UCRL-ID-123713Add.1

Dose Reconstruction for the Urals Population

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Extended Synopsis Prepared for the
Meeting of the American Scientific Review Group

January 1996

Lawrence Livermore National Laboratory

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DOSE RECONSTRUCTION FOR THE URALS POPULATION

Joint Coordinating Committee on Radiation Effects Research
Project 1.1–Final Report

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January 1996

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INTRODUCTION

This extended synopsis has been prepared for the use of the Scientific Review Group at its initial meeting. The material here has been extracted from the draft Final Report for Project 1.1. This Final Report is about 150 pages in length; it will be submitted on schedule to the Executive Committee of the JCCRER in February 1996.

The purpose of the Final Report is to present the results of the first year's collaborative work on Project 1.1 on "Dose Reconstruction for the Urals Population," which is part of Direction 1 on "Medical Aspects of Radiation Exposure Effects on Population." This work is being carried out as a feasibility study to determine if a long-term course of work can be implemented to assess the long-term risks of radiation exposure delivered at low to moderate dose rates to the populations living in the vicinity of the Mayak Industrial Association (MIA). This work was authorized and conducted under the auspices of the U.S.–Russia Joint Coordinating Committee on Radiation Effects Research (JCCRER) and its Executive Committee (EC).

The MIA was the first Russian site for the production and separation of plutonium. This plant began operation in 1948, and during its early days there were technological failures that resulted in the release of large amounts of waste into the rather small Techa River. There were also gaseous releases of radioiodines and other radionuclides during the early days of operation. In addition, there was an accidental explosion in a waste-storage tank in 1957 that resulted in a significant release (the Kyshtym explosion). The "Techa River Cohort" has been studied for several years by scientists from the Urals Research Centre for Radiation Medicine (URCRM), and an increase in both leukemia and solid tumors has been noted (Kossenko and Degteva 1994). This cohort is the primary focus of collaborative studies, but other cohorts have been suggested for study; these cohorts will be considered in this report.

This study was undertaken on the basis of a proposal from the Russian side to the JCCRER. This proposal and its accompanying proposal for epidemiological research (Project 1.2) are provided in the JCCRER (1994) report of its October 1994 meeting. At this October 1994 meeting the JCCRER agreed to the following as concerns Direction 1 (JCCRER 1994).

> "For Direction 1, both parties agree to these research proposals with the stipulation that the EC should modify proposals 1.1 and 1.2 to 1) ensure data identification, quality assurance and preservation and to 2) accommodate the closer integration of the dosimetry (dose reconstruction) with the risk estimation for defined residential populations. Both parties agree that initial epidemiological studies of residential populations should focus on, but not be limited to, stochastic effects in the South Urals populations."

Following this decision Russian and American scientists met at the URCRM in January 1995 to define a more detailed proposal for the work to be conducted under Project 1.1. This proposal was provided to the EC and was considered at the EC's meeting in Moscow in February 1995 (JCCRER 1995). The EC did not adopt the full context of the proposal, but defined a more narrow set of objectives for the first year's collaborative research in terms of a feasibility study. Four Milestones were identified for Project 1.1 (JCCRER 1995):

1. Preserve and verify the existing database and design a searchable database structure, including software and hardware needed. Include the available archived information related to dose reconstruction. Prepare a report describing the data base design by December 31, 1995.

2. Begin calibration of the URCRM whole body counter. Construct a phantom, begin calibration of the counter with the phantom, and prepare a progress report on this milestone by February 29, 1996.

3. Prepare a report that will include the methodology for and an assessment of the feasibility of reconstructing the doses for persons in the cohort considered in Project 1.2 by February 29, 1996.

4. Establish conceptual and mathematical models for sources and pathways of exposure for the Mayak Region population at the St. Petersburg Workshop (June 1995).

Final reports on all milestones are included within the Final Report. An informal report on Milestone 1 was prepared during a visit of two scientists each from the URCRM and the MIA to the Hanford Works, WA, and Washington, DC. A progress report on Milestone 2 was prepared during the JCCRER St. Petersburg Workshop held in July 1995; this progress report was supposed to have been included in the Proceedings of this Workshop. A final progress report on Milestone 2 is provided in this Final Report. The final report on Milestone 3 is provided here for the first time. The final report on Milestone 4 was prepared during the St. Petersburg Workshop; it was supposed to have been published as part of the Workshop Proceedings. As the authors of the present report cannot verify the existence of such Proceedings, the Milestone 4 report is reproduced within the body of this report.

