EVALUATION OF THE STOCHASTIC EFFECTS OF LOW-DOSE RADIATION: DOSE RECONSTRUCTION FOR THE TECHA RIVER COHORT IN RUSSIA*

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INTRODUCTION

Persons traveling in space can accumulate fairly large doses of radiation, up to several Sv, at low-to-moderate dose rates. In general these dose rates are low enough so that deterministic effects can be avoided, although shielding may be necessary. An important question, however, is the stochastic effects (induction of cancer and genetic defects) of these doses. Most radiation-risk estimates are based on dose reconstruction and epidemiologic follow-up of the survivors of the atomic bombings on Japan, events that delivered doses nearly instantaneously. It has been hoped that stochastic effects would be less probable for radiation delivered at lower dose rates, but few opportunities have been available to examine this question in humans.

The Mayak Production Association (MPA) 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 high occupational doses as well as technological failures that resulted in the release of large amounts of waste (about 10^{17} Bq of liquid wastes) into the rather small Techa River. Residents along the Techa River were exposed to external radiation, and they ingested foods contaminated with ^{90}Sr and other radionuclides. The "Techa River Cohort" has been studied for several years by scientists from the Urals Research Center for Radiation Medicine (URCRM). The purpose of the project considered here is to improve the dose-reconstruction system for the Techa River Cohort that has been under development for many years by Russian scientists at the URCRM. This, and the companion epidemiologic studies, are deemed to be unique and important, as members of the Techa River Cohort received red bone marrow doses of up to 3 Gy, but at low-to-moderate-dose rates. An increase in leukemia and cancer mortality has already been noted for this population, and further study should allow the evaluation of dose-rate-reduction factors for this situation..

CURRENT STATUS OF RESEARCH

Studies of the possible effects of radiation on those exposed to the releases to the Techa River were started in Russia in the 1950s. Russian and United States scientists have been involved in collaborative research programs since 1995, and a major phase of the dose-reconstruction work was concluded in March 2000. The specific aims of the project were to develop improvements in the existing dosimetry system for members of the Techa River Cohort by providing more in-depth analysis of existing data, further search of existing records for useful data, model development and testing, evaluation of uncertainties, verification of procedures, and validation of current and planned results. The purpose of the enhanced dose reconstruction is to support companion epidemiologic studies of radiogenic leukemia and solid cancers.

One major aspect of the project was to extend and validate the more than 15,000 measurements of ^{90}Sr in the whole body by use of a unique bremsstrahlung counter. This counter, however, was old and had been calibrated with an anthropomorphic phantom (which was no longer available) only at the beginning of the detector's life. A major activity has been to design and build a new anthropomorphic phantom containing ^{90}Sr uniformly distributed throughout its "bones." Recalibration of the old counter has been finished. In addition a new bremsstrahlung-detector system and associated electronic systems were installed during FY1999. This major upgrade to the system will allow for the continuing measurement of ^{90}Sr in humans over many years post exposure. These data will be used to refine models of ^{90}Sr metabolism in man and the dose coefficients for ^{90}Sr.

Another important aspect of the improvement process has been to check the consistency of available source-term data and historical monitoring data; a major purpose is to confirm the limited information available on the source term and to develop an empirical model of the dependence on distance downstream of the radionuclide composition of river water and to link radionuclide concentrations in water and bottom sediments with gamma-exposure rates on banks and near the river.

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On the basis of the improved description of the radionuclide contents in the river water and sediments as a function of the downstream distance, both the internal doses (for radionuclides other than ^{89,90}Sr) and the external doses have been recalculated. The calculated doses to organs in the gastrointestinal tract have increased by up to a factor of two due to the inclusion of shorter lived, refractory radionuclides. On the other hand, external doses have decreased by up to an order of magnitude. The latter effect is due both to the improved river model and to a more realistic assessment of the details of historical measurements of external exposure rates along the river bank and in the living areas, and to refinements in the estimates of the times spent by the residents along the river and in other areas. Earlier estimates of external exposure were biased upward by considerations having more to do with radiation protection (issues such as possible evacuation of additional villages) rather than risk derivation.

Another major aspect of the completed work has been the first evaluation of uncertainty in the estimates of organ and effective dose. This has been accomplished both by the usual methods of analytic propagation of uncertainties and by further evaluation of the large body of experimental measurements on ^{90}Sr-body burdens.

In general the conclusion has been reached that the accuracy of the estimated doses for the Techa River Cohort has been greatly improved. Further, it is anticipated that the "freezing" of the Techa River Cohort in the year 2000 both in terms of dose reconstruction and epidemiologic follow-up will provide an opportunity for new risk-evaluation analyses. Such analyses should be useful in answering the primary question posed for the combined dosimetric and epidemiologic research: Is low-dose-rate radiation less effective per unit dose in producing stochastic effects of radiation than high-dose-rate radiation?

FUTURE PLANS

Approval has been received for continuation of this project for an additional three years. The major topics to be included in future work are further evaluation of uncertainty in the derived doses and validation of the current estimates of dose. The work on uncertainty will focus not only on better descriptions of current evaluations, but also on work that can be done to achieve future reductions in uncertainties. The validation work is considered to be very important, as the changes in dosimetry that have taken place recently should be verified by independent means. This work will proceed with reevaluation of the existing experimental measurements and with new independent measurements of dose with techniques such as electron paramagnetic resonance of teeth that have been extracted for dental health reasons.

RECENT PUBLICATIONS

Degteva, M. O.; Vorobiova, M. I.; Kozheurov, V. P.; Tolstykh, E. I.; Anspaugh, L. R.; Napier, B. A. Dose reconstruction system for the exposed population living along the Techa River. Health Phys. 76:542-554; 2000.

Degteva, M. O.; Kozheurov, V. P.; Tolstykh, E. I.; Vorobiova, M. I.; Anspaugh, L. R.; Napier, B. A. The Techa River Dosimetry System: Methods for the reconstruction of internal dose. Health Phys. 77:24-35; 2000.

INDEX TERMS

Environmental radiation; Mayak Production Association; Techa River Cohort; Stronium-90; Stochastic effects of radiation; External dose; Dose from ingestion of radionuclides; Dose reconstruction; Evaluation of uncertainty in reconstructed doses