Retrospective dosimetry of the emergency exposed population of the Urals region: Basic concept and scientific advances of Project 1.1

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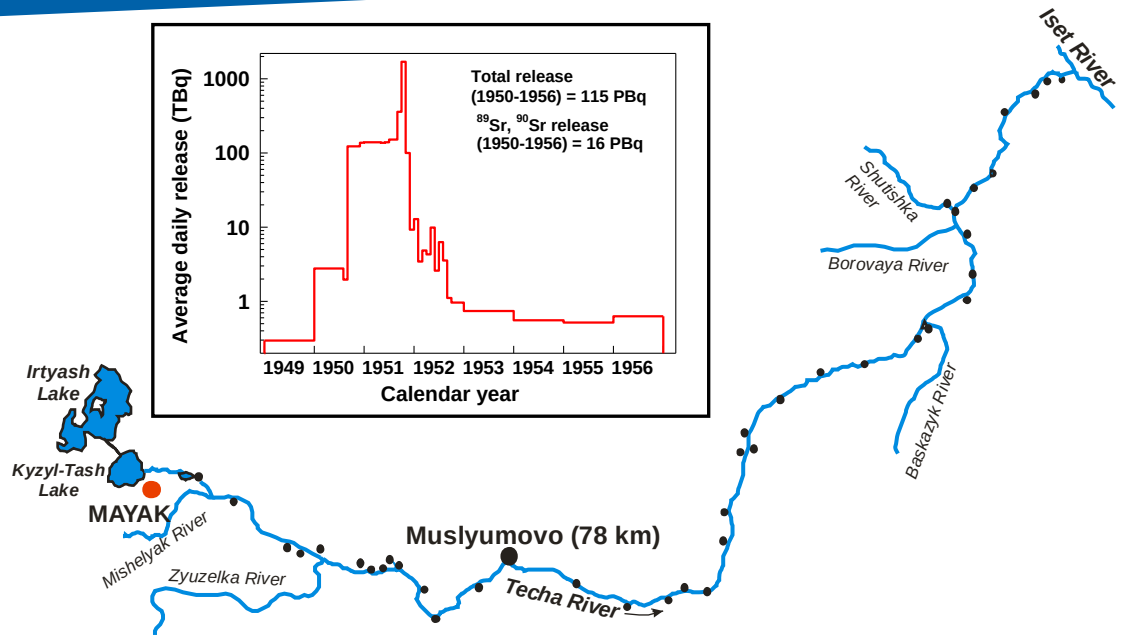
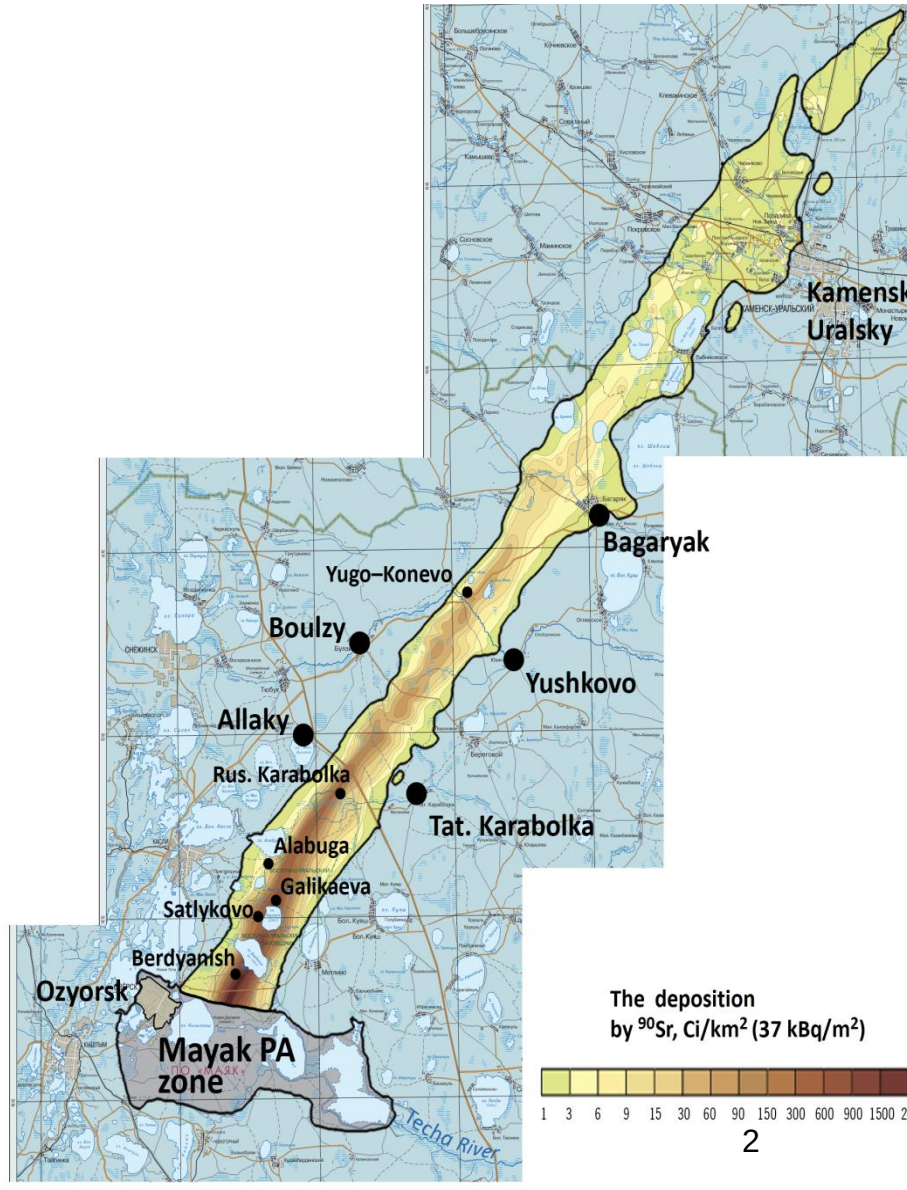
The strategic goals of Project 1.1





