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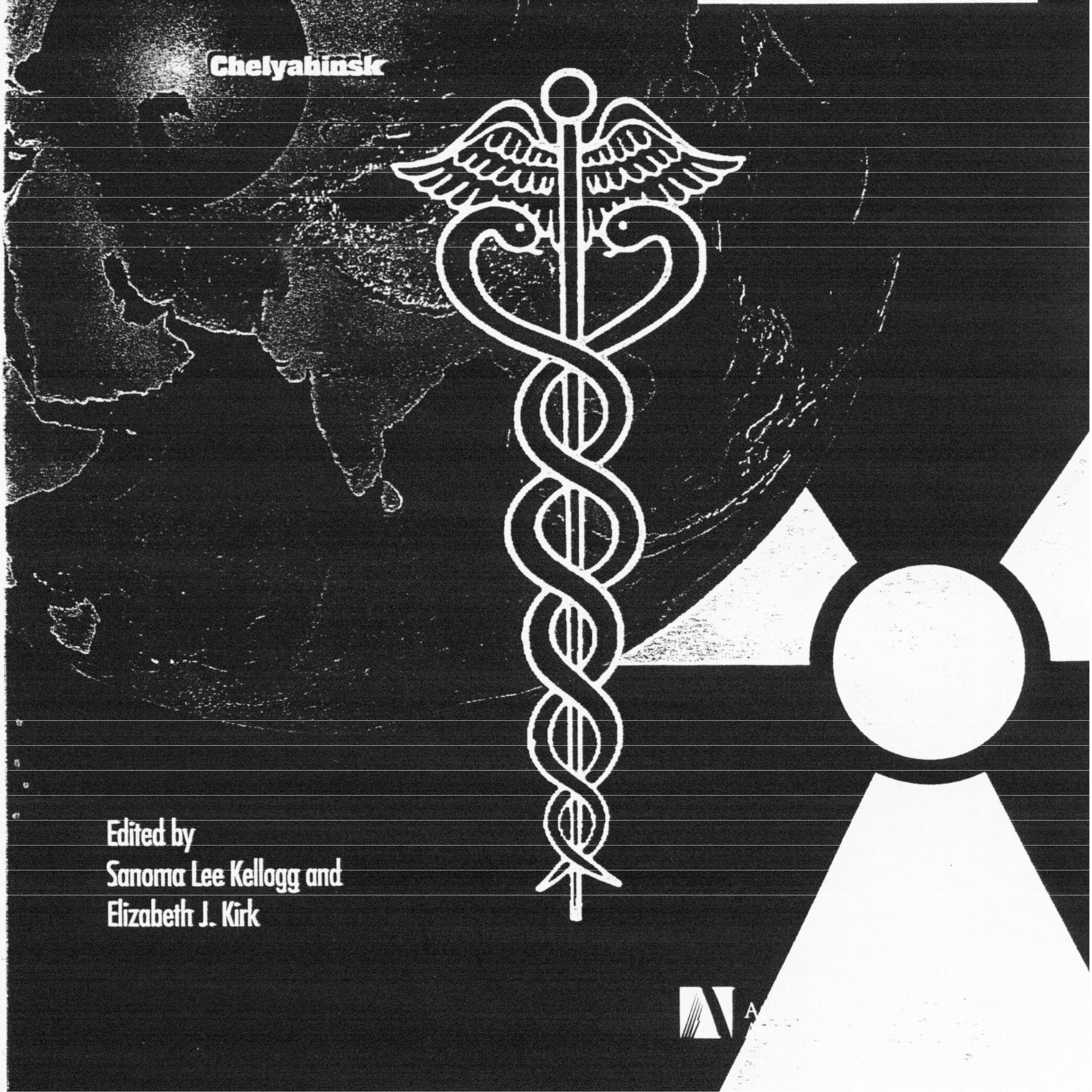

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Population Exposure Dose Reconstruction for the Urals Region

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Introduction

This presentation describes the first preliminary results of an ongoing joint Russian-US pilot feasibility study. Many people participated in workshops to determine what Russian and United States scientists could do together in the area of dose reconstruction in the Urals population. Most of the results presented here came from a joint workshop in St. Petersburg, Russia (11 to 13 July 1995). The Russians at the workshop represented the Urals Research Center for Radiation Medicine (URCRM), the Mayak Industrial Association, and Branch One of the Moscow Biophysics Institute (FIB-1). The US collaborators were Dr. Anspaugh of Lawrence Livermore National Laboratory, Dr. Napier of Pacific Northwest Laboratories, and Dr. Bouville of the National Cancer Institute. The objective of the first year of collaboration was to look at the source term and levels of radiation contamination, the historical data available, and the results of prervious work carried out by Russian scientists, and to determine a conceptual model for dose reconstruction.

Circumstances of Population Exposure in the Urals

Population exposure in the Urals occurred as a result of technicalfailures at the Mayak plutonium facility in the 1950s, which are illustrated in Figure 1. Initially, this complex consisted of three main parts: a reactor plant, a radiochemical facility, and a waste management facility. The major sources of radioactive contamination were:

- the discharge of about three million curies of liquid radioactive wastes into the Techa river between 1949 and 1956;
- an explosion in the radioactive waste storage facility in 1957—the so-called Kyshtym accident—that dispersed two million curies in the atmosphere, thereby forming what is known as the East Ural Radioactive Trace (EURT);
- the resuspension in the atmosphere of 600 curies contained in dry silt from Lake Karachai, an open storage site for liquid radioactive wastes, in 1967; and
- gaseous-aerosol operating releases within the first decade of the facility's operation.