BACKGROUND

Population exposure in the Urals occurred as a result of failures in the technological processes at the Mayak plutonium facility in the 1950's. Construction of the Mayak facility began in 1945 and was completed in 1948. Initially this complex consisted of three main parts: Reactor plant, radiochemical facility, and waste-management facilities. The major sources of radioactive contamination were the discharges of 2.7×10^6 Ci of liquid wastes into the Techa River (1949–1956); an explosion in the radioactive waste storage facility in 1957 (the so-called Kyshtym Accident) that formed the East Urals Radioactive Trace (EURT) due to dispersion of 2×10^6 Ci into the atmosphere; and gaseous aerosol releases (about 560,000 Ci of ^{131}I in total) within the first decades of the facility's operation. The significant portion of activity for the Techa River and EURT consists of long-lived radionuclides, mainly ^{90}Sr. These releases resulted in the long-lived contamination of surrounding territories. The predominant radionuclide for operating gaseous aerosol releases was short-lived ^{131}I resulting from reprocessing of nuclear fuel.

The maximal annual rates, which occurred in 1952–1953, were reconstructed on the basis of technological records by the Mayak team under Dr. E. Drozhko (Khokhryakov et al. 1992).

Systematic measurements of radioactive contamination in and near the Techa River started in the summer of 1951. The contamination of the river water, bottom sediments, flood-plain soils, vegetation, fish, milk, and other food stuffs, and external gamma-exposure rates were measured. In 1957 the monitoring was expanded to include the area covered by the EURT. Systematic control of Mayak operating releases and measurements of ^{131}I concentration in food stuffs started only in 1962. For the town of Ozersk (which was mostly affected by gaseous aerosol releases) regular measurements of ^{90}Sr and ^{137}Cs started in 1956 and the monitoring of exposure rates began in 1964. The results of all these measurements are kept in archives at Mayak and URCRM, mainly on paper media (maps, working notebooks, technical reports, etc.). Some of them are still classified.

The population of the contaminated territories was exposed to external and chronic internal irradiation. Medical checkups of the Techa Riverside communities had been started by 1951. In addition to medical examinations, individual data on the conditions of contact with the contaminated river (the distance of the house from the water's edge, the source of drinking water, fishing, etc.) were collected. Also, radiometric measurements of bioassay and autopsy samples were performed. Medical checkups of the population of the most contaminated area of the EURT were started in autumn 1957. Later, a registry numbering 90,000 subjects in the accidentally exposed population (the residents of the Techa Riverside communities and the residents of the area covered by the EURT) was established at the URCRM. All places and terms of residence inside the contaminated area were collected for the members of this registry for the purposes of individual-dose reconstruction. Also, extensive measurements of ^{90}Sr content in teeth were performed beginning in 1960, in forehead bone beginning in 1976; whole-body counting for ^{90}Sr has been performed since 1974. Now the main part of this information is contained in a computerized data base at URCRM. The registry for the population exposed as a result of the operational releases at Mayak is not established yet, but this work has been started at Branch 1 of Moscow Biophysics Institute (FIB-1). Also, the results of the measurements of ^{90}Sr and Pu in samples collected at autopsy for the residents of Ozersk and nearby territories number several thousand and are kept in the archives of Mayak and FIB-1. So, three cohorts of exposed population can be selected based on the nature of exposure and according to history of follow-up and available data: Techa River Cohort, EURT Cohort and Ozersk Cohort (not yet established). Some efforts addressed to dose reconstruction and risk assessment for the first two cohorts were taken in URCRM and the results have been published in open literature.

Techa River Cohort

The Techa River cohort (TRC) is important because some of its members have received relatively high doses and a significant increased risk of leukemia with increasing dose was observed (Kossenko and Degteva, 1994). There is some evidence that solid tumors may also be in excess. The residents of the villages along the Techa were exposed to both external irradiation (from contaminated river water, sediments, flood plain soils) and internal irradiation due to ingestion of radionuclides with drinking water and diet. The original dose-reconstruction methods for TRC have been described in detail elsewhere (Degteva et al. 1994).

The absorbed doses due to external exposure were estimated on the basis of systematic measurements of gamma exposure rate along the banks of the river, and the typical life patterns of the inhabitants of the riverside villages. This approach has given the average annual absorbed doses from external sources for different age groups in each village. The data available do not provide information on the variations in individual-dose levels among the residents of a village. Instead the average value for specified age groups and specified settlement has been assigned to each member of cohort. Also, it was assumed that the total dose due to external exposure was accumulated during the period 1950–1955. This approach has a number of limitations resulting in both random and systematic errors in individual-dose estimates.

