

Dose reconstruction approach for epidemiological studies of the SNTS population: lessons learned and perspectives for improvement

Sergey Shinkarev¹, Valeriy Stepanenko²

¹State Research Center - Burnasyan Federal Medical Biophysical Center, Moscow, Russia

²Medical Radiological Research Center, Obninsk, Russia

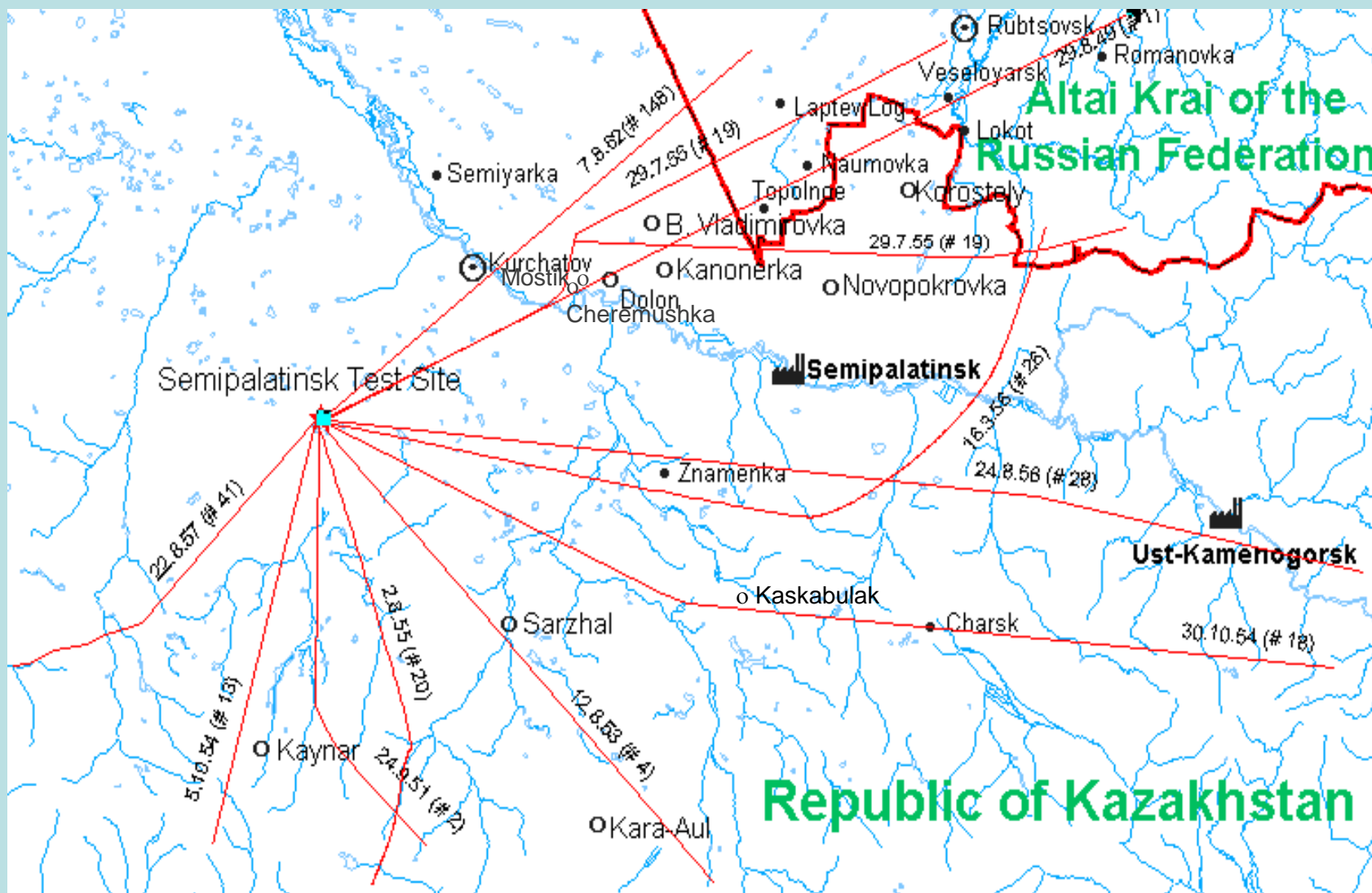
Objective

- **To assess the feasibility of providing dosimetry support in a long-term epidemiological study aiming to reconstruct individual doses from external and internal exposure to the residents living in the areas contaminated due to atmospheric nuclear weapons testing at the SNTS.**