A significant portion of the activity in the Techa river and the EURT consists of long-lived radionuclides, mainly ^{90}Sr. The EURT release resulted in long-lived contamination of surrounding territories. The map of the Techa river and the East Ural Radioactive Trace in Figure 2 shows the Mayak facility, with the site of the 1957 explosion above it, and the density of ^{90}Sr as it extends to the northeast. The radionuclides deposited by the 1967 Lake Karachai incident were superimposed on the already existing contamination of the EURT. The main radionuclide for gaseous areas of operating releases was short-lived ^{131}I resulting from the reprocessing of nuclear fuel. The maximal annual rates occurred in 1952 and 1953, and the contamination levels of short-lived radionuclides can no longer be measured.

Patterns of Exposure

Systematic measurements of radionuclide contamination in the Techa River region began in the summer of 1951 when data were collected on the contamination of river water; bottom sediments; floodplain soils; vegetation; fish, milk, and other foodstuffs; and external gamma-exposure rates. 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 foodstuffs began only in 1962. Data for the town Ozyorsk (Ozersk on map in Figure 2), where the Mayak workers and their families lived and which was the area most affected by gaseous aerosol releases, are housed at Mayak, mainly on paper media: maps, books, technical reports, etc. Some of these records are still classified.

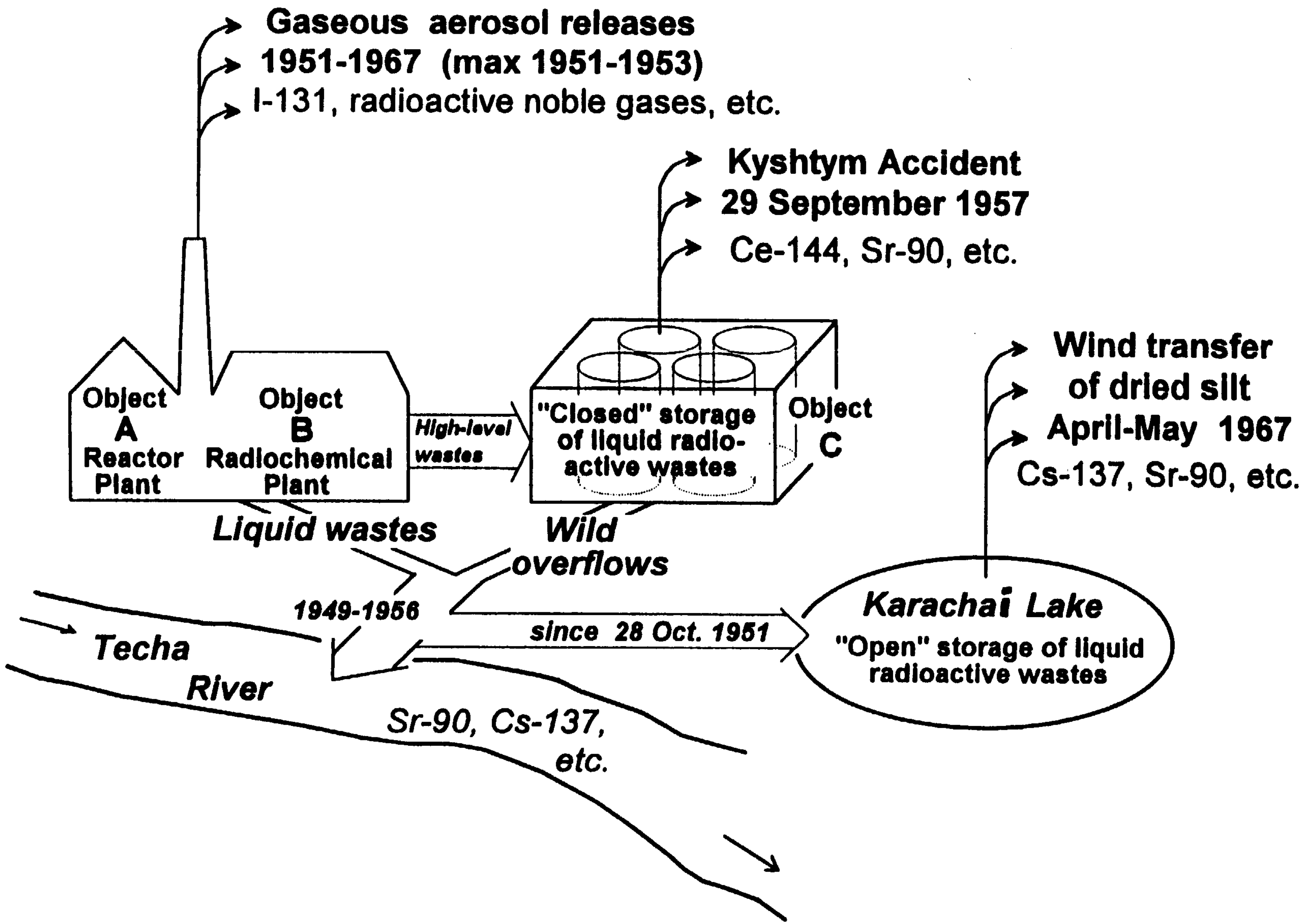


Figure 1. Activities at the Mayak plutonium facility that led to exposure of the population to radioactivity.