The main contributor to the internal exposure among the radionuclides released into the Techa River was ^{90}Sr, which is accumulated in bone tissues and retained there for many years. In vivo beta-ray measurements on teeth, which were performed since 1960, and a large number of ^{90}Sr measurements in whole body have been the basis of internal dose reconstruction (Kozheurov 1994). The internal dose reconstruction depends on both estimates of the intake and models for metabolism of ingested radionuclides. Beta-ray measurements on teeth are utilized to deduce the annual levels of intake of ^{90}Sr in the different villages in the different age cohorts. The ingestion of other radionuclides (^{89}Sr and ^{137}Cs predominantly) occurred mostly with water in the first three years of the river contamination. The intake rates of ^{89}Sr and ^{137}Cs were therefore derived from the ingestion of ^{90}Sr scaled in terms of the radionuclide composition of the river water. These data were used to estimate age-dependent intake rates for all Techa villages (Kozheurov and Degteva 1994). Calculation of absorbed doses in tissues due to radionuclide incorporation is based on age-dependent metabolic and dosimetric models and the corresponding ingestion rates. A large number of measurements of ^{90}Sr-body content made with whole-body counter (WBC) has been utilized for the validation of the metabolic model for strontium retention in human bone (Degteva and Kozheurov 1994). Absorbed doses in red bone marrow (RBM) and bone surfaces (BS) have been calculated for all age cohorts. The absorbed doses in RBM and BS are substantially higher than those in other tissues because of the high contribution of bone-seeking strontium. The upper limit of total doses absorbed in RBM is estimated as about 3 Gy.

EURT Cohort

Initially a sub-cohort of the population evacuated from the most contaminated territories of the EURT numbering 7,854 people was established in the URCRM (Kostyuchenko and Krestinina 1994). Average-dose estimates for the residents of different villages were taken from two independent sources of information (Romanov 1990; Skryabin 1985), which gave different assessments. Dose calculations were undertaken on the basis of the levels of radionuclide contamination of the soil (a significant non-uniformity of contamination being noted) and known isotopic composition of local fall-out. The range of effective doses for this part of the population was from 40 to 500 mSv. No statistically significant changes in cancer mortality as compared to control group have been reported for this sub-cohort (Kostyuchenko and Krestinina 1994). Analogous results for another sub-cohort of 8,000 non-evacuated EURT residents who received effective doses from 50 to 66 mSv were reported in 1994 in Ekaterinburg (Krestinina et al. 1994). The formation of the EURT Cohort is not yet finished and only tentative dose assessments have been done.

FINAL REPORT FOR MILESTONE 1.1.1 "PRESERVE AND VERIFY THE EXISTING DATABASE AND DESIGN A SEARCHABLE DATABASE STRUCTURE, INCLUDING SOFTWARE AND HARDWARE NEEDED. INCLUDE THE AVAILABLE ARCHIVED INFORMATION RELATED TO DOSE RECONSTRUCTION"

The first major, critical goal is to create a searchable data base of the available archived information that would be essential and useful to perform individual and collective dose calculations for the populations effected by the routine and accidental releases from the MIA. Such information would include the data needed to determine the releases to the environment via all pathways, with emphasis on the releases to the Techa River, from the Kyshtym tank explosion, and routine and accidental airborne releases; all environmental monitoring data; all bioassay data; and all previous estimates of releases and doses. It is especially important that this information include working notebooks from the MIA, as well as contamination maps and technical reports. Such bibliographic information will be entered into a data base that would include the author(s), title, and summary with key words.

It is not possible to accomplish this large task during the feasibility phase. Rather, the first proposed effort is to establish the optimum conditions for the conduct of this task. It is recognized that this task could become very consumptive of manpower, if not controlled and limited. The feasibility phase was limited to the design of the hardware and software systems needed to accomplish the larger overall task. First steps were a visit of four staff members from the URCRM/MIA to the United States in order to visit similar systems that have already been successfully demonstrated for the purpose of collecting information for dose-reconstruction. The first priority for visit was the Pacific Northwest National Laboratory (PNNL), which has just completed a similar bibliographic data base and dose-reconstruction project. At the end of the visit US and Russian experts consulted and determined the optimum hardware and software requirements to implement such a system. It is anticipated that this system will operate on a PC platform and will use commercially available software. Two sets of software and hardware, with appropriate backup storage and protection, were purchased during the early phases so that work can proceed promptly on the implementation of this process. One of the early goals of this process is to identify all data sets that will be useful during the dose-reconstruction phases and to identify some unique data sets that might be saved for use in model-validation studies.