- to elaborate the Techa River Dosimetry System (TRDS) providing the individual external and internal doses for population exposed to releases by PA Mayak
- to verify the approaches and validate the dose estimates
- to provide an appropriate description of the

Information basis for dose reconstruction

- **By the beginning of the project, a large pool of biomedical and dosimetric data had been accumulated by the staff of the URCRM**
- **This information was systematized in the relevant databases and registers**
- **Registers had been maintained and updated throughout Project 1.1**
- **The original and archive data on environmental and foodstuffs contamination in 1950 - 2016 are collected in the database "ENVIRONMENT":**
  - radionuclide concentrations in river water (10,500 samples), bottom sediments (2,000 samples), soils (4,200 samples), milk (12,500 samples), other foodstuffs (7,900 samples);
  - measurements of gamma-exposure rates (7,000 measurements)

Information basis for dose individualization

- Individual data on birth, sex and residence history (available for all cohort members)
- Registry of strontium in humans
  - > 10,000 persons with measurements of bone, tooth and excreta samples (1951 -1989)
  - ~ 12,000 persons measured *in vivo* using tooth-beta counter (1959-1997)
  - 21,200 persons measured *in vivo* using unique whole-body counter (1974 - 2021)
- Household registry: 14,300 households, for each there is a distance from the Techa River and the list of residents who lived together in 1949-1960
- X-ray diagnostic registry: 42,500 x-ray diagnostic procedures for 9,200 persons (1952-2004)

Basic approach of the dose reconstruction

The dose-reconstruction process is based primarily on a large number of measurements of radionuclide burden in humans and on measurements of external exposure performed directly in places where people lived

The traditional approach of analyzing all steps of the pathway of exposure is only used as a backup when other approaches have been exhausted

This methodology is rather unique in the worldwide practice of environmental dose reconstruction

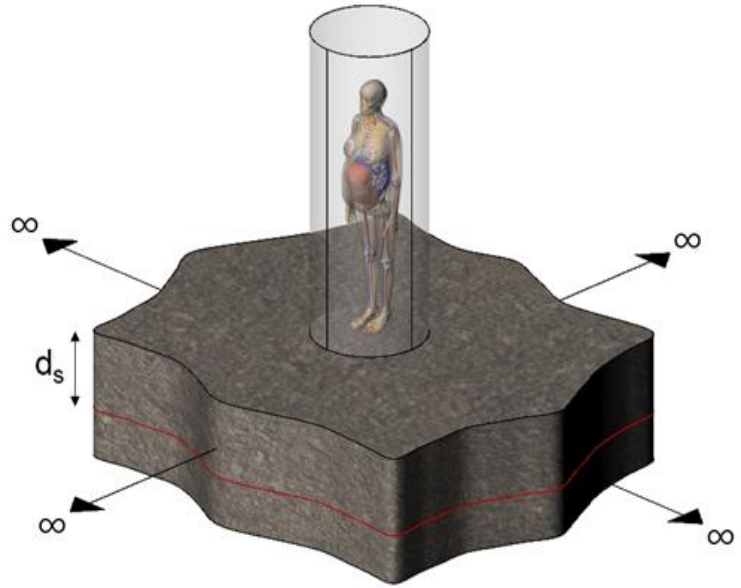
Degteva Marina – the author of the concept, the ideologist and the head of complex long-term research