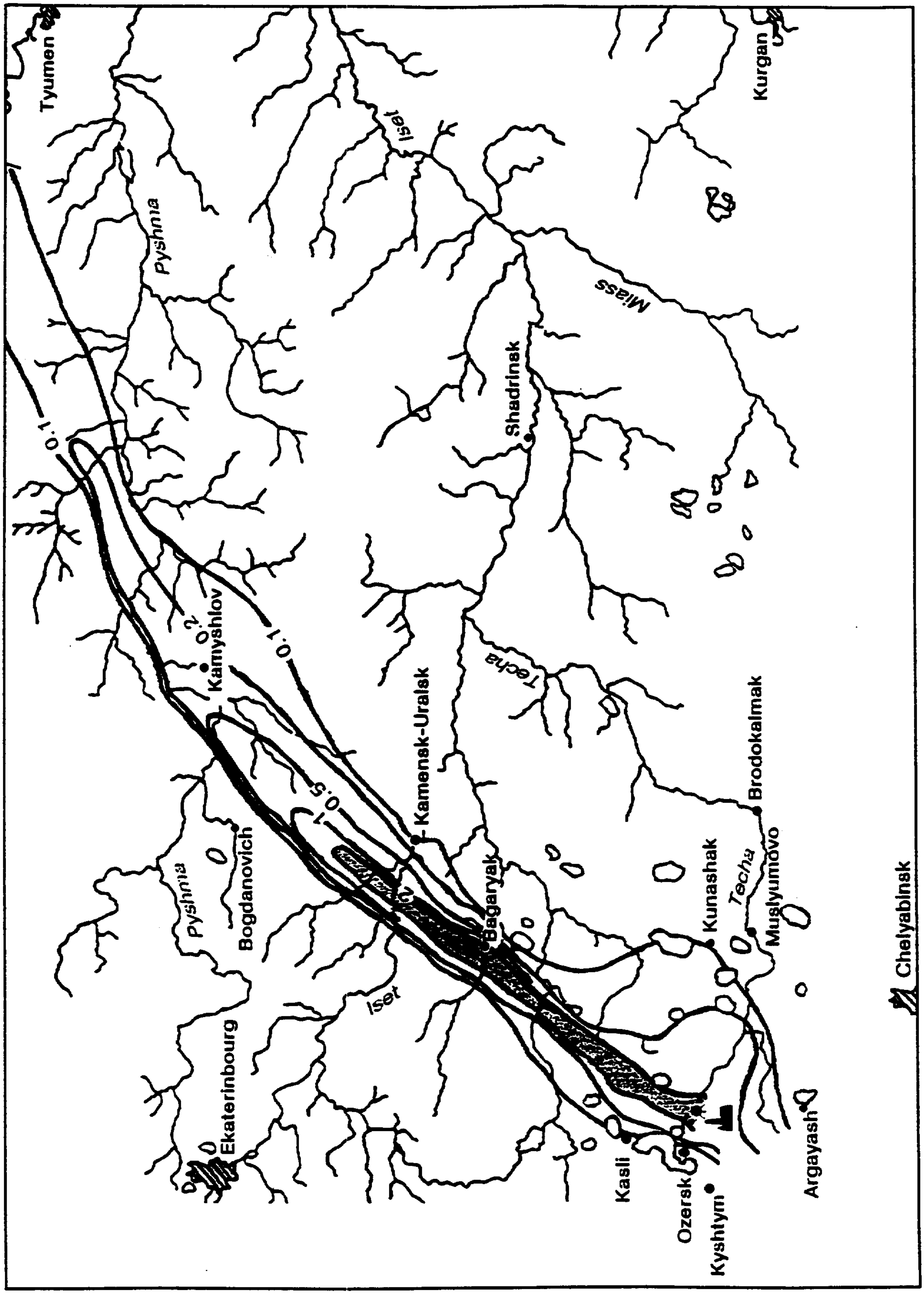


Figure 2. Map of the Urals region, ^{90}Sr contamination (Ci/km^2).

The population of the contaminated territories was exposed to external and chronic internal radiation. By 1951, medical examinations of the Techa riverside communities had begun. In addition to information obtained from these examinations, individual data were collected on conditions of contact with the contaminated river, such as the distance of houses from the water's edge and sources of drinking water and fishing. Radiometric measurements of bioassay and autopsy samples were also taken. Medical check-ups of the population on the most contaminated territories of the EURT area, which are represented by the gray area on Figure 2, began in autumn 1957. This population and that of the upper Techa riverside communities up to the village of Muslyumovo were resettled at the end of the 1950s.

Study Cohorts

Three cohorts of exposed people were selected based on the nature of exposure and the level of dose to which they were exposed. The cohorts were defined as:

- the Techa river population;
- the population of the EURT territories, including the people affected by the 1967 Lake Karachai incident; and
- the Ozyorsk town population.

All three populations were exposed to both external and internal radiation. The pathways of exposure are, however, rather different for each community.

Internal radiation entered the bodies of subjects in the Techa river cohort through the ingestion of radionuclides in river water, milk, and fish. The main sources of external radiation for this group were contaminated bottom sediments and floodplain soils. For the EURT cohort, the main source of external radiation was contaminated soil, while the pathways for internal radiation were inhalation and the ingestion of contaminated foodstuffs. The main pathway for internal exposure in the Ozyorsk population was the ingestion of ^{131}I through milk.

The dose levels varied within these three cohorts, and the populations can be subdivided according to the level and nature of exposure, as shown in Table 1. Techa river residents were subdivided into three subcohorts. The first is composed of 4,500 people who lived in the upper Techa settlements during the period of massive releases. This group received predominantly external exposure. The second subcohort consists of 22,000 people who lived in the lower Techa region during the same period. They were predominantly exposed to ^{90}Sr through internal exposure. The third group is composed of residents who moved to the Techa after the maximal releases had ceased. This subcohort received predominantly internal radiation of a low level.

