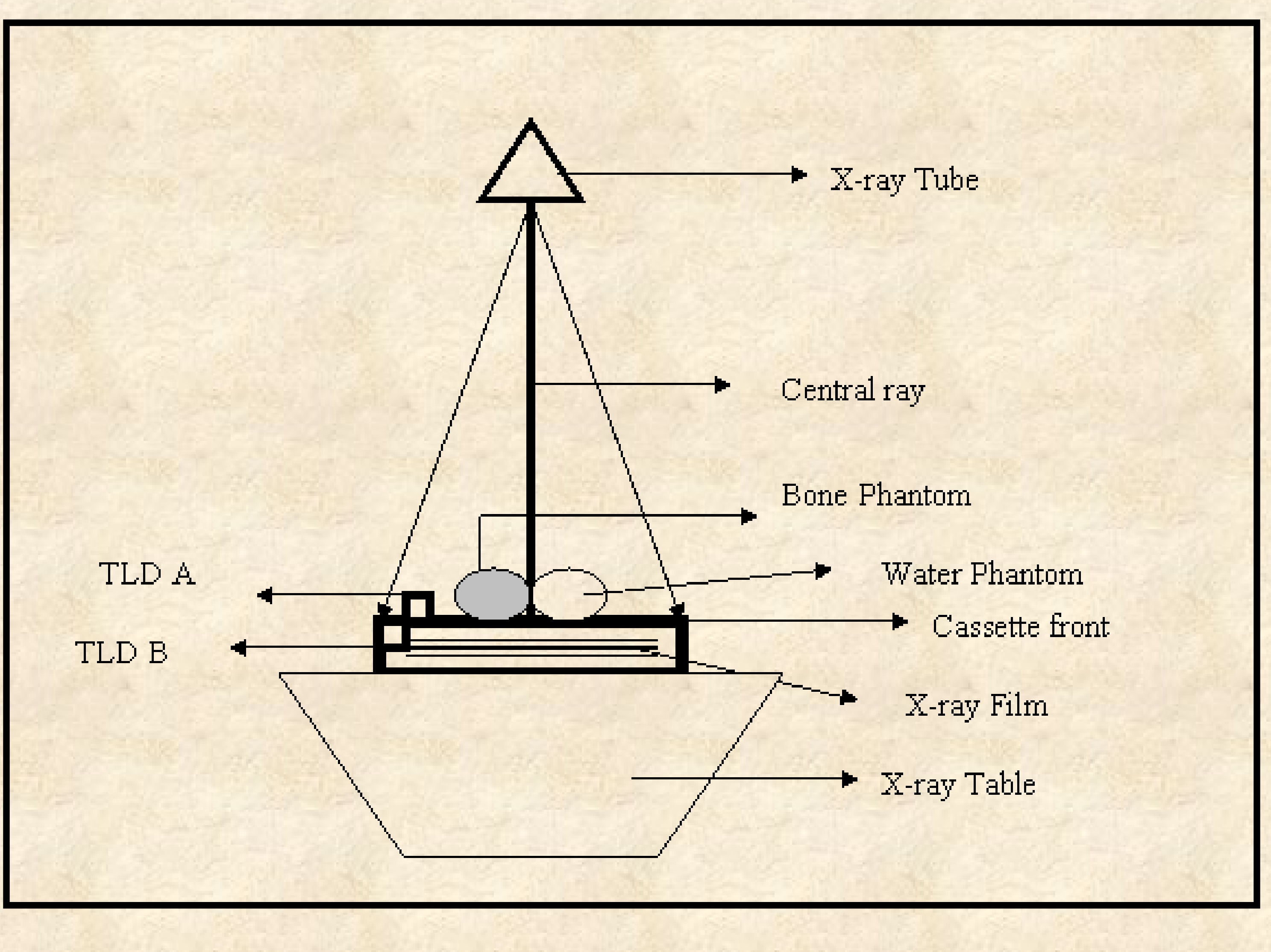
Such densities are themselves heavily dependent on several factors, like exposure factors, thickness of the part irradiated, the attenuation properties of the cassette front radiolucent window, among others (Christensen et al, 1978). The attenuation properties of a material determine its attenuation coefficient, which is a measure of the quantity of radiation attenuated by a unit thickness of that material traversed (Christensen et al, 1978; Hay & Hughes, 1978; Ekpe & Essien, 1999). Different materials have different attenuation properties because of different factors which include the nature of radiation, the properties of the medium - atomic number, density and electrons per cubic centimeter (Mescham & OH, 1984 ; Brant and Helms, 1998).