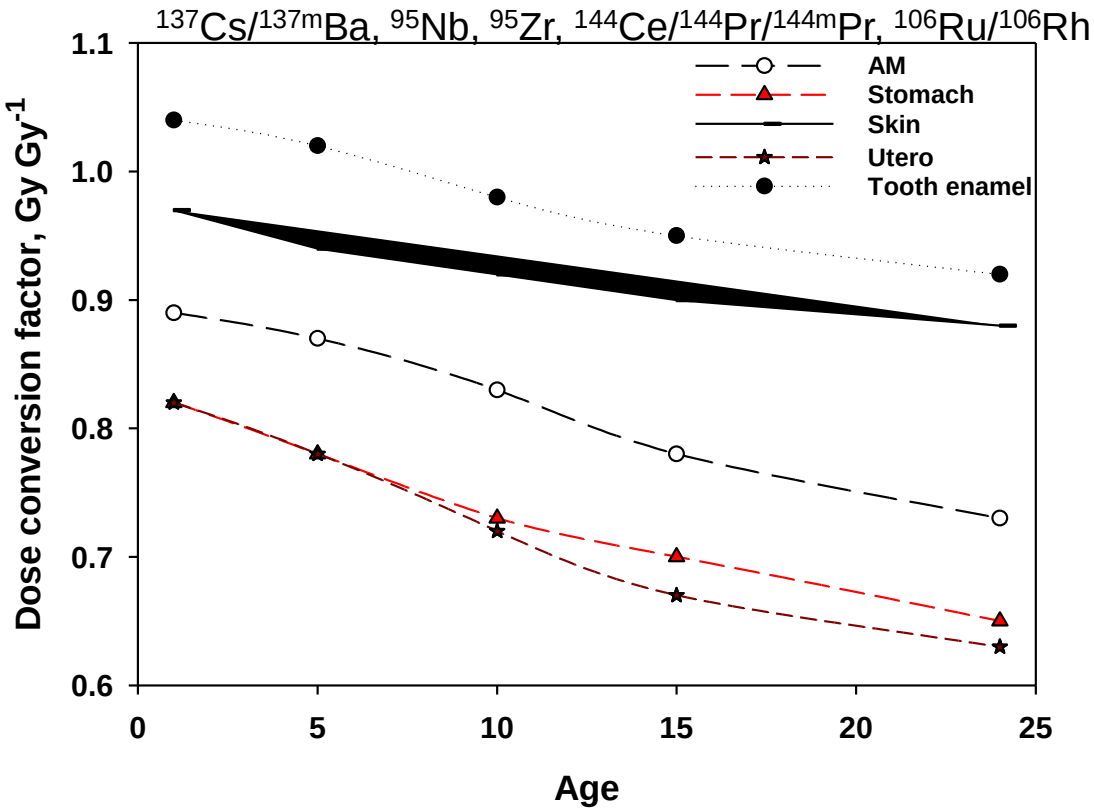
External dosimetry: Basic concepts

- Techa River scenario: the key parameters are the dose rate on shore and its decrease with distance
  - for 1950 – 1951 (single dose rate measurements were available only) the model of radionuclide transport is used (*Shagina et al. 2012*)
  - for the subsequent period, a semi-empirical model was used, taking into account a large amount of experimental data on regular monitoring of dose rates
- EURT scenario: the key parameter is the surface contamination of soil (based on area-average measurement results)
- Important parameters for both scenarios are behavior of residents (depending on season and age). Determined from data from sanitary and hygienic studies

External dosimetry: Scientific advances

Age dependent factors to convert the dose in air at 1 m above ground to dose in target organs were calculated for 23 organs considered in TRDS as well as for tooth enamel to support EPR tooth dosimetry





In collaboration with University of Florida

Bolch 2015; Shishkina et al. 2018

Internal dosimetry: Basic concepts

Dynamics of radionuclide intake into the body

Individual residence histories during the admission period, age and - for women – the period of pregnancy and lactation were taken into account

