

*UOIT – Anthony Waker IRC
– Edward Waller*

UNENE/NSERC Senior and Associate Industrial
Research Chair

Overview

The period 2008/2009 has been one of dynamic growth and academic accomplishment at UOIT. During this period the Faculty of Energy Systems and Nuclear Science has seen its undergraduate programs in nuclear engineering and health physics firmly established with a total of 120 students successfully graduating from these programs and the percentage employment rate in the Canadian nuclear industry of these graduates an encouraging 80%. In September of 2008, OCGS approved UOIT's Masters program in nuclear engineering in the two fields of nuclear engineering and health physics and at the end of the current reporting period UOIT received approval for its Ph.D. program, again in the two fields of nuclear engineering and health physics. Thus, with a complete graduate program in place, UOIT can fully participate in the training of Highly Qualified Persons for the nuclear industry in Canada.



The UNENE/NSERC IRC for Health Physics and Environmental Safety was approved in July, 2008 and research funding started to flow to the Chair holders in September 2008. The core of the IRC research program is intended to enhance radiation protection for nuclear energy workers and the environment through studies in radiation measurement, radiation effects and radiation field modelling and visualization and can be more colloquially described as one of *better measurements, better understanding and better communication*. The research program focuses on improving real-time detection methods for mixed radiation fields and tritium and using signals from these devices to assist in radiation field mapping and visualization as well as developing a greater understanding of the comparative risks of different radiation exposures at low dose. Current research activities within the IRC framework are described in the following sections of this report along with other details related to IRC research at UOIT.

Research Program

Real-Time Measurements

Currently no personal alarming dosimeter for tritium-in-air is available for nuclear energy workers (NEW) and this gap is being addressed by two investigations. One study is of an ultra-thin plastic scintillator detection system to see if it can be used as the basis of a personal tritium monitor for operation in environments with substantial gamma fields. The second project is an investigation to better understand the effects of air and water vapour on the operation of proportional counters to assess if this technology can be optimized to form the basis of a compact tritium-in-air detection system. Another

radiation measurement 'gap' in nuclear power plant (NPP) operational health physics is that no instrument currently exists with an adequate energy response to accurately monitor neutrons or to provide the detection basis for a personal neutron dosimeter. Previous research of the IRC senior Chair has shown that tissue equivalent proportional counters (TEPC) are a good candidate instrument for mixed-field neutron-gamma dosimetry in CANDU power plants and a study is being carried out on a new development in TEPC technology to optimize the sensitivity, response and operation of a TEPC under NPP conditions.

Radiation Quality

Regulator and public concerns are continually raised about the appropriate radiation weighting factor for low energy beta particles, particularly tritium, in the context of CANDU reactor radiation protection. To address this issue a study is under way to describe the dosimetry of tritium irradiation at low doses in terms of the specific energy probability distributions for single and multiple events in mammalian cells and sub-cellular structures (microdosimetry). This study is being carried out combining methods of experimental microdosimetry and stochastic analysis, which have general applicability in low-dose radiation research.

Radiation Field Modelling and Visualization

Dose reduction for NEWs is a continual task of NPP health physics staff and an important objective of the IRC research program is to couple advanced computational methods to real-time measurement technology to greatly enhance training, ALARA and work optimization in NPPs. Consequently, a study is underway to investigate the use of Monte-Carlo methods to map and visualize radiation fields for complex geometries and work environments.

Research Facilities

UOIT was established in 2003 and as such is still in the process of facility building. A significant step forward will be made in 2011 when the construction of an Energy Research Centre will be completed on the UOIT campus. This centre will house laboratories specifically designed to support IRC research including purpose built neutron and gamma irradiation facilities. In the mean time The IRC program will continue to use facilities at other UNENE universities such as the McMaster Accelerator Facility. Presently at UOIT we have established laboratories for detector development, aerosol research and environmental radiation measurements.