The quality of the transmitted beam, is therefore dependent on the attenuation properties of the traversed material and determines the quality of the radiographic image, which is formed on a light sensitive medium, the x-ray film (Jenkins, 1981; Chesney & Chesney, 1981). Materials used in x-ray cassette manufacturing are made into light tight containers and are made to have a uniform radiolucent cassette front (Jenkins, 1981; Egbe, 2004), which serves as the window for x-ray transmission to reach the recording medium. Several materials have been used for this purpose some of which have already been dropped. However research into the possible utility of some other materials is needful, as the search for optimum benefits in image quality (Corr, 2001) and radiation protection (Munro, 2004) continues. Usually low attenuating materials are utilized in the making of x-ray cassettes since much of the radiation beam needs to reach the detector (film) to record the image. Poor film contrast, as one of the determinants of image quality, will introduce the necessity of repeated radiograph with the attendant undesirable effects on patient dose increase.

This work focuses principally on the attenuation of wood (Ebony) and Perspex used as cassette front (window) materials, side by side with aluminium, copper and tin, with a view to possible adoption of these materials for further development as cassette front materials, particularly in places where these materials exist in abundance.

MATERIALS AND METHODS :

Cassettes were constructed using the materials under study - aluminum, copper, tin and Perspex and wood. Construction was such that the cassette window, through which x-radiation passes into the cassettes to reach the film, was made of a thin sheet of the test material (2.0 mm thickness) and calcium tungstate based intensifying screens (which emit blue) attached to the back of the window material. Screen type films of the Konica media were placed within the boxes, which had provision for being locked. The experimental cassettes were then severally and individually exposed to x-radiation from a high frequency single-phase x-ray generator having a maximum output of 150kVp, 500mA and 0.5 seconds, and a minimum output of 45kVp, 50mA and 0.001 seconds, respectively. Exposures were made at 67kVp, 200mA and 0.2 seconds (40mAs), with the selection of factors based on the variable kV method for adult mid-thigh measurement of 20cm, described by Munro, (2004). The experimental set up is as shown in Figure 1, below.



Bone and water phantom materials (dry pelvic bone and a sachet of water in a cellophane bag) were placed above the cassette front window being tested, for determination of contrast (image quality). One thermoluminiscent dosimeter (LiF) chip each, labeled as TLD A and TLD B, respectively, were placed above and immediately below the cassette window to measure the "skin dose" (above) and the transmitted intensity (below), of the x-ray beam, respectively. The TLD chips were read with a vinten solaro TLD reader calibrated in μSv, and the attenuated components of the beam for each material was computed using Equation 1, below :

$$\textit{TLD A} - \textit{TLD B} = \textit{Attenuated quantity} \qquad \text{(Eq. 1)}$$

The exposed films were processed manually for 3 minutes, in a developer bath with temperature 26ºC, then fixed and washed for 10 and 30 minutes respectively. Processed films were dried in a separate dryer (Holm, 2000; Lloyd, 2001) and the recorded densities read with a Sakura model PDA - 85 digital densitometer From these, contrast between the bone and the water phantom determined for assessment of the radiographic contrast by Equation 2, below :

$$D_w - D_b = \textit{Contrast} \qquad \text{(Eq. 2)}$$

where D_w and D_b represent the density readings for bone and water phantom, from the densitometer.

The attenuation coefficients were determined from the mathematical relationship expressed in Equation 3 (Hay & Hughes, 1978; Ekpe & Essien, 1999; Inyang et al, 1999).

$$I = I_o e^{-\mu x} \qquad \text{(Eq. 3)}$$

All the results obtained are presented in Table 1 below.

Table 1: Transmission of the x-ray beam by different window materials

Window material	TLD Readings μSv			% Attenuation	μ mm^{-1}	Mean Contrast with SD
	TLD A	TLD B	TLD A - TLD B			
Tin	1.94 ± 0.01	0.82 ± 0.01	1.12	57.7	- 0.187	0.32 ± 0.01
Copper	1.94 ± 0.01	0.98 ± 0.01	0.96	49.5	- 0.148	0.38 ± 0.01
Aluminium	1.94 ± 0.01	1.61 ± 0.01	0.33	17.0	- 0.040	0.75 ± 0.1
Perspex	1.94 ± 0.01	1.02 ± 0.01	0.92	47.4	- 0.140	0.59 ± 0.01
Wood (Ebony)	1.94 ± 0.01	1.12 ± 0.01	0.82	42.3	- 0.119	0.54 ± 0.01

DISCUSSION :

Usually low attenuating materials are utilized in the making of x-ray cassette front since much of the primary beam is required to reach the detector - x-ray film, to form the image. However, the attenuation of the primary beam is usually not altogether due to absorption by the traversed material, but is equally dependent on the scattered component of the beam (Ching-Shen & Shyi-Ming, 1996; Ekpe & Essien, 1999). Transmitted intensity is dependent on the density and the thickness of the traversed material, as well as other factors, which also include the energy of the beam (Ekpe & Essien, 1999). The absorbed component is due to energy losses within the material as a result of interactions between the radiation and the atoms in the material (Ching-Shen & Shyi-Ming, 1996; Ekpe & Essien, 1999). The magnitude of the aluminium equivalent of the material is a determinant of the image contrast (Egbe, 2004).