A biokinetic model describing the dynamics of radionuclide distribution following a single intake

A dosimetric model describing the dose rate in the target organ from a single dose of radionuclide activity

Correction for individual ^{90}Sr body-burden

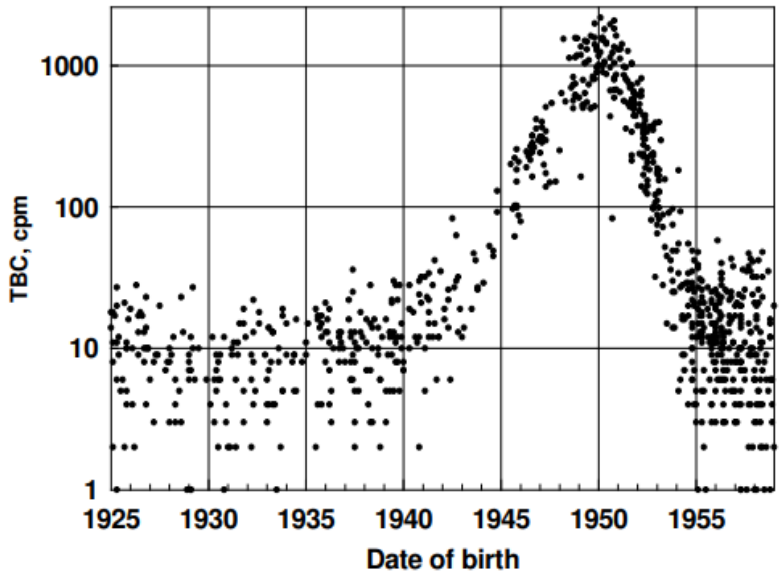
The sum of the contributions of all radionuclides

Cumulative dose in target organ

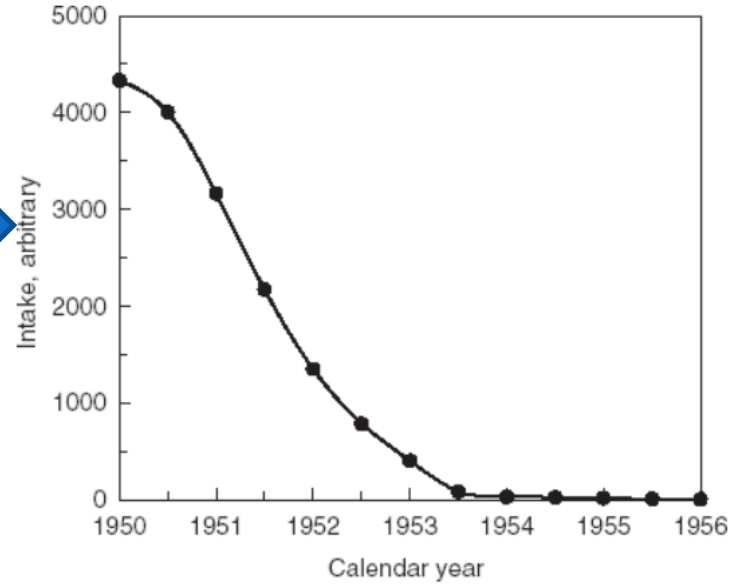
Scientific advances in internal dosimetry: Sr intake reconstruction

Original method for reconstruction of relative ^{90}Sr intakes using *in-vivo* measurements of teeth with Tooth Beta Counter (*Zalyapin et al. 2014*)

