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Further Studies on Uncertainty, Confounding, And Validation of the Doses in the Techa River Dosimetry System: Concluding Progress Report on the Second Phase of Project 1.1

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October 2009

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FURTHER STUDIES ON UNCERTAINTY, CONFOUNDING, AND VALIDATION OF THE DOSES IN THE TECHA RIVER DOSIMETRY SYSTEM

Submitted to the Office of International Health Studies, U.S. Department of Energy for the U.S.–Russia Joint Coordinating Committee on Radiation Effects Research

Concluding Progress Report on the Second Phase of Project 1.1

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Note—We have stopped our usual practice of including copies of recent publications as appendices to this report. Publications are available upon request.

INTRODUCTION

This is the concluding Progress Report for Project 1.1 of the U.S.–Russia Joint Coordinating Committee on Radiation Effects Research (JCCRER). In keeping with the request of November 2008 of the members of the American Scientific Review Group (AmSRG), this report continues in the abbreviated format of providing details only on the work accomplished during this six-month reporting period.

An overwhelming majority of our work this period has been to complete our primary obligation of providing a new version of the Techa River Dosimetry System (TRDS), which we call TRDS-2009D; the D denotes deterministic. This system provides estimates of individual doses to members of the Extended Techa River Cohort (ETRC) and post-natal doses to members of the Techa River Offspring Cohort (TROC). The latter doses were calculated with use of the TRDS-2009D. The doses for the members of the ETRC have been made available to the American and Russian epidemiologists in September for their studies in deriving radiogenic risk factors. Doses for members of the TROC are being provided to European and Russian epidemiologists, as partial input for studies of risk in this population. Project 1.1 was not charged with providing in utero doses, and that is the responsibility of European and Russian investigators.

Two of our original goals for the completion of this nine-year phase of Project 1.1 were not completed. These are completion of TRDS-2009MC, which was to be a Monte Carlo version of TRDS-2009 that could be used for more explicit analysis of the impact of uncertainty in doses on uncertainty in radiogenic risk factors. The second incomplete goal was to be the provision of household specific external doses (rather than village average). This task was far along, but had to be delayed due to the lead investigator's work on consideration of a revised source term.

REVIEW OF WORK PACKAGES FOR PROJECT 1.1

The work for Project 1.1 had been divided into five Work Packages (WP), and these are listed below.

WP-1. Improvements in basic models and further evaluation of uncertainty.

WP-2. Reduction in uncertainty: reassessment of internal doses on the basis of individual measurements and household analogies.

WP-3. Validation of TRDS external doses by combining EPR results with modeling.

WP-4. Evaluation of other sources of exposure that confound the analysis of data for members of the ETRC and the TROC.

WP-5. Development of a new version of the Techa River Dosimetry System (TRDS) code for individual-dose calculations. This revised code will include all sources of exposure, including updates for the calculation of dose from consumption of contaminated water and foods associated with releases to the Techa River.

All tasks within WP-1, WP-2, WP-3 and WP-4 were completed before October 2006. Efforts on these tasks supported twenty milestone or unscheduled reports; the current accomplishments have been described in numerous publications (Appendix 1) and have been summarized in Degteva et al. (2006). Because of changes in the source-term and because additional data on external exposure rates were successfully renormalized, three additional unscheduled reports were prepared and distributed with the April 2009 Progress Report.

TASKS WITHIN WORK PACKAGE 5

Task 5.1. Comparative analysis of potential contributions from different sources of confounding exposure for the members of the ETRC (M. Degteva).

Task 5.2. Development of an algorithm for selection of the best individual estimate of internal dose on the basis of the results of calculations performed using three different protocols (N. Shagina).

Task 5.3. Development of the special code and calculation of individual medical doses for members of the ETRC. (M. Degteva and V. Golikov).

Task 5.4. Creation of the TRDS modules for the calculation of short-lived radionuclides intake on the basis of verified source-term data (M. Vorobiova and E. Tolstykh).

Task 5.5. Creation of the TRDS modules for the calculation of external doses on the basis of verified source-term data (M. Vorobiova).

Task 5.6. (former Task 5.3). Preparation of a protocol for individual-dose reconstruction (M. Degteva and A. Kozyrev).

Task 5.7. Development of the TRDS code and calculation of individual doses for members of the ETRC. (M. Degteva and A. Kozyrev).

