Key results of the Techa River Dose Reconstruction, and Possible Future Endeavors

RHSP – Celebrating 30 Years of Scientific Achievements

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Estimation of Uncertainty in the TRDS

- **All individual doses are being estimated with uncertainties**
- **Uncertainty estimates:**
  - Consider shared uncertainties
  - Consider unshared uncertainties
  - Consider Berkson (grouping) and Classical (measurement) error types
  - Consider individual autocorrelations
  - Are saved for epi studies as complete correlated cohort files
    - The doses or ~70 years for 23 organs for 60,000 people approach one terabyte of information; we use HDF5 heirachical data format for storage and retreival

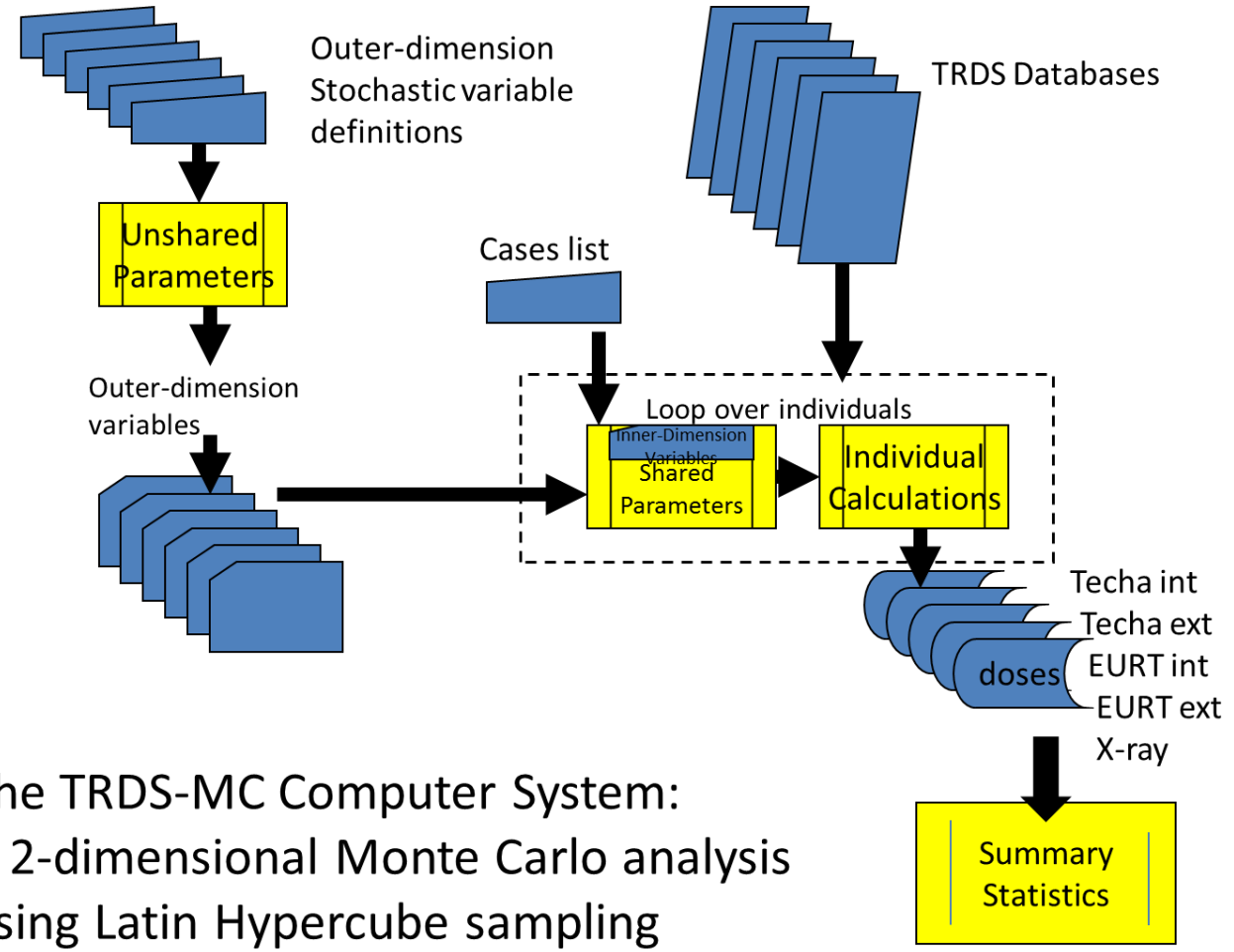
Napier BA, MO Degteva, NB Shagina, and LR Anspaugh. 2013. Uncertainty Analysis for the Techa River Dosimetry System. Meditsinskaya Radiologiya i Radiatsionnaya Bezopasnost 58(1):5-28