This task is also an advance in inverse problem solutions



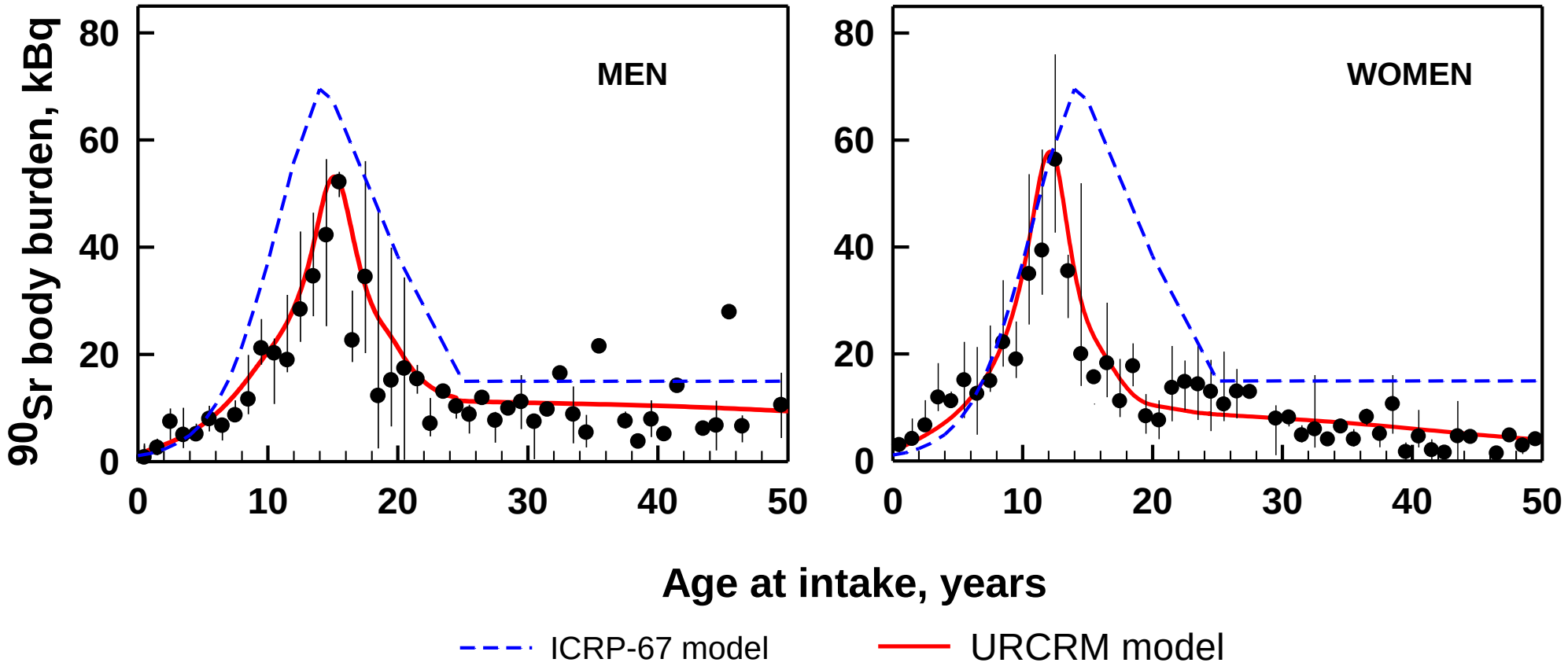
Age-dependent TBC values for permanent residents



Function of relative ^{90}Sr intake

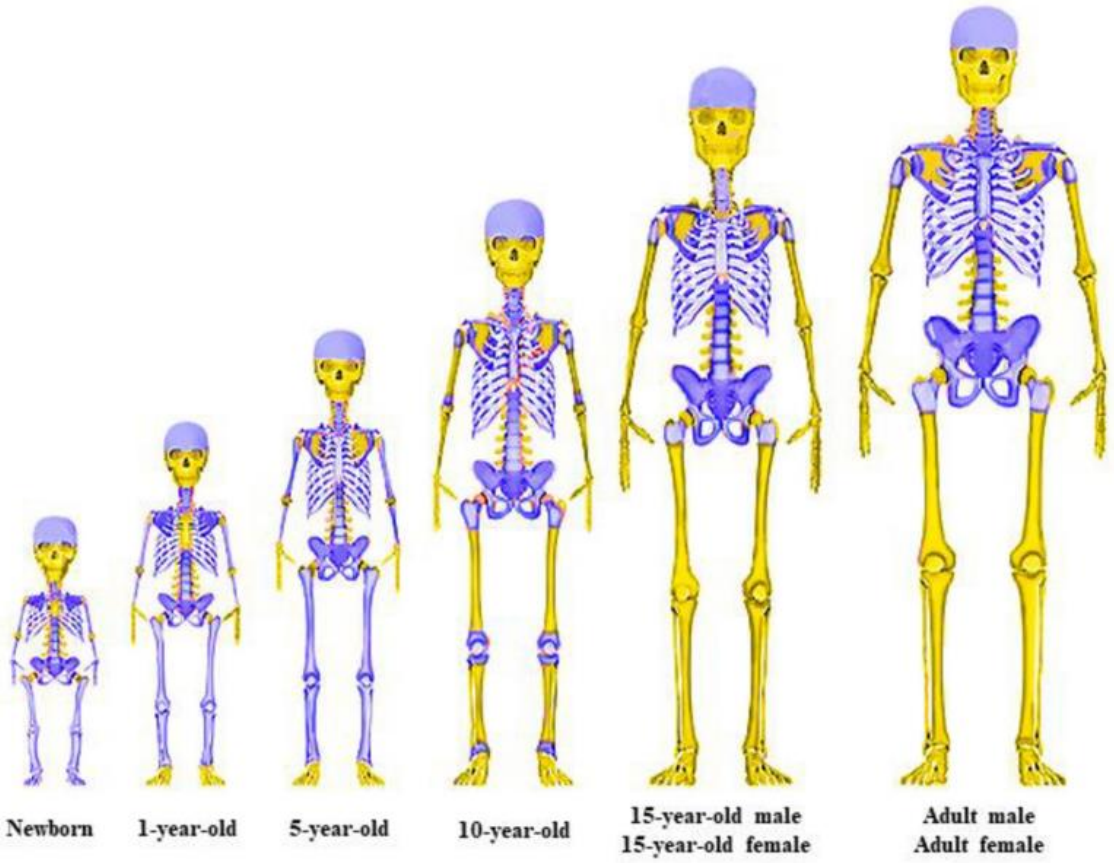
Scientific advances in internal dosimetry: Sr biokinetics