Our results show that the materials used in this study as cassette window for x-ray transmission, showed relatively moderate attenuation of the beam at the energy used. The attenuation properties of Perspex and Ebony wood present some interesting results, suggesting the possibility of their use as radiation shielding materials at low energies. Poor radiographic contrast, as one of the parameters used in assessing image quality, usually will introduce the necessity for repeated radiographs with the attendant undesirable effect on patient dose. This is one reason low attenuating materials that combine production of an image of good diagnostic quality (having acceptable contrast) are preferred for diagnostic radiography.

Images produced by the different materials studied of the bone and water phantoms showed long scale contrast for tin and copper, with significant shades of grey, while the image produced by the aluminium window showed short scale contrast (large difference in densities recorded) (Munro, 2004). Perspex and wood recorded appreciable contrast - somewhere between the two scales. This suggests that Perspex and wood, perhaps with proper treatment, could be used for making specialized cassettes for radiographic examinations requiring mid-scale contrast images.

CONCLUSION :

From the foregoing, Ebony wood and Perspex could be useful as x-ray cassette front materials at energies of less or equal to 67kV.

REFERENCES :

Jenkins, D: Radiographic imaging and Photographic Processes. MTP. England . 302p. (1982).

Christensen, E. E; Curry, T. S. and Danley, J. E. An Introduction to the Physics of Diagnostic Radiology. 2nd Edition. London. Henry Kingston. 450p. (1978).

Hay, G. A. & Hughes, D.: First Year Physics for Radiographers. 2nd Ed. London. Bailliere Tindall. 271p. (1978)

Ekpe, S. D. & Essien, I. O.: Measurements of Attenuation Coefficient of Clay and Laterite Soils as Building materials using Gamma radiation. Integrated Journal of Science & engineering. 2(1): 59 - 62.

Meschem, I; OH. D. J. The scope of Diagnostic Imaging In: Introduction to Diagnostic Imaging. London. W. B. Saunders co. pp 1- 6. (1984)

Brant, W. E & Helms, C. A. (Eds.). Basic Principles In: Diagnostic Imaging Methods. USA. Williams & Williams, pp. 3 - 19. (1998)

Chesney, D. N. & Chesney, M. O. radiographic Imaging. 4th ed. Blackwell Scientific Publications. 487p.

Egbe, N. O.: Laboratory Guide for Radiography Students. University of Calabar Press, Nigeria. 77p.

Corr, P: Image Quality Optimization and Control In: Pattern Recognition in Diagnostic Imaging. WHO. Geneva, pp. 3 - 15. (2001).

Munro, L.: Basics of Radiation Protection - How to Achieve ALARA: Working Tips and guidelines. Ostensen, H & Inglfsdottir, G (Eds.). WHO. Geneva, 83p. (2004).

Holm, T.: Consumer Guide for the Purchase of X-ray Equipment. (Rev.1). WHO. Geneva. 24p. (2000).

Llyod, P. J.: Manual Film Processing In: Quality Assurance Workbook for Radiographers & Radiological Technologists. WHO. Geneva, pp. 78 - 93. (2001)

Inyang, S. O; Egbe, N. O. & Essien, I. E.: Radiological Shielding Property of Clay determined with Thermoluminiscent Detector. Integrated Journal of Science & Engineering. 2(2): 69 - 72

Ching-Shen, Su & Shyi-Ming Yeh : UV attenuation coefficients in water determined by TLD. Radiation Measurements. 26(1): 83 - 86

Previous | Home Page

MEMBERS' REPORTS

Highlights of the 6th Symposium of CRPA

An Introduction to Computational Radiation Physics *Part 2*

Report on the Conference on Accelerators and Radiation Physics Research (ARPR - 05)

Highlights of the 6th Symposium of CRPA

Ines Krajcar Bronic

Rudjer Boškovic Institute, Bijenicka 54, 10000 Zagreb, Croatia

The Sixth Symposium of the Croatian Radiation Protection Association (CRPA, www.crpa.hr) with international participation was held in Stubicke Toplice Spa (near Zagreb) from 18th to 20th April, 2005. The organizers of the Symposium were CRPA, Institute for Medical Research and Occupational Health, and the Rudjer Boškovic Institute.

For the 6th Symposium 77 presentations were registered, and this is 15 more than at the 5th Symposium of CRPA in 2003. All presentations were given orally in thematic sessions:

1. General topics of interest for radiation protections (12 presentations),
2. Dosimetry and instrumentation (13 presentations),
3. Biological effects of radiations (12),
4. Public exposure to radiation (8),
5. Radiation protection in medicine (8),
6. Radioecology (18), and
7. Non-ionizing radiations). (6).

In addition, we had the invited introductory lecture devoted to the World Year of Physics 2005, and the introductory talk to the Round-table discussion. All 79 presentations were published in the Proceedings [1], most of them in the form of an extended abstract of several pages in Croatian with a 1-page English abstract. All abstracts are available at the INIS (International Nuclear Information System) database (http://inisdb.iaea.org/inis/). Some full papers after peer review will be published in the special issue of the journal Archives of Industrial Hygiene and Toxicology, and about 20 abstracts selected by the Scientific Committee will be published in Health Physics.