Main tasks

- **To select and justify the selection of the methodology to assess external and internal doses to the residents of Kazakhstan from radioactive fallout as a result of atmospheric nuclear weapons testing at the SNTS.**
- **To assess availability and completeness of input parameters that are needed for dose reconstruction.**
- **To validate for a group of residents the estimates of individual external dose based on the selected methodology by comparing them with the corresponding dose estimates derived from instrumental ESR tooth enamel measurements.**
- **To provide a strategy for estimation and inclusion of uncertainties in the dose assessment.**

Trajectories of the radioactive clouds related to the most significant events in 1949-1962



First group of significant events

The lifetime effective dose to an adult living off-site at the point of maximum exposure rate would exceed 50 mSv

Event number	Date (dd.mm.yy)	Height above ground, m	Total yield, kt
1	29.08.49	30	22
2	24.09.51	30	38
4	12.08.53	30	400
18	30.10.54	55	10
28	24.08.56	93	27
148	07.08.62	0	9.9

Second group of significant events

The effective dose to an adult living off-site at the point of maximum exposure rate during the year following the event would exceed 5 mSv but the lifetime effective dose would not exceed 50 mSv

Event number	Date (dd.mm.yy)	Height above ground, m	Total yield, kt
13	05.10.54	0	4
19	29.07.55	2.5	1.3
20	02.08.55	2.5	12
26	16.03.56	0.4	14
41	22.08.57	1880	520

Individual doses to be reconstructed

- Whole body dose from external exposure.
- Dose to the thyroid from internal exposure to radioiodines (^{131}I and ^{133}I).
- *Doses to various organs from internal exposure to incorporated ^{137}Cs and ^{90}Sr are very small compared to whole body dose from external exposure (at least by factor of 10 less).*

Selected methodology

- **Joint U.S.-Russian methodology incorporates the strengths of the U.S. methodology and the Russian methodology.**
- **Deterministic dose estimates for the residents.**
- **Two steps of dose reconstruction:**
 - (1) settlement-average dose to air,**
 - (2) individual whole-body dose from external exposure and absorbed thyroid dose from intake of radioiodines as a function of settlement, age, gender, occupation, and ethnicity.**

Input data to reconstruct settlement-average dose to air

- **Historical measurements of exposure rate.**
- **Historical fallout patterns showing isopleths of dose to air from the fallout time of arrival until infinity.**
- **Present day measurements of the ^{137}Cs ground deposition density.**
- **Present day OSL/TL measurements of quartz inclusions in bricks.**
- **Present day ESR measurements of tooth enamel of the residents.**

Input data to assess settlement-average dose to air based on historical exposure rates

- **Type and composition of fission material.**
- **Date and time of explosion.**
- **Height of radioactive cloud top, km.**
- **Height of detonation above ground surface, m;**
- **Average wind speed over the height of the radioactive cloud, km h⁻¹.**
- **Fallout arrival time, h.**
- **Duration of fallout, h.**
- **Exposure rate at time H+12 h, mR h⁻¹.**

Input data to assess individual whole-body dose from external exposure

- **Number of hours spent outdoors as a function of age, gender, occupation, and ethnicity;**
- **Values of the shielding factor related to the ratio of the outdoor and indoor exposure rates for the gamma radiation emitted from the radioactive cloud and that for the activity deposited on the ground as a function of building material;**
- **Age-dependent conversion factor (from absorbed dose to air to absorbed dose in the body).**