The participants in Project 1.1 have considered three groups of initial data necessary for dose reconstruction: (1) Individual information (place and terms of residing on a polluted territory, measurement of the radionuclide contents in the human body, etc.); (2) Primary information on environmental contamination at the places of residence; (3) Archival bibliographic information that describes the radiation situation and methods of research (technical reports, methods of measurement, working journals, etc.). Pursuant to these three groups should be supported three compatible computerized databases, named accordingly: MAN, ENVIRONMENT and ARCHIVE.

The Draft Final Report describes these databases in substantial detail. The first two have already been developed and implemented to a significant extent by scientists from the URCRM. The last database will be developed for this project. Information for the ARCHIVE database will be taken largely from the MIA and the URCRM, but information from other sources will be included, also.

PROGRESS REPORT FOR MILESTONE 1.1.2 "BEGIN CALIBRATION OF THE URCRM WHOLE BODY COUNTER. CONSTRUCT A PHANTOM, BEGIN CALIBRATION OF THE COUNTER WITH THE PHANTOM, AND PREPARE A PROGRESS REPORT"

The URCRM whole-body counter (WBC) has been used since 1974 to measure ^{90}Sr and other radionuclides in people exposed to the effluents released to the Techa River. The detectors and electronics are obsolete, and there are plans to replace them with modern equipment. For the original calibration of the WBC two surrogate human structures were made by different laboratories. Both phantoms were made of natural human skeletons, paraffin imitations of soft tissues and dry paper imitations of lung. Different methods of introducing ^{90}Sr into the bones of the phantoms were used. In one of the phantoms the isotope was introduced by being dripped into uniformly distributed holes drilled the bones. The bones of the other phantoms were impregnated with a ^{90}Sr solution in a vacuum chamber. Each laboratory performed independent experiments aimed at determining bremsstrahlung yields and the influence of human soft tissues and the phantom paraffin on the absorption of the bremsstrahlung. Independent activity measurements were carried out on each phantom. After scanning the phantoms and making the appropriate corrections the difference in calibration coefficients was determined to be 6%. This value represents the estimate of the systematic error in ^{90}Sr counting by means of the spectrometer. Water-filled phantoms made of plastic tanks laid out in such a way as to imitate a human body were used for calibration of ^{137}Cs and ^{40}K. The length of the phantom could be changed by removing one or two tanks. Such calibration was done in 1974 and has not confirmed been during the subsequent twenty years of operation of the WBC.

More than 28,000 of measurements were carried out during this period among more than 14,000 people. This data base of measurements is critical to the success of efforts to provide individual doses. There are plans to update this whole body counter with modern detectors and electronics. However, it is highly desirable to ensure that the old measurement system is once again calibrated in depth on the basis of measurements of a special anthropomorphic phantom. Also, the measurements of the special phantom with the new system will ensure the comparability of the results with the old and the new systems.

The data of concern are of major interest to the reconstruction of dose to the active bone marrow of the members of the Techa River cohort and to the completion of the major study of Sr metabolism that is being undertaken at URCRM. The whole body counter will be used in the future for continuing measurements for these purposes, and it is important to note also that the whole body counter is now an integral part of the public outreach program for the local residents.

Phantoms of two types, namely physical and mathematical, are required for the selection of optimum measurement geometry as well as detector type and for the calibration of the whole-body bremsstrahlung counter. A physical phantom is an anthropomorphic model of the body of an adult with an uniform distribution of ^{90}Sr in the skeleton. The error in the muscle-tissue equivalent, lung-tissue equivalent and bone equivalent of the materials used will be within 5% for the 0.015 to 0.060 MeV range of gamma energy. The activity error will be less than 5%.

A mathematical phantom is a computer model simulating the spectral and angular distribution of the photon radiation, including bremsstrahlung, at the surface of the phantom resulting from the radioactive decay of incorporated radionuclides. Such a phantom uses the Monte-Carlo method, and includes four units:

the source term,
the physical constants for radiation transport,
the geometrical unit, and
the result interpretation.