Evaluation of Parameters and Definition of Distributions

Parameter		Definition	Sharing	Structure
Constants - used to define individual calculation				
Y		The calculational endpoint for a particular individual (can vary within the range 1950–2005);	Definition of case	Constant
y		Year of environmental exposure (external irradiation and intake of nuclides);	Definition of case	Constant
…				
Common to internal and external				
$M_{y,L}$		Fraction of year y spent in location L;	Individual/unshared	Classical
$G_{z,r,L}$		Deposition of radionuclide r at location L for EURT or KT fallout (Bq m^{-2})	Shared within village	Classical
Internal dose parameters				
$A_{ind}(\tau,t_m)$		Individual whole-body counter measurement made at age τ and time t_m	Unshared	Classical
$DF_{r,o,Y\text{-}y}$		Conversion factor (Gy Bq^{-1}) for dose accumulated in organ o in year Y-y from intake of radionuclide r in year y (function of age, related to y);	Shared	Berkson
External dose parameters				
$D_{Riv,L,y}$		Dose rate in air near river shoreline at location L in year y (Gy $year^{-1}$);	Shared within village	Berkson 1949-1951, classical thereafter
	$R_{B\text{-}R}$	Bank to residence ratio (function of distance of individual's home from river)	Unshared	Classical
	$R_{I\text{-}O}$	Indoor/Outdoor ratio (function of building type)	Shared	Berkson
…				
T_2		Time spent outdoors (relative to whole year) (function of age, related to y); and	Shared	Berkson
T_3		Time spent indoors (relative to whole year) (function of age, related to y).	Shared	Berkson
$X_o(e,y)$		Dose (Gy) from medical exposure e in year y	Shared	Berkson