Input data to assess individual thyroid dose from internal exposure to radioiodines

- **Type of milk consumed (cow's, mare's, koumiss)**
- **Age-dependent milk consumption rates**
- **Age-dependent breathing rates**

- **Information on individual residence history during the first two months following the fallout in the residential area**

Availability of input data to assess settlement-average dose to air (1/2)

FMBC has all necessary data on each significant event regarding:

- (1) the main characteristics of a nuclear explosion (*Nuclear tests in USSR, 3 Volumes, V.N. Mikhailov, Ed., VNIIEF M., 1997-2000*).
- (2) meteorological conditions along the radioactive trace.

FMBC has limited information on radiological conditions (historical measurements of the exposure rate) in the settlements contaminated following each significant event.

Availability of input data to assess settlement-average dose to air (2/2)

For contaminated settlements where no historical exposure rate measurements were conducted, there is a need (in a future epi study) to collect additional information important to reconstruct settlement-average dose:

- Present day measurements of the ^{137}Cs ground deposition density.
- Present day OSL/TL measurements of quartz inclusions in bricks.
- Present day ESR measurements of tooth enamel of the residents.

Availability of input data to assess individual external and internal doses

NIIRME has data in the registry on individual residence history of the residents in 1949-1962.

NIIRME does not have individual information on behavior (hours spent outdoors), diet habits, construction materials of houses, etc.

NIIRME and MRRC have limited individual information for the residents who were interviewed in some previous studies.

Typical data related to the above mentioned parameters will be assigned to each individual as a function of settlement, age, gender, occupation, and ethnicity.

Validation of the estimates of individual external dose

Purpose of validation:

To compare the estimates of individual external dose calculated using the joint U.S.-Russian methodology with the estimates of corresponding dose derived from ESR tooth enamel measurements in a group of residents selected within the framework of the current pilot study.