The limitations of the computer model are due to the complexity of the body structures. The mathematical phantom is intended to make allowance for a non-uniform ^{90}Sr distribution in the different bones and structures of the skeleton and for individual body geometries.

The work on the development of anthropomorphic physical phantom for calibration of whole-body counter SICH-9.1 was started in January 1995 in the Institute of Marine Transport Hygiene, St. Petersburg, under contract with Federal Agency of Medical and Extreme Problems. The title of this contract is "Development and manufacturing the standard phantom of human body with incorporated strontium-90 FST-06T". The terms of this contract are: January 1995–June 1996. Two stages of work were planned. The first one (January 1995-December 1995) is: "the design of the phantom" which includes exact determination of the demands (standards) for the phantom, the study addressed to find the composition of the materials for the phantom (tissue-equivalent properties of different mixtures of plastics), the manufacture of a sculptural model of the phantom, and preparation of the documents for taking out a patent. The second stage (January 1996-June 1996) is "the manufacture of the phantom" which includes: proper manufacture, testing and certification of phantom. The stage of 1995 is already done. Three milestones were accomplished:

1. Exact requirements for the composition and construction of the phantom were determined. The main of them are the following. The phantom should be consist of three main tissue substitutes simulating bone, lung and soft tissues (mass densities of these must be equal to 1.3; 0.26 and 1.04 gram per cm^3 respectively).

2. The composition of tissue substitutes were found after testing different compounds based on epoxy resin, acrylics and polyurethane. The most suitable properties were found for epoxy resin compounds.

3. A sculptural model of the phantom was manufactured on the basis of exact copy of man's skeleton developed in the firm "Meduchposobie", St. Petersburg. The models of different parts of whole body were made according to Human Anatomic Atlas by R.D. Sinelnikov, Moscow Publisher "Maditsina" 1978.

According to the contract mentioned above manufacturing is scheduled to start in January 1996. Calibration of the physical phantom is scheduled to be completed in July 1996. Calibration of the whole-body counter is expected to be finished by October 1996. The work on the development of mathematical phantoms was not started during the feasibility study as a result of limited financial support. The participants of the project agreed that it would be very useful to arrange a meeting for Dr. Alexander Kovtun (who is the supervisor of work on creation of physical phantom and calibration of WBC) with Dr. David Hickman from LLNL who is an expert in mathematical phantoms. Both US and Russian PIs will arrange such a meeting as soon as the second half of money for the feasibility study will be received.

FINAL REPORT FOR MILESTONE 1.1.4 "ESTABLISH CONCEPTUAL AND MATHEMATICAL MODELS FOR SOURCES AND PATHWAYS OF EXPOSURE FOR THE MAYAK REGION POPULATION AT THE ST. PETERSBURG WORKSHOP"

This report describes the results of activities is to establish a set of conceptual models that define the relationships, pathways, and parameters that will form the basis of the dose reconstruction efforts. These conceptual models must be determined before any computational scheme can be developed. These models were developed at a meeting in July 1995 in St. Petersburg, Russia. This report describes the conceptual models agreed upon by the contributing scientific organizations.

Further details are not provided in this Extended Synopsis, as we understand that this report is being provided separately to the Scientific Review Group.

FINAL REPORT FOR MILESTONE 1.1.3 "PREPARE A REPORT THAT WILL INCLUDE THE METHODOLOGY FOR AND AN ASSESSMENT OF THE FEASIBILITY OF RECONSTRUCTING THE DOSES FOR PERSONS IN THE COHORT CONSIDERED IN PROJECT 1.2"

1. Introduction

This section of the Draft Final Report is lengthy and contains many tables and figures. The primary purpose is to describe how the future work will be done in order to reconstruct doses for individuals in the Techa River, EURT, and Ozersk Cohorts and to lay out tasks and schedules for this work. ***Included here are some introductory material and selected material for the Techa River Cohort only.*** This complete report will be ready for submittal to the Scientific Review Group and the Executive Committee in February 1996.

2. Dose-Reconstruction Process

Radiation-dose reconstructions are generally structured on a paradigm of release-transport-deposition-uptake/exposure-dose. The initial components are actually the most technically difficult; the individual dose calculation requires individual-specific information that must be obtained from the individual involved. Radioactive materials released to the environment generally are transported, deposited, and taken up in plants and animals in ways that are independent of individual humans. Individuals are exposed to time-varying "fields" of radiation and radioactive materials. Therefore, it is possible to reconstruct the time histories of the radiation fields and radionuclide concentrations without considering the activities of specific individuals. Once the time histories of the radionuclide fields throughout an area are known, it is possible to "introduce" the people into them and estimate the human's uptakes and resultant doses.