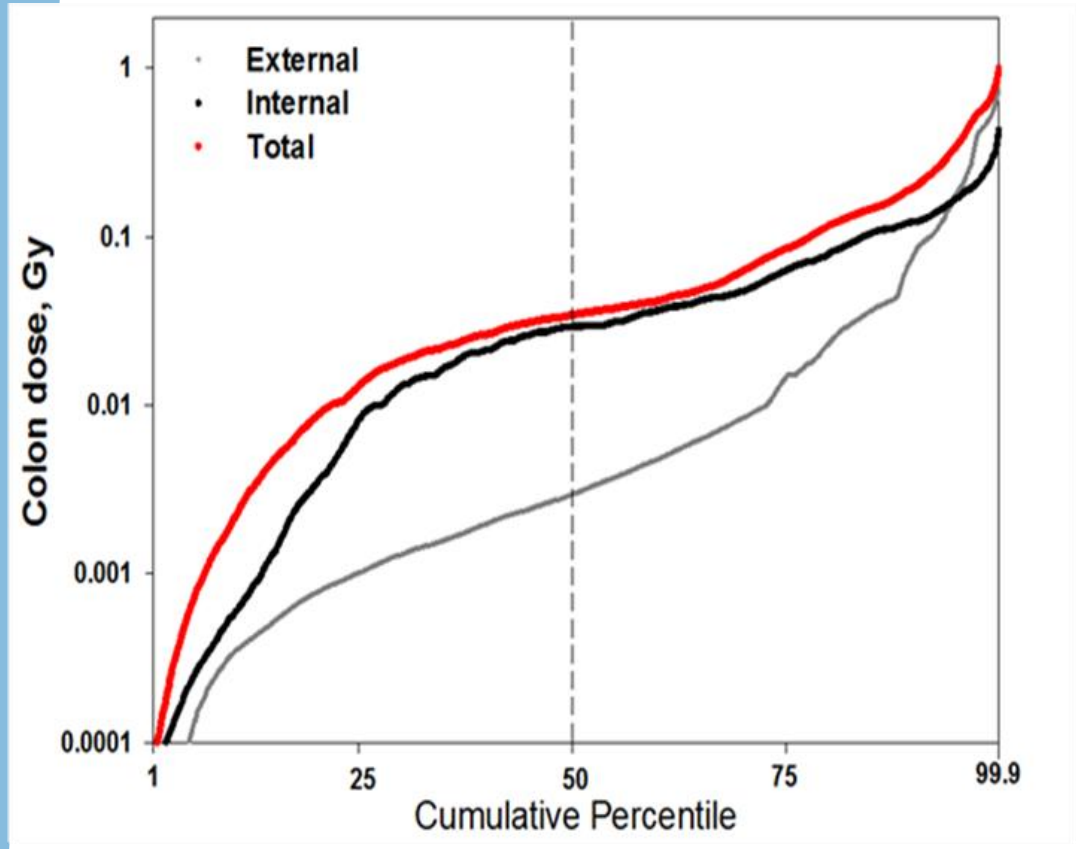
Shishkina et al. 2024. Dose estimates and their uncertainties for use in epidemiological studies of radiation-exposed populations in the Russian Southern Urals. PLoS ONE 18(8): e0288479. https://doi.org/10.1371/journal.pone.0288479