The Research Team

Dr. Anthony (Tony) Waker holds the UNENE/NSERC Senior Industrial Research Chair. Prior to joining UOIT in 2005 Dr. Waker was senior researcher and manager of radiation biology and health physics at the Chalk River Laboratories of Atomic Energy of Canada Ltd. Dr. Waker's career in radiation research started as a graduate student at the Joint European Research Centre in Ispra, Italy and continued with a post-doctorial period at the German Cancer Research Centre in Heidelberg, Germany. This was followed by a lectureship in the department of medical physics at the University of Leeds in the UK, which continued until 1991 when Dr. Waker joined AECL at Chalk River. Throughout his career Dr. Waker has been engaged in radiation detector development research for radiation protection dosimetry; experimental microdosimetry and its application to

neutron therapy, neutron activation analysis and neutron monitoring. His work also includes the measurement and quantification of radiation quality for cellular, sub-cellular and molecular systems for high LET radiation and low energy X-rays and beta particles.

Dr. Ed Waller holds the Associate UNENE/NSERC Chair. Dr. Waller earned his BSc in Physics and MScE in Chemical Engineering at the University of New Brunswick (UNB) and his PhD in Nuclear Engineering at Rensselaer Polytechnic Institute, New York (RPI). He worked for 15 years in industry (SAIC Canada), primarily in radiation safety and applications of radiation. In 2003 he joined the University of Ontario Institute of Technology. Dr. Waller is a Professional Engineer (PEng), Certified Associate Industrial Hygienist (CAIH) and Certified Health Physicist (CHP). He teaches radiation protection, health physics, environmental effects of radiation, Monte Carlo methods and a number of other courses at UOIT, and performs research in areas of dosimetry, applied health physics, radiation safety, counterterrorism and industrial hygiene

Other IRC research team members are:

- *Aslam Ibrahim* – Post-doctorial Fellow specializing in neutron dosimetry, mixed-field microdosimetry and neutron beam design
- *Abdukadir Al-Aydarous* – visiting professor (University of Taif, Saudi Arabia) specializing in skin dosimetry and radiation measurements with scintillation detection systems
- *Mohamad Awal* – Research Associate (Electronics Technician) assisting experimental work and detector development
- *Fawaz Ali* – Ph.D student, about to embark on a PhD in detector design and modelling (graduated MSc Modeling and Computational Science under Dr. Waller, Dec 2009)
- *Joseph Chaput* – M.A.Sc student working on radiation field modelling and visualization
- *Kirk Megna* – M.A.Sc student working on tritium monitoring and scintillation detectors
- *Christopher Woo* – M.A.Sc student working on low energy X-ray and beta particle microdosimetry
- *Nael Qashua* – M.A.Sc student working on mixed field neutron-gamma monitoring
- *Manirul Islam* – M.Eng student working on gas-gain in proportional counters with electronegative counting gases
- *Ada Ho* – M.Eng (graduated) project subject – The modelling of radiation damage to the gastrointestinal tract.

Publications

Neutron Microdosimetric Response of a Gas Electron Multiplier
J. Dubeau and A.J. Waker
Radiat. Prot. Dosim. 128, No 4, pp 413-420, 2008

Opportunities to Improve the In-Vivo Measurement of Manganese in Human Hands
Aslam, D.R. Chettle, A. Pejovic-Milic and A.J. Waker
Phys. Med. Biol. 54, pp17-28, 2009

Orofacial Radiation Detection Device For Detection Of Radionuclide Contamination From Inhalation

Waller, E.

US Patent Application Serial No.PCT/CA2008/002176, 14 December 2008.

Book Review - Radiation Mechanics

Waller, E.J.

Health Phys, Vol. 97, No.4, pp. 357-358, 2009. .

In Vitro Dissolution Study of Uranium Dioxide and Uranium Ore with Different Particle Sizes in Simulated Lung Fluid

Li, W., Skinner, R. Megna, K., Chen, J., Perera, S., Murimboh, J., Waller, E., Erhardt, L. and Cornett, J.

J. Radioanal. Nucl. Chem., Vol. 279, No. 1, pp. 209-218, 2009.

Use of Stable isotopes as Surrogates for Radionuclides for Security Studies

Andrews, W., Waller, E., Brousseau, P., Roy, G., Cao, X., Creber, K., and Erhardt, L.

J. Radioanal Nucl. Chem., Vol. 282, pp. 919-922, 2009.

Overview of Hazard Assessment and Emergency Planning Software of Use to RN First Responders

Waller, E.J., Millage, Blakely, Ross, Mercier, Sandgren, Levine, Dickerson, Nemhauser, Nasstrom, Sugiyama, Homann, Buddemeier, Curling and Disraelly

Health Phys, Vol. 97, No. 2, pp. 145-156, 2009.