Task 5.8. Development of the stochastic TRDS code to be used to evaluate the impact of uncertainty in individual dose upon derived risk coefficients (N. Shagina and M. Degteva).

Tasks 5.1, 5.2, 5.3, 5.4, 5.5, and 5.6 had been completed before this reporting period; eight Milestone or Unscheduled Reports were previously distributed that describe the work on these Tasks. Tasks 5.6 and 5.7 were completed during this six-month period. The results of the two tasks resulted in the creation of TRDS-2009D. Our Final Report for Milestone 22 (Degteva et al. 2009b) describes the results of these four tasks and the results calculations of individual dose for the members of the ETRC and of post-natal doses for members of the TROC.

As noted before and as stated in our previous Progress Report, it was not possible to complete Task 5.8. We have prepared a Status Report (Napier et al. 2009) on Task 5.8, which is

being distributed with this Progress Report. As planned and indicated in our recent proposal (Degteva et al. 2009a) for continuation of Project 1.1, this task will be completed at a later date.

MILESTONE STATUS

As this is the Concluding Progress Report for this phase of Project 1.1, the status of all Milestones for the phase is reviewed. This is the last time that these milestones will be listed in our Progress Reports.

1. Statistical analysis of individual dosimetric data and the evaluation of uncertainties in instrumental techniques used for ^{90}Sr-body-burden evaluation (whole-body count and tooth-beta count).

   Completed in October 2000 with the delivery of the Milestone 1 Report (Kozheurov et al. 2000).

2. Description of the computer database "TOOTH" containing available EPR measurements on tooth samples and exposure histories of tooth donors for the ETRC members and the residents of background areas.

   Completed in April 2001 with the delivery of the Milestone 2 Report (Shishkina et al. 2001).

3. Report on basic models for ^{90}Sr-dose assessments: improved strontium biokinetic model and verified ^{90}Sr-intake model.

   Part 1 was completed in September 2001 with the delivery of the Milestone 3, Part 1, Report (Tolstykh et al. 2001).

   Part 2 was completed in April 2002 with the delivery of the Milestone 3, Part 2, Report (Shagina et al. 2002b).

   An Unscheduled Report *Dosimetric models for strontium in the human bone: A review of available data and researches needed* (Shagina et al. 2005) was prepared in 2005.

   Another Unscheduled Report *Improvement in Strontium-90 reference intake function for residents of the Techa Riverside settlements* (Tolstykh et al. 2008a) was prepared in October 2008 and distributed with our previous Progress Report.

4. Description of the Individual-to-Model Ratio (*IMR*) Registry (or Subcohort 1), which includes the list of measured ETRC members with *IMR* values and their uncertainties.

   A Progress Report for Milestone 4 (Shagina et al. 2002a) was distributed in February 2002.

The Final Report for Milestone 4 (Tolstykh et al. 2002) was completed and distributed in October 2002.

5. Report on an improved Techa River Model and evaluation of uncertainties in radionuclide composition of river water. Verification of intake levels and their uncertainties for non-^{90}Sr radionuclides.

   The Final Report for Milestone 5 (Vorobiova et al. 2003a) was completed and distributed in April 2003.

   An Unscheduled Report, *Improvement in cesium-137 intake with milk contaminated as a result of soil→grass→milk transfer* (Tolstykh et al. 2008b) was prepared and distributed with our previous progress report.

6. Description of the Household Registry for the Techa River settlements that includes a list of ETRC members with household codes, settlement codes and the dates of cohabitation.

   The Final Report for Milestone 6 (Tokareva et al. 2003) was completed and distributed in April 2003.

7. Report on the validation of TRDS external dose assessments by EPR measurements supported by the assessments of ^{90}Sr concentration in tooth tissues and Monte Carlo simulations of dose distribution through human tissues.

   An Unscheduled Report *Commentary on the number of teeth required for analysis by EPR in order to validate estimates of external dose for members of the extended Techa River Cohort* (Anspaugh et al. 2001) was prepared in 2001.

   Another Unscheduled Report *Investigation of the tooth as a complex dosimeter: Formation of dose in tooth enamel* was distributed in June 2002 (Shishkina et al. 2002).

   Part 1 was completed in September 2003 with the delivery of the Milestone 7, Part 1, Report (Shishkina et al. 2003).