The TRDS 2D Monte Carlo System

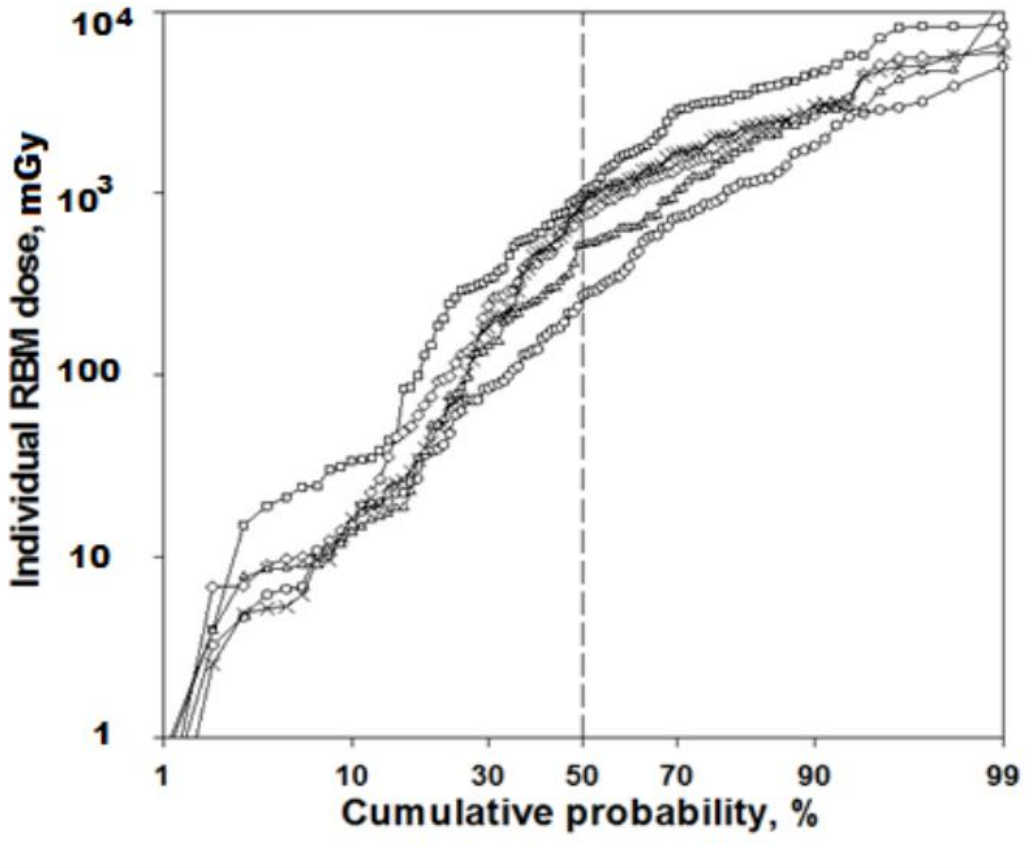


The TRDS-MC Computer System:
A 2-dimensional Monte Carlo analysis
using Latin Hypercube sampling

Uncertainty in SUPER Cohort Member Doses



Deterministic Estimates Calculated Used TRDS-2016 D



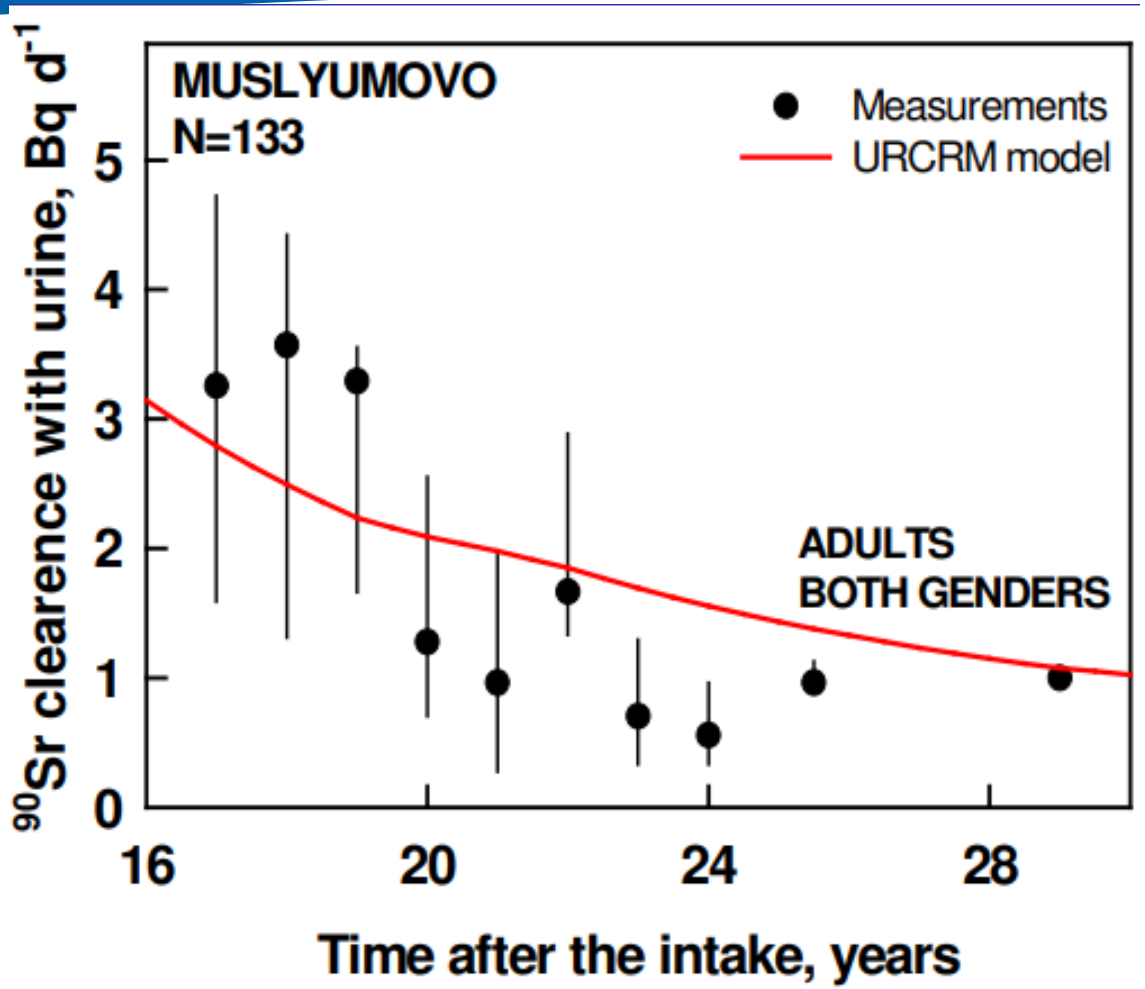
5 Realizations (from 1500) Generated by Stochastic TRDS-MC