EURT residents can be subdivided into two subcohorts. The first consists of about 1,200 people who were evacuated during the first ten days after the explosion in 1957 and were therefore exposed mostly to external sources of radiation. The second subgroup contains 14,000 people who were evacuated after one year from the lower contaminated territory of the EURT or who were not evacuated at all.

Table 1. Exposed population cohorts

Techa River residents	4,500 living on upper Techa, 1949–1952 22,000 living on lower Techa, 1949–1952 7,800 "late entrants" who moved to Techa after 1952
EURT residents	1,200 evacuated early 14,000 evacuated after one year or not evacuated
Ozyorsk residents	not established

The people in both the Techa river and EURT populations were entered into the URCRM computerized registry of accidentally exposed people, which contains personal data (surname, name, paternal name, date of birth) and individual residence histories since 1949. For about half of the Techa riverside residents, measurements of ^{90}Sr in the body taken with a whole body counter were recorded, making it possible to reconstruct individual doses. There is little information on individual body contamination for members of the EURT cohort, but the available data on the contamination of soils, vegetation, milk and other foodstuffs, and external gamma-exposure rates are valuable. Consequently, the doses for these people can be reconstructed by combining environmental data with individual residence histories. A registry has not yet been established for the population exposed as a result of operational ^{131}I releases (Ozyorsk population), but researchers in Dr. Nina Koshurnikova's laboratory at FIB-1 have begun this work.

The next series of figures illustrates exposure patterns and levels for the subcohorts defined in Table 1. Figure 3 depicts a typical exposure pattern for the upper Techa river subcohort. The level on Figure 3 corresponds to Metlino residents (seven kilometers downstream from the site of release). These people were exposed to relatively high levels for all organs and tissues in the body. Ninety percent of the total effective dose occurred due to external sources, but ^{90}Sr also contributed to the total dose, which is why the three "strontium-specific" tissues—red bone marrow, bone surfaces, and the lower part of the large intestine—received elevated levels of absorbed dose.

Figure 4 presents a typical picture for residents of the middle and lower Techa. This population was exposed predominantly to internal sources of radiation, and ^{90}Sr contributed 45 percent of the total effective dose. Therefore, red bone marrow, bone surfaces, and the large intestine received the maximal level of dose in comparison with other tissues. The levels on Figure 4 correspond to Muslyumovo residents (78 kilometers downstream from the site of release). The lowest levels in populations from the lower part of the Techa were five times lower than those of Muslyumovo residents, but the structure of the dose was the same for both groups. People who moved to the Techa after the maximal releases had ceased received very low doses of ^{90}Sr, and again, the structure of the dose was the similar, as is shown in the lower panel of Figure 4.

Figure 5 portrays a typical picture for people who were evacuated early from the EURT. All organs and tissues received very similar doses since external radiation was the predominant source. The levels on Figure 5 correspond to Berdyanish residents (12.5 kilometers downwind from the explosion site). They all received doses at approximately the same level during a one-week period. The radionuclides ^{144}Ce and ^{90}Sr made the largest contributions to the internal dose. Accordingly, the tissues of the large intestine, lungs, bone marrow, and bone surfaces received the highest doses. The lungs and gastrointestinal tract are barrier organs, which are the critical organs for ^{144}Ce.