Subjects selected for a pilot study

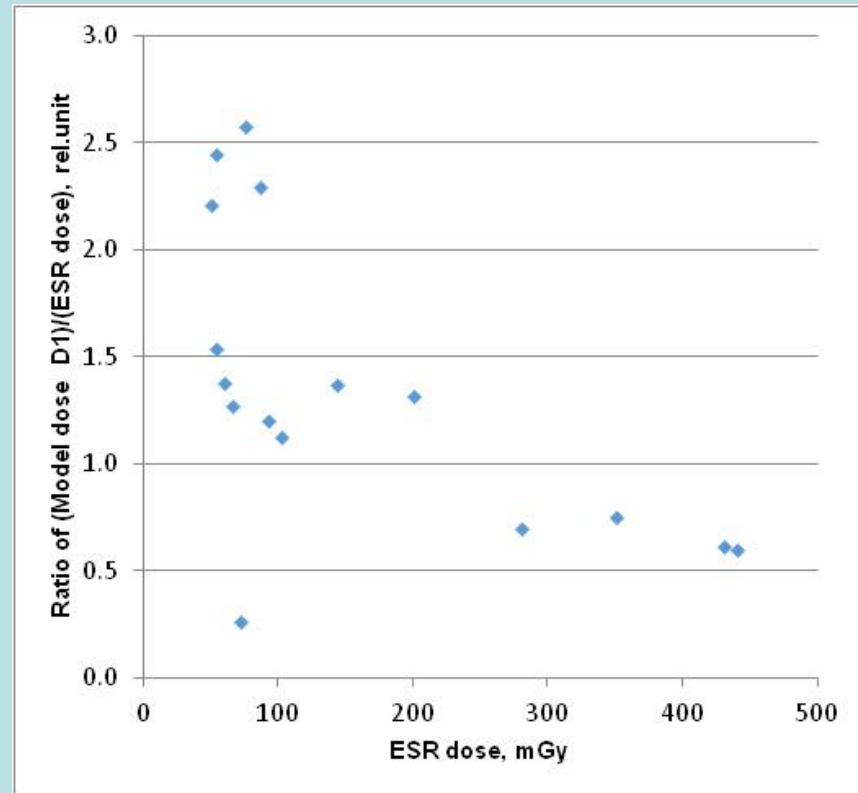
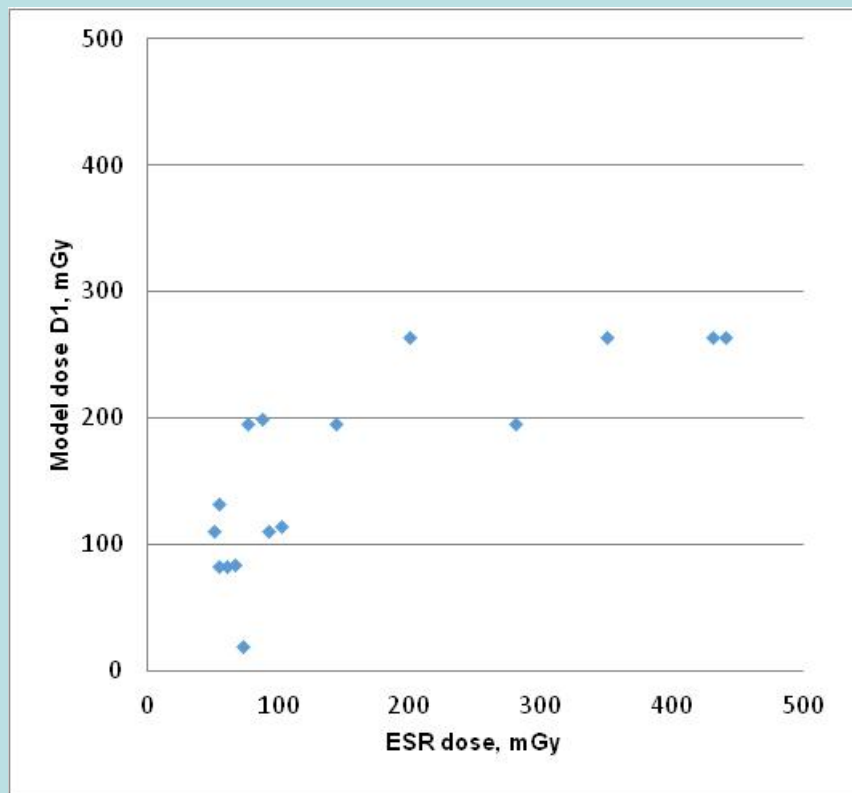
- 10 persons from the settlement of Dolon
- 4 persons from the settlement of Mostik
- 2 persons from the settlement of Cheremushka

MRRC estimated individual external dose based on ESR tooth enamel measurements for each person. Those dose estimates were in the range (50-440) mGy with the uncertainty varying from 20% to 70% in the 95% confidence interval. Seven persons with ESR measurements had information on their behavior and diet habits at the time of testing received from personal interviews in earlier studies.

All above settlements were contaminated due to #1 nuclear test (August 29, 1949).