A sex- and age-specific biokinetic model for Sr was developed based on extensive measurements of ^{90}Sr in the body of residents of the Techa River (*Shagina et al. 2014*)



Scientific advances in bone marrow dosimetry for incorporated beta emitters

- A model of the microarchitecture of the trabecular bone has been developed (Zalyapin et al. 2018)
- A method for creating computational skeletal phantoms has been developed (Shishkina et al. 2020)
- A family of computational phantoms has been developed and dose coefficients for $^{89,90}Sr$ have been calculated (Degteva et al. 2021)



Control of reliability of dose estimates

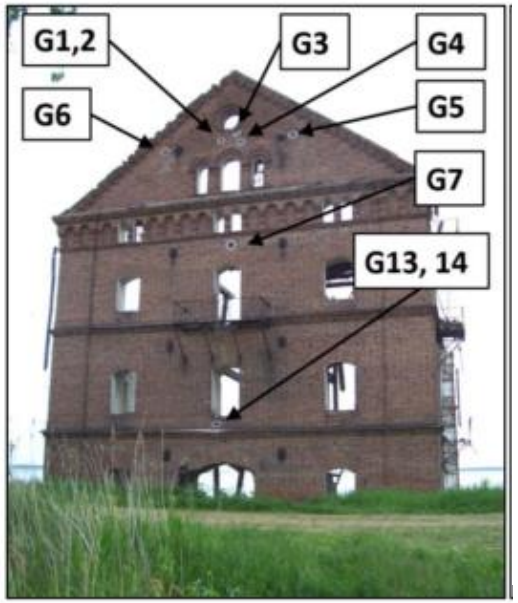
- Among the main principles, there were the verification of the components of the dosimetric system at each stage of development, as well as the validation of basic models and dose estimates
- TRDS-2016 is unique because it is well validated, which is atypical for dose reconstruction in uncontrolled radiation situations (*Degteva et al. 2015, Shishkina et al. 2021, Woda et al. 2023*).
- This makes epidemiological studies with TRDS-2016 dosimetry system promising in terms of the reliability of conclusions about radiation risks to the population.

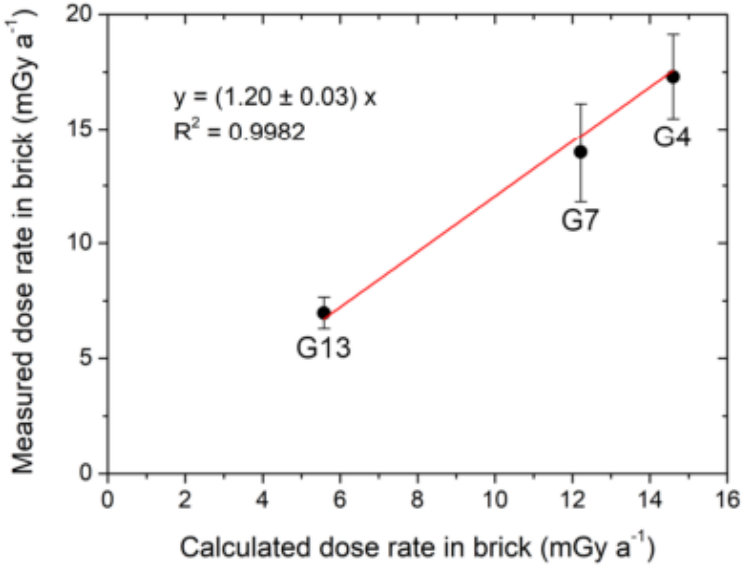
Advances in retrospective dosimetry using thermolumiescence on ceramic building materials