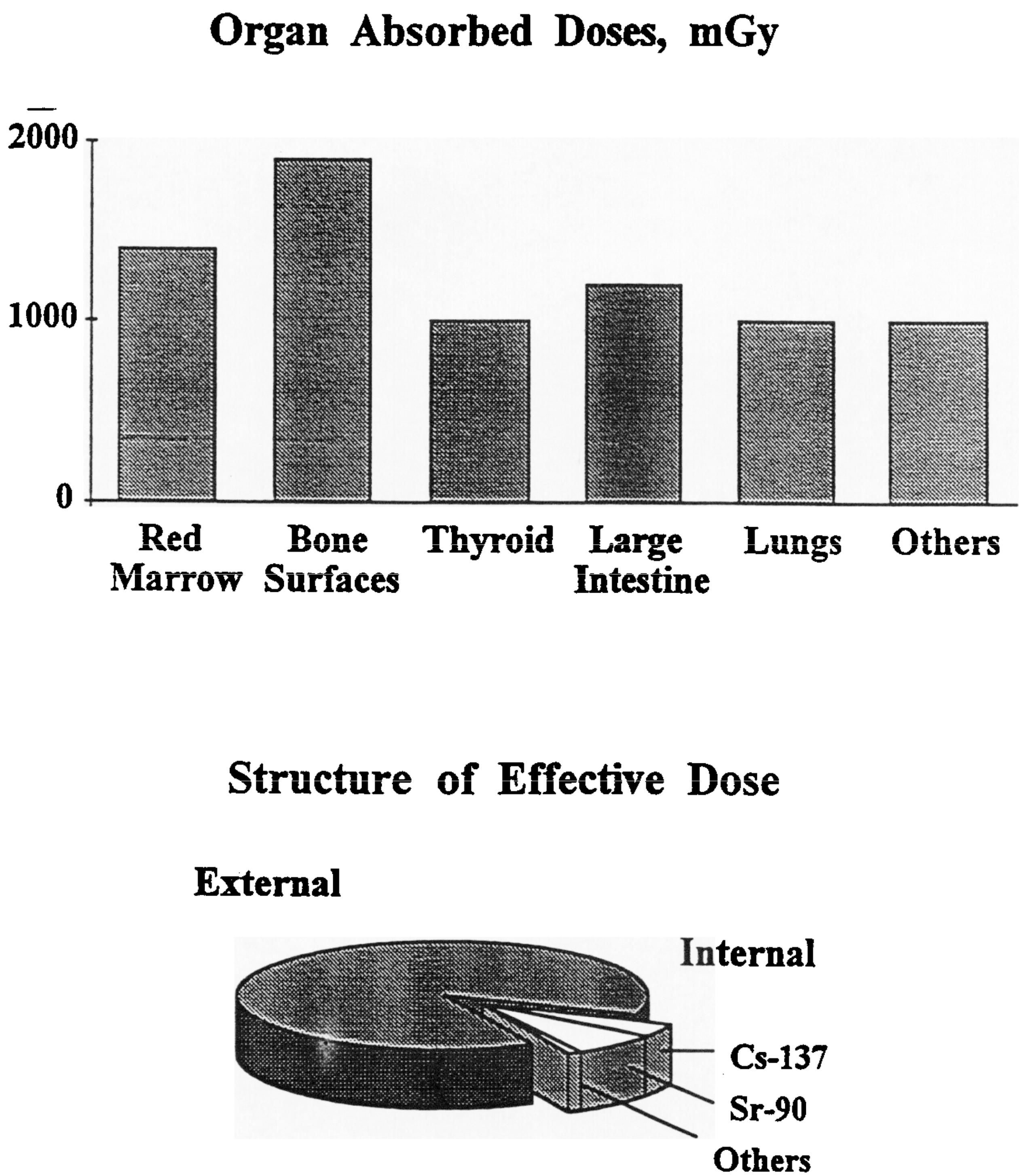


Figure 3. Typical exposure pattern for the upper Techa population.

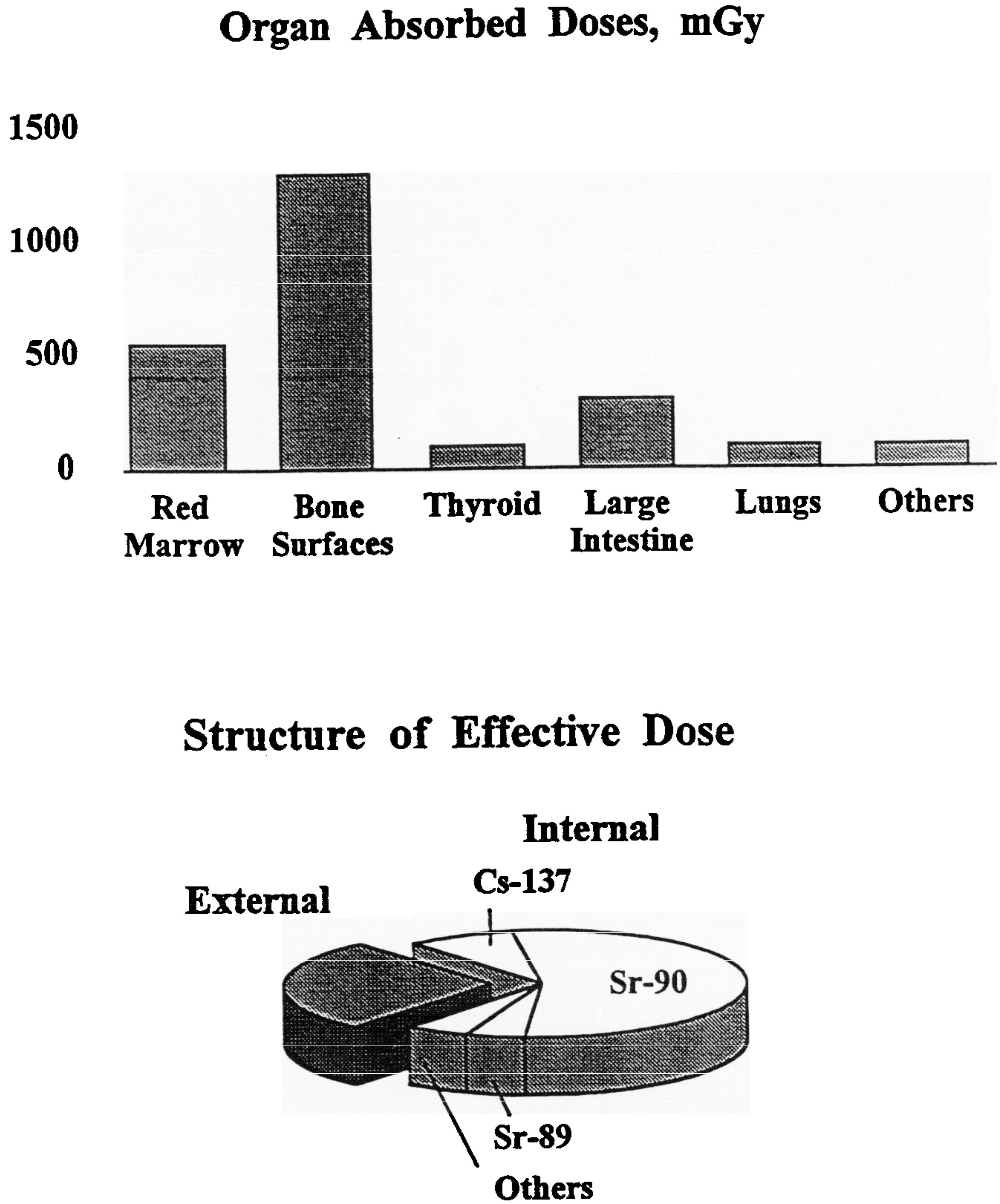
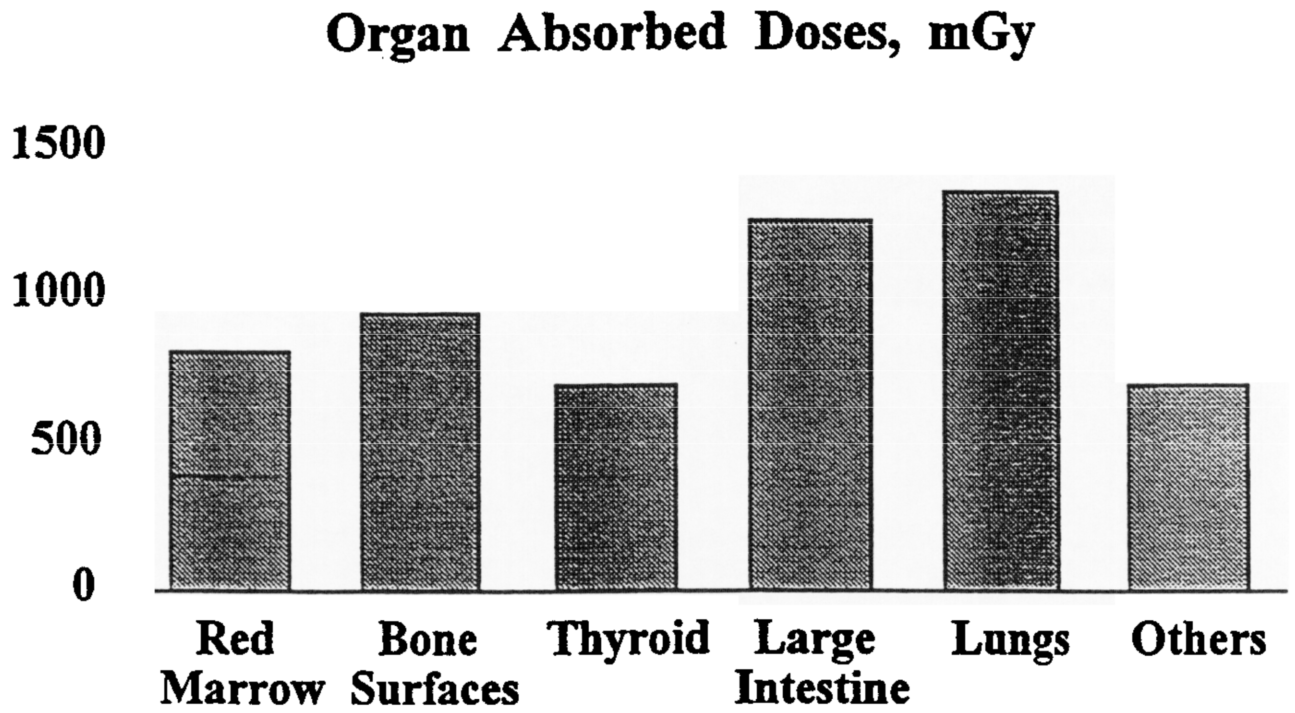