Celebrating the World Year of Physics 2005, CRPA organized, in co-operation with the Croatian Physical Society (www.hfd.hr), an invited lecture that should connect physics and radiation protection. The lecture entitled "Light sources and light pollution" [2] was held on the day of Einstein's birthday, 18 April. After the historical overview of the development of various light sources, the author presented recent technological achievements with "blue" and "white" light diodes. However, the development of new light sources is at the same time also a threat for the wildlife at night. Photo-induced changes at the cell level may completely alter the normal life of plants and animals. The need for legislative regulation also in the field of light pollution is pointed out, and this is the field where our society can be engaged more intensively.

Presentations of the section "General Topics" informed the participants about the current status of radiation protection in Croatia [3] and about medical care for professionals exposed to radiation [4]. The new system of accreditation for testing laboratories in the field of radiation protection was described [5], as well as the new secondary standard dosimetry laboratory [6]. We were also informed about the status of metrology in Austria [7], as well as about current harmonization of the law and other regulations in Croatia and Slovenia with the European Union standards [8,9]. Finally, the activities of Croatian scientists in international organizations such as ICRP and ICRU were also presented [10,11].

In the section "Dosimetry and Instrumention" we were informed about the development of new dosemeters and some new applications of dosemeters [12-14], new read-out systems [15] and data evaluation protocols [16], as well as the new techniques of sample preparation for environmental radioactivity measurement [17,18].

The emphasis of most lectures of the sections "Biological Effects of Radiation" was on the importance of biodosimetry in the risk evaluation after long-term period exposure to radiation, especially chromosome aberrations which were pointed out as the most reliable biological indicator of exposure to low doses of ionizing radiation and as cancer risk biomarkers [19-24]. In the section "Public Exposure" various contributions to total public exposure were discussed, such as radon in air and water in thermal spas [25,26], and radioactivity in precipitation, drinking water and air and water in thermal spas [25,26], and radioactivity in precipitation, drinking water and some food products [27,28].

During the section "Radiation Protection in Medicine" we heard new information about the legislation in the field of radiation protection in medicine [29] and new possibilities in stereotactic radiotherapy [30], as well as various dose evaluation protocols and radiotherapy planning systems [31-33]. As usual, "Radioecology" was the largest section. Presentations included monitoring of various radionuclides in air [34], water [35,36] and soil. Special attention was devoted to monitoring of 137Cs, plutonium and uranium isotopes in soil [37-40], actinides in the river sediment [41], 90Sr in the Adriatic Sea [42,43], and 137Cs and 40K in different biological systems [44,45]. It was observed that honey, as the composite environmental sample from a limited area may be a good bio-indicator for environmental contamination with caesium [46].

During the last several symposia of CRPA the increasing trend of the number of presentations in the section "Non-ionizing Radiations" was noticed. Among others, results of studies of the influence of electromagnetic fields on plants [47], and effects of microwave radiation on cell cultures in vitro [48] and on laboratory animals in vivo were presented [49]. The effect of non-ionizing radiation on humans was also discussed [50,51].

The Round-table discussion with the main topic "Nuclear or Radiological Emergency Plan" started with the introductory talk [52]. In the following discussion experts from various institutions involved in emergency plan preparation and execution discussed various aspects of development of such a plan paying particular attention to relevant requirements set by the Convention on Nuclear Safety and Law on protection against ionizing radiation.

Total number of participants was 145, 120 from Croatia and 25 from other countries: Austria, Bosnia and Herzegovina, Lituania, Hungary, Germany, Romania, Slovenia and Great Britain. A considerable number of young scientists took part in the symposium, and all of them gave well prepared and informative presentations.

During the Symposium, a technical exhibition was also organized, and the following companies took part in it: Canberra Packard Central Europe, Hebe - Perkin Elmer Precisely, LKB Vetriebs, Medicem-servis, and MGP Instruments.

References :

[2] Proceedings of the Sixth Symposium of the Croatian Radiation Protection Association. Eds: V. Garaj-Vrhovac, N. Kopjar, S. Miljanic. CRPA, Zagreb (2005), ISBN 953-96133-5-3, 477 p.

[2] G. Pichler: Light sources and light pollutions. Proceedings [1], 3-8.

[3] D. Kubelka, N. Svilicic, I. Kralik MArkovinovic, D. Trifunovic: Ionising radiation protection in Croatia. ibid., 19-24.

[4] M. Zavalic: Health protection of persons occupationally exposed to ionising radiation in Croatia. ibid., 25-27.

[5] S. Galjanic, Z. Franic: Accreditation of laboratories in the field of radiation protection. ibid., 34-39.

[6] B. Vekic, R. Ban, S. Miljanic: Secondary standard dosimetry laboratory at the Rudjer Boškovic Institute, Zagreb. ibid., 40-48.

[7] F.J. Maringer, A. Leitner, M. Tschurlovits: Radiation protection metrology in Austria: status and needs in a European perspective. ibid., 28-33.