For the first time, the method was used to reconstruct doses accumulated in the bricks during the prolonged period of exposure from radioactive pollution of the environment

During the time, changes in the environmental contamination and source configuration occurred. It was a challenge for dose reconstruction. Monte Carlo simulations of exposure history were involved to support the experimental study (*Woda et al. 2020; Hiller et al. 2022*)

Studies in the area of the Techa River can be considered as a testing ground for retrospective TL dosimetry



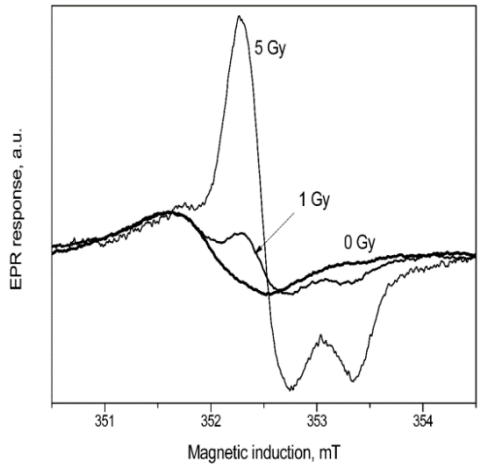


Results of TL dose reconstruction near Metlinsky Pond (*Hiller at al., 2022*)

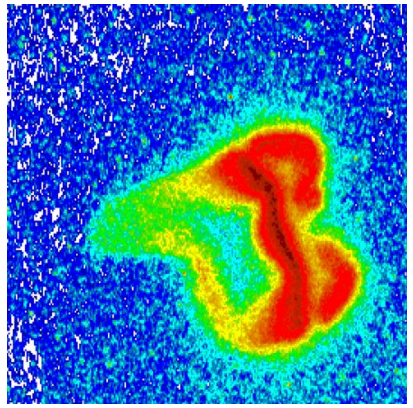
Advances in application of EPR tooth dosimetry

For the first time, a methodology of Electron Paramagnetic Resonance dosimetry has been developed for radiation situations with combined external gamma radiation and chronic internal exposure to bone-seeking radionuclides

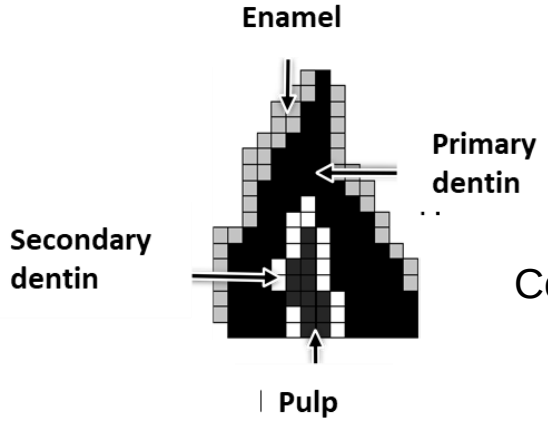
The method is a combination of: EPR dosimetry of tooth enamel + radiometry of dental tissues + dosimetric modeling of dose formation in enamel from ^{90}Sr incorporated in teeth (*Shishkina et al. 2019*)