   Part 2 was completed in September 2004 with the delivery of the Milestone 7, Part 2, Report (Degteva et al. 2004).

8. Description of the algorithm for the evaluation of uncertainty in Household-Specific-Ratios (*HSR*) and Subcohort 2 that includes the list of unmeasured ETRC members with *HSR* values and their uncertainties.

   The Final Report for Milestone 8 (Tolstykh et al. 2003) was completed and distributed in October 2003.

9. Report on the uncertainties in TRDS external dose estimates evaluated on the basis of modeling data and the distributions of external exposure components of EPR measurements.

The Final Report for Milestone 9 (Degteva et al. 2005a) was completed and distributed in April 2005.

An Unscheduled Report *Methodological approaches to evaluation of parameters for external exposure of the Techa River residents* (Vorobiova et al. 2008) was prepared and distributed with our previous progress report.

10. Analytical review of data and models available for the reconstruction of individual doses due to residence on the EURT area and the territory of windblown contamination from Lake Karachay.

    The Final Report for Milestone 10 (Peremyslova et al. 2004) was completed and distributed in May 2004.

11. Analysis of the territorial distribution of residence locations for members of the ETRC within the EURT and Karachay Trace areas with different levels of soil contamination.

    The combined Report for Milestones 11 and 12 (Tolstykh et al 2006) was completed and distributed in April 2006.

12. Description of available databases and the methodological approaches to the reconstruction of radionuclide intake for the EURT and 'Karachay Trace' areas.

    The combined Report for Milestones 11 and 12 (Tolstykh et al 2006) was completed and distributed in April 2006.

13. Report on methodological approaches to external dose reconstruction and validation for the EURT and Karachay Trace areas.

    The Final Report for Milestone 13 (Vorobiova et al. 2006) was completed and distributed in September 2006.

14. Comparative analysis of the possible impact of different sources of environmental and medical exposure for referent persons.

    The Final Report for Milestone 14 (Degteva et al. 2007a) has been completed and was distributed in April 2007.

15. Final Report for Project 1.1 including a Protocol (algorithm) for individual-dose reconstruction due to different sources of confounding exposure for the members of the ETRC. Description will also be given for the structure of a revised Dosimetric System.

    This effort has been completed. The results are included in the Milestone 22 Report (Degteva et al. 2009b), which is being distributed with this Progress Report.

16. (Milestone 1 of the Addendum) Description of the "Registry of X-Ray Procedures" that will include a list of members of the ETRC with the dates and types of radiological examinations that were experienced since 1956.

The Final Report for Milestone 16 (Vorobiova et al 2003b) was completed and distributed in November 2003.

17. (Milestone 2 of the Addendum) Protocol for the reconstruction of individual medical doses for members of the ETRC.

    The Final Report for Milestone 17 (Degteva et al. 2005b) was completed and distributed in September 2005.

18. Algorithm for selection of the best individual estimate of internal dose on the basis of the results of calculations performed using three different protocols.

    The Final Report for Milestone 18 (Shagina et al. 2007) has been completed and distributed in April 2007.

19. Milestone 19. Report describing the results of calculations of individual medical doses for members of the ETRC.

    The Final Report for Milestone 19 (Degteva et al. 2007b) was completed in October 2007 and distributed in April 2008.

20. Milestone 20. Description of the TRDS modules for the calculation of short-lived radionuclides intake and external doses on the basis of verified source-term data using the two-compartment river model.

    Part 1 of the combined Report for Milestones 20 and 21 (Degteva et al 2008) was completed and was distributed with the April 2009 Progress Report.

    Part 2 (Degteva et al. 2009c) was also distributed with the April 2009 Progress Report.

21. Milestone 21. Description of a protocol (algorithm) for individual-dose reconstruction due to different sources of confounding exposure for the members of the ETRC. Description will also be given for the structure of a revised Dosimetric System.

    Part 1 of the combined Report for Milestones 20 and 21 (Degteva et al 2008) was completed and was distributed with the April 2009 Progress Report.

    Part 2 (Degteva et al. 2009c) was also distributed with the April 2009 Progress Report.

22. Milestone 22. Report describing the results of calculations of individual doses for members of the ETRC using the improved TRDS code including different sources of confounding exposure.

    Delayed due to funding cuts. The Milestone 22 Report (Degteva et al. 2009b) is being distributed with this Progress Report.