[8] N. Novosel: What is new in the Act on nuclear safety. ibid., 60-63.

[9] H. Janzekovic: Implementation of the 96/29/EURATOM in industry. ibid., 49-53.

[10] M. Novakovic: New ICRP recommendations 2005: without full consensus? ibid., 54-69.

[11] Krajcar Bronic: Elastic scattering of electrons and positrons. ibid., 78-84.

[12] B. Zorko, D. Jezeršek., M. Štuhec, S. Gobec: Energy dependence of TL dosemeters using CaF2: Mn pellets. ibid., 97-104.

[13] M. Ranogajec-Komor, M. Osvay, S. Miljanic, S. Blagus: Sensitivity of LiF TL detectors in thermal and fast neutron irradiation fields. ibid., 105-110.

[14] S. Miljanic, B. Ilijaš: Chemical dosimetry system for criticality accidents. ibid., 152-157.

[15] S. Deme, I. Apathy, L. Bodnar, A. Csoke, I. Feher, T. Pazmandi: PorTL® - a compact, portable TLD reader for environmental and personal dosimetry. ibid., 91-96.

[16] Z. Knezevic, K. Krpan, M. Ranogajec-Komor, S. Miljanic, B. Vekic, Z. Rupnik: Interface and software development for thermoluminiscent dosimetry. ibid., 111-116.

[17] J. Barešic, I. Krajcar Bronic, N. Horvatincic, B. Obelic: LSC measurements of low 14C activities of samples prepared by the benzene synthesis method. ibid., 158-163.

[18] L. Mikelic, V. Orešcanin, S. Lulic, M. Rubcic: Determination of chromium(III), chromium(VI), manganese(II) and manganese(VII) by EDXRF method. ibid., 433-437.

[19] M. Gamulin, V. Garaj-Vrhovac, N. Kopjar: Evaluation of DNA damage in radiotherapy-treated cancer patients using the alkaline comet assay. ibid., 183-188.

[20] D. Zeljezic, V. Garaj-Vrhovac: Fluorescence in situ hybridisation in chromosome aberration detection in subjects occupationally exposed to ionising radiation. ibid., 189-193.

[21] V. Garaj-Vrhovac, N. Kopjar, M. Poropat: Evaluation of cytogenetic damage in nuclear medicine personnel occupationally exposed to low-level ionising radiation. ibid., 200-205.

[22] V. Kašuba, R. Rozgaj, A. Jazbec: Evaluation of chromosomal aberrations in radiologists and medical radiographers chronically exposed to ionising radiation. ibid., 206-210.

[23] R. Rozgaj, V. Kašuba: Chromosome aberration - the most reliable biological indicator of exposure to low doses of ionising radiation. ibid., 211-215.

[24] A. Znaor, A. Fucic: Chromosomal aberration frequency as a cancer risk biomarker. ibid., 222-226.

[25] B. Momcilovic, G.I. Lykken: Men and radon - a noble gas of many disguise. ibid., 235-247.

[26] V. Radolic, B. Vukovic, D. Stanic, J. Planinic: Radon levels in Croatian spas. ibid., 248-252.

[27] M. Maracic, N. Lokobauer, Z. Franic: 90Sr activity concentrations in milk and fallout in the city of Zagreb. ibid., 271-275.

[28] M. Bronzovic, M. Vrtar, G. Marovic: Long-term exposure to 226Ra in drinking water. ibid., 276-280.

[29] C. Milu, A. Dumitrescu: Improvement of the radiation protection in medicine by implementation of the Council Directive 97/43/EURATOM. ibid., 289-292.

[30] H. Hršak: Leksell gamma knife and quality assurance in stereotactic radiotherapy. ibid., 294-299.

[31] A. Beganovic, S. Džanic, B. Bašic, A. Drljevic, A. Skopljak: Doses in mammography at Institute of radiology. ibid., 306-311.

[32] Đ. Milkovic, M. Ranogajec-Komor, S. Miljanic: Protocol of radiographic examination of children in order to improve the radiation protection. ibid., 312-315.

[33] M. Budanec, T. Bokulic, I. Mrcela, Z. Kusic: Radiation treatment planning system verification. ibid., 325-330.

[34] P. Jovanovic: Activity concentration of caesium in air in Slovenia after Chernobyl accident. ibid., 411-414.

[35] I. Krajcar Bronic, P. Vreca, N. Horvatincic, N. Ogrinc, J. Barešic, B. Obelic, T. Kanduc: Distribution of isotopic composition of hydrogen, oxygen and carbon in the atmosphere of Croatia and Slovenia. ibid., 405-410.

[36] A. Mihalj, L. Saracevic, D. Samek, N. Gradašcevic, E. Lokmic: Natural radioactivity of thermal spring in village Banja, municipality Fojnica. ibid., 415-419.

[37] B. Petrinec, Z. Franic: Radiocaesium in uncultivated soil on some locations in Croatia. ibid., 345-350.