For many of the most significant exposures considered for these cohorts, historical information on the processes and releases is limited. However, measurements of radionuclides in specific people (^{90}Sr in bones or teeth, etc.) are available and may be used to estimate individual doses and, by implication, the fields to which others were exposed. Therefore, the dose reconstruction process planned is based extensively on measurements of radionuclide burden or exposure in humans, and the traditional paradigm is only used as a backup when other approaches have been exhausted.

2.1 Techa River Residents–Internal Dose

The internal dose-reconstruction approach for Techa River residents is described in Section 2.1.1. The tasks that derive from this approach are summarized in Section 2.1.2.

2.1.1 Techa Cohort Internal Dose Reconstruction Hierarchy

The hierarchy of information required for calculating internal radiation doses to people who lived along the Techa River during and after the largest releases is shown in Fig. 20. Internal dose is related to the time integral of the body burden. Information related to time is readily accessible through birthdates and residence histories. A large number of individuals have had at least one whole body count; many have had several. These individual records are the preferred primary data for individual-dose reconstruction. A smaller number of individual-autopsy data are available; these are also preferred starting points. The last resort for estimating body burden histories for individuals is via analogy to family members or residents of the same location—if individual measurements are not available, it is preferable to estimate them via individual intake and metabolic models.

A sufficient number of sequential whole body counts for single individuals have been assembled so that detailed models of radionuclide uptake and retention can be prepared. Default metabolic models from the ICRP may also be employed.

There were a very large number of potential routes of ingestion of radionuclides. Drinking water, eating fish, and eating various contaminated garden crops and animal products could all lead to intake of radionuclides. A technique has been developed based on in-vivo measurements of ^{90}Sr in teeth that provides a reliable estimate of direct intake (Kozheurov and Degteva 1994). For individuals for whom examinations of radionuclide content in teeth have been made, this technique can be used to calculate ingestion rates of radionuclides. Also, as a backup for those individuals for whom tooth counts are not available, intake estimates for similar categories of people may be approximated using this technique. Alternatively, intakes may be approximated using food consumption rates and radionuclide concentrations in foods.

Consumption rates vary by age, sex, ethnicity, and perhaps by village. An extensive set of individual lifestyle and dietary questionnaires were administered to Techa River residents. A separate data set related to sources of drinking water (river or well) is also available in clinic outpatient records; this information is not yet available in digital form. In the 1970s, dietary surveys were made of people living in the EURT areas—these data could provide some default information if individual dietary preferences are not available. As a default, family or village food ingestion rates can be compiled.

Historically measured radionuclide concentrations in some selected environmental media (primarily river water and sediments) are available. However, it is likely that reconstruction of food contamination levels will be required. This can be done using extrapolation in a few instances, but generally concentrations must be calculated from common radioecological transfer factors and estimated river water concentrations. River-water concentration must be estimated from released amounts and a river water transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions.

Members of the Techa River Cohort were primarily exposed to the effluents in the river, however, the atmospheric releases also affected this group—particularly those on the upper Techa near the Mayak facilities. The doses resulting from these atmospheric releases will be added to the doses calculated for this cohort according to the techniques described in Section 2.6 for the Ozersk cohort.

2.1.2 Techa River Cohort Internal Dose Activity Descriptions

The following activities are necessary to complete the full dose reconstruction.

Evaluation of Bioassay Data This subtask will evaluate available whole body count data and autopsy data. This will provide body burden/intake estimates for individuals for whom measurements exist. This task will also assemble a database of whole body count derived body burdens for each family or village to be used as surrogates in case other approaches fail for unmeasured individuals.

Metabolic Models This subtask will use available sequential whole body count data to update radionuclide retention functions. This metabolic model would then be used to help evaluate all whole body counts to provide the integral exposures.

Tooth-Count Analysis This subtask will extend the technique of Kozheurov and Degteva (1994) for dietary intake evaluation based on in vivo measurements of ^{90}Sr in teeth beyond the village of Muslymovo, where it was developed, to other sites along the Techa River.

Establish Food-Consumption Rates This subtask will develop individual dietary intakes of various foods and water as functions of age, sex, ethnicity, and location. The efforts will use individual dietary information, results of local surveys, and information on the sources of drinking water.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in water, sediment, soil, and food. This information will serve as input to the radioecology and river transport subtasks.