23. Report describing the development of the stochastic version of the TRDS code and the results of several iterations of individual doses for the approximately 30,000 members of the ETRC.

    Due to budget cuts, it was not possible to complete this Milestone Report. A status report (Napier et al. 2009) is being distributed with this Progress Report.

PROPOSED NEW WORK PACKAGES AND TASKS FOR FY2010 THROUGH FY2012

These tasks are taken from our proposal (Degteva et al. 2009a) for an extension to this project.

The proposed efforts include specific tasks linked to improvements in the basic models used for dose reconstruction, validation of the improved models, extensions to the current version of the TRDS-2009 code and completion of the stochastic version.

WP-1. River modeling and data harmonization

Task 1.1. Evaluation of historical methods for measurements of gamma- and beta-radiation with the use of Monte Carlo modeling of radiation transport.

This task will allow evaluation of possible systematic errors in historical measurements (dated 1950–1956) for some source-term radionuclides in dependence of the energy of beta-particles or photons.

Task 1.2. Development of a dynamic model for radionuclide transport in the Techa River.

Work on this task will develop the model for radionuclide transport through the Koksharov and Metlinsky ponds, potential deposition and resuspension from the Metlino and Asanov Marshes, and transport along the river. The model will provide concentrations of all source term radionuclides at all village locations, with due account take of radioactive decay. The model will include sediment concentrations, which will be used to estimate external dose rates at locations downstream.

Task 1.3. Harmonization of historical data and river model output.

This task will examine the results of the output of the dynamic Techa River model of Task 1.2 in comparison to historical measurements of the river water and sediments, as well as the ^{90}Sr intake function developed in retrospective fashion from the tooth-beta and whole-body measurements. This could lead to refinement of the Techa River source term, particularly the relative ratios of short-lived nuclides to strontium and cesium. Depending upon the outcome of the comparisons, this could result in an iterative approach to determining the source term.

WP-2. Reduction in uncertainty and validation of TRDS external doses

Task 2.1. Completion of work on associating individuals with a geographic location of their homes for the upper Techa region.

The result of this task will the location of individual households in the villages between Metlino and Muslyumovo. Distances between the river shore and the households will be associated with the individuals within the database.

Task 2.2. Evaluation of household-based deterministic estimates of individual external doses for all individuals associated with the geographic locations of their homes.

Registry of household-based deterministic estimates of individual external doses will be created, a computer program will be written to automate this currently-manual operation.

Task 2.3. Verification and validation of external doses.

Continued evaluation will be made of available and new luminescence measurements (TLD), electron paramagnetic resonance measurements (EPR), and fluorescent in situ hybridization (FISH) measurements with human lymphocytes obtained under the SOUL project, to confirm that the changes made in Tasks 1.3 and 2.2 are compatible with the available monitoring data.

WP-3. Further reduction in uncertainty of TRDS internal doses

Task 3.1. Examination of the results of measurements of ^{90}Sr-body burdens with use of the upgraded WBC system.

It is planned to increase the number of newly measured individuals up to 3,500. Evaluation of these results will provide an important addition to our data base.

Task 3.2. Comparison of data obtained with the old and new WBC systems for persons with high concentrations of ^{90}Sr.

This task will allow pooled analysis of ^{90}Sr-body burdens measured in 1974–1997 and after 2006.

Task 3.3. Updating of the *IMR* and *HSR* registries with use of data derived from newly-measured persons.

This task will allow an increase in the number of cohort members with refined estimates of internal dose.

WP-4. Enhancements in the TRDS

Task 4.1. Incorporation of EURT evacuated villages.

This task will result in the collection of data necessary to estimate doses with existing algorithms for residents in those villages that were evacuated following the 1957 creation of the EURT.

Task 4.2. Consideration of the release from the MPA stack as confounding source of exposure.

This task will allow making a decision on whether to incorporate doses from airborne releases from the Mayak reactor and fuel processing stacks.

Task 4.3. Re-calculation of TRDS-2009D modules supporting computations of external doses and intakes of non-^{90}Sr radionuclides.

This task will incorporate the results of Tasks 1.3 and 2.3 into the TRDS-2009D databases.

Task 4.4. Completion of the stochastic TRDS-2009MC computer code.