Figure 4. Typical exposure pattern for residents of the middle and lower Techa regions.



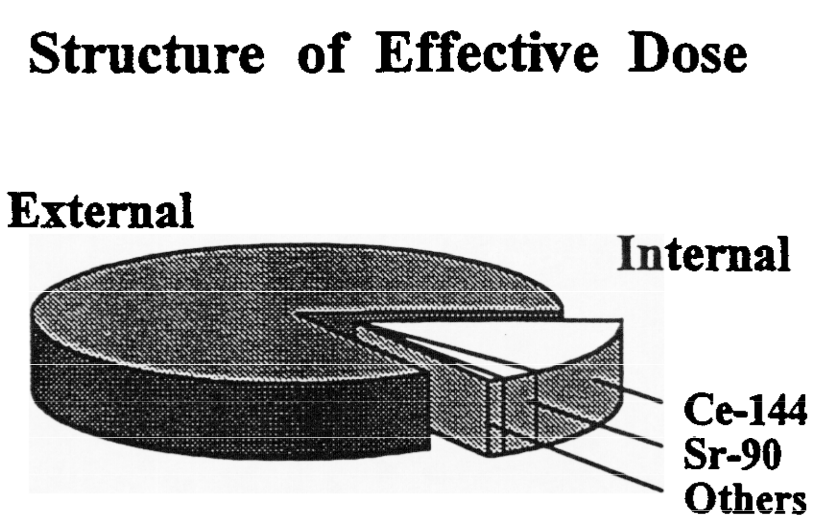
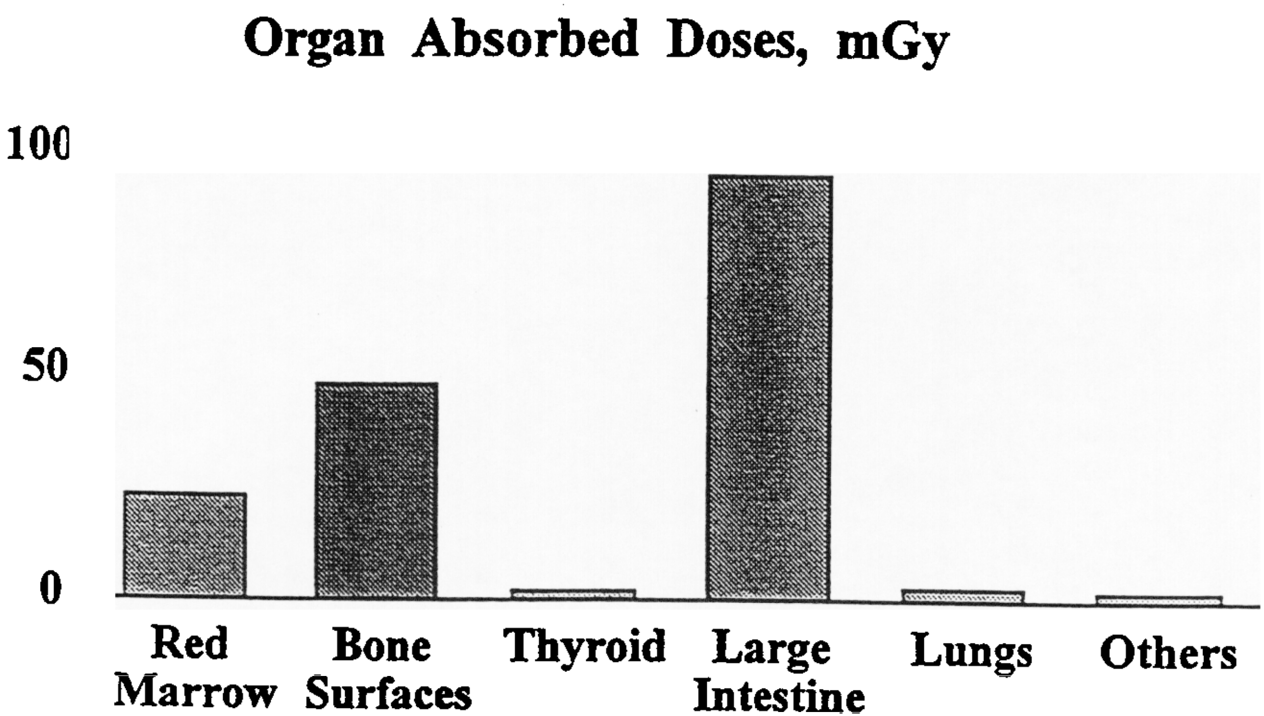