Radiological Hazard Estimates from Contaminated Mask Filters

Waller, E. and Erhardt, L.

Health Phys., Vol. 96, No. 4, 2009.

Comparison of Experimental and Computational Neutron Spectroscopy at a 14 MeV Neutron Generator Facility

Waller, E., Cousins, T., Desrosiers, M., Jones, T., Buhr, R. and Rambousky, R.

Rad. Phys. Chem., Vol. 78, No. 5, pp. 311-317, 2009.

Radiation Protection Issues Related to Canadian Museum Operations

Waller, E., Cole, D. and Jamieson, T.

Health Phys, Vol. 94, No. 2, suppl. 1, pp. S155-S159, 2008.

In press/conferences

Performance of a High Sensitivity Multi-Element Tissue Equivalent Proportional Counter for Radiation Protection Neutron Monitoring Measurements

Aslam and A. J. Waker – Journal of Health physics

A Preliminary Study of the Performance of a Novel Design of a Multi-Element Tissue equivalent proportional Counter for Neutron Monitoring

A.J. Waker and Aslam – presented at the 11th Symposium on Neutron and Ion Dosimetry, Cape Town, October, 2009

Design of a Multielement TEPC for Neutron Monitoring

A.J. Waker, Aslam and J. Lori – presented at the 14th Symposium on microdosimetry, Verona, October, 2009

Spectroscopic Equivalent Proportional Counter for An In Vivo Neutron Activation Facility
A.J. Waker and Aslam – presented at the 14th Symposium on microdosimetry, Verona, October, 2009

Radiological Science Education in the Context of the Nuclear Industry in Ontario

Anthony Waker – 1st International Conference on Advances in Nuclear Instruments, Methods, Measurements and Analysis (ANIMMA), Marseille, France, June, 2009

MEDECOR - A MEDical DECORporation tool to assist first responders, receivers and medical reach-back personnel in triage, treatment and risk assessment after internalization of radionuclides

Waller, E. and Wilkinson, D.
Health Phys, *accepted*, 2009.

CT Diagnostic Reference Levels (DRL) in Ontario (Invited)

Waller, E.

Ontario Association of Radiologists Annual General Meeting, Toronto, Ontario, 24 May 2009

Quantitative Triage Assessment Indicators and Risk Aversion Models for Radionuclide Intake and Incorporation

Waller, E.

Health Physics Society 54th Annual Meeting, Minneapolis, Mn, 12-16 July 2009.

A Coupled Computational Fluid Dynamics – Monte Carlo Radiation Transport Approach to Radioactive Particle Transport Problems

Ali, F. And Waller, E.

Health Physics Society 54th Annual Meeting, Minneapolis, Mn, 12-16 July 2009.

Triage and Treatment Strategies for Radionuclide Inhalation Scenarios

Waller, E.

American Industrial Hygiene Conference & Expo (AIHce), Toronto, ON, 1-4 June 2009

Optimization of MEDical DECORporation (MEDCOR) tool for time and use for improved bio-effects

Waller, E., Wilkinson, D., Boulay-Greene, H., Erhardt, L., Muller, R., Kramer, G., Li, C., Vlahovich, S., Hugron, R., Priest, N., Wyatt, H., Blakely, W. and Österreicher J.

CRTI Summer Symposium, Ottawa, June 2009.

MEDECOR2 – MEDical DECORporation Tool Version 2 – To assist first responders, receivers and medical reach-back personnel in triage, treatment and risk assessment from internalized radionuclides

Waller, E., Wilkinson, D., Boulay-Greene, H., Erhardt, L., Muller, R., Kramer, G., Li, C., Vlahovich, S., Hugron, R., priest, N., Wyatt, H., Blakely, W., and Osstereicher, J.

10th International Conference on Health effects of Incorporated Radionuclides (HEIR), Santa Fe, NM, 10-14 May 2009.

Use of Stable Isotopes as Surrogates for Radionuclides for Security Studies

Andrews, W., Waller, E., and Erhardt, L.

