Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

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LADTAP-PROB: A Probabilistic Model to Assess Radiological Consequences from Liquid Radioactive Releases[a]

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INTRODUCTION

The potential radiological consequences to humans resulting from aqueous releases at the Savannah River Site (SRS) have usually been assessed using the computer code LADTAP or deterministic variations of this code. The advancement of LADTAP over the years included LADTAP II (a computer program that still resides on the mainframe at SRS) [1], LADTAP XL© (Microsoft Excel® Spreadsheet) [2], and other versions specific to SRS areas such as [3]. The spreadsheet variations of LADTAP contain two worksheets: LADTAP and IRRIDOSE. The LADTAP worksheet estimates dose for environmental pathways including ingestion of water and fish and external exposure resulting from recreational activities. IRRIDOSE estimates potential dose to individuals from irrigation of food crops with contaminated water.

A new version of this deterministic methodology, LADTAP-PROB, was developed at Savannah River National Laboratory (SRNL) to 1) consider the complete range of the model parameter values (not just maximum or mean values), 2) determine the influences of parameter uncertainties within the LADTAP methodology, to perform a sensitivity analysis of all model parameters (to identify the input parameters to which model results are most sensitive), and 3) probabilistically assess radiological consequences from contaminated water. This study presents the methodology applied in LADTAP-PROB.

DESCRIPTION OF THE ACTUAL WORK

The potential doses to offsite individuals and the surrounding population from liquid radioactive releases at the SRS are currently assessed using the deterministic computer program LADTAP XL© [1]. In this study, a systematic review of the LADTAP methodology was conducted in which probability density functions were assigned to all input parameters. These distributions were subsequently incorporated within a recently-developed computer code LADTAP-PROB (LADTAP-PROBabilistic) in which Latin hypercube sampling (LHS) techniques [4] are used to generate multiple (e.g., 10000) sets of input vectors (i.e., trials) for all of the model parameters to assess doses to individuals and surrounding populations from liquid radioactive releases. Two distinct methodologies are embedded within LADTAP-PROP: LADTAP and IRRIDOSE. LADTAP methods refer to all methods except those involving irrigation pathways.

The LADTAP transport model estimates river concentrations assuming a continuous and constant release over a period of one year. Dose is determined for an annual exposure. Therefore, it is assumed in the model that the radionuclide concentrations remain constant for an entire year. The analytical methods used for estimating radiation dose to humans from the various liquid pathways include 1) water ingestion, 2) aquatic food consumption, and 3) recreational use of the Savannah River (shoreline, swimming, and boating). For an assumed maximally exposed individual (MEI), the doses from all pathways (water and fish ingestion and recreational use) are summed to determine the total dose.

The IRRIDOSE model determines the concentrations in foodstuffs and the potential doses to an MEI. The analytical methods used in IRRIDOSE include radionuclide concentrations in water used for irrigation, in vegetable crops and fodder, and in meat and milk. IRRIDOSE calculates the dose to an individual who consumes vegetables, meat and milk produced on land irrigated with contaminated water.

LADTAP-PROB was developed as user-friendly software that greatly expands the capabilities of the current deterministic model LADTAP XL© by using the graphical and computational potential of Visual Basic® within Microsoft Visual Studio® 2008. LADTAP-PROB allows the user to open a default project or an existing project, save the project, edit/view the list of radionuclides, edit/view LADTAP/IRRIDOSE input data, view LADTAP/IRRIDOSE output, and create a spreadsheet containing the output data for easy access by Microsoft Excel® or other spreadsheet programs. The user can assign one of the probability density functions provided by the LHS subroutine[b] to each of the input parameters (e.g., normal, lognormal, triangle, uniform, loguniform, and beta). The user also has the option to select a random number generator integrated in the LHS subroutine to obtain the trials. In addition, the user has complete control of the working directory and

filenames for the project file, radionuclide list file, LADTAP and IRRIDOSE input files, LADTAP and IRRIDOSE output files, and Microsoft Excel® output file.

DISCUSSION

LADTAP-PROB LADTAP and IRRIDOSE probabilistic density functions were determined in this study based on an extensive literature review and will be included in a subsequent journal article due to their extent. To demonstrate the methodology presented in this study, five hypothetical scenarios involving ^{3}H, ^{90}Sr, ^{137}Cs, and ^{239}Pu were considered and the results were compared to those obtained by the deterministic model LADTAP XL©. The LADTAP-PROB median results were found to in general agreement with those of LADTAP-XL©.

In addition, the use of LADTAP-PROB was demonstrated by using a source term of 1 mBq L^{-1} (2.70×10^{-2} pCi L^{-1}) for ^{3}H, ^{14}C, ^{36}Cl, ^{60}Co, ^{79}Se, ^{90}Sr, ^{99}Tc, ^{125}Sb, ^{126}Sn, ^{129}I, ^{137}Cs, ^{238}U, ^{239}U, and ^{241}Am. The probabilistic results were compared to the deterministic results obtained from LADTAP XL©. LADTAP and IRRIDOSE probabilistic density functions based on SRS site-specific data were used for these calculations. The methodology implemented in LADTAP-PROB allows using the concentration and dose values generated in this study for other source term values for any of the radionuclides considered in this study.

ENDNOTES

[a]This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

[b]LADTAP-PROB, written in Visual Basic®, incorporates the LHS FORTRAN program developed by Iman and Shortencarier [4] to generate Latin hypercube and random samples for use in LADTAP and IRRIDOSE within LADTAP-PROB.

REFERENCES

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