Figure 5. Typical exposure pattern for residents evacuated early from the EURT.



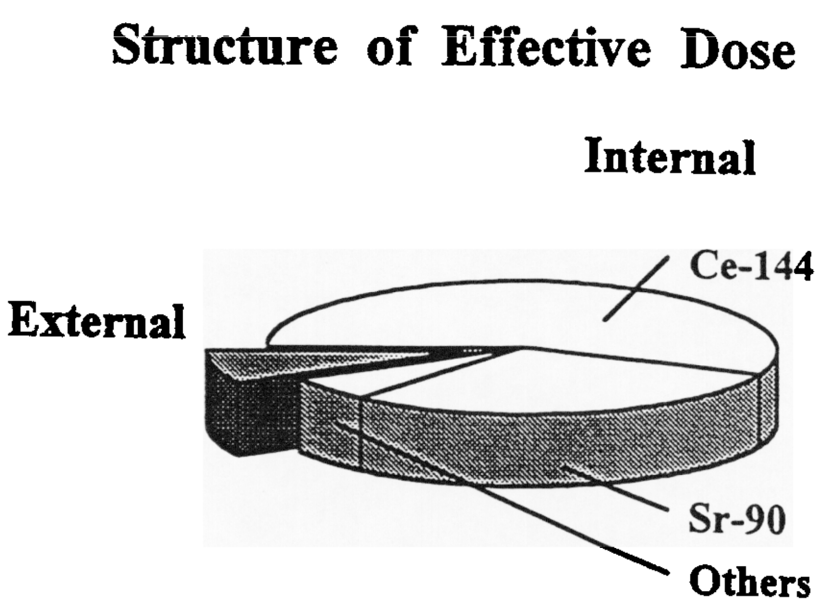


Figure 6. Typical exposure pattern for EURT non-evacuated residents.