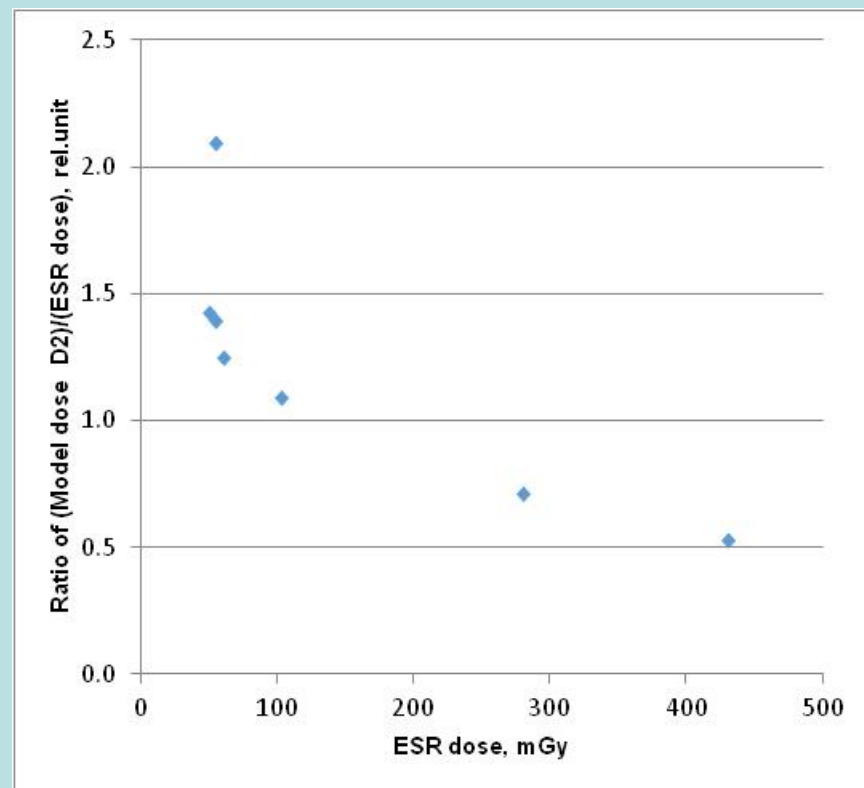
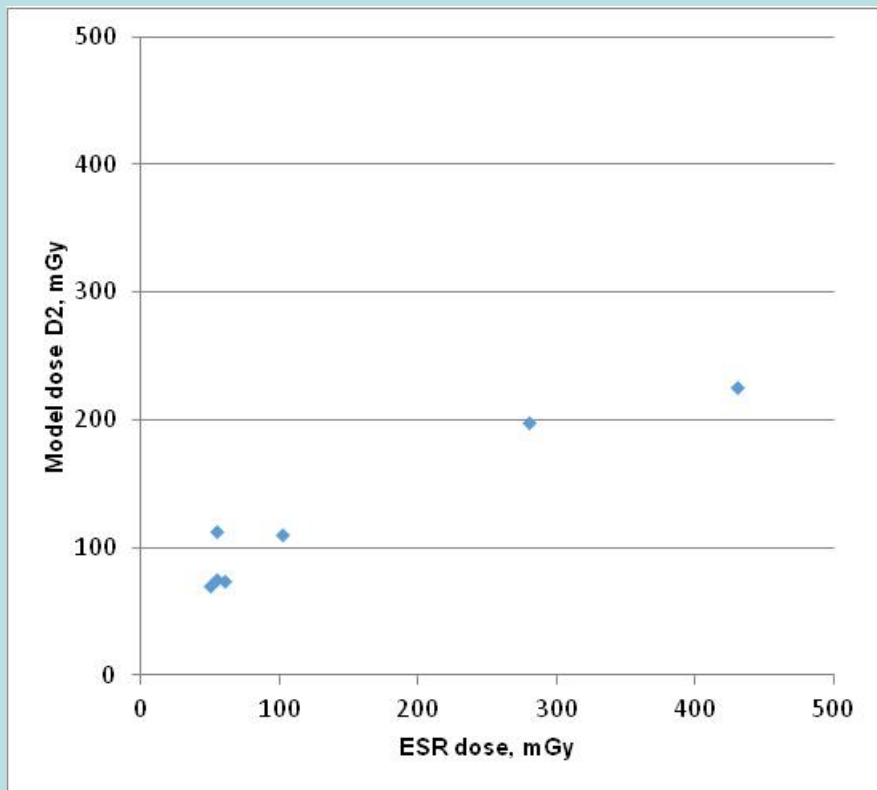
Comparison exercise (1/3)

Comparison of individual estimates of external dose calculated using the joint U.S.-Russian methodology accounting for typical input data on behavior (Model dose D1) with the estimates of corresponding dose derived from ESR tooth enamel measurements (ESR dose). Correlation coefficient is equal to 0.79 (left figure).