[38] R. Druteikiene, B. Lukšiene: Investigation of plutonium chemical compounds sorption in soil. ibid., 351-357.

[39] D. Deljkic, A. Vidic, S. Maric, Z. Ilic, D. Sirko: Radioactivity of the soil in Federation Bosnia and Herzegovina. ibid., 358-362.

[40] A. Vidic, Z. Ilic, D. Deljkic, U. Repinc, Lj. Benedik, S. Maric: Determination of uranium in soil with emphasis on dose assessment. ibid., 363-368.

[41] S. Lulic, L. Mikelica V. Orešcanin, G. Pavlovic: Determination of actinides in Sava river sediments upstream and downstream of NPP Krško by low-level alpha-spectrometry. ibid., 369-372.

[42] Z. Franic: Sensitivity analysis of the model for estimation of the Adriatic Sea turnover time using fallout 90Sr as a radioactive tracer. ibid., 373-378.

[43] M. Rozmaric Macefat, K. Košutic, Z. Grahek: Determination of 89,90Sr in seawater. ibid., 379-383.

[44] I. Lovrencic, D. Barišic, N. Kezic, I. Seletkovic, M. Volner, M. Popijac, S. Lulic: Comparison between the distribution of 137Cs and 40K in fir-tree (Abies Alba). ibid., 384-389.

[45] N. Gradašcevic, L. Saracevic, A. Mihalj, D. Samek: Transfer factors of 137Cs in chain soil-alfalfa. ibid., 390-394.

[46] D. Barišic, I. Lovrencic, V. Orešcanin, N. Kezic, D. Bubalo, M. Popijac, M. Volner: Honey as bioindicator of environment contamination with caesium. ibid., 395-399.

[47] M. Tkalec, K. Malaric, R. Malaric, Z. Vidakovic-Cifrek, B. Pevalek-Kozlina: Effect of electromagnetic fields on duckweed (Lemma minor) and alga (Chlorella kessleri). ibid., 447-453.

[48] I. Pavicic, I. Trošic, A. Šarolic: Comparison of 864 and 935 MHz microwave radiation effects on cell culture. ibid., 454-458.

[49] I. Trošic, I. Bušljeta, I. Pavicic, B. Modlic: Kinetics of induction of micronucleated polychromatic erythrocytes in bone marrow and peripheral blood following subchronic microwave exposure. ibid., 459-463.

[50] V. Brumen, V. Garaj-Vrhovac, J. Franekic Colic, Z. Radalj: Health issues of the operaters on video display units - the consequence of electromagnetic radiation or something else? ibid., 464-467.

[51] B. Vojnikovic: Influence of optical radiations on development of age related macular degeneration (AMD). ibid., 468-470. D. Škanata, S. Medakovic: Nuclear or radiological eme.

An Introduction to Computational Radiation Physics
Part 2

Paul Bergstrom

N.I.S.T, 100 Bureau Drive, Stop 8460 Gaithersburg, MD 20899-8460, U.S.A

email : palko@nist.gov

The first column in this series discussed, from a general point of view, the increasing usage of computations in radiation physics and the increasing sophistication of such computations. It also laid out a general plan for a series of articles of which this one is the second.

This article is concerned with databases that are commonly used in computational radiation physics. These databases, which contain mainly cross sections, are the foundation of all computational techniques for solving problems in radiation physics. The emphasis here is primarily on those databases that are fairly comprehensive in terms of the physical processes that they cover and that are available in electronic format on the internet. In the first article of this series, it was mentioned that the use of such databases over the traditional hard-copy tabulations permits less potential for error and, possibly, the use of finer detail in calculations. The discussion in this paper is focused on databases that contain interaction data for electrons, positrons and photons.

Electrons and positrons interact many times with the underlying medium through which they are traveling in a typical radiation physics scenario. So, except in the case of very thin targets, the usual expedient is to rely on data that take into account the effect of multiple collisions on the particle's motion. Examples of such data are stopping powers, ranges, radiation yields and multiple scattering distributions. Stopping powers determine how much energy the particle loses per unit length in traversing the medium. The stopping power is intimately tied to the cross section differential in scattered electron energy after a single collision. Range, a measure of how far charged particles of a certain energy penetrate a particular material on average, can be determined from a set of stopping power data with energies from near zero to the initial energy of the electron or positron. Stopping powers are sometimes divided into the amount of energy that is deposited locally, the collisional stopping power, and into how much escapes the local interaction site as photons, the radiative stopping power. Knowledge of the relative importance of these components enables one to determine the radiation yield of a particle as it comes to rest. All of these quantities have been extensively tabulated for electrons and for positrons. The most widely used data are those enshrined within the brown covers of the 37th report of the International Commission on Radiation Units and Measurements (ICRU) "Stopping Powers for Electrons and Positrons". Much of the data contained in this table originated from work performed at the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), and can be found on the NIST web site

http://physics.nist.gov/PhysRefData/Star/Text/contents.html

In addition to a web-based interface, one can download copies of the underlying code.

