

Task 7

Development of Dose Coefficients for Radionuclides Produced in Spallation Targets

P.W. Patton and M.J. Rudin

BACKGROUND

Ensuring the safety of workers at accelerator-driven nuclear facilities is paramount before these systems can be deployed for nuclear transmutation or any other mission. Spallation neutron sources produce as many as 660 rare radionuclides in either the target or blanket during the spallation process. No data exists for many of these radionuclides in the current radiation protection guidelines and standards. This research program seeks to address this problem through generating internal and external dose coefficients (DCs) for these “new” isotopes.

Dose coefficients permit simple determination of radiation dose associated with various exposure scenarios, and ultimately permit radiation safety personnel to assess the health risks to workers in a nuclear facility. Specifically, radiation safety personnel use dose coefficients to determine the radiation dose incurred to a tissue or organ system from a given exposure. These parameters are often expressed in terms of Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs).

RESEARCH OBJECTIVES AND METHODS

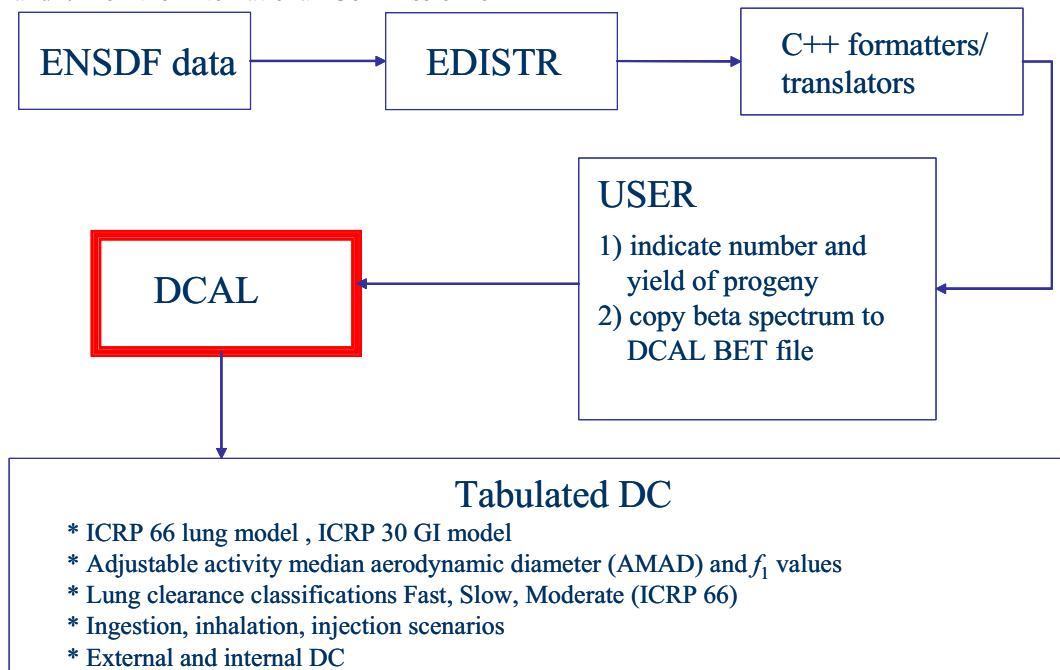
Results from this study will be used to produce ALIs and DACs for these rare radionuclides created by spallation target systems that are not included in Federal Guidance Report (FGR) No. 11. Additionally, DCs developed will augment the radiological data in Publications 68 and 72 of the International Commission on

Radiological Protection (ICRP), contributing to the safe operation of accelerator-driven nuclear systems.

A Dose Coefficient Working Group was established in 2001 (the first year of the project) to direct and oversee consortium activities. Representatives from the Dose Coefficient Working Group developed and verified a methodology to determine internal and external dose for select radionuclides. The first step involved obtaining radiological data from the ENSDF nuclear physics database developed at Brookhaven National Laboratory. Data collected included decay modes, decay energy levels, and radiation energies and intensities.

The DC working group prioritized a list of radionuclides projected to be released via air emissions or in the inventory of a mercury target following a lengthy irradiation period. Only radionuclides with a half-life greater than one minute were considered. These 81 radionuclides were then categorized into three distinct categories, based on half-life, available information, and other technical factors.

All Category 2 radionuclides were investigated to determine which database was most current. However, this task was not straight forward and thus both databases were used to calculate all radionuclides that had complete data. Dose coefficients were then generated for the Category 2 radionuclides using both ENSDF and NUBASE. The results were compared and showed good agreement. Metabolic models and data from ICRP publications



Dose Coefficient Working Group Methodology Flow Sheet. The ENSDF code is used to obtain nuclear physics data. The EDISTR code prepares the data for input into the dose calculation code DCAL.