Comparison exercise (2/3)

Comparison of individual estimates of external dose calculated using the joint U.S.-Russian methodology accounting for individual interview data from the MRRC questionnaires (Model dose D2) with the estimates of corresponding dose derived from ESR tooth enamel measurements (ESR dose). Correlation coefficient is equal to 0.96 (left figure).



Comparison exercise (3/3)

Comparison of the estimates of individual external dose derived by two methods showed:

- Correlation of two sets of dose estimates is better when information on individual's behavior from personal interview is used.
- Variation of dose estimates calculated using the joint U.S.-Russian methodology is more narrow (20-260) mGy compared to the dose estimates derived from ESR tooth enamel measurements (50-440) mGy. However, the uncertainty of individual dose estimates calculated using the joint U.S.-Russian methodology is higher than that related to the dose estimates derived from ESR measurements.

Dynamics of internal and external exposure

It is important to stress:

- More than 90% of total internal absorbed thyroid dose was received during the first month.
- More than 95% of external lifetime whole-body dose was received during the first year.

Example of external dose formation for the residents of Dolon:

- 1 day – 40% of lifetime dose,
- 3 days – 56%,
- 1 week – 68%,
- 1 month – 83%,
- 3 months – 91%,
- 6 months – 95%,
- 1 year – 98%.

Validation of dose estimates

- Estimates of settlement-average dose to air derived from the U.S.-Russian methodology can be validated by TL/OSL measurements of quartz inclusions in bricks.
- Estimates of individual external dose derived from the U.S.-Russian methodology can be validated by ESR measurements of tooth enamel.
- Unfortunately, neither direct measurements of the ^{131}I thyroidal content nor whole-body counting were carried out among the residents at the time of nuclear weapons testing (1949-1962). So it is impossible to verify the model estimate of individual doses from internal exposure by the measurements of ^{131}I in the thyroid and ^{137}Cs in the body.

Uncertainties in the dose estimates

Preliminary analysis showed:

- The main contributor to the total uncertainty of individual dose from external exposure is the uncertainty of settlement-average dose (more than 80%).
- Substantial contribution to the total uncertainty of individual dose from internal exposure is provided by uncertainties of such parameters as:
 - the fraction of fallout debris intercepted by vegetation,
 - the solubility of fallout different particles sizes and at different locations,
 - transfer coefficients for different types of dairy animals,
 - origin and amount of milk consumed by each person.

Perspectives for dose estimates improvement (1/3)

- Further intensive efforts are needed to collect samples and provide TL/OSL measurements of quartz inclusions in bricks and ESR measurements of tooth enamel of the residents of the settlements for which no or few measurements of such kind are available. The above-mentioned present day measurements will be useful for validation of the estimates of settlement-average dose to air, as well as the estimates of individual external dose.
- Additional soil sampling campaign to measure the ^{137}Cs deposition density in the settlements and their vicinities might be useful to reconstruct radiological conditions at the time of fallout and to assess external exposure doses more accurately.

Perspectives for dose estimates improvement (2/3)

- **Some settlements had no schools in 1949-1962 and the children who lived in those settlements went to schools in other settlements. It is necessary to collect information as soon as possible about a) the location of schools in 1949-1962, and b) from which settlements children went to those schools. Collection of this information will allow a more reliable assessment of the individual external dose to children.**
- **Settlements and their vicinities were unevenly contaminated. No information is available regarding location of pastures of cows and horses. Collection of such information is needed to improve internal dose assessment.**

Perspectives for dose estimates improvement (3/3)

- Valuable information from interviews with the residents in the settlements around the SNTS on their behavior and diet habits was collected for previous epidemiological studies. It is important to reach a data access agreement with relevant research institutions. This will substantially increase the amount of information important for dose reconstruction.
- A strategy for estimation and inclusion of uncertainty in the dose estimates is in progress. It is proposed to use the recently developed two-dimensional Monte-Carlo procedure for future long-term epidemiology studies to enable separation of shared and unshared errors.

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**Thank you
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