Turning from the effects of multiple collisions on the energy of the scattered particle to the effects of these collisions on the particle's direction of travel, one has multiple scattering distributions. Two main theories are available here, that of Moliere and the Goudsmit-Saunderson theory. The theory of Moliere requires less input data but is less accurate. The Goudsmidt-Saunderson is generally based on numerical cross sections for the elastic scattering of electrons and positrons. Codes to generate such data can be obtained from the Radiation Safety Information Computational Center at Oak Ridge in the USA

http://www-rsicc.ornl.gov/codes/dlc/dlc2/ dlc-208.html

or at the OECD Nuclear Energy Agency Data Bank in Paris

http://www.nea.fr/abs/html/dlc-0208.html.

In addition to similar elastic scattering single-interaction data, very comprehensive data for inelastic collisions are tabulated in the Evaluated Electron Data Library (EEDL) of Lawrence Livermore National Laboratory (LLNL). These data are not available directly but can be obtained from several data centers such as the International Atomic Energy Agency, Oak Ridge, the Nuclear Energy Data Bank in Paris and the National Nuclear Data Center in Brookhaven, USA. For links to these sites and for more information on EEDL, please visit

http://www.llnl.gov/cullen1/gowhere.htm#codes

Photons typically experience fewer collisions in their passage through matter than do electrons and positrons. As a result, single interaction cross sections are typically used. The dominant processes for a given material are photoeffect at low energies, inelastic photon-atom scattering at intermediate energies and production of electron-positron pairs at high energies. Other important processes are elastic photon-atom scattering and the photonuclear effect. There are many different tabulations of these processes. A good internet resource is

http://plasma-gate.weizmann.ac.il/DBfAPP.html

at the Weizmann institute in Israel. This page points to other types of data as well, including details of atomic structure. Among the listings on that page are the NIST Physical Reference databases, including the XCOM: photon cross sections database

http://physics.nist.gov/PhysRefData/Xcom/Text/XCOM.html.

Using the database search form, one can obtain total cross sections for elements, compounds and mixtures for elastic and inelastic photon-atom scattering, photoionization and pair production (mediated by the field of the nucleus or by the field of an electron). The cross section summed over all of these processes is also given. It is interesting to note that much of the data that are contained in this database, particularly for scattering and for pair production, corresponds to the tabulations of Hubbell and co-workers.

John Hubbell, is of course, one of the first two FIRPS (Fellows of the International Radiation Physics Society). The program that generates the data can be downloaded from this site and run on one's own DOS computer. Of further note, the XCOM program was reengineered for Windows by a frequent contributor to these pages, our own Leif Gerward. A copy of his version of the code may be obtained by sending him email. Regrettably, the emphasis of XCOM being total cross sections and attenuation coefficients, the differential data available for scattering is not available. The Evaluated Photon Data Library (EPDL) of Lawrence Livermore National Laboratory contains the XCOM data and additional data for the scattering factors.

Another LLNL data base, the Evaluated Atomic Data Library (EADL) contains atomic binding energies and relaxation data (both radiative and non-radiative). These data can be obtained from one of the sources previously mentioned, in the discussion of EEDL (http://www.llnl.gov/cullen1/gowhere.htm#codes)

. The emphasis in XCOM and in EPDL was to provide comprehensive sets of data. The tradeoff between accuracy and the ability to provide data "for all elements and energies" was pushed to the limits of the computing technology of the 1970's. Improvements in computing technology have now made it possible to use more exact methods to tabulate data "for all elements and energies" and to provide more differential data. Improvements are on the horizon.

Obviously, the list of internet-based resources presented here is not comprehensive. However, use of the databases that have been listed would enable one to perform coupled photon-electron/positron calculations at the sub-percent level of accuracy for some applications and at the percent level for most applications. A number of Monte Carlo codes incorporate these data to allow the user to do just that. However, there are a number of databases that are not stand-alone, i.e. they only come in electronic format bundled with the transport code in which they are used.

In the next article in this series, we discuss Monte Carlo transport codes used to perform coupled photon-electron calculations and where they may be obtained.

Report on the Conference on Accelerators and Radiation Physics Research (ARPR - 05)

Organised by the Indian Society for Radiation Physics, Bose Institute,
Variable Energy Cyclotron Centre and
International Radiation Physics Society.

D. V. Gopinath

Energy and Environment, 208, IV Cross, I Stage, Gangothri Layout, Mysore 570009, India

The Conference was held at the Bose Institute and the Variable Energy Cyclone Centre, Kolkata, during April 28-30, 2005 in memory of Prof. A.M. Ghose, one of the pioneers of Radiation Physics research, nationally and internationally. The conference was organised by the Indian Society for Radiation Physics, International Radiation Physics Society, Bose Institute and Variable Energy Cyclotron Centre both located at Kolkata, India. The organisers had the twin objectives of

i) Paying homage to Prof. Ghose and deriving inspiration from his work and

ii) providing the State of the Art picture in accelerator radiation safety.