(30 and 66) were applied in order to use the best technology available and to maintain consistency with current standards. In accordance with FGR No. 11, dose coefficients were evaluated for an adult male with the target tissues of gonads, breast, lung, red marrow, bone surface (endosteum), thyroid, remainder, and total committed effective dose equivalent (this considers total dose incurred to specific organs or tissues with respect to radiation type over a period of 50 years). Following determination of these variables, values of ALIs and DACs were then calculated for each radionuclide.

The consortium investigated the competing databases to determine the most appropriate one to use for dose coefficient calculations. However, conflicting data made it unclear which was better suited for this task, therefore the previously calculated coefficients were reported. Additionally, time was devoted to trying to acquire missing nuclear data for radionuclides in category three. The consortium believes large scale accelerator driven experiments are needed to accomplish this goal.

RESEARCH ACCOMPLISHMENTS

The research consortium comprised of representatives from several universities and national laboratories has successfully generated internal and external dose conversion coefficients for twenty radionuclides produced in spallation neutron sources. These dose coefficients fill data gaps exist in Federal Guide Report No. 11 and in Publications 68 and 72 of the International Commission on Radiological Protection (ICRP), and two articles containing the data have been accepted for publication in the *Journal of Health Physics*. Currently, more nuclear data is needed for the rare radionuclides produced from a mercury target. While attempting to develop a workable plan to acquire this missing data, Q-value discrepancies were investigated and reported. A detailed plan was developed to start a research effort at Idaho State University to produce rare radionuclides. This process will allow for the investigation of the missing nuclear data needed to complete dose coefficients.

TASK PROFILE

Start Date: June 2002

Completion Date: April 2006

Theses Generated:

John P. Shanahan, M.S., Health Physics Department, "Dose Coef-

ficients for Radionuclides Produced in a Spallation Neutron Source," August 2003.

Yayun Song, M.S., Health Physics Department, "Investigation and Calculations of Dose Coefficients for Radionuclides Produced in a Spallation Neutron Source Using the ENSDF and NUBASE Nuclear Databases," May 2004.

Publications:

- J. Shanahan, K. Eckerman, A. Arndt, C. Gold, P. Patton, M. Rudin, R. Brey, T. Gesell, V. Rusetski, and S. Pagava, "Calculation of Dose Coefficients for Radionuclides Produced in a Spallation Neutron Source Utilizing NUBASE and the Evaluated Nuclear Structure Data File Databases." *Health Phys* 90:56-65, 2006.
- A. Arndt, J. Shanahan, C. Gold, R. Brey, T. Gesell, P. Patton, M. Rudin, K. Eckerman, V. Rusetski, and S. Pagava "Procedures and Quality Assurance for Calculating Dose Coefficients Using DCAL Software." *Health Phys* 90:74-80, 2006.
- J. Shanahan, K. Eckerman, A. Arndt, C. Gold, P. Patton, M. Rudin, R. Brey, T. Gesell, V. Rusetski, and S. Pagava, "Calculation of Dose Coefficients for Radionuclides Produced in a Spallation Neutron Source Utilizing NUBASE and the Evaluated Nuclear Structure Data File Databases," accepted August 16, 2005 for publication in the *Health Physics Journal*, *Health Phys.* 89(6), 2005.
- A. Arndt, J. Shanahan, C. Gold, R. Brey, T. Gesell, P. Patton, M. Rudin, K. Eckerman, V. Rusetski, and S. Pagava, "The Procedure for Determining and Quality Assurance Program for the Calculation of Dose Coefficients Using DCAL Software," accepted April 2005 for publication in the *Health Physics Journal*.
- J. Shanahan, K. Eckerman, A. Arndt, C. Gold, P. Patton, M. Rudin, R. Brey, T. Gesell, V. Rusetski, and S. Pagava, "An Interdatabase Comparison of Nuclear Decay and Structure Data Utilized in the Calculation of Dose Coefficients for Radionuclides Produced in a Spallation Neutron Source," accepted March 2005 for publication in the *Health Physics Journal*.
- J. Shanahan, A Arndt, C Campbell, R Brey, M Rudin, K Eckerman, and P Patton, "Calculation of Dose Coefficients for Radionuclides Produced in Spallation Neutron Sources," *Health Phys.* 84 (6S): S252 (2003).
- J. Shanahan, P. Patton, and M. Rudin, "Dose Coefficient Methodology Report," Health Physics Department, University of Nevada, Las Vegas, NV, Aug. 2002.

Research Staff

Phillip W. Patton, Principal Investigator, Associate Professor, Department of Health Physics

Mark Rudin, Associate Professor, Department of Health Physics

Students

John Shanahan, Yayun Song, Tserenpagma Chaoui, Ashley Gann, Sung Yop Kim, Deanna Tuttle, and Jeffrey Wyler, Graduate Students, Department of Health Physics

Collaborators

Tony Andrade and Brent Boyack, Los Alamos National Laboratory

Keith F. Eckerman, Oak Ridge National Laboratory

Rich Brey, Associate Professor, Idaho State University

Adam Arndt and Chandra Gold, Graduate Students, Idaho State University

Faculty and graduate students from Georgia Institute of Technology, University of Florida, Francis Marion University