EPR spectrum processing

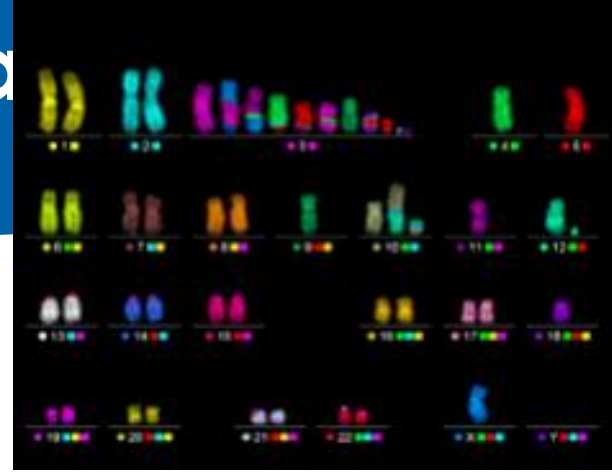


Detection of ^{90}Sr activity concentration

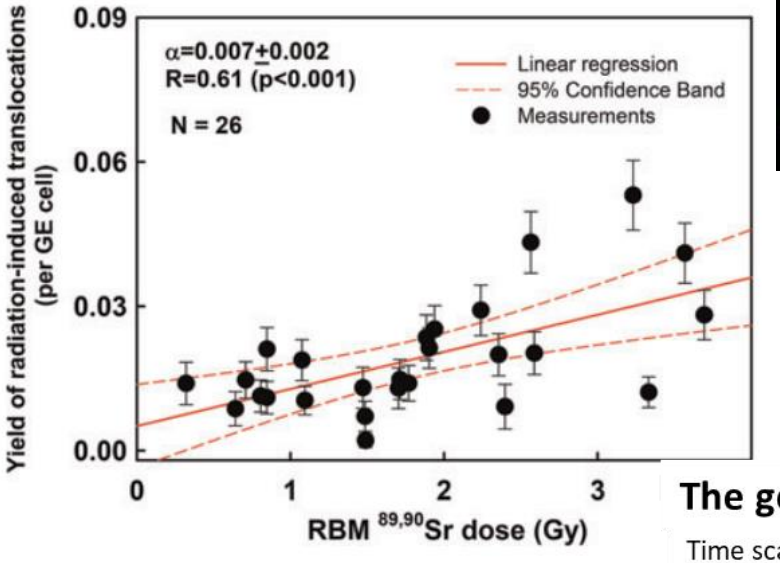


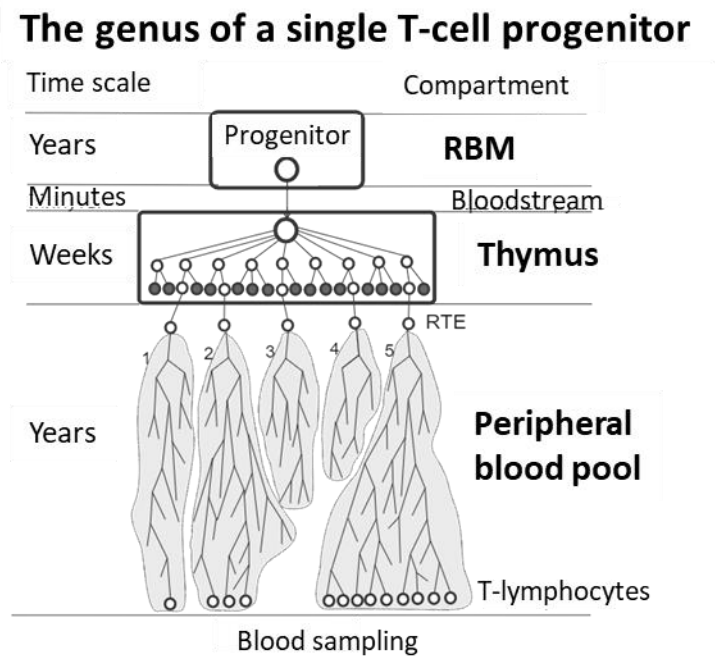
Computational phantoms for calculation of ^{90}Sr dose contribution to enamel

Advances in biodosimetry using sta chromosome aberration (FISH)



- **For the first time, a methodology of biodosimetry has been applied for inhomogeneous chronic exposure of organism**
- **The yield of radiation-induced translocation have being due to contribution of RBM exposure to ^{89,90}Sr and uniform whole-body exposure to external gamma sources**





Two approaches have been developed to interpret the results of biodosimetry:

1. the empirical dependence of the translocation yield on the RBM dose (*Vozilova et al., 2014*)
2. the concept of modeling the formation and circulation of T-lymphocytes (*Tolstykh et al., 2020*)

Publications

- The results were widely presented to the scientific community
- Within the framework of the project, 202 scientific articles have been published in peer-reviewed journals; a few more are in preparation
- The results were presented annually at scientific conferences

Principal investigators

Lynn Anspaugh, Marina Degteva and Bruce Napier
2005. Celebration of 10 years of the project

Michael Smith and Bruce Napier
2020 y. Checking the implementation of the plan items

Participants