

# **Annual Report**

## **Development of Dose Coefficients for Radionuclides Produced in Spallation Neutron Sources**

Research Staff: Phillip W. Patton, Principal Investigator, Assistant Professor,  
Department of Health Physics  
Mark J. Rudin, Chair, Department of Health Physics

Graduate Students: John P. Shanahan and Yayun Song

DOE Collaborator: Keith F. Eckerman, Oak Ridge National Laboratory

Other Collaborators: Faculty and students from Idaho State University, Georgia Institute of Technology, and Tbilisi State University, and faculty from the University of Florida.

### **Goals and Background**

The University of Nevada, Las Vegas (UNLV) Transmutation Research Program has been tasked to support U.S. Department of Energy (DOE) efforts to assess the health risks associated with the operation of each of their accelerator-driven nuclear facilities for both NEPA and PSAR development. Quantifying the radiological risks to workers will have to be addressed during the design and siting of each of these facilities. U.S. Environmental Protection Agency (EPA) Federal Guidance Report No. 11 “Limiting Values of Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion”, developed two derived guides, Annual Limit on Intake (ALI) and the Derived Air Concentration (DAC), to be used to control radiation exposure in the workplace. The ALI is the annual intake of a radionuclide which would result in a committed effective dose equivalent of 0.05 Sv/yr for stochastic effects, or a committed dose equivalent to an individual organ or tissue of 0.5 Sv/yr for deterministic effects, to Reference Man (ICRP 1975). A DAC is that concentration of a radionuclide in air which, if breathed by Reference Man for a work-year, would result in an intake corresponding to its ALI (EPA 1988). Therefore, ALIs and DACs can be used for assessing radiation doses due to accidental ingestion and inhalation of radionuclides and are used for limiting radionuclide intake through breathing of, or submersion in, contaminated air.

In addition to determining ALIs and DACs, in many situations it is useful to know the committed dose equivalent to an organ or tissue per unit intake, the committed effective dose equivalent per unit intake, the dose equivalent rate per unit air concentration of radionuclide, or the effective dose equivalent rate per unit air concentration of radionuclide. These dose coefficients (DCs) allow simple determination of radiation dose associated with various exposure scenarios, and ultimately, assess the health risks to workers in a nuclear facility.

Even though the ALIs, DACs, and DCCs calculated in Federal Guidance Report No. 11 adhere to the derived limits in Publication 30 (ICRP 1979), which incorporate current knowledge of radionuclide dosimetry and biological transport in humans, the report is not

exhaustive in reference to anthropogenic radionuclides. Unfortunately, many of the rare radionuclides produced during the spallation process are not addressed in current radiation protection standards either. There may be as many as several hundred radionuclides that would be produced in either the target or blanket of proposed accelerator facilities for which no data exists in Federal Guide Report No. 11 or in Publications 68 and 72 of the ICRP.

It is the intent of the current research to implement the methodology developed in the first year of the research and generate internal and external dose coefficients for radionuclides produced in spallation neutron sources. Results from this study will expand the ALI and DAC data of Federal Guidance Report No. 11 in order to include radionuclides produced by current technology, such as that used in the AAA and SNS programs.

### **Project Objectives**

There were three research objectives for Year 2 of this project:

- expand the number of participants and the role of the existing AAA DC Working Group
- further refine a reproducible methodology to determine internal and external DC
- generate internal and external DCC values for selected radionuclides

In addition to the three research objectives for Year 2, there were three additional minor goals of this project:

- generate results that will be considered for inclusion in future ICRP Reports
- create additional opportunities for students to present project results at national professional conferences
- graduate students who have worked on the project

### **Research Accomplishments**

Each of the above project objectives were accomplished through the completion of specific tasks. Completed tasks associated with each objective are identified below:

Objective 1 – Expand the number of participants and the role of the existing AAA DC Working Group

Work performed under this project has continued to draw upon the experience and expertise residing at a number of respected health physics academic programs across the United States and representatives from DOE national laboratories. Faculty and students from the following academic institutions have been added to the consortium established in Year 1: Tbilisi State University in Tbilisi, Georgia and Francis Marion University. Their role is to help address the lack of nuclear data of some of the radionuclides.