8th International Conference on Methods and Applications of Radioanalytical Chemistry (MARC VIII), American Nuclear Society Biology and Medicine Division, Kailua-Kona, Hawaii, April 2009

Radiation Triage Mask

Waller, E.

World's Best Technologies Showcase, Arlington, Texas, 23-25 March 2009.

A Combined Hardware-Software Strategy for Triage of Internally Contaminated Persons

Waller, E. and Wilkinson, D.

Health Physics Society 42nd Annual Midyear Meeting, San Antonio, TX, 31 Jan – 3 Feb 2009.

Parallelization of Neutron Transport Approximation via Monte Carlo

Ali, F. and Waller, E.

23rd Nuclear Simulation Symposium, Ottawa, Ontario, 4 November 2008.

Training the Next Generation of Radiation Protection Professionals in Canada

Waller, E.

12th International Congress of the International Radiation Protection Association, Buenos Aires, Argentina, 19-24 October 2008.

Teaching Effective Problem Solving Skills to Radiation Protection Students

Waller, E.

12th International Congress of the International Radiation Protection Association, Buenos Aires, Argentina, 19-24 October 2008.

Assessing Risk from Low Energy Radionuclide Aerosol Dispersal

Waller, E., and Perera, S.

12th International Congress of the International Radiation Protection Association, Buenos Aires, Argentina, 19-24 October 2008.

Canadian Space Agency Discipline Working Group for Space Dosimetry and Radiation Science

Waller, E., Waker, A., Wilkinson, D. and Lewis, B.

12th International Congress of the International Radiation Protection Association, Buenos Aires, Argentina, 19-24 October 2008.

MEDECOR - Software to Assist Medical Personnel and First Responders in Determining Appropriate Triage and Treatment for MEDical DECORporation of Internalized Radionuclides

Waller, E., and Wilkinson, D.

Health Physics Society 53rd Annual Meeting, Pittsburgh, Pa, 13-17 July 2008 (INVITED – Special Session).

Miscellaneous Software Applications of Interest to RN Emergency Responders and Planners

Waller, E.

Health Physics Society 53rd Annual Meeting, Pittsburgh, Pa, 13-17 July 2008 (INVITED – Special Session).

An Orofacial Radiation Detection Device for Rapid Triage of Personnel at Risk of Internal Radionuclide Contamination from Inhalation

Waller, E.

Health Physics Society 53rd Annual Meeting, Pittsburgh, Pa, 13-17 July 2008.

The Long Path of Tc-99m in North America

Cevera, M., Johnson, T., and Waller, E.

Health Physics Society 53rd Annual Meeting, Pittsburgh, Pa, 13-17 July 2008.

An Orofacial Radiation Detection Device For Detection Of Radionuclide Contamination From Inhalation

Waller, E.

NATO Human Factor and Medicine (HFM) Panel 099, Research Task Group (RTG) 033 – Radiation Bioeffects and Countermeasures Meeting, La Tronche, France, June 2008

The Role of the Industrial Hygienist in Assessing Aerosol Threat from a Radiological Dispersal Device

Waller, E.

2008 American Industrial Hygiene Conference & Expo (AIHce), Minneapolis, Mn, 4-7 June 2008.

Collaborations and Interactions

Both senior and associate Chairs are engaged in collaborative research across Canada and internationally. Regular contact is maintained with the IRC industrial partners and advantage is taken of the close proximity of UOIT with OPG Health Physics at Whitby through joint seminars and discussions. UOIT also maintains an MOU with OPG to act as a back-up emergency response site for environmental radiation measurements. Research collaborations include McMaster University, RMC, INFN – Legnaro, Italy, Fukui University of Technology, Japan.

Other interactions that are relevant to the work and development of the IRC are:

- Senior Chair serves on the Health, Safety and Environment Technical Committee of the Candu Owners Group Inc (COG)
- UOIT is a member of the Durham Nuclear Health Committee and is represented by Dr. Waker
- Associate Chair is a Canadian delegate to the NATO Human Factors in Medicine Research Task Group (HFM-099 RTG-033) in Radiation Bioeffects and Countermeasures.
- Associate Chair invited to **Nuclear Energy Institute** Nuclear Industry Expert list, <http://resources.nei.org/ExpertsList/Home.aspx>