The intense deliberations of the conference for 2 ½ days appeared to have met the organisers' objectives to a great extent. There was a large amount of presentation and discussion on subjects close to Prof. Ghose's heart and the work inspired by him. Innovation, achieving the maximum on shoe-string budget and developing a strong scientific temper in the Society were the strong points of Prof. Ghose's career and they were very well brought out by almost all the speakers. There were in all 32 presentations on topics such as

- Gamma Ray Scattering
- Super Heated Drop Detectors
- Radiation Applications,
- Accelerator Radiation Safety
- General Review on different aspects of Radiation Physics.

Highlights of the presentations are summarised below.

Prof. Kane from IITB, Powai, talked about several techniques initiated by Prof. Ghose and his own group at IITB, gainfully employed in Radiation Physics measurements. He discussed the theoretical formalisms needed to understand the presently available experimental data, with the instance of Rayleigh and Delbruck scattering and lastly touched up on the new studies that need to be taken up.

Talking on the theoretical developments in the gamma ray scattering, the doyen of scattering computational studies, Prof. Richard Pratt of the University of Pittsburgh, presented a State of the Art picture in gamma ray scattering theory and computations. He discussed about the elastic scattering in edge regions, anomalous scattering for determining the structure, polarization phenomena as a new tool and Delbruck scattering. His talk also covered Resonant Raman Scattering and the validity of impulse approximation in inelastic scattering.

There were three papers on Super-Heated Drop Detectors (SDDs). The thrust of all the papers was on the use SDDs for neutron spectrometry. While the presentation by Dr. Mala Das of VECC dealt with the energy calibration of SDDs for neutron spectrometry by varying the operating temperature and pressure, Dr. Sarkar of Bose Institute discussed certain basic aspects of nucleation phenomena in SDDs in the context of neutron spectrometry. The paper by Ponraju and Viswanathan of IGCAR dealt with different aspects of SDD as a practical neutron spectrometer and dosimeter, such as immobilization of the bubbles, bubble formation efficiency and detection limits for fast and thermal neutrons etc.

There were five papers on Radiation Applications. The emphasis was on the use of radiation as probe for studying the material properties. Prof. Tajuddin and Prof. Shurki of Universiti Sans Malaysia made a detailed presentation of the Low Angle X-ray Scattering system constructed at their centre and its extensive use for characterisation of biomedically relevant materials. Dr Shivaramu from IGCAR described the construction and use of a novel gamma ray scattering setup for studying the change in the properties of concrete in the context of fast reactor radiation shielding. The talk by Prof. Bradley dealt with the application of synchrotron radiation in several areas of basic research as well as XRF analysis of trace elements in human tissues. Dr Ganguly of SINP talked on the Positronium annihilation technique for the study of micro-structural aspects of porous polyamide membrane materials used in desalination industry.

As to be expected there were a large number (14) of papers on Accelerator Radiation Safety. Six of them were computational papers on topics such as estimation of neutron yield in proton and light ion reactions, simulation of detector response for high energy (>10 MeV) gamma rays and neutrons, modeling the beam parameters in treatment planning and empirical calculation of radiation fields around accelerators. Three papers dealt with spectral measurements of neutrons in the accelerator environment. Four papers were concerned with radiation safety per se, such as shield evaluation for accelerators, radiation field and radioactivity measurements around accelerators and radiological safety measures. Looking at all the presentations, it appears that more efforts would be gainful in the area of high-energy (10 to 100 MeV in the Indian context) spectrometry as well as dosimetry both for gamma rays and neutrons. In gamma ray dosimetry, concepts such as KERMA dose and electron equilibrium still need to be validated in the region above 10 MeV. In the same energy region, energy calibration and response matrix evaluation for spectral inversion also call for more efforts. From the radiological safety point of view, neutron-field measurements (Spectrometry as well as dosimetry) in accelerator installations play an important role and they need to be firmly established. Different devices such as liquid scintillators, SDDs and activation foils are being used for neutron spectrometry in the high-energy region. There is strong need for their validation and inter-comparison.

There were five review presentations on related topics. Dr Bhandari of VECC made an excellent presentation on the development and present status of accelerators and accelerator-related work in India. Dr Gopinath gave an account of the bases for the presently accepted radiation risk coefficients and pointed out that with compliance of the prevalent radiation standards, the risk from radiation exposure compares quite favorably with several other risks we seem to accept. With the increasing use of ionising radiation and radioactivity in several fields, an issue of significant concern is the pilferage of radiation sources or their loss in the public domain. In his review talk, Dr Sharma from BARC gave a detailed account of the efforts being made nationally and internationally for maximising the security of radiation sources in public domain. Finally, Dr. Bikas Sinha of VECC, in his inimitable style and with captivating viewgraphs, made an exiting presentation of the story of evolution - from BIG BANG to the present day.

Almost all the presentations were highly informative and focused. There was considerable amount of interesting and meaningful discussion. Arrangements for the conference deliberations and hospitality for outside delegates were excellent. Over all, it was a compact and successful Conference.

Previous | Home Page | Next