Techa and EURT Cohort Doses

Population distribution parameters	M, Gy	CV	GM, Gy	GSD
Active Marrow				
Arithmetic mean	0.21	1.56	0.21	2.93
Standard deviation	0.36	0.47	0.30	0.81
min	0.00002	0.67	0.00001	1.80
5%	0.001	0.89	0.001	2.02
25%	0.009	1.15	0.03	2.19
50%	0.06	1.61	0.09	2.70
75%	0.26	1.85	0.27	3.67
95%	0.93	2.24	0.78	4.34
max	6.75	7.75	4.98	4.95
Stomach				
Arithmetic mean	0.04	1.10	0.03	2.32
Standard deviation	0.08	0.25	0.06	0.33
min	0.000002	0.58	0.000001	1.68
5%	0.0002	0.68	0.0002	1.78
25%	0.002	0.95	0.001	2.18
50%	0.01	1.11	0.01	2.32
75%	0.03	1.23	0.02	2.41
95%	0.17	1.50	0.13	2.90

Shishkina et al. 2024. Dose estimates and their uncertainties for use in epidemiological studies of radiation-exposed populations in the Russian Southern Urals. PLoS ONE 18(8): e0288479. https://doi.org/10.1371/journal.pone.0288479

TRDS predictions as well as models for dose reconstruction were validated



- Example of biokinetic model validation

Dose results have been extensively compared to TL, EPR, and FISH measurements

All available information supports the overall validity of the dose estimates

Project 1.1: Desirable Future Improvements

- **Update bone marrow dosimetry**
  - Extensive efforts to develop age- and sex-specific dose factors for strontium isotopes in bone have been undertaken. The results are now available – but have NOT been incorporated in the stochastic dose calculations yet
- **Create computational phantoms of the fetus at different stages of development and calculate dose factors for bone marrow exposure**
  - The models have sections reserved for fetal exposures, but they have NOT been updated yet
- **Update the probability density function for T1 (individual time spent on the Techa River banks) in the stochastic dose code**
  - Earlier versions did not appropriately understand the variability of the survey observations used to estimate this parameter

Project 1.1: Desirable Future Improvements (continued)

- **Update dose individualization**
  - More information has been developed to discriminate individuals based on household location
  - Currently, doses for individuals with whole body counter results are scaled to match the measurements. Because so many others have tooth beta counter measurements, a method of radionuclide intake individualization based on the TBC measurements has been developed, but NOT yet implemented
- **Verification (and correction) of intakes for Techa residents after 1953**
  - A discrepancy between monitored and modeled intakes has been noticed for individuals born after 1953; there could be an underestimation. This needs to be evaluated and updated as necessary