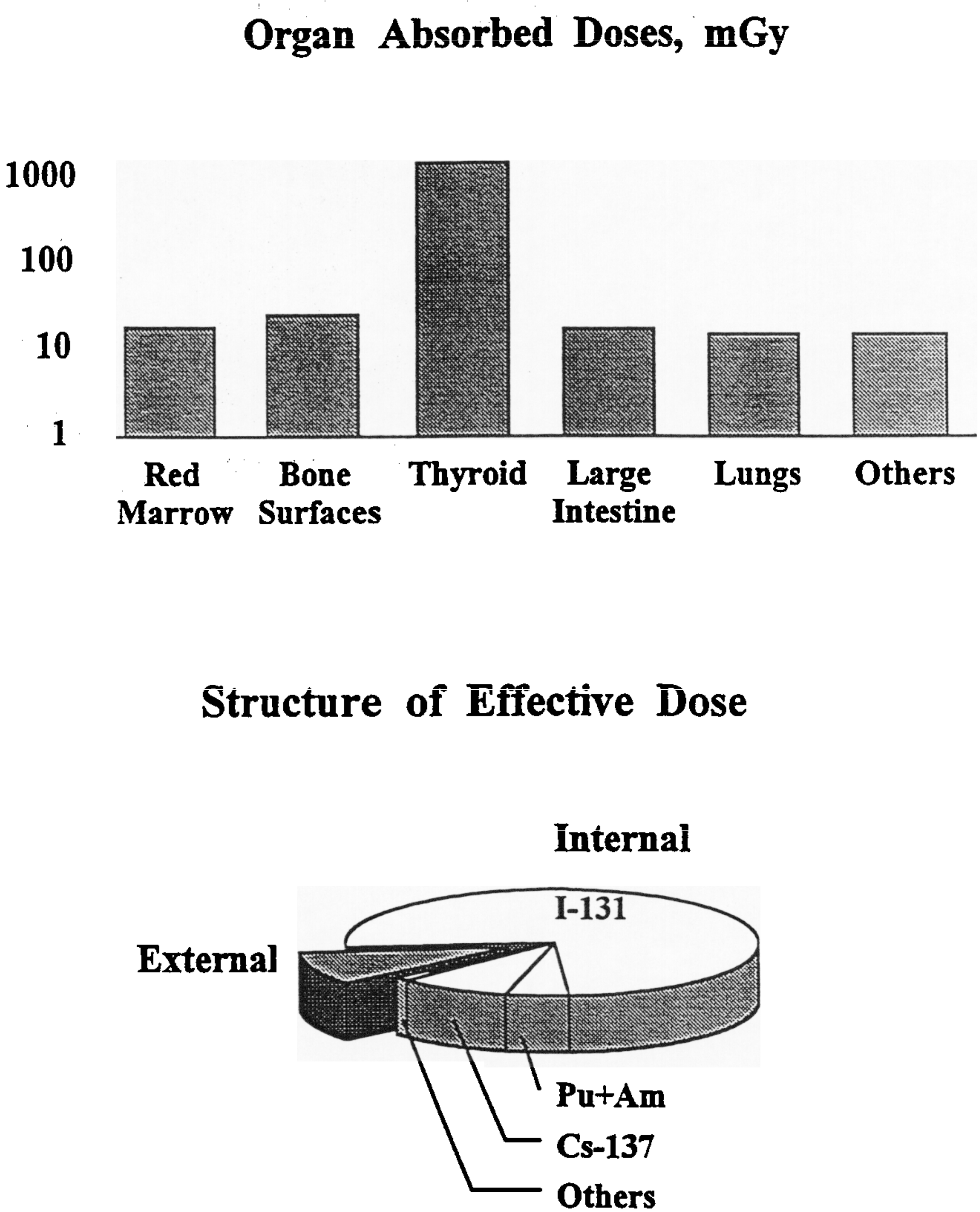


Figure 7. Typical exposure pattern for Ozyorsk town residents.

Figure 6 provides a typical exposure pattern for residents of the area of the EURT with lower-level contamination who were evacuated more than one year after the accident or not at all. The levels correspond to the density of one curie of ^{90}Sr per square kilometer. These people were exposed to radiation mostly through internal sources, and ^{144}Ce and ^{90}Sr were the predominant radionuclides responsible for almost the entire effective dose.

It is important to stress that the doses for the EURT population were calculated based on environmental measurements, as opposed to individual measurements, and that the objective for carrying out this assessment was to protect the population, not to determine risk assessment. Consequently, Figures 5 and 6 depict a conservative value of doses for the EURT population.

Figure 7 represents a typical exposure pattern for the Ozyorsk population. It is obvious that ^{131}I is the absolute champion in comparison with other sources of exposure. The thyroid gland is the only organ that received substantial exposure in this cohort. These dose assessments are also very, very preliminary and conservative because they are based on tentative estimates of atmospheric releases derived from old technological records. There was no special project for the reconstruction of environmental doses due to routine technological ^{131}I releases.

Table 2. Major and minor exposure pathways in the Urals region

Cohort	Sources	Transport mechanism	Environmental data and models	Exposure pathways
Techa	Techa River**	Techa River Transport	Milk*	Ingestion*
			Fish*	Ingestion*
			Water**	Drinking**
				Home Use*
			Sediments**	External**
			Floodplain**	External**
EURT	Kyshtym explosion**	Acute atmospheric transport	Air*	Inhalation*
			Soil**	External**
	Lake Karachai*		Crops**	Ingestion**
			Animal products**	Ingestion**
Ozyorsk	Plutonium*	Chronic atmospheric transport	Air*	Inhalation*
	Iodine-131**		Crops*	Ingestion*
			Milk**	Ingestion**
	Other*		Soil*	External*

**Major pathways   *Minor pathways

Pathways

Table 2 illustrates that the exposure situation in the Urals is very complex, which means that the dose reconstruction task is very complicated. Consequently, it is important to separate the exposure pathways. The separation into major and minor pathways was determined as follows for this joint US-Russian and for future joint dose reconstruction studies. Major pathways are those that result in doses greater than ten rad to any organ, while minor pathways are those that result in doses less than about ten rad to any organ, according to the above preliminary evaluation. This difference defined the strategy for the project. Individual dose assessments will be determined for major pathways and generic dose assessments will be determined for minor pathways. Based on previously completed dose assessments, all pathways have been devided into major and minor, as indicated in Table 2.

Conclusion

The activity with the highest priority is to either reconstruct individual doses or make a scientific reconstruction. To obtain real dose assessments, it is necessary to have the results of measurements and initial data for model validation. The reconstruction and validation of valuable data on the Techa river cohort are of the highest priority because, for about half of the Techa population, data already exist on individual measurements of ^{90}Sr in residents' bodies. Complete residence histories are also available for all members of the Techa cohort, as are genealogical data, which is important because a family analogy can be used to determine individual dose. The last reason for the high priority of the Techa river cohort is that excess leukemia cases were found for the Techa river residents in comparison with the unexposed population of the Urals region. Therefore, the data exist to directly assess the risk of chronic exposure of human subjects on the basis of the Techa river cohort.

The second reconstruction priority is the EURT cohort, for which there is an established registry (roster) of the residents of the most contaminated territories. Residence histories are also available, but there is little information on individual body contamination for members of EURT cohort. Therefore, dose reconstruction will have to be based on environmental contamination measurements and residence histories.

The third priority is the Ozyorsk population, which has not been established as a fixed cohort. This population is also very interesting because the Mayak site is an analog of the Hanford site, and if the doses are reconstructed for the Ozyorsk cohort, it will be possible to compare these two different studies that have a very similar nature.

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