Radioecology This subtask will review available data to determine the most appropriate transfer factors for radionuclides in fish, milk, and food crops. Sources of data may include site-specific measurements as well as generic sources such as the International Union of Radioecologists. This information will be used to develop estimates of radionuclide content in food crops.

Techa River Source-Term Development This subtask will prepare estimates of the time history of radionuclide release to the Techa River. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the MIA will be key participants in this task.

Techa River Transport Modeling This subtask will accumulate data describing the historical Techa River hydrologic data, sediment loading, and dam construction history. This will be used as input to a numerical transport model to simulate the flow and contaminant loading of the Techa River from the Mayak facility to its confluence with the Iset River. The model will provide concentrations of radionuclides in water and sediment at specified locations along the river.

Techa River Cohort Internal Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.2 Techa River Residents - External Dose

The external dose reconstruction approach for Techa River residents is described in Section 2.2.1. The tasks that derive from this approach are summarized in Section 2.2.2.

2.2.1 Techa Cohort External Dose-Reconstruction Hierarchy

Measurements of tooth samples made with Electron Paramagnetic Resonance techniques have been shown to give very reliable and accurate indications of absorbed dose. This would be the highest priority technique for determining external exposure; however, very few individuals have been measured to date. A continuation of these studies is proposed. In addition, there is interest to evaluate whether biodosimetric techniques (e.g., florescent in-situ hybridization, T-Cell receptor, and others) can provide reliable estimates of external dose. Studies to date on these techniques have been inconclusive (Akleyev 1995*), and pilot efforts to continue the research are proposed because the potential return on the investment is very high.

External dose is related to the time integral of the dose rate field to which individuals were exposed. Information related to time is readily accessible through birthdates and residence histories.

Some historical measurements of radiation dose rate were made in the vicinity of the Techa River. Most of these were made after the period of greatest release. Current environmental measurements can provide information about recent exposures; however, they lack any details of the contribution of short-lived radionuclides. A promising source of external dose rate data is the use of environmental thermoluminescent materials. This technique has been shown to be effective (Bougrov et al. 1995), but its use to date has been limited. Thus, it will be necessary to also approach the problem by investigating classical radiation-shielding calculations.

Historically measured radionuclide concentrations in some selected environmental media (primarily river water and sediments) are available. However, it is likely that reconstruction of contamination levels will be required. This can be done using extrapolation in a few instances, but generally, concentrations must be calculated from released amounts and a river water transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions.

Members of the Techa River Cohort were primarily exposed to the effluents in the river, however, the atmospheric releases also effected this group - particularly those on the upper Techa near the Mayak facilities. The doses resulting from these atmospheric releases will be added to the doses calculated for this cohort according to the techniques described in Section 2.5 for the Ozersk cohort.

2.2.2 Techa River Cohort External Dose Activity Descriptions

The following activities are necessary to complete the dose reconstruction process.

* Urals Research Center for Radiation Medicine, Chelyabinsk, Russia, personal communication.

Electron Paramagnetic Resonance (EPR) This subtask will perform additional measurements as tooth samples become available through routine dental work and postmortems (no active recruitment of samples from exposed individuals is planned). These measurements will be used as the basis for external dose for the affected individuals and also placed into a database from which statistical regressions based on age and residence can be made to provide a source of analog information for persons without direct measurements. It is anticipated that this subtask would be performed by staff of the Metal Physics Institute in Ekaterinburg. Procurement of an EPR spectrometer will simplify and greatly increase the number of samples that could be analyzed annually.

Environmental Thermoluminescent Dosimetry (TLD) This subtask will perform additional measurements in environmental samples collected at predetermined locations along the Techa River. A detailed sampling plan will be developed to optimize the number of samples required. The dose rates evaluated will be used to prepare a regression of dose rate for various distances away from the river at locations downstream of the release point. This will also serve to validate the radiation transport and shielding calculations.

Biodosimetry Pilot Study A feasibility study will be undertaken to evaluate the accuracy and reliability of measurements made with a suite of biodosimetric techniques, including fluorescent in-situ hybridization, T-cell receptor, and other techniques. If any of the techniques compare well with measurements made by other methods (EPR, etc.), further requests will be made to the JCCRER Executive Committee to incorporate the techniques into the ongoing dose reconstruction efforts.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in water and sediment. This information will serve as input to the river transport and radiation transport/ shielding subtasks.