The stochastic version of the TRDS code will include all sources of exposure as within the deterministic version. However, parameters within the code will be assigned distributions. These parameters will be allowed to vary during each iteration of the process with due consideration of which parameters are shared versus those that may vary on an individual basis. Distinction will be made between Classical and Berkson-type error structures. The recent improvement of knowledge about the Techa River source term (e.g., Degteva et al. 2008a; b) adds computational complexity, but does not alter the basic structure proposed.

PROPOSED NEW DELIVERABLES AND MILESTONES FOR FY2010 THROUGH FY2012

The dates given below are given with the assumption that funding would have been received on October 1, 2009.

1. Evaluation of historical methods for measurements of gamma- and beta-radiation with the use of Monte Carlo modeling of radiation transport. (E. Shishkina).

   Task 1.1 – March 2010

2. Description of a dynamic model for the transport of radionuclides within the Techa River and comparison of model results with historical measurements (M. Vorobiova and M. Degteva).

   Tasks 1.2 and 1.3 – September 2010

3. Individualization and validation of external doses for the upper Techa River villages (E. Tokareva and E. Shishkina)

Tasks 2.1, 2.2 and 2.3 – March 2011

4. Comparison of data obtained with the old and new WBC systems for persons with high contents of ^{90}Sr (N. Bougrov and E. Tolstykh)

   Tasks 3.1 and 3.2 – September 2011

5. Description of the revisions to TRDS-2009D code and databases (M. Vorobiova, E. Tolstykh and A. Kozyrev)

   Tasks 3.3, 4.1, 4.2 and 4.3 – March 2012

6. Description of the TRDS-2009MC computer code and stochastic dose estimates (M. Degteva and N. Shagina)

   Task 4.4 – September 2012

OTHER ACTIVITIES

We continue to be in close contact with the investigators of our companion US epidemiologic studies. We also are part of and maintain close contact with all investigators of the related studies being conducted by the European Union in the framework of their SOUL project.

We continue to publish papers and to participate in scientific meetings, although this activity has slowed due to the pressure to complete TRDS-2009D. We did participate in the NCI-sponsored conference, "Late Health Effects of Ionizing Radiation: Bridging the Experimental and Epidemiologic Divide Conference," Washington DC, USA, May 4–6, 2009, (Degteva et al. 2009d; Krivoshchapov and Shishkina 2009a; Shagina et al. 2009) and we provided an abstract and a summary for the Annual Meeting of the JCCRER, September 16–17, 2009. One of our young investigators participated in the 2009 annual meeting of the Health Physics Society (Krivoshchapov and Shishkina 2009b).

A paper, "Bone Tissue Reactions to ^{90}Sr radiation exposure: Analyses of data from Techa Riverside residents," has been prepared and will be submitted to a journal in the near future. This activity was also funded by the Russian Foundation for Basic Research Grant 07-04-96084.

A complete list of project publications is given in Appendix 1. Additions since the last Progress Report are shaded.

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APPENDIX 1

UPDATED LIST OF PUBLICATIONS FOR PROJECT 1.1

LIST OF PUBLICATIONS FOR PROJECT 1.1

Note—The Russian dosimetrists receive funds from the U.S. Department of Energy (in prior years funds were also provided for Project 1.1 by the U.S. National Aeronautics and Space Administration and the U.S. Environmental Protection Agency) for 60% support of their salary; the Federal Department of the Ministry of Health of the Russian Federation has provided through JCCRER Project 1.1 most of the remaining salary support. Some of the publications listed below have resulted from small, specific projects with a majority of funding from other sources;* however, the work could not have been undertaken without the backbone support of JCCRER Project 1.1. The Russian Principal Investigator has managed effectively to combine the activities into a coherent project. In some cases the Russian dosimetrists of Project 1.1 have made the results of their work available to other projects without specific financial compensation, but the use of their results has been recognized through co-authorship of publications.

The total number of reports of various types are listed in Table 1.

Table 1. Numbers of reports of various types that have been published by investigators of Project 1.1.

Type	Total No.[a]	No. in English	No. in Russian
Articles in peer-reviewed journals	89	68	27
Other open literature publications	187	102	117
Milestone and other scientific reports	41	41	30
Progress reports and proposals	30	30	0

[a] Because some documents have been published in both languages, the sum of the papers in English and in Russian is greater than the total number of documents.

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