Objective 2 – Further refine a reproducible methodology to determine internal and external DC

The methodology that was developed in Year 1 of the project was reviewed by all participants including the DOE collaborator. From this review it was determined that minor issues arose during the calculation of the DC's that required subjective decisions by the person running the code. Each issue was addressed and a standard method was developed to handle all situations.

Objective 3 - Generate internal and external DCC values for selected radionuclides

External dose coefficients and internal dose coefficients for inhalation and ingestion scenarios were determined using the methodology refined in Objective 2 above for 15 radionuclides identified by the DC Working Group as having complete and consistent nuclear data. The fifteen radionuclides selected for this report are presented in Table 1 as well as the source of the nuclear decay data sets. Source information can be found and is documented in the journal *Nuclear Data Sheets*.

**Table 1.** Category One Radionuclides.

Atomic Number	Nuclide	Physical Half-Life	Source of the Nuclear Decay
78	Pt-201	2.5 m	ENSDF
70	Yb-161	4.2 m	ENSDF
64	Gd-144	4.5 m	ENSDF
57	La-128	5.0 m	ENSDF
61	Pm-153	5.25 m	ENSDF
26	Fe-61	5.98 m	ENSDF
51	Sb-113	6.67 m	ENSDF
74	W-173	7.5 m	ENSDF
67	Ho-160	25.6 m	ENSDF
67	Ho-161m	6.76 s	ENSDF
67	Ho-161	2.48 hrs	ENSDF
63	Eu-144	10.2 s	ENSDF
68	Er-157	18.65 m	ENSDF
68	Er-160	28.58 h	ENSDF
68	Er-161	3.21 h	ENSDF
68	Er-161m	7.5 us	ENSDF
69	Tm-161	33.0 m	ENSDF

The effective dose coefficients for workers and the general population were calculated but not presented here due to the amount of data for each radionuclide.

Minor Goal 1 – Generate results that will be considered for inclusion in future ICRP Reports

John Shanahan, a graduate student at UNLV calculated DC's for radionuclides in Category 1. Currently, other members of the consortium are duplicating this work in order to adhere to the quality control measures that were established in Year 1.

Minor Goal 2 – Create additional opportunities for students to present project results at national professional conference

The results of Year 2 were presented at several local and national conferences, primarily the Health Physics Society National and Local Conferences, the American Nuclear Society Student Section Meeting, and the UNLV Graduate Forum.

Minor Goal 3 – Graduate students who have worked on the project

In August of 2003, John Shanahan completed his graduate education at UNLV. He defended his thesis in June of 2003 at the Health Physics Society Conference in front of members of the consortium including the DOE Collaborator, Keith Eckerman.

### **Deliverables**

The following deliverables were completed during Year 1 of the project:

Annual Report (October 2003)

Monthly Progress Reports

Professional Meeting Presentations/Publications (September 2003)

### **Project Highlights**

- The research consortium, including Georgia Institute of Technology, Idaho State University, University of Florida, UNLV, Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), and Tbilisi State University in Tbilisi, Republic of Georgia, met and refined the methodology adopted in Year 1.
- Two consortium meetings were hosted at UNLV to train graduate students from participating universities on the methodology of generating dose coefficients and to discuss methods to address any problems that had arisen over the year.
- Researchers presented the “Development of Dose Conversion Coefficients for Radionuclides Produced in Spallation Neutron Sources” at the Annual Meeting of the Health Physics Society, San Diego, CA July 2003, at the UNLV Graduate Forum, Las Vegas, NV April 2003, and at the American Nuclear Society Winter Meeting, Student Mini-Conference in Reno, NV April 2003.
- Project personnel used the DC methodology to generate internal and external DCs for fifteen radionuclides for which no DCs currently exist. The results are going to be submitted for publication to the Journal of Health Physics.