Techa River Source Term Development This subtask will prepare estimates of the time history of radionuclide release to the Techa River. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the MIA will be key participants in this task.

Techa River Transport Modeling This subtask will accumulate data describing the historical Techa River hydrologic data, sediment loading, and dam construction history. This will be used as input to a numerical transport model to simulate the flow and contaminant loading of the Techa River from the Mayak facility to its confluence with the Iset River. The model will provide concentrations of radionuclides in water and sediment at specified locations along the river.

Radiation Transport/Shielding Calculations This subtask will extend available measurements (from TLD and conventional sources) to provide dose rates as a function of location away from the Techa River. Inputs to the modeling will generally come from the Techa River source term and transport modeling activities.

Techa River Cohort External Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

4. Cohort Summary Schedules

A summary schedule, showing estimated staffing requirements, time lines, task interdependencies, and milestones, is provided for each of the three dose-reconstruction cohorts.

4.1 Techa River Cohort Summary Schedule

The individual milestones, which may be published as separate reports by the participating authors, are:

1. Description of radionuclide metabolic models to assist in evaluation of bioassay data.
2. Completion of updating and calibration of the SICH-9.1 whole body counter.
3. Final report on individual body burden histories and resulting doses evaluated for Techa River cohort.

4a. Completion of procurement, installation, and calibration of EPR spectrometer.

4b. Final report on individual external doses measured for specific individuals using EPR, and description of methodology for extrapolating to other individuals in the Techa River cohort.

5. Final report on environmental thermoluminescent dosimetry measurements and description of methodology for extrapolating to other individuals in the Techa River cohort.
6. Final report of feasibility study on use of biodosimetric techniques. If selected techniques are deemed to be useful, additional measurements would be proposed to the executive committee.
7. Final report of the dietary intake evaluation and dosimetric modeling for the Techa River residents based on in-vivo measurements of radionuclides in teeth, to be used as input to the development of individual dietary information.
8. Final report on development of individual dietary information.
9. Final report on historically measured dose rates, radionuclide concentrations in water, sediment, soils, and foods.
10. Final report on default transfer factors for use in estimating radionuclide concentrations in fish, crops, and animal products, including references and derivations.

11. Final report on derivation of the radionuclide release rates from Mayak facilities to the Techa River. Includes time histories of individual radionuclides.
12. Final report of modeled concentrations of radionuclides in Techa River water and sediments at specified locations over time. Includes description of hydrologic data and model(s) employed.
13. Initial individual dose models and estimates for specific individuals for uncertainty analysis.
14. Refined individual dose estimates for use in sensitivity analysis.
15. Description of uncertainty in individual dose estimates for use in sensitivity analysis.
16. Final report to epidemiological study on radiation doses to individuals within the Techa River cohort.
17. Final report on parameters resulting in uncertainty in the individual doses.
18. Final report on uncertainties associated with radiation doses for individuals within the Techa River cohort.
19. Placeholder milestone to indicate connection with analyses for the Ozersk cohort for atmospheric pathways. Data regarding dose from atmospheric releases is input here (Section 4.3, Milestone 14).

INTERACTIONS WITH THE PUBLIC

We are in the process of developing a plan for interaction with the public as part of the dose-reconstruction process. It is planned to proceed carefully in this, as American ideas on public interaction may not be transferable to another culture. Maximum use will be made of public outreach activities already being carried out by the URCRM, the MIA, the government of the Chelyabinsk Oblast, and the local arm of the EMERCOM. The URCRM is itself a major outreach activity, and we hope to join in continuing its success. For example, any member of the affected community may come to the URCRM for a whole body count and for consultation with medical authorities. More detailed ideas on this process are now being formulated.

ACKNOWLEDGEMENTS

This work was performed under the sponsorship of the U.S.–Russia Joint Coordinating Committee on Radiation Effects Research. Russian participants received funding or support from the Federal Department of the Ministry of Health and Medical Industry; the Ministry for Civil Defense Affairs, Emergencies and Elimination of the Consequences of Natural Disasters; the Mayak Industrial Association (Ministry of Atomic Industry); and the Office of International Health Programs, U.S. Department of Energy. American participants received funding or support from the Office of International Health Programs of the Assistant Secretary for Environment, Health and Safety, U.S. Department of Energy; the National Cancer Institute; and the Centers for Disease Control and Prevention. Portions of this work were performed at the Lawrence Livermore National Laboratory under the auspices of the U.S. Department of Energy under contract number W.7405-Eng-48.

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